

# Proceedings of the International Conference on Innovation - driven Knowledge Economies and Transformation in the Global South



# Proceedings of the International Conference on Innovation - driven Knowledge Economies and Transformation in the Global South

## Volume VII Skilling for Knowledge Economy: Industry - Academy interaction, intellectual property rights, open innovation and development

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Bangalore | Kerala Development and Innovation Strategic Council







## Preface / A word of welcome and thanks

It is a matter of great pride that the 20th-anniversary Globelics International Conference is being held in Thiruvananthapuram. This conference deliberates on an issue of much contemporary relevance – Innovation-driven Knowledge Economies and Transformation in the Global South, which is at the centre stage of development strategy both at the national and that of the government of Kerala. In 2006, when inclusive development was a major issue of global concern, Globelics conference was held in Trivandrum and deliberated on Innovation Systems for International Competitiveness and Shared Prosperity.

This Conference intends to bring together scholars across disciplines from over 50 countries to pool together experiences and expertise to reflect on varied issues involved in the process of transforming developing economies into sustainable, resilient, and inclusive innovation-driven knowledge economies.

In the conference, to be inaugurated by Shri Pinaryi Vijayan, the Hon'ble Chief Minister of Kerala, scholars of eminence will join as keynote speakers and panelists in plenary sessions and special sessions. The conference, organized in nine parallel tracks, will also have book presentations, excursions, and cultural events. As part of the conference, about 20 leading scholars from Globelics will visit different universities and colleges in Kerala to deliver lectures and interact with faculty and students, which is facilitated by Kerala Higher Education Council and Kerala Economic Association.

We welcome with great appreciation the Honourable Chief Minister Shri Pinarayi Vijayan and all the dignitaries who joined us for the inaugural address and eminent scholars delivering keynotes and addressing in different plenary sessions, special sessions, and parallel sessions. While the invisible hand of our honourable Chief Minister is there in all the important initiatives of GIFT, this program has been ably guided and steered by our Chairperson Shri K N Balagopal, Hon'ble Finance Minister of Kerala.

This important event is the outcome of the collective effort of all those involved, especially the Co-organising institutions: RIS, New Delhi, who inter alia managed the political clearance from the Ministry of External Affairs, IIM Bangalore, K DISC and the Digital University of Kerala. Our partnering institutions, ICSSR, Kerala State Higher Education Council, Centre for

Development Studies, Kerala Economic Association, and the Centre for Latin American Studies also have been helpful in organising this conference.

With much appreciation for all of you for being with us, we welcome you

K J Joseph  
For the local organising Committee

## About the 20th Anniversary Conference

The central theme of the 20th Anniversary Globelics International conference is Innovation-driven Knowledge Economies and Transformation in the Global South.

This conference intends to bring together scholars across disciplines from over 50 countries to pool together experiences and expertise to reflect on varied issues involved in the process of transforming developing economies into sustainable, resilient, and inclusive innovation-driven knowledge economies. Episodes of development in economic history highlight the successful experience of countries that have managed to harness Learning, Innovation and Competence-building Systems at the global, national, subnational and sectoral levels in order to transform their social and economic structures for achieving prosperity. In the current times, the constellation of innovations driven by rapid advances in digital technologies has given rise to a new technological revolution, commonly referred to as the fourth industrial revolution, or Industry 4.0, with profound impacts on all sectors of the economies and sections of societies. New and persisting developmental challenges have driven a renewed interest in different types of innovations that highlight their impact on society and the natural environment, such as inclusive innovation, responsible innovation, transformative innovation, grassroots innovation and Jugaad. At the core of all these approaches is how knowledge, both science-based and experience-based, is harnessed for addressing development challenges, the basic premise being “the knowledge divide is at the root of the development divide”

At the current juncture, wherein globalization is at the crossroads, the economies across the world, ravaged by the once-in-a-century pandemic and external shocks, consider strengthening the innovation system as a strategic approach towards building resilience. Evidently, there is an across-the-board drive among developing countries to transform their economies into innovation-driven knowledge economies. Such a transformation is often viewed as capable of building resilience by addressing many of the downsides of globalization-induced high growth, like excessive exploitation of exhaustible resources and accentuated divides within and between countries. Such

initiatives in India are manifested, among others, in Atal Innovation Mission (AIM), Digital India, Skill India, and Make in India and other concerted efforts to transform India into an innovation-driven knowledge economy. It is also in sync with the national agenda of harnessing Science, Technology, and Innovation (STI) to achieve sustainable development. The choice of the location of the conference is inspired by Kerala's strategy towards transforming the state into a knowledge economy, as explicitly stated in the budgets starting with 2020-2021 and the subsequent concerted efforts that followed. It is in this background that Globelics revisits India for the 20th Globelics International conference with the chosen central theme: 'Innovation-Driven Knowledge-Economies and Transformation in the Global South'.

The 20th Anniversary Globelics is also an occasion to celebrate the journey of Globelics from Brazil 2003 to India 2023 and its varied achievements. At the same time, it is also a forum for critically reflecting on our perspective and the approaches *inter alia* in terms of its achievements and limits. This is especially important at the current juncture wherein there is growing disenchantment with the development experience under globalisation on the one hand and the need on the other hand, for reimagining innovation systems in the COVID and Post COVID world towards building the much needed resilience in the South.

Globelics-India 2023 coincides with India's Presidency of G-20 that *inter alia* aims at influencing the development dynamics of Global South and it is an appropriate time for translating the insights of the conference with respect to strengthening Learning, Innovation and Competence-building Systems (LICS) into policy action. For the past two decades, we have observed an increasing influence of Global South in shaping the paradigms and trajectories of the global development agenda—sustainability, climate change, pandemic, and energy security issues—with India playing a key role; all being closely linked to the research domains of the Globelics.

World-leading scholars are set to give this year's keynote address on innovation and development. It is planned that the conference will be inaugurated by the Chief Minister of Kerala and there will be a special keynote on the conference theme along with a Globelics Lecture and Freeman Lecture. The conference will combine plenary sessions, presentations of research papers in parallel tracks, thematic panel sessions or special sessions, poster presentations, book presentation sessions, excursions, and cultural events.

## Conference Tracks

While submissions on the central theme of the conference have been especially encouraged, submissions on all the issues conventionally deliberated in the Globelics international conferences are also included. Submissions have been organized around the following themes:

1. Science, technology, innovation: Theory and policy for a knowledge economy
2. Transformative innovation, responsible innovation and mission-oriented innovation
3. Knowledge-driven development of national, regional, local and sectoral innovation systems, including Agricultural innovation systems and rural development
4. Measurement of the knowledge economy: Indicators, data requirements, different approaches and methodologies
5. Skilling for the knowledge economy: Industry-academy interaction, Intellectual property rights, open innovation and development
6. Industry 4.0 and development: Digitalization and automatization, productivity and employment implications, gig economy and quality of employment
7. Economic and social upgrading for sustainable Catch-up: trade policies, FDI, value chains and innovation networks in a knowledge-driven economy
8. Innovation for inclusive development: Indigenous knowledge, Grassroot innovations, Jugaad, informal economy, micro and small enterprises
9. Entrepreneurship, employability and gender dimension in innovation and development
10. The green economy and financing innovation: Low carbon innovations, environmental technologies and renewable energy



Volume VII

Skilling for Knowledge Economy: Industry -  
Academy interaction, intellectual property rights,  
open innovation and development





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# Impact of prestigious-STEM education of corporate board members on innovation effort: Evidence from india

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## Abstract

This article studies the innovation effort in India through the education of corporate board members obtained from prestigious STEM higher education institutes known as the Indian Institute of Technology (IITs). Our primary aim is to enquire whether firms with director/s having an IIT-Bachelors' degree in their corporate boards positively impact the firm's innovation effort. To answer this question, we build a novel dataset merging two micro-level databases: CMIE- Prowess (firm innovation) and NSE-Infobase (board of directors' characteristics). Based on the sample of 6151 Indian firms for 2006-2015, we find that overall, having board members with IIT- Bachelor's qualifications do enhance innovation efforts to some extent. However, the positive effect on innovation effort becomes more robust when the director has a research degree over their IIT- Bachelors' degree. The paper highlights that when it comes to innovation efforts, the dominant narrative of relying solely on IIT-STEM elite undergraduate education (IIT-Bachelor's) is insufficient and should also focus on and prioritize research education.

**Keywords:** Innovation Effort, R&D, STEM Education, Corporate Boards

**JEL Classification:** O31, G30, I23

## 1. Introduction

In India, investing in human capital is a relevant path for families for upward social mobility, as it is also the case in many other emerging economies. Given that education is an essential source of economic and social status, the middle classes, in particular, put an enormous effort into their children to achieve the highest educational attainment (Brown, 2013). In this context, access to prestigious universities can guarantee a privileged entry to the labour market with a better work position and higher income (Haverman & Smeeding, 2006). However, entering a prestigious university in India is highly competitive, primarily through its national exams. The more prestigious, the more competitive it is to access a particular institution, as the university's reputation is critical in defining a student's future career. In Indian society, relevant authors have argued that education has operated in the past as an essential gatekeeper of socioeconomic mobility (Cheney et al., 2005; Subramanian, 2009). For the rising middle classes of post-1985 India, however, STEM education has played an important role and is a gateway for reaching higher social status (Saxena et al., 2010; Nambissan, 2009). Though there are various STEM education institutes in India, the most reputable are the Indian Institutes of Technology (IIT), which comprises 23 nationwide universities. Regarding STEM education, IITs are highly preferred by every engineering and science degree aspirant (Leslie & Kargon, 2006), given the perception that IIT students are trained and given ample opportunity to acquire technical, business, and leadership skills. Because of their reputation as elite universities, the market highly demands IIT graduates.

The need to train (and supply) graduates from elite schools matches the demands of firms in a competitive market environment. Following the classical perspective of Edith Penrose (Penrose, 1959), firms are a collection of assets. Among those assets, the capacity of the labour force and the competence of leaderships are crucial for the growth of firms that are always looking to recruit the most talented graduates to increase their stock of human capital.

Regarding human capital, the literature agrees that the leadership capacity to make key decisions is a central aspect of the strategic behaviour of the firms (Nahum & Carmeli, 2020). These decisions involve allocating a strategic amount of innovative effort, such as the R&D budget. Successful leaders are willing to take a step forward in innovation in a system in which innovations guarantee competitive advantages (Borgelt & Falk, 2007). Hence, innovation decisions require high focus, knowledge, and risk-taking behaviour (Borgelt & Falk, 2007). Considering the high uncertainty involved in innovative activities, leadership that can navigate risks and challenges would help the firm increase innovation and productivity (Balsmeier et al., 2017). Therefore, a board of

directors that can make bold but calculated decisions are fundamental for innovation effort.

However, most of the focus of those STEM elite schools, in the Indian context, is on undergraduate degrees. Research degrees, such as PhDs and other research activities, receive a much smaller focus. Considering the aim of supplying human capital capable of engaging assertively with innovative activities, the lack of focus on research might harm the potential positive effects of hiring graduate students from top institutions.

Given the abovementioned context, our research question addresses the causal relationship between the presence of graduates from Indian elite schools (IITs) - with and without a research degree - on the boards of directors and their decision to increase innovation efforts. We aim to contribute to the literature by merging elements of corporate governance (leadership), human capital (education and cognitive traits), and innovation (R&D efforts).

One of the critical concerns for India is the lack of a precisely dedicated database containing detailed information about patents or patent citations at the firm level or any other innovation survey to gauge the status of such firm-level innovation<sup>1</sup>. Hence, to answer our research question, we develop a unique database by merging two databases, i.e., the individual-level board of directors' NSE-Infobase dataset, with the firm-level CMIE-Prowess database. The latter provides us with all financial and R&D spending-related information, whereas the former provides information on the personal characteristics of the board of directors.

Furthermore, given the presence of reverse causality, we consider the possibility of endogeneity. We test if boards with more directors with an IIT-Bachelor degree might lead to higher R&D opportunities; however, higher innovation effort can induce a firm to hire more directors with IIT-Bachelor's qualifications. Furthermore, unobservable firm-level heterogeneity might impact the contribution of directors with IIT-Bachelor qualification. We address those issues in the methodology section using fixed effect estimation (FE) and instrumental variable approach (IV).

We organize the rest of the paper into six more sections. Section 2 discussed the literature review followed by Section 3, which focuses on the Research Context. In Section 4 we discuss the data and related descriptive statistics while in Section 5 we focus on the methodology and the empirical model. Section 6 presents the main results of our study. Finally, section 7 presents the policy implications and concluding remarks.

## **2. Literature review**

This review draws primarily from the corporate entrepreneurship literature, linking it with the field of innovation economics. We mainly discuss literature on innovation, competition, leadership, cognitive traits, social mobility, and the role of STEM education in India.

### **2.a. Innovation and competition**

In a market-based economic system driven by a dynamic competitive environment, innovation plays a central role in shaping its direction (Nelson & Winter, 1982). To survive in the market or retain one's monopoly power, firms must constantly focus on upgrading their assets and products, which requires persistence in innovation efforts (Malerba, 2005). Innovation, however, is not an automatic process (Verspagen, 1991). Most firms must engage in innovative activities, primarily R&D, to develop new products and processes and appropriately introduce them to the market (Mairesse and Mohnen, 2004). One crucial element to engaging successfully in innovative activities is the development of absorptive capacity that allows firms to learn and create (Cohen and Levinthal, 1989; Bell, 2009). A central aspect in the generation of absorptive capacity is related to strengthening human capital (Edquist, 2010). In that sense, a sensitive asset for a successful innovative firm is hiring adequate high-skilled workers.

The R&D activities of the firm do not guarantee success (Lhuillery & Pfister, 2009) but reflect innovation efforts and innovative capabilities. To mitigate the possibility of failure and risks associated with R&D, firms require efforts to innovate in a persistent way (Arqué-Castells, 2013). Given the importance of innovation effort, one of the fundamental questions that many researchers or policymakers in innovation economics face are: what is the source of the innovation effort, and what drives it? (Taalbi, 2017; Nieto & Quevedo, 2005) An important aspect is to look at the highest levels of governance inside the firm, which makes crucial decisions concerning R&D or production. In the current corporate structure, leadership is delegated to the board of directors, which defines the short- and long-term firms' strategies (Merendino & Melville, 2019).

### **2.b. Corporate governance: Leadership, cognitive traits, and innovation**

A central theory in the corporate governance literature is the positivist agency theory (Johnson et al., 1996). The agency theory opens the debate to discuss how the characteristic of board members can affect a firm's performance. Depending on the organization of a firm's leadership, we may see different outcomes happening.

A second theoretical stream regards the Upper echelons theory (Hambrick, 2007, Hambrick & Mason, 1984). This theory asserts that the different individual traits of the managers, such as education level and diversity in terms of gender, age, and tenure, highly determine a firm's innovation decisions and strategies. Notably, the educational background plays a pivotal role in improving one's cognitive abilities (Hambrick, 2007), which later helps the board of directors determine and execute complex corporate strategies (Baysinger & Hoskisson, 1990). The upper echelons' literature focuses on behaviour aspects such as leadership style, entrepreneurship, and technology orientation to affect innovation (Carmeli et al., 2011; Tang, et al., 2012).

### *Risk-taking and innovative performance*

The literature on corporate governance highlights that if a firm lacks risk-taker competent leadership (Oke et al., 2009; Naranjo-Valencia et al., 2011), it tends to choose a more conservative strategy, reducing the efforts allocated to R&D (Baysinger & Hoskisson, 1990). Risk-taking (but competent and calculated) leadership is a fundamental characteristic of innovative firms (Garcia Granero et al., 2015). In principle, directors are more risk-averse than shareholders (Deutsch, 2005). Shareholders should then consider that and invest in improving the board's capability by hiring better-quality, competent, risk-taker directors (Deutsch, 2005; Tylecote & Visintin, 2007).

The time frame also plays a central role in innovative incentives – tolerating early failure and rewarding long-term success is essential (Manso, 2011). González-Uribe & Xu (2014) add the contract horizon to the innovation literature. Long-horizon managers produce more important innovation (on average) in terms of patent citations and increases in R&D. Higher-quality innovation relates to managerial practices, including the abovementioned risky strategies, which have a high opportunity cost in the short run. Another time frame dimension is ownership (Brossard et al., 2013). Firms with ownership dominated by institutional investors have higher R&D ratios, while “impatient” institutional investors (short-term profit seekers) are linked to lower R&D ratios, hindering innovation (David et al., 2001).

### *Stem education, top institutions, research degree, and innovation*

Considering the cognitive enhancing capacity of education, there is a strong defense of STEM education as a way forward for development and innovation strategy (Bybee, 2013). However, few studies in corporate governance and innovation economics indicate the correlation between the type and the level of higher education with innovation (Ackerman et al, 2013) and managerial competencies<sup>2</sup> (Shet and Pereira, 2021).

The literature on diversity suggests that diverse educational backgrounds

combined with the heterogeneous work experience of directors can be a vital factor in critical decision-making, promoting a range of perspectives (Khatib et al., 2021; Yang et al., 2019). In opposition to this view on education diversity, another strand of literature (Alderman et al., 2022) argues that high R&D spending firms tend to place more specialized and highly educated STEM-background people in the top management. The argument is that R&D is a scientific activity; hence, essential decisions about innovative efforts require specific in-depth knowledge (Tödtling et al., 2009).

There is consensus in the literature that both levels of education and the educational background of the board of directors play a significant role in determining a firm's innovation effort (Li et al., 2019; Hsieh et al., 2022). The education of the top management acts as a vital proxy not just for its innovation outcomes but also for the intellectual wealth of the firm (Adnan et al., 2016). However, our focus is not only on the overall STEM education, as in Hsieh et al. (2022), but on STEM education obtained from the top institutions. Elite education is a potential element of individual cognition and knowledge that have the power to guide R&D decisions and innovation effort. Education obtained at elite institutes can be connected to the human capital theory (Sweetland, 1996), as students invest in their education and skills, with the incentives to place themselves virtuously in a competitive job market. Those students then focus on developing the technical knowledge fundamental to making relevant decisions related to R&D.

Thus, this ever-present connection of personal cognition and knowledge acquired through STEM education; from specific "prestigious" schools, particularly in STEM, made us question how it could facilitate increases in innovation efforts in a firm. In summary, we argue that STEM education obtained at a highly "prestigious" school is one first potential solid sources of higher scientific cognitive abilities.

A second source of higher scientific ability is higher scientific comprehension. The acquisition of a Ph.D. degree can capture that. While a prestigious undergraduate gives a strong signal about capacity, a Ph.D. degree shows a strong scientific ability to understand how to perform research. Based on works such as Dalziel et al. (2011) and Swift (2018), we then argue that directors who understand how science operates can make better-informed decisions regarding R&D.

## **2.c. Social mobility, aspirations, and elite STEM institutions in India**

Emerging economies present solid opportunities for upward social mobility through education, particularly for low-middle and middle-income families. Families see education as the most relevant legacy for the next generation (Brown, 2013; Marginson, 2018). They aspire to admit their children into the



best institutions, which may guarantee a solid career and an upward social and economic shift.

Similarly, in India, the widespread perception is that students who reach the top STEM institutes receive the best STEM education in the country. In that way, they can acquire desired social status, which allows for success, prosperity, prestige, and even opportunity to work in Western developed countries (Varma & Kapur, 2010). Achieving a high educational achievement also results in social status and a strong psychological element. It fosters a strong sense of self-esteem, capacity, and persistence (Srivastava, 2013), fundamental leadership characteristics towards a more risk-taking and innovative mentality (Krueger & Dickson, 1994).

Indian firms, private or government, give the utmost value to the highly reputable Indian Institute of Technology (IIT). Indian firms compete for more IIT graduates in their organizations to symbolize status and merit (Subramanian, 2019). Access to IIT requires students to clear a challenging and competitive science and engineering-based national-level annual entrance examination<sup>3</sup> at the post-secondary level. Clearing the examination allows post-secondary students to pursue STEM bachelor's education at the top STEM institution in India<sup>4</sup>. Hence, Indian society regards IITs as a symbol of aspiration and a medium of social mobility<sup>5</sup> (Aygün & Turhan, 2017). The competition for access is so high that more than millions of students sit for this examination and compete for around just 12,000 seats<sup>6</sup> every year. Furthermore, once getting access, graduating from IITs is a challenging task. The subjects studied during undergrad aim to test the students at their most, and many fails and drop out before graduation.

### **3. Research context**

Given the nature of elite education, IIT graduates tend to be confident in their technical capabilities, which allows them to be risk-takers. This specific profile makes IIT graduates a potentially good match for being part of any firm's board of directors. However, are firms that rely on a higher share of IIT graduates more innovative? Furthermore, can a higher achievement, such as a Ph.D., increase further innovation?

Based on the literature review, the channel through which a board of directors could yield a positive return for a firm's innovation effort is through a strong sense of belief of the members in their strong STEM cognitive abilities to perform better, take the risk, and put more effort in innovation (Deutsch, 2005; Tylecote & Visintin, 2007). We argue that the source of this overpowering belief in own cognitive abilities for yielding a positive return for the firm's innovation effort comes from the privilege of studying in the premier STEM institutes of the country at an early age. Those who, as teenagers, successfully graduate from

IITs with a STEM degree in India are prone to take more R&D-related risks. These IIT graduates are more inclined towards R&D later in life as corporate board members, thus leading the firm to put more effort and persistence into innovation.

As discussed in the previous section, a firm's human resources possess the capacity not just to influence the firm's performance but also to determine the innovation effort. In a framework of an agency relationship, the foundation of corporate governance consists of the firm's different management levels, and the board of directors is the highest and prime importance. In this respect, the top management of the firm, where the personal characteristics and behaviour of the board members play an essential role, makes the majority of the decisions concerning production or R&D.

On a similar note, resource dependence theory asserts that the individual characteristics of the directors, including their education, affect a firm's R&D effort and its value (Dalziel et al., 2011; Hillman et al., 2009). Hence, the board of directors' organizational values and cognitive abilities are critical in key corporate decisions. Features such as tenure, age, and educational background then play important roles in decision-making.

Therefore, following the above mechanism of top-STEM education and cognitive abilities, we hypothesize the following relationship for the structure of corporate governance and innovation effort:

*Hypothesis: Firms having director/s with an IIT-Bachelors' degree in their corporate boards should have a significant positive relationship with the firm's innovation effort.*

We also explore the broad array of related questions, such as the importance of incremental education attainment over IIT-Bachelors' degree.

#### **4. Data and descriptive statistics**

We use three different datasets. The first one, which gives us the indicators of the innovation effort, is the CMIE-Prowess<sup>7</sup> dataset. It provides financial details of 20,000 firms listed on the Bombay Stock Exchange (BSE), of which 5,000 firms belong to the manufacturing sector. CMIE collects the financial details of those firms through the firm's published annual reports. The broad spectrum of firms in the database constitutes 70% of the economic activity of the organized industrial sector in India. To classify firms by industry affiliation, we sort them into industries at a level equivalent to a two-digit standard industrial classification (SIC) and use categories for 32 distinct industries<sup>8</sup>.

The second dataset is the NSE-Infobase, which consists of the firm's board of director-level details. This dataset provides all of the detailed personal information at the director level of the firm listed at the National Stock

Exchange (NSE). The database offers details on the personal demographic characteristics, all education details, and the history of directorial positions.

The third dataset is the one we use to address our endogeneity issue, which is based on the data on post-secondary education enrolment. The data has been collected and compiled from the Ministry of Human Resource Development, India (HRD)<sup>9</sup>.

This paper covers ten years (2006-2015). The year 2006 is chosen as starting year because the WTO's TRIPs agreement became binding from 2005 onwards as India has a ten-year transition period (1995-2005) to make the domestic legislation compatible with TRIPs. Apart from that, NSE-Infobase, i.e., the board of directors' dataset, is only available from 2006. Concerning the CMIE database, and specifically the R&D<sup>10</sup> figures and categories, several papers like Kathuria and Das (2005), Aggarwal (2018), Nair & Bhattacharyya (2019), and Jose et al. (2020), among others, use the CMIE database. It is the only available firm-level database covering different financial details, including most of the R&D activities, widely used in the stated context. Concerning NSE-Infobase, the information is available at the director/individual level. Given that our analysis is at the firm-level, we converted this directorial/individual level dataset by aggregating them to the board level and ultimately to the firm-level.

The final dataset consists of an unbalanced panel of 6151 firms belonging to 32 different two-digit manufacturing industries spanning ten years, from 2006 to 2015.<sup>11</sup> This broad dataset has a combination of all firms that engage in R&D. Given, the nature of the dataset, the majority of the firms engage in some sort of R&D.<sup>12</sup>

#### 4.a. Descriptive statistics

**Table 1.** Distribution of directors with IIT-Bachelor's degree and their other education qualifications

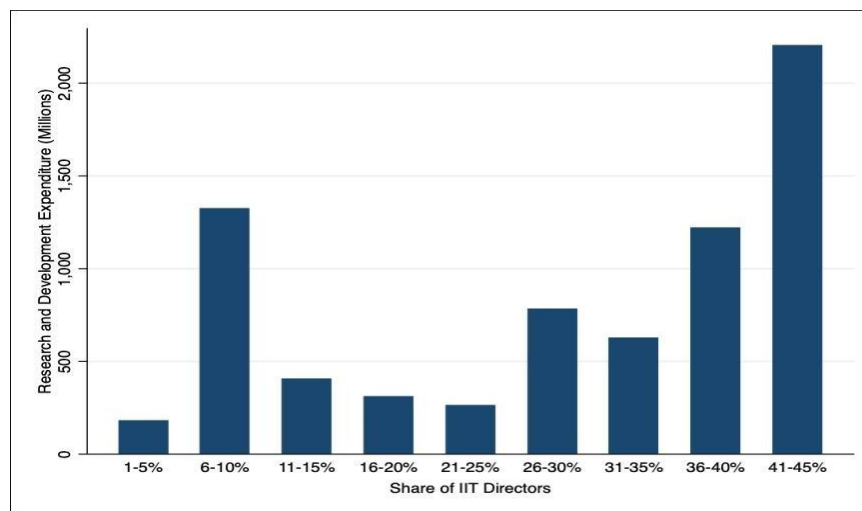
| <b>Directors</b>             | <b>Total numbers</b> | <b>% of total</b> |
|------------------------------|----------------------|-------------------|
| All Directors                | 15140                |                   |
| IIT-Bachelor's qualification | 2372                 | 15.67%            |
| IIT and Postgraduate         | 2309                 | 15.25%            |
| IIT and IIM                  | 541                  | 3.60%             |
| IIT and PhD                  | 762                  | 5.03%             |
| IIT and Foreign Degrees      | 825                  | 5.45%             |

*Source: Author's calculations*

Table 1 presents the primary distribution of directors with IIT-Bachelor's qualifications (IIT Undergraduate Degree). Directors with IIT-Bachelor's

qualifications comprise 16% of the total. Many directors with IIT undergraduate qualifications have a postgraduate degree, and around 5% have a Ph.D. over IT-Bachelor's qualification. Most of these directors obtained their Ph.D. abroad, mainly from different top universities in the US, Canada, Europe, and Australia. 5.45% of directors with an IIT degree have a degree from a foreign country (mainly from the abovementioned countries) over their IIT-Bachelor's degree.

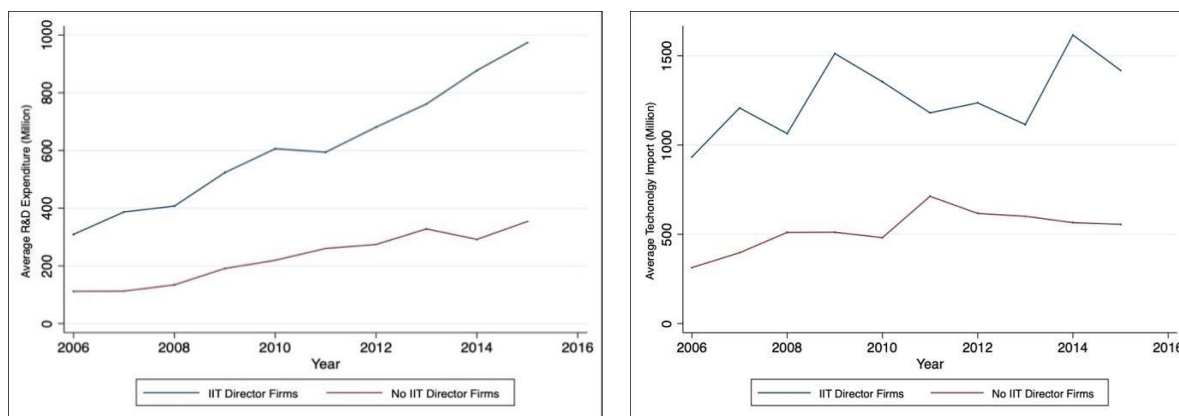
**Figure 1:** Share of the board of directors of firms having IIT-Bachelor's qualification and R&D expenditure



*Source: Author's calculations*

Figure 1 shows the share of firms' board of directors with IIT-Bachelor's qualification and their respective average R&D expenditures. Boards with 41-45% of directors with an IIT qualification spend the most on R&D, followed by 6-10%. In the 26-45% range, most of the R&D-oriented firms with "IIT and Ph.D." directors are concentrated. For the 11-25% range, less R&D-oriented firms with no or fewer directors with "IIT and PhD" degrees are concentrated. This finding, specifically the relationship between high "IIT and PhD" and R&D expenditure, carries important implications for results obtained from the regression analysis.

**Figure 2:** Comparison of R&D expenditure and Technology imports of firms with IIT-Bachelor's qualification and with no IIT-Bachelor's qualification from 2006 to 2015.



(a) R&D expenditure of firms with IIT-Bachelor's directors and with no IIT-Bachelor's directors  
(b) Technology imports of firms with IIT-directors and with no IIT-Bachelor's directors

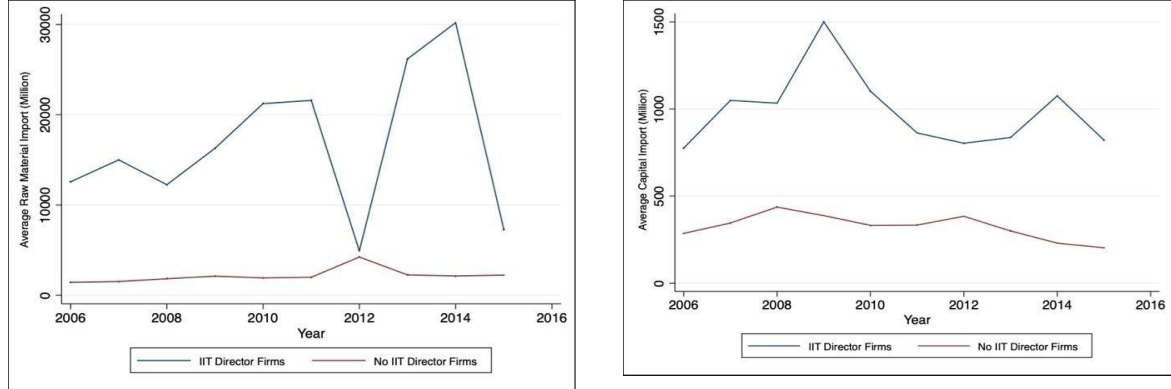
Source: Author's calculations

Figure 2 combines the firm-level R&D information with the board of directors of firms having IIT-Bachelor's qualifications. Over ten years, firms with directors with IIT-Bachelor's qualifications tend to put more effort into innovation by spending in R&D. In terms of the expenditure in R&D, firms with directors having IIT-Bachelor's qualification in their boards tend to spend more in R&D compared to other firms.

For most emerging economies, technology import is the primary source of technology transfer and innovation effort. Regarding technology imports, firms with directors with IIT-Bachelor's qualifications on their boards tend to import more than others. Though there are a few ups and downs, the technology imports of firms with directors having IIT-Bachelor's qualifications remained higher than the firm with no IIT-Bachelor's directors.

In emerging economies, many firms face budget constraints to carry out innovation, which forces them to import raw materials or capital, limiting the resources to invest in R&D (Naude et al., 2011). In the case of India, the relevance of the import of capital and raw material increased post- 1991 reform, as firms became free to import capital or raw materials without any hindrance (Sasidharan & Kathuria, 2011).

**Figure 3:** Comparison of Raw material imports and Capital imports of firms with IIT-Bachelor's director and with no IIT-Bachelor's directors from 2006 to 2015.

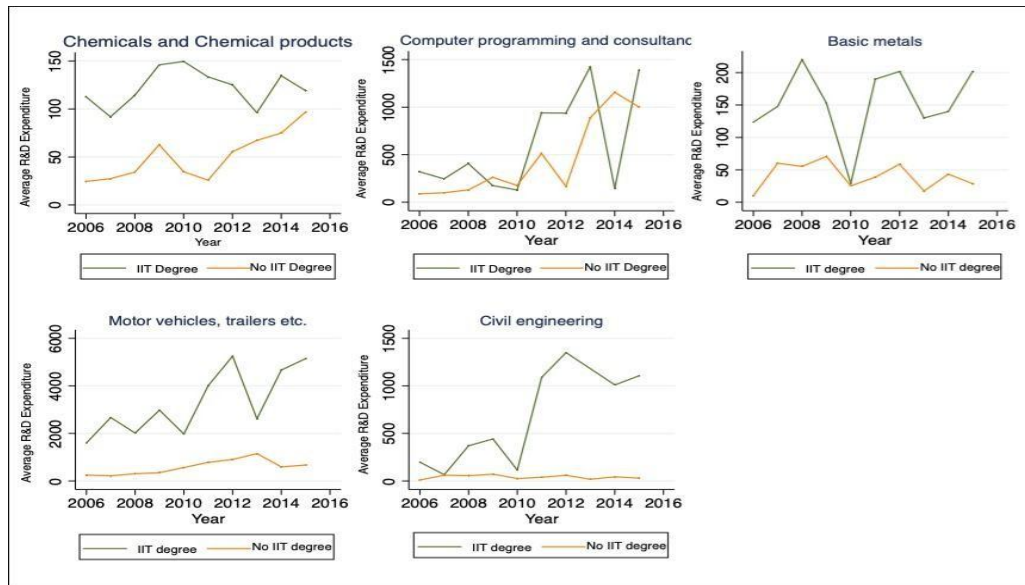


(a) Raw material imports of firms with IIT-directors and with no IIT- Bachelor's directors

(b) Capital imports of firms with IIT-Bachelor's directors and with no IIT-directors

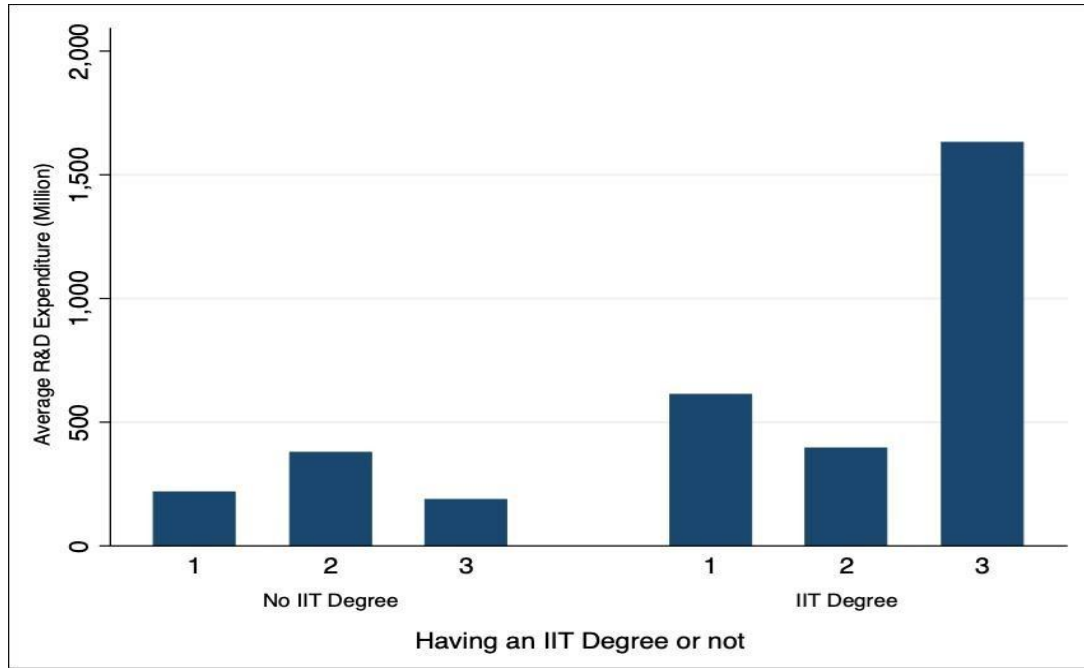
Figure 3 compares the extent of raw material imports and capital imports for firms with and without directors having IIT-Bachelor's qualifications in their boards. Overall, the raw material and capital imports for the firms with directors with IIT-Bachelor's qualifications on their boards have remained high compared to others.

**Figure 4:** Comparison of R&D expenditure for the top five R&D spending industries on the basis of having a director with IIT-Bachelor's qualification and with no IIT-Bachelor's qualification from 2006 to 2015.



We also looked at the top five R&D spending industries (Figure 4) to see whether the above-stated trend is visible. For most of the years across the industries presented, overall, firms with directors having IIT-Bachelor's qualifications on their boards tend to spend more on R&D.<sup>13</sup>

**Figure 5:** Firm Ownership, directors with IIT-Bachelor's qualification and corresponding R&D expenditure.



*Note: Domestic firm= 1, Foreign firm=2, and Government-owned firms=3*

Though initial statistics show that IIT-Bachelor's seemed to be an essential factor in the innovation effort, we look at the ownership pattern of firms to observe what type of firms place IIT-Bachelor's qualifications as directors. Figure 5 shows that irrespective of the ownership patterns, R&D spending of firms is lower if they do not have any directors with IIT-Bachelor's qualifications. Among those, government-owned firms tend to have more of them, and directors with IIT- Bachelor's qualifications are generally in high demand among Indian firms, be they private or domestic, compared to foreign firms. Figure 5 shows that government-owned firms with directors having IIT-Bachelor's qualifications on their boards tend to spend more on R&D compared to other types of firms.

#### 4.b. Dependent variable

As stated earlier in the sections, we use R&D as the primary indicator to capture the innovation effort. In R&D, we use three measures; R&D expenditure<sup>14</sup> (Fu and Gong, 2011; Santos et al., 2014), R&D intensity (R&D\_Sales\_Ratio) (Driver and Guedes, 2012; Chen et al., 2013; Hwang et al., 2013; Schmid et al. 2014; Kuo

et al., 2018), and R&D investment ratio (R&D\_Total\_Asset\_Ratio) (Hwang et al., 2013; Singh and Gaur, 2013; Kuo et al., 2018). Following the above stated literature, R&D expenditure variable is constructed by combining firm's capital and current expenditures on R&D activities and CMIE database directly reports these two variables. The final R&D expenditure variable has been deflated using the CPI values provided by the Reserve Bank of India (RBI)<sup>15</sup>. The R&D intensity variable is constructed by taking the ratio of R&D expenditure variable to total sales of the firm. Finally, the R&D investment ratio is constructed by taking the ratio of R&D expenditure to total assets of the firm. The total asset of the firm is calculated by adding firm's owner's equity to its liabilities.

#### **4.c. Variables of interest**

The prime variable of interest is directors with IIT-Bachelor's qualifications in a firm's board. We use two variables under our primary variable of interest. We use, first, IIT-Bachelor's directors as a dummy variable, which assigns a value of 1 if the board of that firm has any directors with IIT- Bachelor's qualification and 0 otherwise. Second, we use the share of IIT-Bachelor's directors in a board, which is IIT-Bachelor's directors in a board divided by the total size of the board in a specific year.

#### **4.d. Control variables**

Based on the literature, our control variables may influence a firm's composition of the board, corporate governance, and other critical firm-level characteristics. We consider three essential variables influencing firm performance and innovation effort at the board level: board size, composition, and gender. The board size of a firm may determine the extent of its performance and valuation. Yermack (1996) stated that board size negatively affects the firm's valuation, and a small board of directors is more effective. We define fraction of insider-outsider as the number of outside directors and independent directors, scaled by board size. Fich and Shivdasani (2012) used board composition to indicate the extent of outside directors. They found that a higher fraction of outside directors positively impacts the firm's performance and return on assets. Furthermore, the literature argues that gender diversity has a positive impact on firm performance; radical innovation; patent outcome; and reduction of fraud (Adams and Ferreira, 2009; Díaz-García et al., 2013; Chen et al., 2013; Cumming and Leung, 2021).

At the firm level, we consider the traditional control variables, i.e., firm size, firm age, ROA (return on total assets), debt ratio, free cash flow, number of segments, sales growth, and ownerships. We measure firm size by the firm's total financial valuation and sales (Kumar and Aggarwal, 2005; Kuo et al., 2018). Many previous studies argue that the firm's age can play an important role in determining R&D capabilities, positively affecting the number of innovations it



brings up (Hansen, 1992). Different market and firm-level factors act as complementary factors in the spectrum of influence of age on innovation efforts (García-Quevedo et al., 2014).

Following Bhagat (2017), we measure profitability by the return on total assets (ROA), calculated as the median return on total assets for all firms listed under the Indian National Industrial Code (two-digit NIC). Though mixed, most previous studies found a negative relationship between ROA and R&D (Hitt et al., 1991). This outcome supports the prospect theory (Kahneman and Tversky, 1979), in which the managers take a more risk-averse stance as firms' performance and R&D capacity improve.

To address the impact of a firm's capital structure, we incorporate a financial leverage variable in our model measured as a ratio of debt to total assets (Block, 2012; Munari et al., 2010). Debt financing generally requires a stable stream of cash flows, which affects the fund diversion of innovation projects and the firm's financial wealth. Also, we include cash flows (the ratio of cash flows to equity to the dividend to the total book value of assets) to account for the firm's liquidity status. The elasticity of ordinary and R&D investments concerning cash flow is generally positive, but there could be variation from country to country (Hall, 1992).

We also try to capture the extent of business diversification of firms in terms of their products using the number of business groups in which a firm operates within the specified two digits NIC in India (Khanna and Palepu, 2000). The impact of business diversification on innovation in the larger body of literature is inconclusive. Baysinger and Hoskisson (1989) argued that business diversification strategy consistently impacts R&D intensity in diverse and multiproduct firms. However, Hsieh et al. (2010) contended that diversification based on the business group positively affects firm-level innovation (context of Taiwan). The positive relationship between diversification and innovation stems from the logic of knowledge sharing (Cohen and Levinthal, 1990).

We use the net sales growth rate following Kuo et al. (2018) to measure firm-level growth. Recent studies (Fich and Shivdasani, 2012; Bhagat and Bolton, 2013) state that firm growth is essential while considering the firm's performance. But concerning R&D, Kuo et al. (2018) found that growth proxied by sales growth tends to affect the R&D performance of the firm.

We use ownership data to control whether a domestic/foreign, private or government entity owns the firm. Park et al. (2018) suggested that foreign ownership does not matter for R&D intensity in Japan. Still, overall foreign ownership may boost the chances of carrying out R&D<sup>16</sup>. For the context of India, Aggarwal (2018) suggested that most foreign-owned firms tend to spend less on R&D rather than focus on cheap technology transfer. In India, most of

the R&D performing firms used to be only foreign rather than domestic firms<sup>17</sup>, but it has changed since the last decade. We may expect that with foreign ownership, the probability of carrying out R&D activities may increase compared to domestic firms (Sasidharan and Kathuria, 2011), but not necessarily high R&D.

#### 4.e. Summary statistics

Table 2 presents the summary statistics for the main variables and board and firm-level control variables. We have 6151 observations considered for the final analysis after eliminating irregularities from the dataset. The summary statistics below display the values before taking logarithms.

**Table 2:** Summary statistics of dependent and explanatory variables

| Variables                                           | Mean    | P25     | Median | P75    | SD      | Min    | Max     |
|-----------------------------------------------------|---------|---------|--------|--------|---------|--------|---------|
| <b>Board Level</b>                                  |         |         |        |        |         |        |         |
| Board Size                                          | 11.57   | 8       | 10     | 14     | 5.12    | 3      | 25      |
| Share of IIT- Bachelor's                            | 3.89    | 2.24    | 0.91   | 6.67   | 7.50    | 0      | 50      |
| Share of IIT- qualification- PhD                    | 1.45    | 0.92    | 0.86   | 2.67   | 2.04    | 0      | 25      |
| Share of IIT- qualification - Foreign Degree        | 1.04    | 0.52    | 0.77   | 1.89   | 2.53    | 0      | 42      |
| Share of Female Directors                           | 5.10    | 2.22    | 2.10   | 9.50   | 7.01    | 0      | 50      |
| Share Independent Director                          | 53.58   | 46.15   | 54.54  | 61.53  | 12.86   | 0      | 100     |
| Share Insider Director                              | 46.41   | 38.46   | 45.45  | 53.85  | 12.86   | 0      | 100     |
| Term Length                                         | 7.66    | 3.49    | 5.95   | 10.34  | 5.74    | 0.04   | 42.58   |
| <b>Firm level</b>                                   |         |         |        |        |         |        |         |
| R&D Expenditure (Million Rupees)                    | 372.32  | 8       | 33.33  | 148.1  | 1451.51 | 0      | 22043   |
| R&D intensity (in %) (R&D_Sales_Ratio)              | 5.00    | 0.02    | 0.04   | 3.21   | 1.12    | 0      | 54.09   |
| R&D Investment Ratio (in %) (R&D_Total_Asset_Ratio) | 1.10    | 0.28    | 0.62   | 1.68   | 1.2     | 0      | 2.1     |
| Age                                                 | 31.04   | 14.76   | 26.00  | 36.10  | 19.34   | 5      | 49.69   |
| ROA (in %)                                          | 93.07   | 45.78   | 83.63  | 95.66  | 60.07   | 5      | 98      |
| Size (Million Rupees)                               | 2519.09 | 1145.53 | 1517.4 | 2875.7 | 14758.6 | 8.72   | 3298.95 |
| Debt Ratio (in %)                                   | 34.67   | 7.22    | 31.48  | 38     | 31      | 3.33   | 201.74  |
| Cash Flow Ratio (in %)                              | 1.79    | 0.23    | 0.50   | 3.26   | 0.14    | -0.30  | 46.33   |
| Business Diversification                            | 1.52    | 1       | 1      | 3      | 0.76    | 1      | 8       |
| Growth                                              | 178.18  | 0       | 8.05   | 22.90  | 635.058 | -99.99 | 304.60  |
| Number of observations                              | 6151    |         |        |        |         |        |         |

Figures in Table 2 indicate that the average R&D expenditure is 372.32 million

rupees, whereas the average R&D intensity and investment ratio is 5 and 1.1 percent. Firms in our dataset have, on average, around 4 percent of their directors with an IIT-Bachelor's qualification. At the same time, boards have only 5 percent of female directors. In terms of firms operating in different business segments, most firms are operating in at least one business segment/s. The average firm age in our dataset is around 31 years.

Table 3 below presents the Pearson correlations among variables. Correlations are consistent with our hypothesis that a higher fraction of the board of directors with IIT-Bachelor degrees positively correlates with innovation effort. The table indicates that the extent of correlation among the variables is low. The correlation matrix points toward the direction of our predictions; however, correlation does not control causality and shows an association. It cannot capture the genuine causal relationship (John, 1995). Hence, in the next section, we discuss the empirical results in more detail, exploring the nature of the proposed relationship between innovation efforts and IIT- Bachelors.

**Table 3:** Correlations among the variables in consideration

|                                            | R&D<br>expenditu<br>re | R&D<br>intensity<br>(R&D_S<br>ales_Rati<br>o) | R& D<br>investment<br>(R&D_Tota<br>l_Asset_Ra<br>tio) | Fraction<br>of IIT<br>graduates | Only IIT | Board<br>Size | Owner<br>ship | Fracti<br>on of outsid<br>e direct<br>or | ROA   | Age   | Firm<br>size | Debt<br>ratio | FCF   | Busi<br>ness<br>diver<br>sifica<br>tion | Gro<br>wth | Gend<br>er |
|--------------------------------------------|------------------------|-----------------------------------------------|-------------------------------------------------------|---------------------------------|----------|---------------|---------------|------------------------------------------|-------|-------|--------------|---------------|-------|-----------------------------------------|------------|------------|
| R&D expenditure                            | 1                      |                                               |                                                       |                                 |          |               |               |                                          |       |       |              |               |       |                                         |            |            |
| R&D intensity<br>(R&D_Sales_Ratio)         | 0.52                   | 1                                             |                                                       |                                 |          |               |               |                                          |       |       |              |               |       |                                         |            |            |
| R& D investment<br>(R&D_Total_Asset_Ratio) | 0.57                   | 0.54                                          | 1                                                     |                                 |          |               |               |                                          |       |       |              |               |       |                                         |            |            |
| Fraction of IIT graduates                  | 0.70                   | 0.65                                          | 0.67                                                  | 1                               |          |               |               |                                          |       |       |              |               |       |                                         |            |            |
| Only IIT                                   | 0.70                   | 0.62                                          | 0.68                                                  | 0.82                            | 1        |               |               |                                          |       |       |              |               |       |                                         |            |            |
| Board Size                                 | 0.23                   | 0.02                                          | 0.01                                                  | 0.60                            | 0.24     | 1             |               |                                          |       |       |              |               |       |                                         |            |            |
| Ownership                                  | -0.002                 | 0.009                                         | -0.01                                                 | 0.07                            | 0.04     | -0.11         | 1             |                                          |       |       |              |               |       |                                         |            |            |
| Fraction of outside director               | 0.16                   | -0.02                                         | 0.07                                                  | 0.06                            | 0.14     | 0.46          | 0.02          | 1                                        |       |       |              |               |       |                                         |            |            |
| ROA                                        | 0.03                   | -0.08                                         | 0.04                                                  | -0.06                           | -0.07    | -0.02         | -0.04         | 0.02                                     | 1     |       |              |               |       |                                         |            |            |
| Age                                        | 0.09                   | 0.07                                          | 0.09                                                  | 0.07                            | 0.12     | 0.24          | -0.18         | 0.09                                     | 0.02  | 1     |              |               |       |                                         |            |            |
| Firm size                                  | 0.39                   | 0.11                                          | 0.03                                                  | 0.18                            | 0.27     | 0.48          | -0.12         | 0.23                                     | 0.22  | 0.27  | 1            |               |       |                                         |            |            |
| Debt ratio                                 | -0.041                 | -0.01                                         | 0.18                                                  | -0.06                           | -0.03    | -0.06         | 0.15          | -0.02                                    | 0.09  | -0.12 | -0.09        | 1             |       |                                         |            |            |
| FCF                                        | 0.006                  | 0.002                                         | 0.009                                                 | 0.03                            | 0.007    | -0.02         | -0.007        | 0.09                                     | -0.08 | 0.04  | -0.02        | -0.007        | 1     |                                         |            |            |
| Business diversification                   | -0.04                  | -0.02                                         | -0.05                                                 | 0.09                            | 0.1      | 0.15          | -0.07         | 0.038                                    | 0.009 | 0.15  | 0.18         | 0.02          | -0.01 | 1                                       |            |            |
| Growth                                     | 0.002                  | 0.03                                          | 0.02                                                  | -0.03                           | 0.008    | 0.01          | 0.01          | -0.07                                    | 0.02  | -0.04 | 0.11         | 0.02          | 0.01  | 0.05                                    | 1          |            |
| Gender                                     | -0.3                   | 0.06                                          | 0.01                                                  | 0.05                            | -0.05    | -0.26         | -0.023        | -0.03                                    | -0.02 | -0.03 | 0.023        | 0.02          | -0.01 | -0.04                                   | 0.05       | 1          |

## 5. Methodology and empirical econometric model

We apply three different models to investigate the relationship stated in our hypothesis. First, we apply OLS as baseline specifications. Second, we use the fixed effect regression to correct for firm-level heterogeneity since the analysis includes both cross-sectional and time series data. Finally, we employ 2SLS (IV) approach to correct for the endogeneity. We specify our model as follows:

$$Innovation\_Effort_{it} = \beta_0 + \beta_1 IIT\_Bachelors_{it} + \gamma X_{it} + \zeta Z_{it} + F_i + T_i + I_i + e_{it}$$

Our outcome variable is innovation effort (*Innovation\_Effort<sub>it</sub>*), which we proxied by *R&D\_expenditure*, *R&D\_Intensity* (*R&D\_Sales\_Ratio*), and *R&D\_Investment\_Ratio* (*R&D\_Total\_Asset\_Ratio*)

The main independent variable of interest is *IIT\_Bachelors<sub>it</sub>*. We initially use *IIT\_Bachelors\_Dummy*, a dummy variable, which assigns 1 if the board of the firm has director/s with IIT qualification. Later, to check whether more directors with IIT-Bachelor's qualification on the board is better or not for the innovation effort, we use *IIT\_Bachelors\_Share*. *X<sub>it</sub>* includes all of the board-level important control variables, whereas *Z<sub>it</sub>* includes all of the firm-level important control variables. Apart from them, *F<sub>i</sub>* is the firm-level fixed effect, *T<sub>i</sub>* is the industry trend, and *I<sub>i</sub>* is the industry fixed effect; and *e<sub>it</sub>* is an error term.

### Endogeneity

Other unobserved variables likely influence the proposed relationship between directors with IIT- Bachelor's qualifications and the innovation effort of a firm. For the above specification, corporate governance and entrepreneur literature highlight the issue of endogeneity<sup>18</sup> which might create bias in our analysis. We argue that having more directors with IIT-Bachelor's qualification on the boards might lead to high R&D opportunities, which in turn might enhance the productivity (performance) of the firm. Furthermore, the possibility of reverse causality also exists" higher innovation effort might induce a firm to hire more directors with IIT-Bachelor's qualification. Enhanced productivity will open more opportunities and scopes for R&D activities which, in turn, will attract or create more opportunities through campus placements after graduation for IIT graduates to join the firms. Thus, we contend that the variable *IIT\_Bachelors<sub>it</sub>* is endogenous, and there could be certain unobservable firm-level heterogeneity (firm's performance related) which will affect *IIT\_Bachelors<sub>it</sub>*.

To address the potential endogeneity issue, we adopt two alternative methods. First, we use the fixed effect model to address the issue of unobserved time-invariant heterogeneity by depending on within-firm variation over time. Second, we use the IV-2SLS approach to address the potential endogeneity of

our interest variable. Cumming and Leung (2021) contended that, in the case of China, regional demographics play an important role in determining the R&D of a firm with its board of directors having STEM qualifications. Following Triana and Garcia (2009), regions of a country with higher technological and pure science graduates tend to have higher proportions of graduates with such degrees. Regions with a higher number of social science graduates should have a higher share of social science graduates on boards of those regions. If the boards of regions deviate from their graduate demographic characteristics, such changes are reflected in biased appointments and could exacerbate the agency cost attached to boards. If the firm's board's diversity in terms of education, expertise, etc., reflects the region's demographic characteristics, then there is a lower likelihood of severe agency problems within the firm. Following that logic, and up to a lesser extent following McGuirk and Jordan (2012), Parrotta et al. (2010), we instrument the "IIT\_Bachelor's" on the total enrolment of students in STEM undergraduate degree in state/s that base firms having directors with IIT qualifications. We extracted all post-secondary school enrolment data from the Statistics of Higher and Technical Education and the All India Survey on Higher Education (AISHE). We then arranged the enrolment of post-secondary school STEM qualification by gender and each state of India from 2006-2015. Finally, we calculate total enrolment numbers and total enrolment ratios of STEM qualifications by state and gender-wise. Using an instrumental variable in this setting has three key benefits. First, complementing the fixed effect estimation with the instrumental variable allows us to test the robustness of the identification strategy by evaluating the stability of estimates based on two types of unrelated variations (Bolli et al., 2018). Second, the instrumental variable approach addresses endogeneity concerns caused by unobserved heterogeneity and reverse causality (Bolli et al., 2018). Third, apart from addressing unobserved heterogeneity issues, it will also address potential measurement error issues, as our data for the instrumental variable approach relies upon surveys/census.

Nevertheless, we also scan through different media stories of big and medium corporate firms and others for our instruments. The use of instruments is consistent with the view that R&D-driven firms do not appoint diverse boards and prefer people from STEM backgrounds from a top college (Cumming and Leung, 2021). Consistent with statements of appointment in practice<sup>19</sup>, we infer that regional educational demographics can directly influence board appointments. Still, they do not directly affect the innovativeness of the firm. That is, the diversity of the board in terms of education strongly reflects the current regional demographic characteristics as it influences the supply of available pool of directors in the present and future times.

Highly educated STEM board directors are always short in supply and high in demand (Gillan, 2006). Within each region of a country as diverse as India,

there are differences in the general population regarding gender, educational attainment, STEM environment, and experience. For example, in some areas of the country, such as the South, where educational attainment is higher, focus on science-based education and scientific training is prevalent. In turn, it is natural to expect that the board of directors from these regions will comprise a higher number of people with STEM or advanced STEM degrees with specializations (Carter et al., 2010). But the regional educational demographics generally do not have a direct causal impact on the innovation capacity of a firm, and prior studies have not recognized a causal effect on regional educational demography and innovation effort.

Our dataset shows little connection between the regional STEM qualification and innovation effort. But while looking at all top STEM institutes, states with more STEM graduates tend to have firms that also reflect those characteristics in their boards. Thus, the regional STEM educational enrolment could be an exogenous instrument to predict the extent of the IIT-Bachelor's director's influence in the innovation effort. Still, it is uncorrelated with the innovation effort. Hence, we specify our first stage regression as follows;

$$IIT\ Bachelors_{it} = \beta' STEM\_Enrolment_{sit} + \delta X_{it} + S_i + e' \quad (2)$$

Here,  $STEM\_Enrolment_{sit}$  indicates the Enrolment of undergraduate students in STEM the state  $S$  in year  $t$ , where the firm  $i$  based.  $X_{it}$  is the vector of all of the important control variables. Finally,

$S_i$  is a vector of fixed effects indicating all of fixed effects such as the state fixed effect, firm fixed effect, and industry fixed effect; and  $e'$  is an error term. The crucial identifying assumption in this model is that, conditional on the controls, the Enrolment of undergraduate students in STEM courses in all states of India is orthogonal to the error term in (1). Hence, under this identification assumption, our estimate of  $\beta$  in (1) will be interpretable as the causal impact of having IIT- Bachelor's degree holders in the board on innovation effort of the firm.

## 6. Results and discussions

### 6.a. Main results: Innovation effort and directors with IIT-Bachelor's qualification

To test hypothesis 1, we first run the OLS as a baseline; then, we run our fixed effect panel data estimates. In our first specification, we use the dummy variable of IIT-Bachelor's, and later we use the share of IIT-Bachelor's. Table 4 presents the results of baseline OLS and Fixed effect regressions on three indicators for innovation effort, i.e., R&D expenditure, R&D intensity, and R&D investment ratio.

**Table 4:** Baseline OLS and Fixed effect Regression of Innovation Effort and directors with IIT- Bachelor's qualification

|                            | <b>Panel A</b><br><i>R&amp;D Expenditure</i> |                      | <b>Panel B</b><br><i>R&amp;D Intensity</i><br>(R&D_Sales_Ratio) |                         | <b>Panel C</b><br><i>R&amp;D Investment Ratio</i><br>(R&D_Total_Asset_Ratio) |                           |
|----------------------------|----------------------------------------------|----------------------|-----------------------------------------------------------------|-------------------------|------------------------------------------------------------------------------|---------------------------|
| <b>Dependent variables</b> | <i>OLS</i>                                   | <i>FE</i>            | <i>OLS</i>                                                      | <i>FE</i>               | <i>OLS</i>                                                                   | <i>FE</i>                 |
| <b>IIT-Bachelors_Dummy</b> | 143.9***<br>(60.93)                          | 135.58***<br>(49.87) | 0.042<br>(0.059)                                                | 0.043<br>(0.62)         | 0.008***<br>(0.0003)                                                         | 0.001***<br>(0.0004)      |
| Log(Board_size)            | 106.5<br>(87.27)                             | 40.67<br>(87)        | 0.12<br>(0.084)                                                 | 0.12<br>(0.09)          | -0.002<br>(0.0004)                                                           | 0.003<br>(0.0004)         |
| Frac_Insider_Outsider      | 117.62***<br>(30.84)                         | 147.47**<br>(71.99)  | 0.026<br>(0.029)                                                | 0.03<br>(0.03)          | 0.00005<br>(0.0001)                                                          | 0.00009<br>(0.0002)       |
| Board_Gender_Dummy         | -291.17**<br>(133.62)                        | -267.79<br>(204.59)  | 0.068<br>(0.123)                                                | 0.08<br>(0.14)          | 0.0007<br>(0.0006)                                                           | 0.0005<br>(0.0005)        |
| Ownership_Dummy            | 194.47**<br>(102.26)                         | 166.06***<br>(69.03) | -0.031<br>(0.099)                                               | -0.03<br>(0.1)          | 0.0005<br>(0.0006)                                                           | 0.00008<br>(0.00050)      |
| ROA                        | -1.08<br>(0.97)                              | -0.84* (0.5)         | -0.00006<br>(0.0009)                                            | 0.0002<br>(0.0004)      | 0.0002***<br>(5.47E-06)                                                      | 0.0004***<br>(4.24E-06)   |
| Ln(Age)                    | 63.05<br>(51.28)                             | 60.17<br>(48.94)     | -0.092*<br>(0.049)                                              | -0.094* (0.05)          | -0.0004**<br>(0.0002)                                                        | -0.0004<br>(0.0003)       |
| Log(Size)                  | 408.98***<br>(23.12)                         | 417.37***<br>(63.82) | 0.12***<br>(0.022)                                              | -0.13***<br>(0.024)     | 0.0006***<br>(0.00009)                                                       | 0.0004***<br>(0.0001)     |
| Debt_Ratio                 | 0.718<br>(1.37)                              | 2.36<br>(1.6)        | -0.002<br>(0.001)                                               | -0.002<br>(0.0016)      | 0.0002***<br>(4.89E-06)                                                      | 2.37e-08<br>(6.36E-06)    |
| Cash_Flow_Ratio            | -0.0002<br>(0.004)                           | 0.00003<br>(0.0018)  | -1.70E-07<br>(4.71E-06)                                         | -7.11E-08<br>(5.00E-06) | -2.31E-09<br>(2.24E-08)                                                      | 1.43e-08***<br>(6.43E-09) |
| Business_Diversification   | -94.78***<br>(37.82)                         | -86.78***<br>(23.99) | 0.02<br>(0.03)                                                  | 0.02 1<br>(0.038)       | 0.00003<br>(0.0002)                                                          | -0.00004<br>(0.0001)      |
| Growth                     | -1.29<br>(0.81)                              | -1.48*** (0.65)      | 0.002**<br>(0.00080)                                            | 0.001**<br>(0.0008)     | -4.77E-09<br>(2.27E-08)                                                      | -4.42E-09<br>(3.20E-09)   |
| Intercept                  | Yes***                                       | Yes***               | Yes***                                                          | Yes***                  | Yes***                                                                       | Yes***                    |
| Industry Fixed Effect      | Yes                                          | No                   | Yes                                                             | No                      | Yes                                                                          | No                        |
| Year Fixed Effect          | Yes                                          | Yes                  | Yes                                                             | Yes                     | Yes                                                                          | Yes                       |
| Firm Fixed Effect          | Yes                                          | Yes                  | Yes                                                             | Yes                     | Yes                                                                          | Yes                       |
| Industry Trend             | No                                           | Yes                  | No                                                              | No                      | No                                                                           | No                        |
| Number of Observations     | 6151                                         | 4837                 | 6151                                                            | 4837                    | 6151                                                                         | 4837                      |
| Adjusted R2                | 0.251                                        | 0.16                 | 0.261                                                           | 0.16                    | 0.1145                                                                       | 0.17                      |
| F value                    | 16.87                                        | 8.66                 | 11.38                                                           | 5.21                    | 11.6                                                                         | 12.05                     |

(a) Note: The coefficients and p-values (in parentheses) are reported. Heteroscedasticity robust standard errors are shown in brackets. \*, \*\*, and \*\*\* indicate a significance level of 10%, 5%, and 1%, respectively. Industry dummies include 32 industrial categories, and time dummies include nine time periods. In panel A we have R&D expenditure as the dependent variable, in panel B, we have R&D intensity (R&D\_Sales\_Ratio), and in panel C, we have R&D investment ratio (R&D\_Total\_Asset\_Ratio) as the main dependent variable to indicate the extent of the innovation effort.

Panel A of Table 4, where we take R&D expenditure as a dependent variable, reports that *IIT -Bachelors\_Dummy* is positive and significant at a 5% level. This indicates that firms that have directors with IIT-Bachelor's qualifications tend to spend more on R&D compared to other firms that do not have any of



them on their boards. Similar to R&D expenditure, the coefficients are positive for R&D intensity in panel B and R&D investment ratio in panel C. But, in panel B, *IIT – Bachelors\_Dummy* is insignificant, whereas, in Panel C, *IIT – Bachelors\_Dummy* is positive and significant at a 1% level. While our main interest variable in Panel B is insignificant, the overall results indicate a positive association between IIT-Bachelor's qualifications of directors and innovation effort indicated by R&D. Thus, Hypothesis 1 is supported. We find a similar outcome in our Fixed effect result. Though the signs and significance level are similar to OLS, their intensity is smaller than OLS since fixed effect regression controls for the firm-level unobserved heterogeneity.

Apart from OLS in panel C, board size has a positive sign, but it is not significant in any of the specifications. These results add to the literature's existing mixed response to board size. In both OLS and fixed effect, *Frac\_Insider\_Outsider* is positive, but only significant in panel A. The gender dummy is negative and significant at 5% in panel A, adding to a few debates where researchers argue that gender diversity is attributed to risk aversion, affecting R&D effort (Barber and Odean, 2001; Byrnes et al., 1999). The ownership estimator is only positive and significant in panel A (OLS and fixed effect), showing that Indian firms tend to spend more than foreign firms. The firm size estimator is positive and significant (as in Bolli et al., 2018, and Kumar and Aggarwal, 2005) in all specifications (except for the fixed effect part of panel B). While the firm's age does not have much impact on the R&D expenditure, it negatively affects both R&D intensity and the R&D investment ratio. It indicates that in old firms, organizational rigidities, and rent-seeking behaviour causes lower firm performance (Fich and Shivdasani, 2012; Loderer and Waelchli, 2010). The coefficients are negative in panel A in the business diversification variable, measured by the firm's presence in different business segments. In the rest of the panels, they are insignificant, though signs may vary. A negative sign of this variable may indicate the fact that higher diversification takes out the attention from innovation effort and performance too, similar to outcomes contented by Baysinger and Hoskisson (1989), Hitt et al. (1991), and Fich and Shivdasani (2012).

#### **5.a. Innovation effort and many directors with IIT-Bachelor's qualification, the better?**

In this section, rather than taking the primary interest variable as a dummy variable, we take it as a continuous variable. We define a new interest variable, which is *IIT – Bachelors\_Share*. We define it as the total share of directors in a firm's board that has an IIT-Bachelor's degree in a given year. This section checks if having a higher percentage of directors with an IIT-Bachelor's degree has any significant positive impact on the innovation effort of the firm. The idea is here to confirm the prevalent narrative in the Indian corporate scenario, which believes

that more directors with IIT-Bachelor's degrees can positively enhance the firm performance<sup>20</sup>.

**Table 5:** OLS and Fixed effect regression of innovation effort and share of directors with IIT- Bachelors qualification

| Dependent variables          | Panel A<br><i>R&amp;D Expenditure</i> |           | Panel B<br><i>R&amp;D Intensity<br/>(R&amp;D_Sales_Ratio)</i> |            | Panel C<br><i>R&amp;D Investment Ratio<br/>(R&amp;D_Total_Asset_Ratio)</i> |            |
|------------------------------|---------------------------------------|-----------|---------------------------------------------------------------|------------|----------------------------------------------------------------------------|------------|
|                              | <i>OLS</i>                            | <i>FE</i> | <i>OLS</i>                                                    | <i>FE</i>  | <i>OLS</i>                                                                 | <i>FE</i>  |
| IIT-Bachelors_               | 7.9**                                 | 7.95**    | 0.0032                                                        | 0.0031     | 0.00003*                                                                   | 0.00004*** |
| Share                        | (4.12)                                | (3.83)    | (0.004)                                                       | (0.0042)   | (0.000018)                                                                 | (0.00001)  |
| Log(Board_size)              | 127.09                                | 59.65     | 0.122                                                         | 0.13       | 0.00016                                                                    | 0.0002     |
|                              | (87.03)                               | (84.4)    | (0.84)                                                        | (0.899)    | (0.0004)                                                                   | (0.0003)   |
| Frac_Insider_Outsider        | 118.70***                             | 148.67*** | 0.026                                                         | 0.026      | 0.00006                                                                    | 0.0001     |
|                              | (30.85)                               | (71.69)   | (0.29)                                                        | (0.33)     | (0.0001)                                                                   | (0.0002)   |
| Board_Gender_<br>Dumm y      | -290.34**                             | -267.29   | 0.069                                                         | 0.00003    | 0.0007                                                                     | 0.00058    |
|                              | (133.68)                              | (205.24)  | (0.129)                                                       | (0.00007)  | (0.0006)                                                                   | (0.0005)   |
| Ownership_Dummy              | 197.52**                              | 166.52**  | -0.033                                                        | -0.029     | -0.0005                                                                    | 0.0001     |
|                              | (102.37)                              | (69.63)   | (0.099)                                                       | (0.0.1)    | (0.0006)                                                                   | (0.0002)   |
| ROA                          | -1.09                                 | -0.87*    | 0.00005                                                       | 0.0002     | 0.000018***                                                                | 0.00003*** |
|                              | (0.97)                                | (0.5)     | (0.0009)                                                      | (0.0004)   | (5.47E-08)                                                                 | (4.22E-06) |
| Ln(Age)                      | 64.6                                  | 61.73     | -0.092*                                                       | -0.094*    | -0.0003                                                                    | -0.0004    |
|                              | (54.49)                               | (48.03)   | (0.049)                                                       | (0.052)    | (0.0002)                                                                   | (0.0003)   |
| Log(Size)                    | 410.35***                             | 418.69*** | -0.12***                                                      | -0.13***   | 0.0006***                                                                  | 0.0004***  |
|                              | (23.12)                               | (62.96)   | (0.02)                                                        | (0.024)    | (0.00009)                                                                  | -0.0001)   |
| Debt_Ratio                   | 0.803                                 | 2.5       | 0.0019                                                        | 0.0024     | 0.00002***                                                                 | -1.11E-07  |
|                              | (1.37)                                | (1.62)    | (0.0013)                                                      | (0.0016)   | (4.89E-06)                                                                 | (6.40E-06) |
| Cash_Flow_Ratio              | -0.0002                               | 0.00004   | -1.83E-07                                                     | -8.06E-08  | -2.05E-09                                                                  | 1.47e-08** |
|                              | (0.004)                               | (0.0017)  | (4.71E-06)                                                    | (5.00E-06) | (2.24E-08)                                                                 | (6.51E-09) |
| Business_Diversificati<br>on | -96.93***                             | -88.63*** | 0.022                                                         | 0.02       | 0.00003                                                                    | -0.00004   |
|                              | (37.88)                               | (24.05)   | (0.037)                                                       | (0.38)     | (0.0001)                                                                   | (0.00015)  |
| Growth                       | -1.27                                 | -1.44**   | 0.0016**                                                      | 0.0017**   | -4.98E-09                                                                  | 3.67E-09   |
|                              | (0.81)                                | (0.64)    | (0.0007)                                                      | (0.0008)   | (2.27E-08)                                                                 | (3.24E-09) |
| Intercept                    | Yes***                                | Yes***    | Yes***                                                        | Yes***     | Yes***                                                                     | Yes***     |
| Industry Fixed Effect        | Yes                                   | No        | Yes                                                           | No         | Yes                                                                        | No         |
| Year Fixed Effect            | Yes                                   | Yes       | Yes                                                           | Yes        | Yes                                                                        | Yes        |
| Firm Fixed Effect            | Yes                                   | Yes       | Yes                                                           | Yes        | Yes                                                                        | Yes        |
| Industry Trend               | No                                    | Yes       | No                                                            | No         | No                                                                         | No         |
| Number of<br>Observations    | 6151                                  | 2267      | 6151                                                          | 2267       | 6151                                                                       | 4837       |
| Adjusted R2                  | 0.25                                  | 0.1594    | 0.139                                                         | 0.16       | 0.1245                                                                     | 0.598      |
| F value                      | 16.81                                 | 10.95     | 5.95                                                          | 11.65      | 11.52                                                                      | 13.11      |
| Board_Gender_<br>Dumm y      | -290.34**                             | -267.29   | 0.069                                                         | 0.00003    | 0.0007                                                                     | 0.00058    |
|                              | (133.68)                              | (205.24)  | (0.129)                                                       | (0.00007)  | (0.0006)                                                                   | (0.0005)   |
| Ownership_Dummy              | 197.52**                              | 166.52**  | -0.033                                                        | -0.029     | -0.0005                                                                    | 0.0001     |
|                              | (102.37)                              | (69.63)   | (0.099)                                                       | (0.0.1)    | (0.0006)                                                                   | (0.0002)   |
| ROA                          | -1.09                                 | -0.87*    | 0.00005                                                       | 0.0002     | 0.000018***                                                                | 0.00003*** |
|                              | (0.97)                                | (0.5)     | (0.0009)                                                      | (0.0004)   | (5.47E-08)                                                                 | (4.22E-06) |

| Dependent variables      | Panel A              |                      | Panel B                            |                         | Panel C                                         |                          |
|--------------------------|----------------------|----------------------|------------------------------------|-------------------------|-------------------------------------------------|--------------------------|
|                          | R&D Expenditure      |                      | R&D Intensity<br>(R&D_Sales_Ratio) |                         | R&D Investment Ratio<br>(R&D_Total_Asset_Ratio) |                          |
| Ln(Age)                  | 64.6<br>(54.49)      | 61.73<br>(48.03)     | -0.092*<br>(0.049)                 | -0.094*<br>(0.052)      | -0.0003<br>(0.0002)                             | -0.0004<br>(0.0003)      |
| Log(Size)                | 410.35***<br>(23.12) | 418.69***<br>(62.96) | -0.12***<br>(0.02)                 | -0.13***<br>(0.024)     | 0.0006***<br>(0.00009)                          | 0.0004***<br>-0.0001)    |
| Debt_Ratio               | 0.803<br>(1.37)      | 2.5<br>(1.62)        | 0.0019<br>(0.0013)                 | 0.0024<br>(0.0016)      | 0.00002***<br>(4.89E-06)                        | -1.11E-07<br>(6.40E-06)  |
| Cash_Flow_Ratio          | -0.0002<br>(0.004)   | 0.00004<br>(0.0017)  | -1.83E-07<br>(4.71E-06)            | -8.06E-08<br>(5.00E-06) | -2.05E-09<br>(2.24E-08)                         | 1.47e-08**<br>(6.51E-09) |
| Business_Diversification | -96.93***<br>(37.88) | -88.63***<br>(24.05) | 0.022<br>(0.037)                   | 0.02<br>(0.38)          | 0.00003<br>(0.0001)                             | -0.00004<br>(0.00015)    |
| Growth                   | -1.27<br>(0.81)      | -1.44**<br>(0.64)    | 0.0016**<br>(0.0007)               | 0.0017**<br>(0.0008)    | -4.98E-09<br>(2.27E-08)                         | 3.67E-09<br>(3.24E-09)   |
| Intercept                | Yes***               | Yes***               | Yes***                             | Yes***                  | Yes***                                          | Yes***                   |
| Industry Fixed Effect    | Yes                  | No                   | Yes                                | No                      | Yes                                             | No                       |
| Year Fixed Effect        | Yes                  | Yes                  | Yes                                | Yes                     | Yes                                             | Yes                      |
| Firm Fixed Effect        | Yes                  | Yes                  | Yes                                | Yes                     | Yes                                             | Yes                      |
| Industry Trend           | No                   | Yes                  | No                                 | No                      | No                                              | No                       |
| Number of Observations   | 6151                 | 2267                 | 6151                               | 2267                    | 6151                                            | 4837                     |
| Adjusted R2              | 0.25                 | 0.1594               | 0.139                              | 0.16                    | 0.1245                                          | 0.598                    |
| F value                  | 16.81                | 10.95                | 5.95                               | 11.65                   | 11.52                                           | 13.11                    |

(a) Note: The coefficients and p-values (in parentheses) are reported. Heteroscedasticity robust standard errors are shown in brackets. \*, \*\*, and \*\*\* indicate a significance level of 10%, 5%, and 1%, respectively. Industry dummies include 32 industrial categories, and time dummies include nine time periods. In panel A we have R&D expenditure as the dependent variable, in panel B, we have R&D intensity (R&D\_Sales\_Ratio), and in panel C, we have R&D investment ratio (R&D\_Total\_Asset\_Ratio) as the main dependent variable to indicate the extent of the innovation effort.

Results in Table 5 indicated that in all specifications except for panel B, the *IIT –Bachelors\_Share* variable is positive and significant at various levels. In panel A, in both OLS and FE, *IIT – Bachelors\_Share* is positive and significant at 5 percent, whereas in panel B, though it is positive but insignificant. In Panel C, though it is positive and significant at 10 and 1 percent in OLS and FE, the extent of the positive impact is small. Most board and firm-level control variables follow the signs and significance levels observed in previous results in the preceding sections. The results indicate that firms with a higher share of directors with an IIT-Bachelor's degree seem to have higher R&D expenditure and R&D investment ratio but not R&D intensity. Thus, we contend that a higher share of IIT-Bachelor's directors in a firm put relatively more effort into their innovation effort by making more coherent, scientific, and informed R&D decisions.

## 6.b. Innovation effort, directors' IIT-Bachelor's qualification, and incremental educational attainment

In this section, we test whether the positive effect of IIT directors is solely coming from IIT- Bachelor's qualification or the advanced degree above IIT-Bachelor's undergraduate qualification. We contend that incremental educational attainment beyond a bachelor's degree could foster and ignite IIT students' research ability and mindset. Thus, we segregate the IIT-Bachelor's directors based on educational attainment into a total of 4 categories. First, directors with only an IIT- Bachelor's degree. Second, directors who have an IIT-Bachelor's degree and a postgraduate degree. Third, directors with IIT-Bachelor's degree as well as a Ph.D. degree. Last, directors with an IIT-Bachelor's degree and an advanced degree from abroad<sup>21</sup>. We report the results for incremental educational attainment in Table 6.

**Table 6:** OLS and Fixed effect regression of Innovation Effort, directors with IIT-Bachelor's and advanced qualifications

| Dependent variables   | Panel A<br><i>R&amp;D Expenditure</i> |           | Panel B<br><i>R&amp;D Intensity</i><br>(R&D_Sales_Ratio) |          | Panel C<br><i>R&amp;D Investment Ratio</i><br>(R&D_Total_Asset_Ratio) |             |
|-----------------------|---------------------------------------|-----------|----------------------------------------------------------|----------|-----------------------------------------------------------------------|-------------|
|                       | OLS                                   | FE        | OLS                                                      | FE       | OLS                                                                   | FE          |
| IIT-Bachelors(only    | 74.93                                 | 99.08*    | 0.19                                                     | 0.023    | -0.0007**                                                             | -0.001**    |
| IIT graduates)        | (69.97)                               | (51.23)   | (0.06)                                                   | (0.07)   | (0.0003)                                                              | (0.0004)    |
| IIT-Bachelors_PG      | -84.78                                | -6.17     | -0.05                                                    | -0.062   | 0.0006                                                                | 0.00067     |
|                       | (168.69)                              | (229.45)  | (0.167)                                                  | (0.17)   | (0.0009)                                                              | (0.001)     |
| IIT-Bachelors_ PHD    | 744.42***                             | 800.47*** | 0.31                                                     | 0.014    | 0.0014*                                                               | 0.0018*     |
|                       | (128.03)                              | (330.26)  | (0.12)                                                   | (0.13)   | (0.0007)                                                              | (0.001)     |
| IIT- Bachelors_       | 258.39**                              | 260.17    | 0.06                                                     | 0.062    | 0.0005                                                                | 0.0008      |
| FORGN                 | (103.66)                              | (206.55)  | (0.1)                                                    | (0.1)    | (0.006)                                                               | (0.0006)    |
| Log(Board_size)       | 99                                    | 39        | 0.11                                                     | 0.12     | -0.00013                                                              | 0.00002     |
|                       | (86.21)                               | (84.27)   | (0.08)                                                   | (0.09)   | (0.0004)                                                              | (0.0003)    |
| Frac_Insider_Outsider | 98.95***                              | 129.41*   | 0.023                                                    | 0.027    | 0.00005                                                               | 0.00009     |
|                       | (30.53)                               | (70.26)   | (0.09)                                                   | (0.033)  | (0.0001)                                                              | (0.0002)    |
| Board_Gender_         | -279.70**                             | -262.67   | 0.07                                                     | 0.079    | 0.0007                                                                | 0.0005      |
| Dummy                 | (131.93)                              | (195.3)   | (0.13)                                                   | (0.14)   | (0.0006)                                                              | (0.0005)    |
| Ownership_Dummy       | 181.2*                                | 157.57*** | -0.31                                                    | 0.024    | -0.0005                                                               | 6.15E-06    |
|                       | (101.04)                              | (63.69)   | (0.09)                                                   | (0.033)  | (0.0006)                                                              | (0.0006)    |
| ROA                   | -0.9                                  | -0.79*    | -0.0006                                                  | 0.0002   | 0.00002                                                               | 0.0003***   |
|                       | (0.96)                                | (0.47)    | (0.0009)                                                 | (0.0004) | (5.47E-06)                                                            | (4.27E-06)  |
| Ln(Age)               | 59.18                                 | 56.66     | -0.092*                                                  | -0.095*  | -0.0003                                                               | 0.0004      |
|                       | (50.61)                               | (47.04)   | (0.049)                                                  | (0.050)  | (0.0002)                                                              | (0.0003)    |
| Log(Size)             | 386.73***                             | 392.64*** | 0.122***                                                 | -0.127** | 0.0005***                                                             | 0.00038***  |
|                       | (22.98)                               | (59.12)   | (0.022)                                                  | (0.024)  | (0.00009)                                                             | (0.001)     |
| Debt_Ratio            | 0.933                                 | 2.62*     | -0.002                                                   | -0.0024  | 0.0002***                                                             | -1.64E-08   |
|                       | (1.34)                                | (1.56)    | (0.001)                                                  | (0.016)  | (4.89E-06)                                                            | (6.63e- 06) |

| Dependent variables      | Panel A             |                      | Panel B                            |                         | Panel C                                         |                          |
|--------------------------|---------------------|----------------------|------------------------------------|-------------------------|-------------------------------------------------|--------------------------|
|                          | R&D Expenditure     |                      | R&D Intensity<br>(R&D_Sales_Ratio) |                         | R&D Investment Ratio<br>(R&D_Total_Asset_Ratio) |                          |
| Cash_Flow_Ratio          | -0.0002<br>(0.004)  | 9.61E-06<br>(0.001)  | -1.58E-07<br>(4.27E-06)            | -6.93E-08<br>(5.00E-06) | 2.53E-09<br>(2.24E-08)                          | 1.44e-08**<br>(6.55E-08) |
| Business_Diversification | -84.53**<br>(37.43) | -75.32***<br>(24.97) | 0.02<br>(0.03)                     | 0.02<br>(0.39)          | 0.00004<br>(0.0001)                             | -0.00002<br>(0.0001)     |
| Growth                   | -1.55**<br>(0.8)    | -1.76***<br>(0.66)   | 0.0016**<br>(0.0008)               | 0.0017**<br>(0.0008)    | -3.71E-09<br>(2.27E-08)                         | 5.20E-09<br>(3.97E-09)   |
| Intercept                | Yes***              | Yes***               | Yes***                             | Yes***                  | Yes***                                          | Yes***                   |
| Industry Fixed Effect    | Yes                 | No                   | Yes                                | No                      | Yes                                             | No                       |
| Year Fixed Effect        | Yes                 | Yes                  | Yes                                | Yes                     | Yes                                             | Yes                      |
| Firm Fixed Effect        | Yes                 | Yes                  | Yes                                | Yes                     | Yes                                             | Yes                      |
| Industry Trend           | No                  | Yes                  | No                                 | No                      | No                                              | No                       |
| Number of Observations   | 6151                | 2267                 | 6151                               | 2267                    | 6151                                            | 2267                     |
| Adjusted R2              | 0.271               | 0.18                 | 0.293                              | 0.16                    | 0.115                                           | 0.598                    |
| F value                  | 17.53               | 6.95                 | 12.25                              | 11.65                   | 11.11                                           | 10.21                    |

(a) Note: The coefficients and *p*-values (in parentheses) are reported. Heteroscedasticity robust standard errors are shown in brackets. \*, \*\*, and \*\*\* indicate a significance level of 10%, 5%, and 1%, respectively. Industry dummies include 32 industrial categories, and time dummies include nine time periods. In panel A we have R&D expenditure as the dependent variable, in panel B, we have R&D intensity (R&D\_Sales\_Ratio), and in panel C, we have R&D investment ratio (R&D\_Total\_Asset\_Ratio) as the main dependent variable to indicate the extent of the innovation effort.

After incorporating different types of incremental educational attainment over IIT-Bachelor's qualification, only having an IIT-Bachelor's limits the effect of the innovation effort. IIT and PhD combined is strongly positive in all of the panel and is significant except for panel B. We could infer from this outcome that simply having an IIT-Bachelor's degree is important. However, to ignite the innovation potential of a firm and put maximum effort towards it, the directors would require a research degree like PhDs. Research degree over IIT-Bachelor's would unlock those IIT- bachelor directors' research mindset and abilities and provide the research aptitude/experience to carry out R&D.

In opposition to the expected results, Panel A *IIT – Bachelors\_Dummy* is only significant at 10 percent level in the fixed effect part of the panel. Contrary to that, in Panel C, *IIT – Bachelors\_(only IITgraduate)* is significant in both of the specifications along with IIT-Bachelor's and Ph.D. After iterations, the control variables from Table 6 remain somewhat similar in sign and significance. Overall, from this experiment, we note that the incremental educational attainment factor, mainly IIT-bachelors and Ph.D., plays a positive and significant role in explaining innovation efforts to some extent. This result holds essential conclusions for the overall narrative of this

paper. As we can see that only *IIT – Bachelor's* is insignificant, we could conclude that merely having an IIT (bachelors) degree is not sufficient for firm's innovation effort. Instead, having a research degree over an IIT-Bachelor's degree increases the effect on innovation. These results allow us to question the Indian firms' obsession with IIT-Bachelor's degrees in private and government sectors while disregarding research degrees. We observe that a good research degree along with an IIT- Bachelor's degree can contribute to a firm's innovation effort. Furthermore, most IIT-bachelor holders with a Ph.D. obtained their PhDs abroad rather than from the IITs. Only very few of the board of directors obtained their Ph.D. from IITs.

It makes sense that directors with a research degree positively affect R&D. We contend that the undergraduate degree holders may be intelligent, confident, and risk-takers but do not have a research-oriented mindset in particular required to make R&D-related decisions. The IIT- Bachelor's degree, however, lays the solid cognitive foundation for future STEM research-oriented degrees. Hence, when these IIT graduates complete their research degrees, they take back their strong research abilities to the firm's decision-making level. Therefore, we contend that this mix of IIT-Bachelor's degree, which provides strong STEM cognitive skills and a complementary STEM research degree, enhances the research abilities, which can positively impact a firm's innovation effort and simultaneously handle all R&D-related risks. Hence, we argue that a research degree alongside an IIT-Bachelor's degree acts as a solid complementary in boosting the innovation potential of the firm.

### **6.c. Endogeneity concerns and IV estimations**

In previous sections, we mentioned the potential endogeneity problem and the solutions to deal with the same. In this sub-section, we present the results from our instrumental variable estimation. We instrument *IIT\_Bachelors* with the total enrolment of students in STEM undergraduate degree in state/s that locate firms having directors with IIT-Bachelor qualifications. Table 7 presents the results, where we use the same instruments for all three panels.

**Table 7:** Endogeneity concerns and the results of IV estimations for innovation effort and IIT- Bachelor's qualified directors.

| Dependent variables      | Panel A <i>R&amp;D Expenditure</i> | Panel B <i>R&amp;D Intensity (R&amp;D_Sales_Ratio)</i> | Panel C <i>R&amp;D Investment Ratio (R&amp;D_Total_Asset_Ratio)</i> |
|--------------------------|------------------------------------|--------------------------------------------------------|---------------------------------------------------------------------|
|                          | <i>2SLS-IV</i>                     | <i>2SLS-IV</i>                                         | <i>2SLS-IV</i>                                                      |
| IIT-Bachelors_Share      | 39.03***<br>(11.6)                 | 0.011<br>(0.009)                                       | 0.0007<br>(0.0006)                                                  |
| Log(Board_size)          | 129.78*<br>(73.88)                 | 0.13<br>(0.105)                                        | -0.0003<br>(0.0004)                                                 |
| Frac_Insider_Outsider    | 116.66***<br>(46.31)               | 0.27<br>(0.021)                                        | 0.00003<br>(0.002)                                                  |
| Board_Gender_Dummy       | -307.9<br>(239.95)                 | 0.07<br>(0.057)                                        | 0.0002<br>(0.0006)                                                  |
| Ownership_Dummy          | 128.04*<br>(79)                    | -0.051<br>(0.04)                                       | -0.0011<br>(0.001)                                                  |
| ROA                      | -1.09<br>(1.17)                    | -0.0001<br>(0.0002)                                    | 0.00018***<br>(5.83E-06)                                            |
| Ln(Age)                  | 47.42<br>(42.58)                   | -0.103<br>(0.077)                                      | -0.00035<br>(0.0002)                                                |
| Log(Size)                | 393.78***<br>(40.87)               | 0.134<br>(0.1)                                         | 0.0007***<br>(0.0001)                                               |
| Debt_Ratio               | 1.25<br>(1.22)                     | -0.002<br>(0.0015)                                     | 0.0002***<br>(6.49E-06)                                             |
| Cash_Flow_Ratio          | -0.00096<br>(0.001)                | -2.63E-07<br>(1.12E-06)                                | -3.93E-10<br>(9.90E-09)                                             |
| Business_Diversification | -113.87***<br>(29.67)              | 0.017<br>(0.017)                                       | 0.00002<br>(0.0001)                                                 |
| Growth                   | -1.04*<br>(0.56)                   | 0.0017<br>(0.0018)                                     | -8.44E-09<br>(2.32E-08)                                             |
| Intercept                | Yes***                             | Yes***                                                 | Yes***                                                              |
| Industry Fixed Effect    | Yes                                | Yes                                                    | Yes                                                                 |
| Year Fixed Effect        | Yes                                | Yes                                                    | Yes                                                                 |
| Industry Trend           | Yes                                | No                                                     | No                                                                  |
| Number of Observations   | 2193                               | 2193                                                   | 4655                                                                |
| R2                       | 0.2524                             | 0.29                                                   | 0.1698                                                              |
| Wald – Chi <sup>2</sup>  | 67903.9                            | 21079.33                                               | 416.88                                                              |

(a) Note: The coefficients and *p*-values (in parentheses) are reported. Heteroscedasticity robust standard errors are shown in brackets. \*, \*\*, and \*\*\* indicate a significance level of 10%, 5%, and 1%, respectively. Industry dummies include 32 industrial categories, and time dummies include nine time periods. In panel A we have R&D expenditure as the dependent variable, in panel B, we have R&D intensity (R&D\_Sales\_Ratio), and in panel C, we have R&D investment ratio (R&D\_Total\_Asset\_Ratio) as the main dependent variable to indicate the extent of the innovation effort.

In Table 7, panel A, *IIT – Bachelors\_Share* variable is positive and significant at a 1 percent level, which suggests that the instrumental variables for IIT-Bachelor's directors have a positive and significant relationship with R&D expenditure. But, in the rest of the panels, the *IIT –*

*Bachelors\_Share* though positive, is not significant. This may indicate the fact that the impact of having more board members with IIT-Bachelors qualification can affect the R&D expenditure positively but does not necessarily have an effect on other indicators of the innovation effort which are ratios and can get influenced by sales and assets. Overall, we do see a positive and significant impact of IIT-Bachelor's qualification on R&D expenditure which indicates that higher the share of these confident directors in the boards high will be the risk taking behaviour leading more experiments with research and hence, higher R&D expenditure. We contented that this might be since, in India, when it comes to the innovation effort, firms tend to focus on the R&D expenditure more, given R&D tax benefits offered from the government's side.

**Table 8:** Weak instrument tests for instrumental variables.

| <b>Instrument:</b>                | Enrolment of STEM undergraduate degree students in state/s, where the firms that have board of directors with IIT-Bachelor's qualifications are situated. |                                                                 |                                                                              |
|-----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|------------------------------------------------------------------------------|
| <i>Tests</i>                      | <b>Panel A</b><br><i>R&amp;D Expenditure</i>                                                                                                              | <b>Panel B</b><br><i>R&amp;D Intensity</i><br>(R&D_Sales_Ratio) | <b>Panel C</b><br><i>R&amp;D Investment Ratio</i><br>(R&D_Total_Asset_Ratio) |
| Durbin                            | 15.74***<br>(0.0001)                                                                                                                                      | 1.41<br>(0.23)                                                  | 1.21<br>(0.27)                                                               |
| Wu Hausman                        | 8.88***<br>(0.0029)                                                                                                                                       | 1.28<br>(0.25)                                                  | 1.19<br>(0.2738)                                                             |
| First-stage F value               | 72.33***<br>(0.0000)                                                                                                                                      | NA                                                              | NA                                                                           |
| Minimum eigenvalue                | 72.1391***                                                                                                                                                | NA                                                              | NA                                                                           |
| 2SLS Size of nominal 5% Wald test | 64.69<br>-5%                                                                                                                                              | NA                                                              | NA                                                                           |
| Sargan                            | 27.82<br>-0.1137                                                                                                                                          | NA                                                              | NA                                                                           |
| Basman                            | 27.29<br>(0.1273)                                                                                                                                         | NA                                                              | NA                                                                           |

(a) Note: In brackets, we report the P values. In the 2SLS size of nominal 5% Wald test, we report the figure at 5% level. \*, \*\*, and \*\*\* indicate a significance level of 10%, 5%, and 1%, respectively. For detailed discussions about the endogeneity issue, please refer to section 4e.



To avert the problem of exogeneity of the endogenous variable, overidentification, and to test the validity of the instruments, we run a series of post-estimation tests. Table 8 presents the results of the post-estimation tests for all three specifications that lead us to confirm the validity of the instruments.

In Panel A, the endogenous variable satisfies the endogeneity test at a 1 percent level. In Panels B and C, however, the Durbin and Wu-Hausman test rejects the endogeneity, and we can proceed with the result obtained from OLS and Fixed effect regressions. But for Panel A, the IV approach is justified, given the presence of the endogeneity issue. The F value is high and significant at 1 percent in the first regression stage. For the eigenvalue, it is 72.19, and it is higher than the 2SLS size of the nominal 5% Wald test, which is 64.69%. These results justify the validity of our instruments for specification A. We also check for the possibility of over-identifications, which our tests reject. This exercise overall confirms validity of our instrument and results of the table 7 supporting our overall hypothesis.

## **7. Conclusion**

In this paper, we explored how an extensively competitive examination and degree obtained at the top STEM institutes may affect the innovation effort in India. This particular question and education qualification is essential because it unravels the mix of the board of directors' specific type of STEM educational attainment, India's fixation with that particular STEM education, and its broader implication for innovation. Though various institutions provide STEM education, we looked at only one specific set of top institutions in India, the Indian Institutes of Technology (IITs). Given that IITs are renowned for high-quality education, competitive entry, and entrepreneurship, we explore their contribution to the overall innovation ecosystem in India. Based on the datasets covering ten years from 2006 to 2015 for Indian firms, we determined a positive relationship between IIT-Bachelor's qualification of the board of directors and innovation efforts. Still, the effect is limited, and research training significantly strengthens this relationship.

The overall nexus of the IIT-Bachelor's qualification and innovation is not as simple as it looks. In all cases, the effect on R&D intensity remained insignificant while R&D expenditure and, to some extent, the R&D investment ratio were positive and significant. The positive impact confirms the importance of an IIT-Bachelor's qualification in the innovation effort. However, this positive relationship is not only driven by the IIT-Bachelor's degree. The research training of the board plays an essential role in determining innovation efforts.

Our results allow us to question the immense Indian focus and corporate and social pride attached to hyper-competitive examinations like IIT-Bachelor's.

When it comes to the issue of the innovation effort, the dominant narrative of valuing IIT-Bachelor's is sufficient for enhancing the effort but focusing and prioritizing research education should play an equally relevant role. Also, most of those with an IIT-Bachelor's and Ph.D. degree acquired their PhDs abroad. The lack of IIT graduates with an IIT Ph.D. also allows us to question India's preferential attitude towards only IIT-Bachelor's without much focus on enhancing the research infrastructure of the IITs itself.

The general trend in India is that there are more discussions over the IIT-Bachelor's degree but seemingly less focus on the research degrees and improving the research infrastructures of these premier institutes. Given that innovation requires not just requires confidence and risk-taking behaviour but also strong research aptitude. Hence, building a better research infrastructure should also grasp the government's attention as public. Better research infrastructure shall ignite the research abilities of young minds so that later in life, they can carry the same attitudes and aptitude to boost the innovation potential of the firm and the country.

Following our results, we suggest that first, from the perspective of the innovation effort, a focus should be on the research degree rather than simply on the IIT-Bachelor's. Second, with each state of India getting at least one IIT, aligning with our overall results, India may hope for better innovation efforts with more IIT-Bachelor's degree holders and creating more space for research at IITs. Third, determinants for sales/profits differ from innovation, so having an IIT-Bachelor's degree may enhance sales/profits. Still, for innovation efforts recognizing the importance of a Ph.D. degree, we must be cautious at directly linking both to frame national innovation and STEM education policy.

We recognize that the scope and aim of this research have limitations. There could be many relevant socioeconomic issues, such as Ph.D. and non-IIT education, as well as how caste dynamics can influence social mobility or the skewed gender ratio in STEM education and R&D. We recognize the importance of those elements. Still, we opt to leave them unaddressed in this article. These issues, though very pertaining, are out of the scope of this current research, being a topic for future extensions. The present work sets our base for more studies on the complex dynamics of India's STEM education and innovation.

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## Appendices

### A1. Descriptions of the variables

#### *Dependent variables*

| Dependent variable                                                | Descriptions                                                                                                                                                                              |
|-------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $R\&D\ Expenditure_{it}$                                          | Total R&D expenditure, including all capital and current expenditure of the firm $i$ the year $t$ . The R&D expenditure has been deflated CPI values provide by the Reserve Bank of India |
| $R\&D\ Intensity_{it}$<br>( $R\&D\_Sales\_Ratio$ )                | Ratio of R&D expenditure to the total sales (deflated) of the firm $i$ in the year $t$ .                                                                                                  |
| $R\&D\ Investment\ Ratio_{it}$<br>( $R\&D\_Total\_Asset\_Ratio$ ) | Ratio of R&D expenditure to the total assets of the firm $i$ in the year $t$ .                                                                                                            |

#### *Instrumental variables*

| Instrumental variables | Descriptions                                                                                      |
|------------------------|---------------------------------------------------------------------------------------------------|
| STEM Enrolment         | Enrolment of undergraduate students in STEM the state $S$ in year $t$ , where the firm $i$ based. |
| States                 | A dummy variable defining each state of India.                                                    |

#### *Independent variables*

| Independent Variable  | Descriptions                                                                                                                                                                                                                                  |
|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| IIT-Bachelors_Dummy   | A dummy variable, which assigns a value 1 if the board of firm $i$ has any directors with IIT-Bachelor's qualification and 0 otherwise, in the year $t$ .                                                                                     |
| IIT-Bachelors_Share   | Share which indicates the number of IIT-Bachelor's directors in a board divided by the size of the board of firm $i$ in the year $t$ .                                                                                                        |
| Log(Board_size)       | Log of the size of the board, i.e., number of directors of the board of firm $i$ in the year $t$ .                                                                                                                                            |
| Frac_Insider_Outsider | The number of outside directors and independent directors, scaled by board size of firm $i$ in the year $t$ .                                                                                                                                 |
| Board_Gender_Dummy    | Dummy variable indicating the gender status of the board of firm $i$ in the year $t$ . If the variable takes the value 1 if the board has at least a female director and if the variable is 0, then there is no female director in the board. |
| Ownership_Dummy       | Dummy variable indicating ownership structure. The variable takes the value 0 if the firm $i$ is owned by a foreign entity and if the variable is 1 then, it is owned by the Indian entity.                                                   |

|                          |                                                                                                                                                                                     |
|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ROA                      | Indicates return on assets, defined as the ratio of net income before interest, tax and depreciation to total assets of firm <i>i</i> in the year <i>t</i> .                        |
| Ln(Age)                  | Natural log of how old the firm <i>i</i> is in the year <i>t</i> based on its incorporation year.                                                                                   |
| Log(Size)                | Log of the size of the firm <i>i</i> in terms of its financial valuation and sales in year <i>t</i> .                                                                               |
| Debt_Ratio               | Defined as the ratio of total debts to total assets of firm <i>i</i> in the year <i>t</i> .                                                                                         |
| Cash_Flow_Ratio          | Defined as the ratio of cash flows to equity to the dividend to total book value of assets of firm <i>i</i> in the year <i>t</i> .                                                  |
| Business_Diversification | The total number of business groups in which firm <i>i</i> is operating within the specified 2-digit NIC in year <i>t</i> .                                                         |
| Growth                   | The percentage of the difference between the net sales of the current year and the previous year divided by the net sales of the previous year for firm <i>i</i> in year <i>t</i> . |

## A2. Robustness checks

**Table A.2.1.** Regressions with log (R&D expenditure)

| Dependent variables                | Panel A <sup>\$</sup><br><i>Log(R&amp;D Expenditure)</i> |                     | Panel B <sup>\$</sup><br><i>Log(R&amp;D Expenditure)</i> |                     | Panel C <sup>\$\$\$</sup><br><i>Log(R&amp;D Expenditure)</i> |                     |
|------------------------------------|----------------------------------------------------------|---------------------|----------------------------------------------------------|---------------------|--------------------------------------------------------------|---------------------|
|                                    | <i>OLS</i>                                               | <i>FE</i>           | <i>OLS</i>                                               | <i>FE</i>           | <i>OLS</i>                                                   | <i>FE</i>           |
| IIT-JEE_Dummy                      | 3.224***<br>(0.72)                                       | 0.223***<br>(0.072) |                                                          |                     |                                                              |                     |
| IIT-Bachelors Share                |                                                          |                     | 3.186***<br>(0.64)                                       | 0.149***<br>(0.039) |                                                              |                     |
| IIT-Bachelors (only IIT graduates) |                                                          |                     |                                                          |                     | 0.122*<br>(0.067)                                            | 0.126**<br>(0.57)   |
| IIT-Bachelors PG                   |                                                          |                     |                                                          |                     | -0.0153<br>(0.180)                                           | -0.006<br>(0.2)     |
| IIT-Bachelors PHD                  |                                                          |                     |                                                          |                     | 0.277**<br>(0.109)                                           | 0.285**<br>(0.101)  |
| IIT-Bachelors_FORGN                |                                                          |                     |                                                          |                     | 0.241**<br>(0.111)                                           | 0.236<br>(0.148)    |
| Log(Board_size)                    | 0.40***<br>(0.10)                                        | 0.335***<br>(0.112) | 0.349***<br>(0.092)                                      | 0.316***<br>(0.097) | 0.346***<br>(0.092)                                          | 0.258***<br>(0.097) |
| Frac_Insider_Outsider              | 0.62***<br>(0.35)                                        | 0.64**<br>(0.34)    | 0.007<br>(0.032)                                         | 0.002<br>(0.03)     | 0.009<br>(0.032)                                             | 0.005<br>(0.04)     |
| Board_Gender_Dummy                 | -0.123**<br>(0.59)                                       | -0.111<br>(0.148)   | -0.192*<br>(0.105)                                       | -0.187*<br>(0.1)    | -0.202**<br>(0.101)                                          | 0.197<br>(0.155)    |

|                          |                      |                       |                      |                      |                      |                       |
|--------------------------|----------------------|-----------------------|----------------------|----------------------|----------------------|-----------------------|
| Ownership_Dummy          | 0.47*<br>(0.26)      | 0.37***<br>(0.12)     | -0.031<br>(0.102)    | 0.051<br>(0.117)     | 0.229**<br>(0.108)   | 0.212**<br>(0.102)    |
| ROA                      | -0.08<br>(0.07)      | -0.05<br>(0.5)        | -0.00001<br>(0.0001) | -0.0008<br>(0.0005)  | -0.0003<br>(0.001)   | -0.0002<br>(0.005)    |
| Log(Age)                 | 0.13**<br>(0.058)    | 0.142**<br>(0.65)     | 0.151***<br>(0.054)  | 0.157***<br>(0.05)   | 0.153***<br>(0.054)  | 0.158***<br>(0.056)   |
| Log(Size)                | 0.91***<br>(0.068)   | 0.923***<br>(0.035)   | 0.841***<br>(0.024)  | 0.852***<br>(0.036)  | 0.869***<br>(0.024)  | 0.852***<br>(0.035)   |
| Debt_Ratio               | 0.003**<br>(0.013)   | 0.002<br>(0.002)      | 0.002*<br>(0.001)    | 0.0009<br>(0.0019)   | 0.002**<br>(0.001)   | 0.001<br>(0.02)       |
| Free_Cash_Flow           | -0.0002<br>(0.006)   | 0.00003<br>(0.0016)   | -0.00003<br>(0.0005) | 0.00002<br>(0.0005)  | -0.00003<br>(0.0008) | 0.00002<br>(0.0007)   |
| Business_Diversification | -0.85**<br>(0.041)   | -0.708*<br>(0.411)    | -0.057<br>(0.04)     | -0.019**<br>(0.0007) | -0.061<br>(0.04)     | -0.048<br>(0.038)     |
| Growth                   | -0.001**<br>(0.0009) | -0.002***<br>(0.0009) | -0.001**<br>(0.0008) | -0.047<br>(0.038)    | -0.001**<br>(0.0008) | -0.002***<br>(0.0006) |
| Intercept                | Yes***               | Yes***                | Yes***               | Yes***               | Yes***               | Yes***                |
| Industry Fixed Effect    | Yes                  | No                    | Yes                  | No                   | Yes                  | No                    |
| Year Fixed Effect        | Yes                  | Yes                   | Yes                  | Yes                  | Yes                  | Yes                   |
| Firm Fixed Effect        | Yes                  | Yes                   | Yes                  | Yes                  | Yes                  | Yes                   |
| Industry Trend           | Yes                  | No                    | No                   | No                   | No                   | No                    |
| Number of Observations   | 6151                 | 4837                  | 6151                 | 4837                 | 6151                 | 4837                  |
| Adjusted R2              | 0.548                | 0.426                 | 0.568                | 0.457                | 0.576                | 0.17                  |
| F value                  | 56.53                | 47.95                 | 62.52                | 86.58                | 58.81                | 12.05                 |
| Firm Fixed Effect        | Yes                  | Yes                   | Yes                  | Yes                  | Yes                  | Yes                   |
| Industry Trend           | Yes                  | No                    | No                   | No                   | No                   | No                    |
| Number of Observations   | 6151                 | 4837                  | 6151                 | 4837                 | 6151                 | 4837                  |
| Adjusted R2              | 0.548                | 0.426                 | 0.568                | 0.457                | 0.576                | 0.17                  |
| F value                  | 56.53                | 47.95                 | 62.52                | 86.58                | 58.81                | 12.05                 |

The coefficients and p-values (in parentheses) are reported. Heteroscedasticity robust standard errors are shown in brackets. \*, \*\*, and \*\*\* indicate a significance level of 10%, 5%, and 1%, respectively. Industry dummies include 32 industrial categories, and time dummies include nine time periods. In panel A we have R&D expenditure (deflated) as the dependent variable, in panel B, we have R&D intensity, and in panel C, we have R&D investment ratio as the main dependent variable to indicate the extent of the innovation effort.

\$ Panel A: Table 4 of main text with log(R&D expenditure), \$\$ Panel B: Table 5 of main text with log(R&D expenditure), \$\$\$ Panel C: Table 6 of main text with log(R&D expenditure).

**Table A.2.2. IV Regression with log(R&D expenditure)**

| Dependent variables      | R&D_Expenditure      |
|--------------------------|----------------------|
|                          | <i>2SLS-IV</i>       |
| IIT-Bachelors Share      | 0.44***<br>(0.016)   |
| Log(Board_size)          | 0.361***<br>(0.093)  |
| Frac_Insider_Outsider    | 0.089**<br>(0.0.41)  |
| Board_Gender_Dummy       | -0.181**<br>(0.85)   |
| Ownership_Dummy          | 0.118<br>(0.102)     |
| ROA                      | -0.00002<br>(0.008)  |
| Ln(Age)                  | 0.181***<br>(0.05)   |
| Log(Size)                | 0.835***<br>(0.033)  |
| Debt_Ratio               | -0.0018<br>(0.0015)  |
| Free_Cash_Flow           | 0.00009<br>(0.0003)  |
| Business_Diversification | -0.097***<br>(0.038) |
| Growth                   | -0.001*<br>(0.0008)  |
| Intercept                | Yes***               |
| Industry Fixed Effect    | Yes                  |
| Year Fixed Effect        | Yes                  |
| Industry Trend           | Yes                  |
| Number of Observations   | 2193                 |
| Adjusted R2              |                      |
| F value                  |                      |
| R2                       | 0.5782               |
| Wald - Chi2              | 86236.82             |

The coefficients and p-values (in parentheses) are reported. Heteroscedasticity robust standard errors are shown in brackets. \*, \*\*, and \*\*\* indicate a significance level of 10%, 5%, and 1%, respectively. Industry dummies include 32 industrial categories, and time dummies include nine time periods. Here, we have R&D expenditure (deflated) as the main dependent variable to indicate the extent of the innovation effort.

## Notes

- <sup>1</sup> Like in many emerging nations, India does not have a yearly National Innovation survey. For this reason, extraction of data from Indian patent database is a hard task. When searched in the database for data extraction we found mismatch among innovators, applicants, and address. This made it impossible to map patents back to firms in the CMIE database.
- <sup>2</sup> i.e. Ability to keep up with and assimilate the latest technology, acquire, process, evaluate information, and ability to resolve issues caused by problems related with R&D (Bhardwaj & Punia, 2013)
- <sup>3</sup> The IIT exam happens around May of every year. The subject matters of this exam are physics, chemistry and mathematics. Only 2% of student appearing receive an offer from IIT.
- <sup>4</sup> Some feature in the world's top engineering and science institutions list, such as IIT Delhi and IIT Mumbai.
- <sup>5</sup> There is even a far-fetched perception that the "Campus Placement" offers - made by firms recruiting IIT graduates - are highly lucrative; with attractive positive and salary, and sometimes possibility of being placed in reputed firm in OECD countries.
- <sup>6</sup> Parents and student's aspirations to join IITs are so high that some parents start preparing their kids for IIT from as early as grade 6. This has led to mushrooming of a huge coaching business across different cities of India whereby classes are offered to help clear the IIT-Bachelor's examination. The city of Kota in India is famous for IIT coaching classes, where students join them as early as grade 6-10 onwards. The whole craze about the IITs lead to a business which is estimated to be worth of more than 30 million Rupees. See <https://www.dailymail.co.uk/indiahome/indianews/article-2313660/Inside-Kotas-Rs-300-crore-coaching-industry-How-students-aiming-crack-IIT-JEE-join-mushrooming-institutes.html>
- <sup>7</sup> Prowess classifies industries as per the National Industrial Classification provided by the "Ministry of Statistics and Program Implementation", Government of India at the website (<http://mospi.nic.in>).
- <sup>8</sup> There are a total of 94 two-digit categories of industries in the standard industrial classification. But not all of the 94 industry-classifications are present in the CMIE dataset. Thus, we end up with only 32 different industrial classifications.
- <sup>9</sup> We collected the data from two reports, i.e. Statistics of Higher and Technical Education and All India Survey on Higher Education (AISHE). For few of the years data was not broken down into different educational streams; so we extrapolated them and predicted them based on the previous information.
- <sup>10</sup> There were certain abnormalities observed in terms of R&D spending to sales for certain firms which might have occurred due to human errors. We avoided those errors by excluding the R&D expenditure exceeding more than 3S.D (standard deviation) of the R&D expenditure to sales ratio.
- <sup>11</sup> For the purpose of our final analysis, we drop the anomalies observed in our dataset in order to maintain the consistency of our dataset as well as our analysis. Thus, whenever any anomalies are observed, we keep dropping or correcting them to keep our dataset as robust as possible.
- <sup>12</sup> Firms that rarely do R&D are operating in the food processing sector, furniture or wood and wooden products sector etc.
- <sup>13</sup> We found that the dataset has few anomalies, p
- <sup>14</sup> Even after correcting for all anomalies related to R&D expenditures, dropping unusual values, and controlling for firm size, there might be some concerns still left with regards to R&D expenditure. So, we scale it again by taking logarithm of R&D expenditure. The

- 
- results with and without log show similar outcome.
- <sup>15</sup> The widely accepted financial values and deflators can be accessed through: <https://www.rbi.org.in/>
- <sup>16</sup> They suggested that if a foreign corporate group from a technologically advanced nation establishes a subsidiary firm in a country, this may lower the average R&D intensity of firms in the local economy.
- <sup>17</sup> In many developing nations such as India and China the situation has been changing, specifically in the post-liberalization period. Many Chinese firms such as Huawei, ZTE, etc., and Indian firms such as TATA, Hero, etc., undertake R&D activities regularly.
- <sup>18</sup> Triana and Garcia (2009); McGuirk and Jordan (2012); Parrotta et al. (2010); Kuo et al. (2018); Cumming and Leung (2021); Bolli et al. (2018) etc. pointed to the existence of endogeneity in this context.
- <sup>19</sup> See examples likes of <https://careers.microsoft.com/us/en/diversityandinclusion>; <https://www.bmo.com/main/about-bmo/corporate-governance/board-of-directors/board-diversity/>; <https://diversity.google/annual-report/> etc.
- <sup>20</sup> <https://www.livemint.com/companies/news/iits-in-delhi-mumbai-churn-out-most-tech-entrepreneurs-1568652902193.html>
- <sup>21</sup> Almost all of the IIT-Bachelor's directors in this category have an advanced degree from prestigious universities of OECD countries, mainly USA, EU, Canada and Australia.

## Characterization of colombian industries under schumpeter's patterns of innovation

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### **Abstract**

The literature has continuously examined the relationship between market structure and innovation. In particular, Joseph Schumpeter's Mark I and Mark II innovation patterns inquired on what type of firm drives innovation based on competitive structures. Schumpeter marks, together with innovation systems theory have been widely used to classify productive sectors across the world. This article aims to deploy an exercise of this nature for Colombia in two steps. First, exploit innovation-related metrics, like stability of innovation, technological opportunities and market concentration, through an unsupervised learning method. Second, take advantage of geographical data to map and compare the sectors of each group. Statistical analysis of the cluster reveals that each group's features align with Mark I and II archetypes. Moreover, geographical information shows patterns of agglomeration similar to those previously explored in the literature. Policy implications are discussed afterwards, concluding that the need of heterogeneous policy designs that tackle specific regional features is paramount for the country, and a potential Colombian policy instrument to channel these findings is suggested.

**JEL Codes:** C38, L60, O30

**Key words:** radical innovations, incremental innovations, marketstructure, k-means clustering, innovation systems.



## Introduction

Who drives innovation within an industry? According to mainstream economics, a variety of factors influence on whether it is a small or established firm, among these, market structure, entry barriers, specialization, and patent legislation. The interaction of these factors is complex and multifaceted, and has spurred concepts like innovation systems, as they can concentrate or disperse efforts, disincentivize novel ideas in favor of established paradigms, place industries at the source of a supply chain, motivate cooperation, or foster the appropriation of gains from innovation.

The question of who drives innovation is both challenging and important, particularly for emerging countries seeking to develop. In this article, we will explore this by examining Joseph Schumpeter's Mark I and Mark II innovation patterns (Schumpeter, 1911; Schumpeter, 1942), Mark I contends that small firms are the primary drivers of innovation, while Mark II suggests that such role falls in large corporations. By examining these archetypes, we can gain a better understanding of the factors that contribute to innovation within different industries, laying the groundwork for potential policy implications.

According to Fontana et al, (2021), Mark I and Mark II innovation patterns have untapped potential for characterizing innovative activities within industries, and existing characterizations have been found to "*stand the test of time quite well*" (p. 19), Various studies have used these patterns to characterize industries at a national level, offering insights into innovation activities and providing a platform for innovation-related policy making (Breschi et al., 2000; Castellaei & Zheng, 2010; Malerba & Orsenigo, 1996),

However, these authors focus on developed economies, leaving aside characterization exercises in countries outside the global north, such as Colombia, On the other hand, while some studies have made cross-country comparisons (Malerba & Orsenigo, 1996; Breschi et al., 2000), regional differences have not been thoroughly explored. The role of regions in innovation has been recently acknowledged (Malerba & Breschi, 1997), and literature on the field has been emerging in the past years, pointing out that factors such as the type of knowledge, cultural diversity, wealth, institutional and geographical proximities shape much of the innovation process of a region (Gossling & Eutten, 2007; Boschma, 2005; Asheim et al., 2011), Such set of interactions has close similarities with Nelson's (1993) concept of Innovation Systems,

The limitations of existing literature place Colombia as a potential candidate for a study of this type. In one hand, as an emerging economy, it can add value to the understanding of the country's industrial landscape, specially in manufacturing, one of Colombia's most important industries, accounting for 10% of its Gross Domestic Product (GDP) and more than one-third of the economy's aggregated value chain (Arbelaez et al., 2021), On the other hand, the cultural influences of Colombia, reflected in strongly distinct features

across regions (Melo, 2017), motivate a regional analysis of its relationship towards industrial, and more specifically, innovative activities.

That said, this document will utilize data from Colombia's statistic department, known as the *Departamento Administrativo Nacional de Estadística* (DANE), Specifically, we will utilize DANE's (2020) *Encuesta de Desarrollo e Innovación Tecnológica* (EDIT) survey and DANE's (2019) *Encuesta Anual Manufacturera* (EAM) survey for manufacturers to characterize industries as Mark I or Mark II according to their International Standard Industrial Classification code (ISIC, or CIIU in Spanish), with a focus on Section C: Manufacturing, Furthermore, borrowing the idea from past literature, we will exploit geographical information to provide additional insights, but adding novelty with a focus across Colombia's regions instead of cross-country comparisons. Finally, concepts from innovation systems will prove useful in the concluding parts of this work, as they have close relationship with the topic.

This article will proceed in the following order: First, an examination of existing literature to provide background and identify key theoretical elements. Second, a methodology outline for processing and analyzing the data obtained from DANE's surveys. Third, presentation of quantitative results, highlighting significant findings and trends. Finally, concluding with potential policy implications and how the results can inform future innovation-related policies,

## **2. Relevant background literature**

### **The concept of innovation**

To establish a clear understanding of the concept of innovation and innovative activities, it is important to acknowledge that these concepts are contested in the literature. For this research, we will adopt the definition provided by the Organization for Economic Co-operation and Development (OECD) OSLO Manual (2018), According to the OECD, innovation is a "*New or improved product or process (or a combination thereof) that significantly differs from the unit's previous products or processes and has been made available to potential users (product) or brought into use by the unit (process)*" (p. 20),

The OSLO Manual acknowledges the subjective nature of innovation, which is the subject of an ongoing literature debate. However, in practice, innovation can be considered objective if we focus on shared motives such as novelty, utility, and significant differences. Accordingly, the manual defines innovative activities as "*all developmental, financial, and commercial activities undertaken by a firm that is intended to result in an innovation for the firm*" (p. 20), Although the concept is firm-centric, it can be applied to markets and industries as well.

Two taxonomies of innovation are relevant to this study. Schumpeter (1942) emphasizes on radical innovations, which depart from known opportunities, create novelty, and destroy something old. This creates the concept of "creative destruction." Conversely, Kirzner (1973) emphasizes on incremental innovations, arguing that human alertness to new opportunities yields more profits when directed toward enhancements that do not disrupt the *status quo* and operate within the realm of known opportunities.

### **Schumpeter, markets and innovation**

Market structure is a crucial factor for this study, and the literature has explored its impact on innovative activities. Lourv (1979) found that innovation incentives can reach optimal levels in a market with limited competitive firms, even if the number of firms falls below the traditional "entry until profits are zero" rule. The author also contends that atomistic competition is the ideal market structure for innovation.

Mansfield (1963) identified a correlation between firm size, market concentration, and the share of innovative activities. The author holds three propositions: innovation costs are high and only larger firms can afford them, innovation requires a large scale for success and failure to balance out, and firms need sufficient market control to reap the benefits of their innovations. As a result, large firms tend to carry out a disproportionate share of innovations.

Raider's (1998) research suggests that a combination of market structure and adversity drives innovation. The author found that firms facing high pressure from market competition tend to innovate more, while markets without this phenomenon tend to innovate less. Raider's analysis incorporates a network market approach. Here, constraints imposed by buyers and sellers, together with extreme upstream and downstream competition, can determine of innovation.

Before delving deeper into the relationship between innovation taxonomies and market structure, it is worth reviewing Schumpeter's (1911; 1942) pioneering work on differentiated innovation archetypes. In his book, *The Theory of Economic Development* (1911), Schumpeter uses a metaphor to encapsulate his early thoughts on new combinations and who carries them: "*new combinations are, as a rule, embodied, as it were, in new firms which generally do not arise out of the old ones but start producing beside them; (...) in general, it is not the owner of stagecoaches who builds railways*" (p. 66). This idea would be coined as Schumpeter's Mark I, which posits that entrant firms are the drivers of innovation,

Schumpeter's ideas evolved in his 1942 book "*Capitalism, Socialism and Democracy*," where he reflected on previous remarks, contrasting them with the continuous standard of living improvements during the era of unrestrained "*big business*." Upon examining this phenomenon, Schumpeter

discovered that recent productive improvements were largely attributable to large firms: " (...) *a shocking suspicion dawns upon us that big businesses may have had more to do with creating that standard of life than with keeping it down* " (p. 82), This perspective departs from Schumpeter's Mark I and becomes Mark II, Here, Schumpeter appoints tried and true, large corporations as the drivers of innovation,

Malerba & Orsenigo (1996) use the terms "*widening pattern*" and "*deepening pattern*" to describe Schumpeter's Mark I and Mark II, respectively. The former is characterized by fierce competition, low entry barriers, low appropriability, less technological opportunities and a large population of innovators, while the latter is defined by stable environments with large firms, high entry barriers, more technological opportunities, high appropriability and fewer players. Although these descriptions provide a useful starting point, we can further examine this relationship.

Two propositions can help us understand the relationship between innovation and market structure. Firstly, according to Gilbert (2006), the incentive for a firm to innovate is the difference in profits it can earn by doing so. Secondly, Arrow (1962) argues that innovation incentives are higher in competitive markets since existing monopoly power discourages new ideas, as the incumbent firm already profits from its operations, Baumol (2004) further supports this view, stating that "*major breakthroughs have tended to come from small new enterprises* " (p. 10), Thus, risky innovations that seek to disrupt markets are Mark I related,

Baumol (2004) continues: "*(...) while the invaluable incremental contributions that 'multiply capacity and speed, and increase reliability and user-friendliness have been the domain of the larger firms'*" (p. 10), This observation helps us define the market structure that is conducive to incremental innovations. Considering Arrow's replacement effect and Gilbert's statement on innovation incentives, we can argue that incremental innovations suit concentrated markets. While it is true that entry barriers and high resource endowments discourage new entrants, when it comes to innovation, monopolies have less incentives as it risks their existing profits. Thus, incremental innovation align with Mark II.

While it may look like both archetypes are opposites, Shapiro (2012) notes that they share underlying principles: both consider contestable markets and potential profits as drivers of innovation. In summary, the literature suggests that Mark I relates to dispersed markets, where small firms lead radical innovations, resulting in a highly competitive, turbulent, and unstable environment. In contrast, Mark II archetypes are observed in concentrated market structures, such as monopolies or oligopolies, where large firms focus on incremental innovations, resulting in a stable but less competitive market. In such markets, new ideas are disincentivized as they pose a threat to the dominant position of incumbents.

## The state of characterization GXGFC1SGS

Based on this, we can pinpoint a first prominent Schumpeterian characterization exercise in Malerba & Orsenigo (1996) article. There, Schumpeterian archetypes were identified across 49 technological classes of six countries: the US, Japan, Germany, France, the UK, and Italy. The study found that innovative activities vary across different technological classes. Moreover, innovation patterns within each technological class were similar in cross-country comparison, suggesting that knowledge-base features play a significant role. It is also important to remember that these were the authors that suggested the deepening and widening patterns exposed earlier,

Breschi et al, (2000) provide further evidence that aligns with earlier findings by Malerba & Orsenigo (1996), suggesting that patterns of innovative activities are similar across countries in the same technological class. Utilizing patent data from the United Kingdom, Germany, and France, as well as measures built from the *Policy, Appropriability and Competitiveness for European Enterprises* (PACE) questionnaire, the study reveals that Mark II is associated with high degrees of cumulativeness and appropriability, while Mark I is associated with low degrees of cumulativeness and appropriability. What is more, the authors suggest that a pattern of innovation is the result of multiple technological regimes, which at the same time, are the result of particular combinations of technological opportunities, appropriability of innovations, cumulativeness of technical advances, and properties of the knowledge base,

Fontana et al, (2012) builds upon the work of Breschi et al, (2000) by utilizing similar measures in their econometric exercise. Their findings maintain Mark I as the disperse and turbulent archetype, while Mark II is characterized as stable and concentrated. Landstrom & Schon (2010) make further distinction between these two, while noting some similarities between them. Notably, both patterns highlight the importance of innovation in economic development, and both require the capitalist to assume risk. This highlights the role of risk-taking in driving innovation,

Schumpeterian archetypes are not uncontested in the literature, Pavitt's (1984) taxonomy offers a classification based on the requirements of its users, the sources of its technologies, and the degree of appropriability in four different patterns: Supplier-dominated sectors; scale-intensive industries employing process and product innovation; specialized suppliers that market technology to other firms; finally, science-based, knowledge industries with a high degree of appropriability and tailored towards exploring innovative technological breakthroughs,

Archibugi (2001) has identified close links between Pavitt's taxonomy and Kondratiev's long waves of capitalist development, Castellaei (2008), in contrast, connects it to the sectors that fueled the growth of advanced economies during the Fordist era, Schumpeter's Mark I and II, on the other

hand, are anchored in the dynamics of an industry life cycle, Mark I characterizes the early stage of an industry, while Mark II refers to a more mature, late-stage phase (Malerba, 2005, as found in Maleki & Rosiello, 2014),

The selection of either Schumpeter's or Pavitt's framework depends on the scope and objectives of the research. Within the literature, Fontana et al, (2021), Breschi et al, (2000), Castellaei & Zheng (2010), Malerba & Orsenigo (1996), and Corrocher et al, (2007) have focused on Schumpeter's patterns, Breschi et al, (2000) drew upon elements from Malerba & Orsenigo (1996) but narrowed their study to three countries and omitted control variables for the effects of a country's national innovation system, Corrocher et al, (2007) aimed to distinguish sectors focused on information and communications technologies (ICT), while Castellaei & Zheng (2010) focused their efforts on industry- level productivity characterizations.

In contrast, authors like Van Dijk (2000), Marsili & Verspagen (2002), and Leiponen & Drejer (2007) advocated for an approach utilizing Pavitt's taxonomy. Van Dijk (2000) demonstrated that certain groups within Dutch manufacturing do not fit neatly into either of Schumpeter's archetypes. Similarly, Leiponen & Drejer (2007) observed a comparable phenomenon within Danish industries. Meanwhile, Marsili & Verspagen (2002) refined Pavitt's taxonomy by introducing a new classification proposed by one of the authors.

Focusing on those using Schumpeterian archetypes, they have developed measures to quantify them. For example, Malerba & Orsenigo (1996) approach, and eventually, Breschi et al, (2000) work tested variables such as concentration, entry, firm size, hierarchy of innovators and turbulence of markets, Malerba & Orsenigo (1996) approach also explored a relation between appropriability and technological opportunities. On the other hand, Maleki et al, (2018) used patenting growth rate as a measure for technological opportunities, Similarly, Fontana et al, (2021) inquires into technological opportunities, but also on accumulateness and appropriability of knowledge. Finally, Castellaei & Zheng (2010), productivity analysis approach focuses on appropriability and technological opportunities, discriminating by mode and source,<sup>1</sup>

### **Innovation systems and the role of regions**

When multiple countries are involved, such as Germany, the UK, France, the US, and others, authors recognize specific country differences, Malerba & Orsenigo (1996) acknowledged the historical evolution and country-specific effects of national firms, using binary variables to capture their causal effect in their study. Similarly, Breschi et al, (2000) employed a similar method to capture country-specific effects. The question arises, how can we explain these differences? This is where innovation systems play a role.

Innovation systems (IS) encompass a set of interactions that facilitate, generate, transform, and disseminate knowledge within a specific territory. Nelson (1993) was among the first authors to introduce this concept, coined as National Innovation Systems (NIS), Malerba (2002, 2003, 2005) expanded it to Sectoral Innovation Systems (SIS), while Asheim & Gertler (2006) examined Regional Innovation Systems (EIS), a notion that was later reinforced by authors such as D'Allura et al, (2012),

Innovation systems are intertwined with institutional, urban, and spatial economics. Firms tend to locate near sources of labor, financing, and raw materials, and in areas with favorable transport conditions. Non-tangible interactions like economies of scale, institutional coverage, and spillover effects also play a role, Schrempp et al, (2012) identify two main interactions within an IS: between firms and government offices, and between firms and higher education institutions. Policy incentives, regional governance structures, and informal institutions like culture also affect industry localization.

Given the research's scope, it is pertinent to detail the role of regions and innovation, Breschi & Malerba (1997) made relevant contributions to this topic, pointing out that the features of a technological regime have varying impacts on firms located in different geographical areas and are not uniformly distributed. Technological regimes (and the subsequent patterns it creates) impact the environment around them through mechanisms like modifying the source of opportunities for innovation, increasing the concentration of innovators, defining the means of knowledge transmission, and the extent of positive knowledge externalities,

Breschi & Malerba (1997) summarize their findings in two core ideas. One is that innovators are geographically concentrated when there are conditions of high technological opportunity, high appropriability, and high firm accumulateness, fitting the Mark II archetype. The other idea is that innovators are geographically dispersed when there is low opportunity, low appropriability, and low firm accumulateness, something that fits the Mark I innovation archetype.

### **The case of colombia**

Finally, making an emphasis on Colombia, Schumpeter's theory has been applied in some articles (Umana-Aponte et al., 2013; Marroquín, 2010; Arrovo-Mina & Guerrero, 2018; Langebaek-Eueda & Vasquez, 2007), However, is not used to characterize industries, Although there have been attempts to develop sector-specific entrepreneurship and innovative profiles (Ceron et al, 2010; Ovallos-Gazabon & Amar-Sepulveda, 2014), they do not employ Schumpeterian patterns of innovation.

Colombia is considered a peripheral economy, and according to the Dependence Theory (Prebisch, 1950) and empirical evidence (Arezki et al.,

2013), markets in peripheral economies function differently than those in developed and core economies. In peripheral economies, low-value goods flow outwards and high-value goods flow inwards through imports, while in developed and core economies, the opposite occurs.

A problem may arise if we characterize peripheral economies under core economies frameworks. This is why Pavitt's Taxonomy may be non-suitable, as it inquires on industrial features proper of advanced economies, like science-based sectors and specialized high-tech. However, Schumpeterian archetypes do not have this problem. Both archetypes find what type of firm drives innovation through common market metrics like concentration, firm size, or stability of innovation. Moreover, per Malerba (2005) observation, it may shed light on the dynamic of an industry, whether it is in an early stage, or it is entering a late phase of maturity.

Characterizing peripheral economies using frameworks designed for core economies can present problems, Pavitt's Taxonomy, for instance, focuses on industrial features typical of advanced economies such as science-based sectors and specialized high-tech industries, unsuitable for peripheral economies. In contrast, Schumpeterian archetypes use common market metrics like concentration, firm size, and innovation stability. Additionally, as observed by Malerba (2005, as found in Maleki & Rosiello, 2014), Schumpeterian archetypes can provide insights into the dynamics of an industry, including its stage of maturity.

### **3. Methodology**

For this study, we use a cross-section combination of DANE's (2020) EDIT survey and DANE's (2019) EAM survey, both conducted in 2018. The EAM survey is a national census of firms that meet the classification criterion of having at least ten employees and sales exceeding 517 million Colombian Pesos<sup>2</sup>. A "*Numero de Orden*" (NORDEMP) number is used to identify firms across surveys, simplifying the merging of databases.

In addition, EAM includes geographic data using DANE's "*DIVIPOLA*" classification, which assigns a unique number to each department in Colombia. Although this is not necessary for the initial cluster analysis, we will use it after to assign each firm within industries a geographic location. This will allow for geographically specific analyses.

The EDIT survey provides information on the innovative activities undertaken by firms and their impact on their industrial activities. As stated in DANE's (2020) methodological overview, the survey is based on a theoretical framework that largely follows the OECD's methodological guidelines, with a focus on the innovation-specific OSLO Manual. Annex 1 presents the universe of study for the EDIT survey at a four-digit ISIC level, based on DANE's Methodology (2018, p. 7)<sup>3</sup>.



Since EDIT samples EAM sectors instead of individual firms, not all industries in EAM are included in the EDIT dataset. However, this can be resolved by performing an inner join of both databases in Rstats, using their ISIC code and NORDEMP registrations as keys. The resulting database has 6405 observations. Based on exposed background literature, we can quantify a Schumpeterian pattern of innovation using three dimensions: stability of innovation, technological opportunities, and market concentration. We will use similar variables from both surveys that correspond to these dimensions, as listed in the following table:

**Table 1:** Relevant variables for the cluster

| Description                 | Description                             | Description | Description                                                                                                                                                     |
|-----------------------------|-----------------------------------------|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Stability                   | Amount of radical innovations           | I1R4C2N     | Goods and services that are new or different from those existing in the market, and were introduced in the 2017-2018 period.                                    |
|                             | Amount of incremental innovations       | I1R4C2M     | Goods and services that are improvements to existing goods or services in the market, and were introduced in the 2017-2018 period.                              |
| Concentration               | Total sales                             | I3R2C1      | Income or operational sales, both local and foreign, perceived by the firm between 2017 and 2018. In thousands of Colombian Pesos.                              |
|                             | Total spending on innovative activities | II1R10C2    | Total investment by the firm on innovative activities for the 2017-2018 period.                                                                                 |
|                             | Total employees                         | PERTOTAL    | Permanent amount of employees within a firm. Includes owners, temporal employees and permanent roster.                                                          |
|                             | Total output                            | PRODBIND    | Firm output accounting for the value of goods and services at the end of the production process, excluding intermediate goods. In thousands of Colombian Pesos. |
| Technological Opportunities | Possession of conventional protection   | VI1R8C2     | Prior to the 2017-2018 period, and valid until the end of said year, how                                                                                        |

|  |                                                                   |                                                                                   |                                                                                                                |
|--|-------------------------------------------------------------------|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
|  | mechanisms valid until 2018                                       |                                                                                   | many conventional protection mechanisms were in possession of the _rm. Ex: Patents, IP, Copyright, Trademarks. |
|  | Obtention of conventional protection mechanisms between 2017-2018 | VI2R8C2                                                                           | Between 2017 and 2018, how many conventional protection mechanisms did the _rm acquire.                        |
|  | Usage of non-conventional protection mechanisms                   | VI3R5C2<br>Between 2017 and 2018, how many non-conventional protection mechanisms | Did the _rm acquire.<br>Ex: Non-Disclosure Agreement, industrial secrets, high complexity on design.           |

Source: Own elaboration based on DANE's (2019; 2020)

After running these variables in Rstats, three industry-level dimensions are constructed: Concentration (*CON*), Technological Opportunities (*TO*), and Stability (*STA*). Below, we provide a comprehensive explanation of each dimension along with its proposed way to measure it:

1. *CON*: The measurement technique utilized by *CON* is based on the research of Malerba and Orsenigo (1996) and utilizes the Herfindahl-Hirshman Index (HHI, or HH Index) to measure the concentration of innovative activities and firm size.

In addition to these conventional market concentration variables, *CON* also employs a variable representing investment in innovative activities and another measuring the number of employees in each firm, enabling analysis of whether labor for innovative activities is concentrated within one particular firm. To ensure uniformity between each index, variations are smoothed out through the use of a geometric mean, as follows:

$$CON = (HH_{ms} * HH_{msa} * HH_{lds} * HH_{ss})^{1/4} \quad (1)$$

In the above equation, HH is a Herfindahl-Hirshman index, with each subindex representing a particular measure. Specifically, *ms* denotes Market Share, *msa* denotes Innovative Activities, *lds* denotes Labor Demand Share, and *ss* denotes Supply Share. Based on the literature, it is anticipated that low values of *CON* will be associated with Mark I, whereas high values will associate with Mark II,

2. *TO*: Constructed based on Maleki et al, (2018) approach, which employs patent growth rate. However, relying solely on patents is inadequate, as more mechanisms are used. Additionally, due to the in comparability of EDIT surveys, conducting a continuous growth rate analysis is not feasible. To

overcome this challenge, a solution is devised by calculating the proportion of new protection mechanisms relative to registered mechanisms such as:

$$TO = \frac{PM_{1718} + NCPM_{1718}}{PM} \quad (2)$$

In the equation,  $PM_{1718}$  denotes the industry-wide aggregate of all protection mechanisms acquired between 2017 and 2018, Similarly,  $NCPM_{1718}$  represents the same for non-conventional protection mechanisms such as Non-Disclosure Agreements, Industrial Secrets, and Complex Design. Lastly,  $PM$  encompasses all protection mechanisms that remain valid until the end of the year in question (2018).

Technological opportunities are closely connected with appropriability, A high value of technological opportunities indicates a high level of appropriability, whereas a low value suggests the opposite. Based on the literature, Mark II industries are likely to have high values, while Mark I industries tend to have lower amounts,

3. *STA*: Stability is closely related to the entry and exit of firms in the innovative market, necessitating a dynamic analysis. Due to the ineomparability of EDIT surveys, conducting such an analysis is not possible. As an alternative, we will utilize the number of radical and incremental innovations introduced by firms to construct an industry-level measure. The literature suggests that radical and incremental innovations can provide insight into the stability of an industry. As Baumol (2004, p. 10) notes, "major breakthroughs have tended to come from small new enterprises, while the invaluable incremental contributions (...) have been the domain of larger firms". Hence, to quantify that stability approach, the following mathematical form is proposed:

$$STA = Sr - Si \quad (3)$$

In the previous equation,  $Sr$  is calculated as the ratio of the number of radical innovations to the total number of innovations,  $Si$  is calculated as the ratio of the number of incremental innovations to the total number of innovations. Following Baumol's observation, we expect that Mark I will have a high share of radical innovations, while Mark II will have the opposite.

The literature has suggested additional measures, such as entry and exit rates and changes in the ranking of top innovative firms. However, data availability issues arise when attempting to measure these elements in Colombia, as the data may be incomplete, incompatible, or unavailable. It is important to note that the NORDEMP registration is a fundamental basis for differentiating firms in this study. Therefore, data obtained from sources without this data column cannot be compared since there is no reference point to determine which information belongs to which firm.

To ensure the reliability of the concentration measure, additional filters were applied to the data. For instance, in cases where some industries reported zero spending on innovative activities, the concentration measure would result in zero, leading to unreliable results. This was particularly problematic for industries with less than 20 observations. Therefore, the minimum number of observations required per industry was set at 20. For a detailed overview of the industries included in the study and their respective results in each dimension, please refer to Annex 2.

The data is analyzed using unsupervised machine learning techniques, specifically principal component analysis (PCA) and k-means clustering. The Lloyd algorithm is used with 10 repetitions and two groups. As explained by MacKav (2003), k-means calculates a mean for each group and assigns industries to a group through the following mechanism:

1. *Assignment phase*: Assign each observation to the group with the closest mean (by Euclidean distance). Each generated group is composed by a centroid that serves as reference point for the following steps,
2. *Update phase*: Group parameters adjust to match the means of the data points,
3. *Repetition phase*: Assignment and Update phases repeat until cluster positions do not change anymore.

All information is standardized prior to the cluster calculation. This is made to prevent problems that may arise due to non-normalized euclidean distance, such as those noted by Martinez et, al, (1999):

1. Distance sensibility: To avoid overestimation by extreme values, it is important to standardize the Euclidean distance. In our dataset, which consists of  $i$  points, each point  $x_i$  has a coordinate  $\mu_i$ . To standardize the data, we follow the definition of standardization:

$$\mu_i := \sigma \frac{x_i}{\sigma_i} \quad (4)$$

Where  $\sigma$  is an hypothetical measurement of standardization. If we consider that equation (4) normalized a data point by its standard deviation, then we have to hold true that the variance of the normalized dataset will be 1, as required by the properties of standard distributions. This stems from the variance property:

$$\begin{aligned}
Var(\alpha X) &= Var(X)\alpha^2 \\
Var\left(\frac{1}{\sigma}X\right) &= \frac{Var(X)}{\sigma^2} \\
Var\left(\frac{X}{\sigma}\right) &= \frac{\sigma^2}{\sigma^2} \\
&= 1
\end{aligned} \tag{5}$$

With this in mind, the formulae of an Euclid distance  $d$  between two vectors of points  $q$  and  $p$ :

$$d = \sqrt{\sum_{i=1}^n (q_i - p_i)^2} \tag{6}$$

Will adopt the form

$$d = \sqrt{\sum_{i=1}^n \left(\sigma \frac{x_{iq}}{\sigma_{iq}} - \sigma \frac{x_{ip}}{\sigma_{ip}}\right)^2} \tag{7}$$

The resulting distance will be a  $d$  value of  $\sigma$  standard units. Thus, an initial standardization of the data yields a normalized Euclid distance. In other words, if we compute Euclidean distances on hypothetical u' normalized coordinate vectors of our data, the resulting distances will be measured in units of standard deviations. This solves the distance sensibility problem,

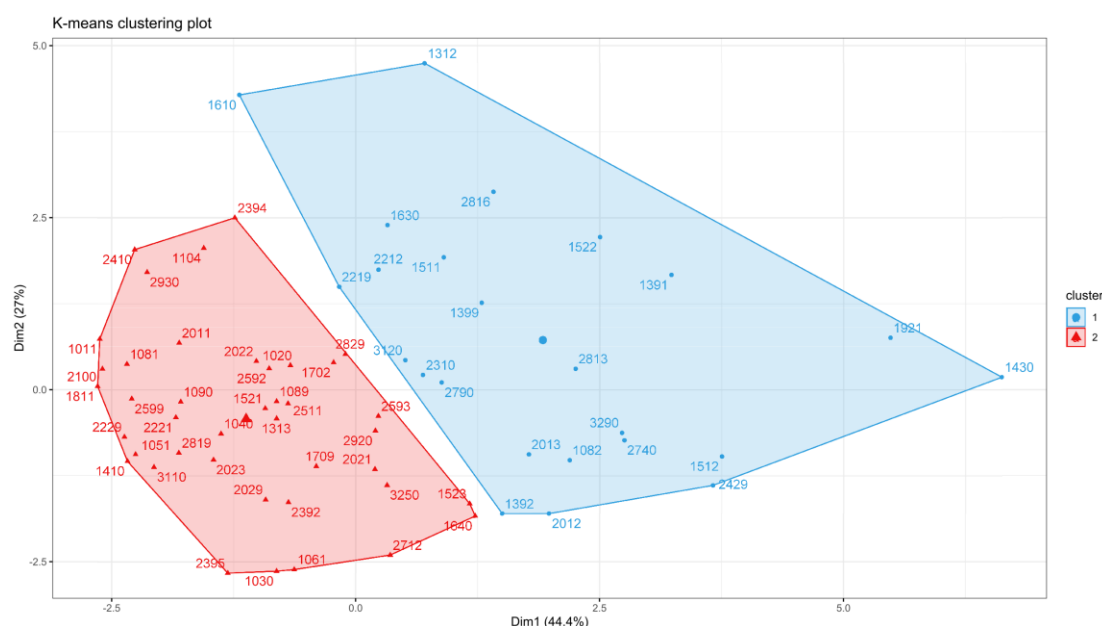
2. Redundancy by correlation: If variables are similar in construction, correlation may provide redundancy, and thus, overestimation of the distances. However, a previous calculation of Pearson correlation coefficients between  $TO$  and  $STA$ ,  $TO$  and  $CON$ , and  $CON$  with  $STA$ , yielded very low  $p = 0.12$ ,  $p = 0.08$  and  $p = -0.17$  values respectively. Thus, redundancy is low and the problem is not present.

## 4. Results

### 4.1. The cluster

The figure below displays the cluster after employing both learning methods, First, the PCA dimensional reduction algorithm is employed with our three dimensions ( $STA$ ,  $TO$ ,  $CON$ ) to reduce the data to a traditional two-axis form, capturing 44,4% and 27% of the variation in the original dataset with shadow variables,  $Dim1$  and  $Dim2$ . Then, k-means clustering was employed.

**Figure 1:** Resulting k-means cluster for Colombian manufacture and the results were plotted.



Source: Own elaboration based on DANE (2019;2020) databases.

Cluster results show two groups. Cluster Group 2 (CG2), coloured red, has 5192 observations, while Cluster Group 1 (CG1), coloured blue, has 794 observations. Initial descriptive statistics for both groups are shown in the following table.

**Table 2:** Initial descriptive statistics of the two groups

|         | Cluster Group 2 |         |        | Cluster Group 1 |         |        |
|---------|-----------------|---------|--------|-----------------|---------|--------|
|         | TO              | CON     | STA    | TO              | CON     | STA    |
| Max     | 3.500           | 1023.11 | 0.586  | 6.000           | 2702.96 | 1.000  |
| Min     | 0               | 160.28  | -1.000 | 0.047           | 1068.11 | -1.000 |
| Mean    | 0.522           | 572.22  | -0.294 | 0.983           | 1507.72 | -0.345 |
| Std Dev | 0.651           | 262.98  | 0.414  | 1.496           | 416.08  | 0.550  |

Regarding CG2, technological opportunities exhibit a wide range of values, with a representative value of 0.52 and a standard deviation of 0.65. Market concentration values in CG2 tend to be smaller, ranging from 160 to 1023 on the HHI, with a representative value of 1507. The standard deviation across concentration stands at 262 index points. Furthermore, stability of innovation reports values between 0.586 and -1, with a standard deviation of 0.414 and a mean of -0.294.

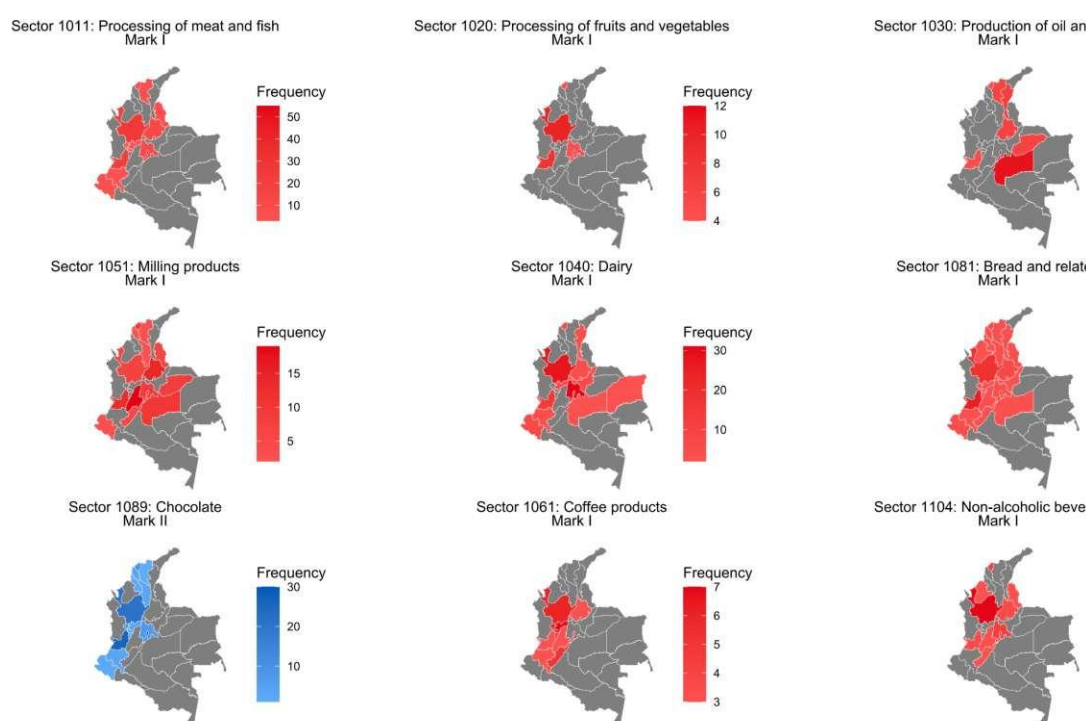
In contrast, CG1 exhibits larger values of technological opportunities compared to CG2, with a mean near 1 and a standard deviation of 1.496. Additionally, HHI reports a significant increase, with values ranging from

1068 to 2702 within the HHI and a representative value of 1507. Finally, the stability of innovation on average shows slightly higher values towards incremental innovations.

## 4.2. The maps

This section discusses the results obtained from mapping the DIVIPOLA classification contained within the EAM survey, not captured by the k-means clustering. These findings will be complemented later on by incorporating theoretical elements from innovation systems. To begin with, the spatial localization of industries related to food products is shown in the figure below.

**Figure 2:** Spatial distribution of firms elaborating food products



*Source: Own elaboration*

Both the Andean and Caribbean regions exhibit the highest number of firms. Although Atlántico and Magdalena are the most frequently occurring regions in the Caribbean, they fall behind the Andean Region, where Bogotá

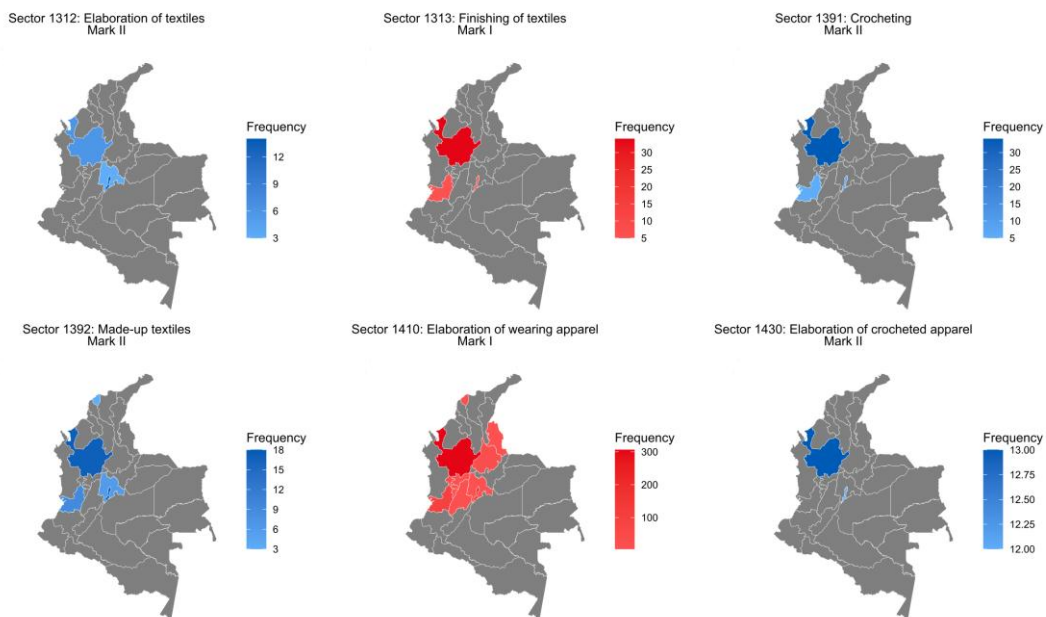
<sup>4</sup>, Antioquia, and Cundinamarca have the majority of firms. Among them, Antioquia holds the densest clusters across sectors.

In the case of a predominantly Mark I segment, spatial distribution spread across several departments, which is evident in sectors such as oil and fats (1030), dairy (1040), milling products (1051), and bread (1081). On the other hand, the only Mark II industry (chocolates, 1089) spans across both the Caribbean and Andean regions, without major breaks in the distribution.

However, it has only two dense centers located in Cauca Valley and Antioquia.

For textile products, the following figure shows maps narrower distributions. Across all sectors in Mark II, and one in Mark I, dense agglomerations appear near important regions in central Colombia. Only the elaboration of wearing apparel (1410) is somewhat disperse, but even its dispersion falls mostly within the Andean Region.

**Figure 3:** Spatial distribution of firms in the textile segment

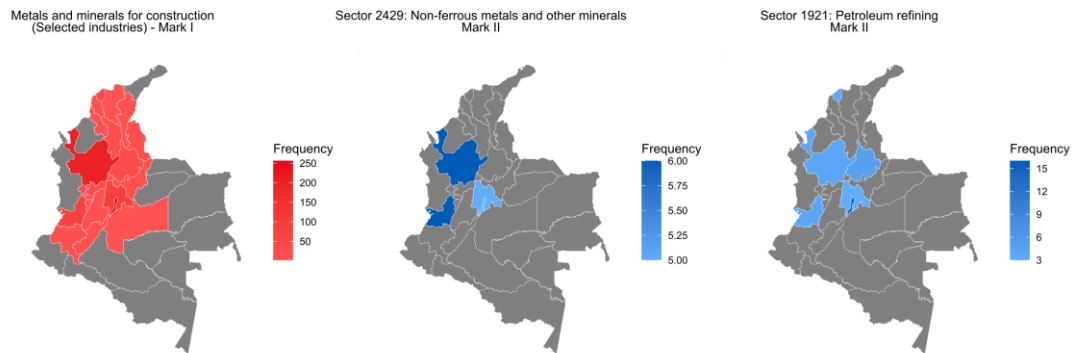


*Source: Own elaboration*

Moving forward, the next figure displays the spatial distribution of industries involved in the production of petroleum, metal, or minerals<sup>5</sup>.



**Figure 4:** Spatial distribution of firms processing metals, minerals and petroleum



*Source: Own elaboration*

Regarding ferrous metals and minerals commonly used in construction and foundries, there is an extensive distribution across the country. Notably, previous maps (e.g., maps for 1011 and 1081) have revealed a similar distribution that extends across both the Caribbean and Andean regions. These industries have demonstrated the most extensive spatial distributions throughout the study, and all of them belong to the Mark I segment.

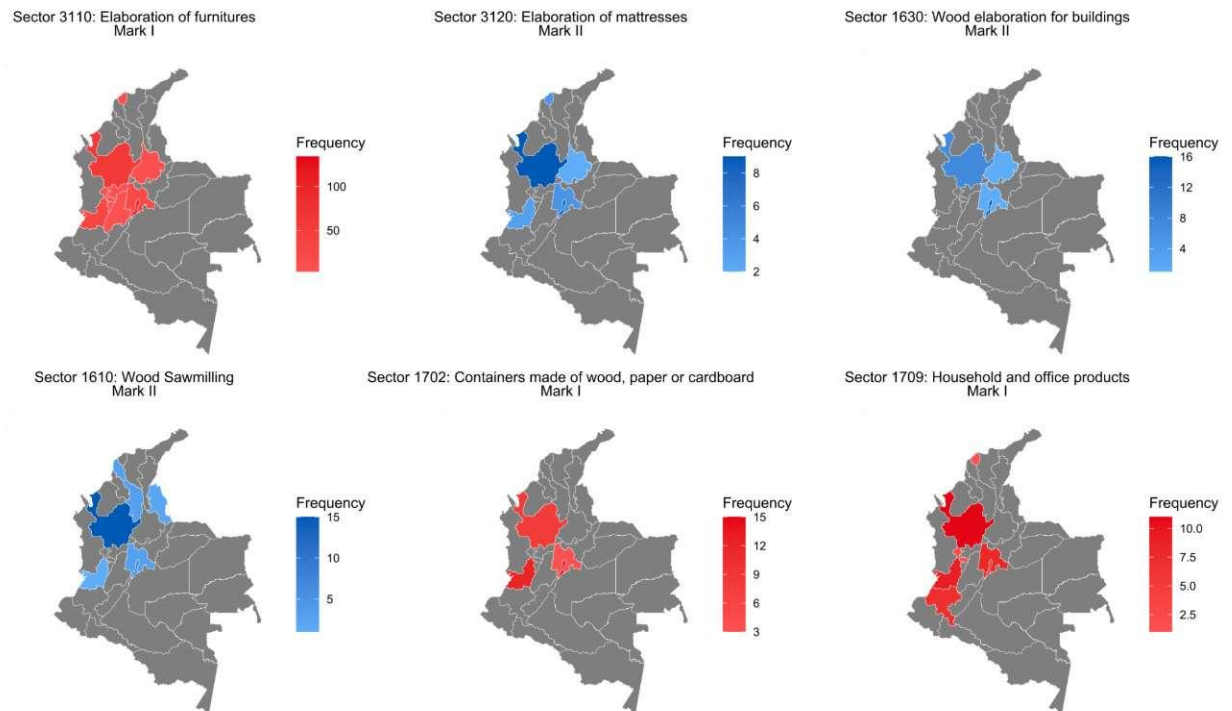
However, this is not the case for more specialized metals and minerals (2429), which are very concentrated. Antioquia, once again configures itself as the main region for agglomerations, with Cauca Valley, Cundinamarca and the capital city following. Finally, the last segment to analyse is the elaboration wood, cardboard and paper products, together with furnitures and mattresses. The following figure presents their spatial distribution. This is not the case for more specialized metals and minerals (2429), which demonstrate a high level of concentration. Once again, Antioquia emerges as the primary region, with Cauca Valley, Cundinamarca, and the capital city following closely.

Finally, the last segment to be analyzed is the elaboration of wood, cardboard, and paper products, along with furniture and mattresses. The spatial distribution of these industries is presented in the following figure.

These results show a mixed picture. For instance, the elaboration of containers (1702) displays a spatial distribution typically seen only in Mark II until now. On the other hand, wood sawmilling (1618) exhibits a dispersion characteristic of Mark I, the elaboration of furniture (3110), Mark I, distributes across the central Andean region like if it was Mark II. Finally, the elaboration

of mattresses (3120), Mark II, is concentrated in major centers of interest, consistent with previous findings.

**Figure 5:** Spatial distribution of firms elaborating household furnitures, wood, paper and cardboard products



Source: Own elaboration

Antioquia remains the primary national cluster regardless of the archetype. The Caribbean has fallen behind as we move forward in segments, with only Atlantico displaying firms, in contrast to previous maps where Magdalena, Bolivar or Cordoba were colored. The trend seems to be towards centralism around the Andean region, with one or two followers elsewhere. Notably, there is yet to be any discernible pattern in the Orinoco or Amazonas regions.

## 5. Analysis of results

### 5.1. Inferential analysis

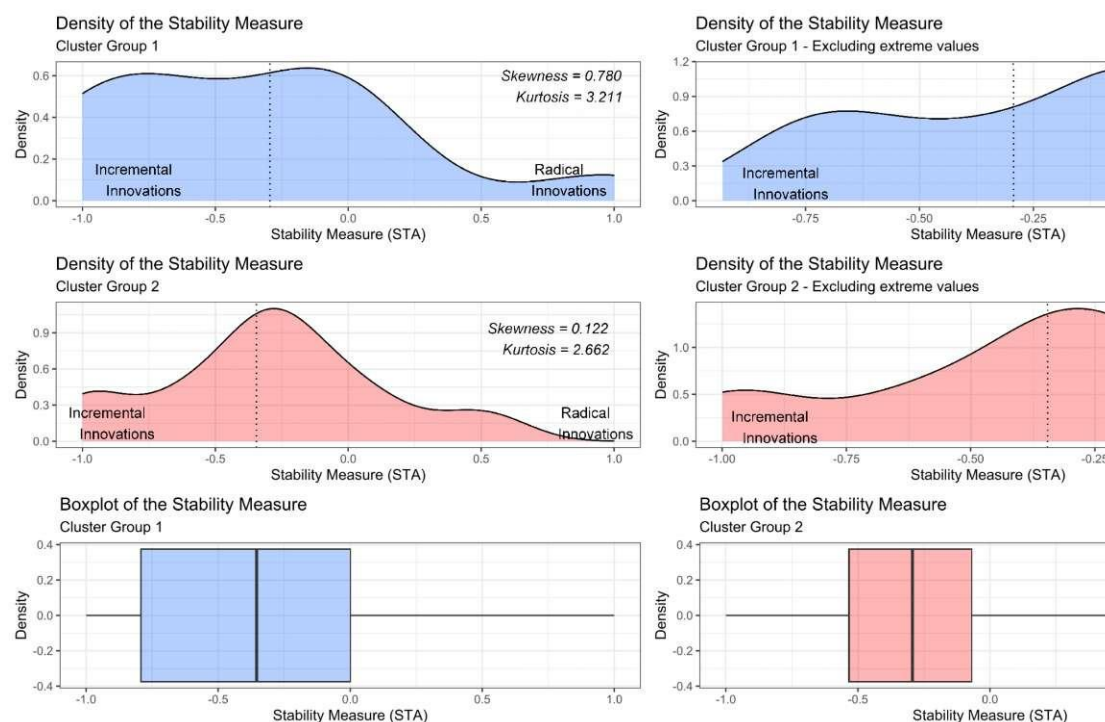
Further statistical tools may shed more light into the nature of both groups and its relationship with innovation archetypes. Based on data distribution as per Figure 2, CG2 has lower stability values when compared to CGI, the density plot for CGI shows a prominent number of observations between 0 and -1, which based on the measure employed, means that CGI has many industries with a predominance of incremental innovations in their

aggregates. This remark is reinforced by a highly positive skew of the distribution.

CG2, also distributes below 0, but its differentiating factor is its lower density when compared to CGI across said interval. Even accounting for non-extreme values, results remain consistent. Skewness and kurtosis moments further support this idea.

We may conclude that CGI industries tend to be dominated by larger shares of incremental innovations in their aggregate, while industries in CG2 do not show this tendency, instead, they have smaller differences between radical and incremental shares rather than disproportions towards one of the two types. Box plots support this conclusion, considering that CGI left box is wider than its CG2 equivalent.

**Figure 6:** Distribution of both groups in the stability dimension.

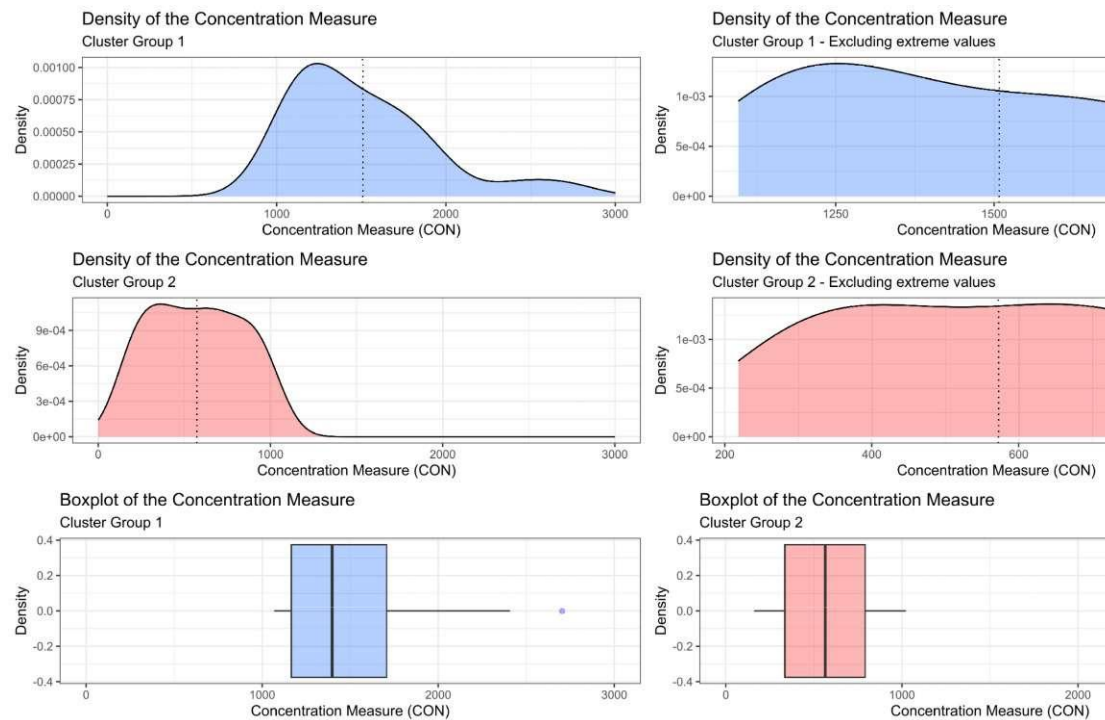


Source: Own elaboration

Within the concentration dimension, density plots in the next figure show a clear difference between both groups. CG2 distribution finds its peak near 500 and reaches 1000 HHI points at most, but CGI is above 1000, with a long-tailed right side until 2700. This evidence persists after excluding extreme values.

Box plot of both groups provides a different visualization of this phenomenon, but confirms that CGI market concentration is, on average, much larger than industries on CG2. All this statistical insight points out to one conclusion: CGI industries are highly concentrated, while CG2 ones are not.

**Figure 7:** Distribution of both groups in the concentration dimension.



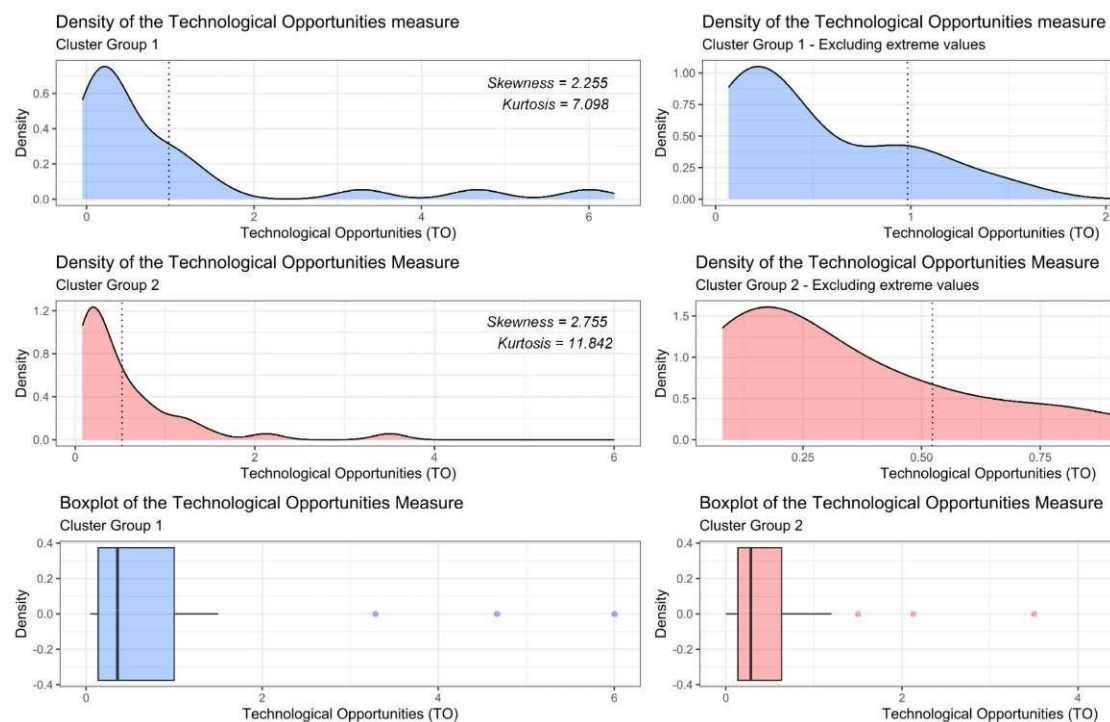
Source: Own elaboration

Finally, the behaviour of technological opportunities shows that both groups distribute mostly near zero. However, statistical moments show that skewness in CG2 is larger than CGI, which may lead us to infer that their registry of new protection mechanisms relative to the existing ones is low, which in turn may indicate low appropriability. Kurtosis in CG2 is also higher, which indicates that the TO measure industries classified on CG2 is highly concentrated around its mean.

In the case of CGI, both moments are lower. Thus, CGI industries register a higher proportion of protection mechanisms compared to CG2, which may indicate an overall higher level of appropriability. Box plots reinforce this idea, as CGI right box is wider. Expanding this inference exercise by excluding extreme values, we find a similar result. CG2 distributes mostly between 0 and 1, while CGI spans wider, from 0 to 2.

Let us go over again our three discoveries. First, we found a trend in CGI towards high shares of incremental innovations, while CG2 tends to be more balanced between shares. Second, CGI market concentration is clearly larger in average than CG2. Finally, CGI industries register more protection mechanisms relative to the existing ones compared to CG2. Per this inferential analysis, and based on reviewed theory, we can characterize CGI industries under the Mark II pattern, while features of CG2 industries gravitate towards the Mark I Archetype.

**Figure 8:** Distribution of both groups in the technological opportunities dimension.



*Source: Own elaboration*

This shows consistency with reviewed literature and theory. Malerba & Orsenigo (1996) concentration approach is consistent in this work, and including novel measures has not shown distorted results. The measure based on Maleki et al. (2018) form for technological opportunities behaves similarly. Finally, proposing a novel measure for stability, based on Baumol (2004), yielded intriguing yet coherent results. In short, we have one of the groups with highly concentrated, with several registrations of protection mechanisms and high share of incremental innovations. On the other hand, there is a disperse group, with less protection mechanisms, and high share of radical innovations.

## 5.2. Analysis of segments

Due to its position as a periphery economy, food products, commodities (e.g., petroleum, metal and minerals) and first-generation manufacturing (textiles, clothing, footwear) are strategic sectors in Colombia, while advanced manufactures and technological appliances (computers, chipsets, telecommunications) are not. Therefore, we will use these three crucial segments as starting point. In that sense, the relevant ISIC codes for this analysis are production of meat and fish products (101), general food products (102, 103, 104, 105, 108, 110), coffee products (106), petroleum (192), metals and non-metallic minerals (239, 242, 251, 259, 241, 243), furnitures (311, 312), wood, paper and cardboard products (161, 163, 164, 170), and textiles (131, 139, 141, 143).

For food products, nine sub sectors are Mark I, Only one exception in this segment arises, cacao and chocolates (1082) find itself in a Mark II environment. The main Mark I trend implies that flagship industries in Colombia like Coffee elaboration, which sustained its early economic growth in the 20th Century (Luzardo-Luna, 2019), has dispersed efforts, low market concentration and less technological opportunities reflected in less appropriability.

In the case of early manufactures like textiles, most sub sectors are Mark II, Among these, weaving of textiles (1312), made-up articles for home and related (1392), knitting and crocheting (1391, 1430), and other textiles (1399), However, the elaboration of wearing apparel (1410) using several types of materials (wool, leather, fabric, lace, et cetera) behaves as a Mark I industry. Similarly, finishing textiles (1313) through dyeing, dressing, drying or bleaching, behaves as Mark I, It is true that Mark II spans across several sectors, however, manufacture and finishing of clothing in general do not follow this trend.

Another early manufacture has mixed results, while the elaboration of furnitures (3110) in general has features of a Mark I industry, elaboration of mattresses (3120) behaves as a Mark II industry. Something similar occurs in the segment of wood, cardboard and paper products, Sawmilling of wood (1610) and elaboration of wood components for building (1630) behave as Mark II, but the elaboration of wood (1640), cardboard or paper containers (1702), and other manufactures of the same concern, like household and office products (1709) operate under Mark I environments.

Finally, commodities like petroleum have only one sub sector in the study, which is the manufacture of several fuel types used in modern industrial activities (1921), making it a crucial sub sector today. This study has found it to be Mark II , On the other hand, metals and non-metallic minerals have a

Mark I trend. Manufacture of clay (2392), cement (2394), concrete (2395), basic iron and steel (2410), structural metals (2511), hand tools (2592), metal coating (2593), among others (2599) are Mark I. However, production and refining of non-ferrous metals like nickel, copper, lead, chrome, manganese, zinc, aluminium, among others (2429) fall into the Mark II category. Note that sub sectors who treat conventional metals or minerals (iron, steel, clay, cement, et cetera) have, but more specialized metals tend to be more concentrated.

### **5.3. Spatial analysis and innovation systems**

In this section, we will argue about the potential set of interactions that may shape innovation systems and spatial localization within those regions. The maps presented earlier show hints of localization behavior similar to those pointed out by Breschi & Malerba (1997, with Mark II industries concentrating in fewer departments when compared to Mark I. In this part, let us look at the most notable findings in terms of localization and the potential interactions behind.

An interesting segment to kick off this analysis is the food products one. Note that sectors like dairy (1040), together with meat and fish (1011), agglomerate close to needed inputs, which could be valleys for livestock, or coasts for fish. A similar phenomenon occurs with coffee products (1061), which distributes around Colombia's coffee region (*Eje cafetero*). Localization can also be influenced by access to major labour centers. To give an example, note that the distribution of manufactured products using fruits or vegetables (1020) coincides with the location of major cities (Cali in Cauca Valley, Barranquilla in Atlantico, Medellfn in Antioquia and the zone near Bogota), where labour supply for manufactures is abundant.

Cultural differences also seem to be important. Historically, as presented by Melo (2017), culture has strongly shaped the country's regions, with rural zones being great suppliers of agriculture, mining or fishing resources, inhabited by low-income households traditionally dedicated to said activities (e.g, laborers, small farmers, fishers). On the other hand, urban centers leaned towards early manufactures and services, with higher wages that allowed the rise of a small middle class, which teehnified itself through education, informal ties and entrepreneurship. Whats more, urban centers laid the groundwork for innovation, as it benefits from knowledge spillovers and agglomeration economies.

These elements may be behind of Antioquia's position as the department with most firms locating here, Antioquia's position echoes with its 19th and 20th century economic history. As noted by Ocampo (2015) and Luzardo-Luna (2019), hard-currency profits from coffee exports, human capital formation, cultural informal ties between citizens, railway infrastructure, and other



resource endowments consolidated Antioquia as an industrial powerhouse, with domestic textile companies like Coltejer (*Colombiana de tejidos*) and Fabricato (*Hilados y tejidos del hato*). In the light of these elements, results suggest that these effects may have had a long term impact on the department, serving as a differentiating factor from other departments. In fact, the textile legacy of the region, in the form of a large spatial concentration of firms, can be seen in all of the six analyzed sectors in the textile segment.

Institutional factors and transport routes are also important. The decision to locate on certain regions also depends on nearby access to transport hubs. To name a few in Colombia, *El Dorado* cargo terminal in Bogota, Buenaventura port in Cauca Valley, Magdalena river and Caribbean ports like Barranquilla or Cartagena. Similarly, access to government authorities, rule of law and cultural differences between highly urbanized regions and mostly rural ones affect this decision.

This is evident in one of Colombia's most strategic sector (1921, petroleum), spatial distribution shows close proximity to major cities and urban centres like Bogota in Cund- inamarca, but with emphasis on shipping routes and transport. Take for example Cauca Valley and Atlantico, both have petroleum refineries in their territory, and major ports to ship petroleum to international markets. Similarly, Santander and Antioquia's proximity to the Magdalena river allows for ease in transport.

An interesting contrast is the one between non-ferrous metals and minerals (2429) versus metals and minerals commonly used in construction activities. Due to DANE's methodology, sectors from 241 to 243 are aggregated in one map, and since said sectors have different scopes, distribution can be more spread than if we map each sector separately. However, based on DANE's document on ISIC (2022a), most of them share the usage of iron, steel and common minerals, which are widely used in many buildings, and thus, not only access to labour or transport routes influences, but also the potential demand they can find in the construction sectors. These interactions between suppliers and consumers, together with an easier knowledge diffusion due to wide use of it foster a disperse environment, where suppliers localization decision considers potential buyers in the construction sector.

But non-ferrous metals and minerals (2429) such as aluminium, zinc, lead are not as widely used as those mentioned earlier. What's more, treating such minerals required special processes due to particular chemical features, and have more specialized uses, such as in batteries, airplanes, metal coatings, welds or pipelines, that have a narrow set of buyers and demand a more teehnified use of knowledge when compared to metals and minerals commonly used in construction. This results in an environment where efforts



and suppliers concentrate in specific regions of the country, seeking to exploit close distance relationships, access existing buyers and exploit knowledge spillovers.

## **6. Conclusions and implications**

This article aimed to characterize Colombian industries using Schumpeterian Mark I and II patterns through a k-means clustering algorithm. We were limited to certain measures and non-dynamic variables due to data availability and comparability across DANE's databases. Nevertheless, the study found what type of firm drives innovation on each inquired industry, CGI, the less dense group, has been labeled as Mark II, thus, larger firms drive innovation. On the other hand, CG2, the densest group, gravitates toward Mark I, placing small firms as the drivers of innovation. This contributes to an already existing body of literature about characterization exercises, but made in an emerging economy as Colombia,

The differences in quantity between groups shows that Colombian manufacture is more of a Mark I than Mark II, Sectors like groceries are predominantly characterized as Mark I, including Colombia's flagship coffee sector. Sectoral analysis found that textiles are predominantly Mark II, but its most traditional sector, the elaboration and finishing of wearing apparel, has a Mark I environment. On the other hand, oil refining, one of the most important commodities in the modern world, is a Mark II industry in Colombia, but the set of industries supplying the construction sector are Mark I,

We noted that, in general, Mark II industries are less disperse, concentrating in major cities and regions (e.g, Barranquilla, Cali, Bogota and Medellfn), while Mark I ones spread across several regions. This reinforces what was said in the literature review about the features of concentration and dispersion of innovators within a geographical space, and contributes to the discussion of regional innovation in the country, Antioquia positions itself as the main point of interest in our study, perhaps due to long term effects of its industrial history, but the effect of cultural differences and institutions can not be underestimated. What was found within Antioquia reinforces reviewed theoretical elements about innovation systems. Specifically, how cultural, economic and institutional pre-requisites such as transport access, or rule of law together with interactions between agents such as informal ties, knowledge spillovers and consumer-buyer relationships foster innovation and are a differentiating factor from other regions.

Policy implications revolve around the need for heterogeneity in design, echoing with what was said about innovation systems in the theoretical framework and results. It is important to consider specific sectoral

relationships, usage of goods, strategic relevance to the country, historical features, presence (or absence) of clusters, nearby infrastructure and other agglomeration dynamics. A suitable policy instrument for these findings can be the Colombian Science Ministry PEDCTI (*Planes Estratégicos Departamentales en Ciencia, Tecnología e Innovación*) report, a context-wise diagnosis instrument that assesses strengths, vulnerabilities and potential opportunities of each region in terms of innovation, science and technology.

For example, sectors whose output is widely used as input in other activities, like petroleum refining and supplies for construction, where a change in that sector may spread to the entire market demands carefulness, as an inadequate innovation policy or change into the legal framework may negatively disrupt activities. In contrast, sectors where the output is a final good (e.g. tooling workshops or groceries), the improvement final user and producer relationship can be very beneficial. On the other hand, historical significance of some food products (e.g. Colombian coffee) may benefit from policies that foster producer- foreign relationships, together with improvements on market access through transport.

As the literature continues to explore the relationship between market structure and innovation through characterizations, new findings contribute to a more robust and informed discussion in policy making around the nature of innovation in each industry and leave the door open for potential complements.

Even if these results are relevant and coherent from a theoretical viewpoint, further quantitative research is encouraged. Let us not forget that the variables employed in this study were static in nature due to data limitations, and the analyses made on innovation systems and regions relied heavily on theoretical elements instead of its own quantitative evidence (aside from the DIVIPOLA classification).

Therefore, adding dynamism to variables and employing econometric methods could be a good starting point in the future. Similarly, developing quantitative measures to analyze the set of interactions within Colombian innovation systems could enrich the discussion and set the way forward for more comprehensive characterizations.

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**A. Annex 1: Universe of study for the EDIT survey.**

| <b>ISIC code</b> | <b>Economic activity</b>                                       |
|------------------|----------------------------------------------------------------|
| 101              | Processing and preservation of meat and sh                     |
| 102              | Processing and preservation of fruits, vegetables and tubers   |
| 103              | Production of oils and fats                                    |
| 104              | Dairy Processing                                               |
| 105              | Production of milling products, starches and their derivatives |
| 106              | Elaboration o f coee products                                  |
| 107              | Sugar and panela processing                                    |
| 108              | Manufacture of other foodstus                                  |
| 109              | Preparation of prepared feedingstufss for animals              |
| 110              | Beverage production                                            |
| 131              | Spinning, weaving and nishing of textiles                      |
| 139              | Manufacture of other textiles                                  |
| 141              | Manufacture of clothing                                        |
| 143              | Manufacture of knitted and crocheted articles                  |
| 151              | Tanning and retanning of hides and manufacture of travel goods |
| 152              | Footwear manufacturing                                         |
| 161              | Sawing, waxing and impregnation of wood                        |
| 162              | Manufacture of sheets of wood for plating, boards and panels   |
| 163              | Manufacture of wooden parts and pieces                         |
| 164              | Manufacture of wooden containers                               |
| 169              | Manufacture of other wood products                             |
| 170              | Manufacture of paper and cardboard                             |
| 181              | Printing activities and related services                       |
| 190              | Coking, oil rening and fuel mixing                             |
| 201              | Manufacture of basic chemicals and their products              |
| 203              | Manufacture of synthetic and articial bres                     |
| 221              | Manufacture of rubber products                                 |
| 222              | Manufacture of plastic products                                |
| 231              | Manufacture of glass and glass products                        |
| 239              | Manufacture of non-metallic mineral products                   |
| 242              | Basic precious and non-ferrous metal industries                |
| 251              | Manufacture of metal products for structural use               |
| 259              | Manufacture of other products made of metal                    |
| 260              | Manufacture of computer, electronic and optical products       |
| 270              | Manufacture of electrical appliances and equipment             |
| 281              | Manufacture of machinery and equipment for general use         |
| 282              | Manufacture of machinery and equipment for special use         |
| 291              | Manufacture of motor engines and their engines                 |
| 292              | Manufacture of bodies for motor vehicles                       |
| 293              | Manufacture of parts, auto parts and vehicle accessories       |



|     |                                                                        |
|-----|------------------------------------------------------------------------|
| 300 | Manufacture of other types of transport equipment                      |
| 311 | Furniture manufacturing                                                |
| 312 | Manufacture of mattresses and box springs                              |
| 321 | Manufacture of jewellery and related articles                          |
| 323 | Manufacture of articles and equipment for the practice of sport        |
| 324 | Manufacture of games, toys and headbutts                               |
| 325 | Manufacture of medical and dental instruments, apparatus and materials |
| 329 | Other manufacturing industries                                         |
| 330 | Maintenance and repair of metal products, machinery and equipment      |
| 202 | 1 Manufacture of pesticides or chemicals for agricultural use          |
| 202 | 2 Manufacture of paints, varnishes and similar coatings                |
| 202 | 3 Manufacture of soaps, detergents and perfume                         |
| 202 | 9 Manufacture of other chemicals                                       |
| 210 | 0 Manufacture of pharmaceutical products and medicinal chemicals       |
| 241 | to 243 Metal foundry                                                   |

## B. Annex 2: Industry-level results

| Three-Digit<br>ISIC | Four-Digit<br>ISIC | TO    | CON     | STA    | Mark |
|---------------------|--------------------|-------|---------|--------|------|
| 101                 | 1011               | 0.157 | 305.89  | 0.234  | I    |
| 102                 | 1020               | 0.353 | 815.72  | -0.111 | I    |
| 103                 | 1030               | 0.121 | 396.99  | -0.933 | I    |
| 104                 | 1040               | 0.136 | 488.88  | -0.294 | I    |
| 105                 | 1051               | 0.094 | 198.09  | -0.279 | I    |
| 106                 | 1061               | 1.192 | 412.75  | -1     | I    |
| 108                 | 1081               | 0.136 | 334.15  | 0.099  | I    |
|                     | 1082               | 0.062 | 1389.42 | -0.784 | II   |
|                     | 1089               | 0.172 | 674.37  | -0.217 | I    |
| 109                 | 1090               | 0.14  | 423.24  | -0.12  | II   |
| 110                 | 1104               | 0.109 | 790.62  | 0.467  | I    |
| 131                 | 1312               | 0.308 | 1753.45 | 0.926  | II   |
|                     | 1313               | 0.818 | 656.25  | -0.333 | I    |
|                     | 1391               | 0.5   | 1904.26 | -0.143 | II   |
| 139                 | 1392               | 0.404 | 1156.52 | -1     | II   |
|                     | 1399               | 0.102 | 1504.79 | -0.077 | II   |
| 141                 | 1410               | 0.252 | 160.28  | -0.313 | I    |
| 143                 | 1430               | 0.048 | 2702.96 | -1     | II   |
| 151                 | 1511               | 1.5   | 1291.6  | 0      | II   |
|                     | 1512               | 0.158 | 1847.33 | -1     | II   |
|                     | 1521               | 0.092 | 651.43  | -0.25  | I    |
| 152                 | 1522               | 0.211 | 1913.61 | 0      | II   |
|                     | 1523               | 1.5   | 1017.81 | -1     | I    |
| 161                 | 1610               | 1     | 1093.55 | 1      | II   |
| 163                 | 1630               | 6     | 1105.45 | 0      | II   |
| 163                 | 1640               | 0     | 1023.11 | -1     | I    |
| 170                 | 1702               | 0.766 | 933.74  | -0.176 | I    |
|                     | 1709               | 0.054 | 716.54  | -0.534 | I    |
| 181                 | 1811               | 0.866 | 193.94  | 0      | I    |
| 192                 | 1921               | 1.25  | 2407.87 | -0.667 | II   |
|                     | 2011               | 0.425 | 528.27  | 0.091  | I    |
| 201                 | 2012               | 0.195 | 1316.55 | -1     | II   |
|                     | 2013               | 0.138 | 1281.94 | -0.692 | II   |
|                     | 2021               | 0.086 | 866.59  | -0.613 | I    |
| 202                 | 2022               | 0.114 | 740.74  | -0.048 | I    |
|                     | 2023               | 0.324 | 414.61  | -0.402 | I    |
|                     | 2029               | 0.205 | 499.38  | -0.622 | I    |
| 210                 | 2100               | 0.1   | 259.39  | 0.107  | I    |
| 221                 | 2212               | 3.286 | 1068.11 | 0      | II   |

|     |      |       |         |        |    |
|-----|------|-------|---------|--------|----|
|     | 2219 | 1     | 1081.54 | 0.111  | II |
| 222 | 2221 | 0.16  | 386.37  | -0.19  | I  |
|     | 2229 | 1.179 | 164.87  | -0.258 | I  |
| 231 | 2310 | 0.283 | 1186.85 | -0.333 | II |
|     | 2392 | 0.28  | 544.95  | -0.647 | I  |
| 239 | 2394 | 0.129 | 919.09  | 0.586  | I  |
|     | 2395 | 0.585 | 231.47  | -0.905 | I  |
| 241 | 2410 | 0.165 | 583.96  | 0.545  | I  |
| 242 | 2429 | 0.133 | 1690.52 | -1     | II |
| 251 | 2511 | 1.2   | 628.54  | -0.371 | I  |
|     | 2592 | 2.125 | 693.44  | -0.2   | I  |
| 259 | 2593 | 0.299 | 974.42  | -0.44  | I  |
|     | 2599 | 0.448 | 285.49  | -0.07  | I  |
| 271 | 2712 | 0.408 | 750.81  | -1     | I  |
| 274 | 2740 | 0.92  | 1626.86 | -0.818 | II |
| 279 | 2790 | 0.821 | 1168.34 | -0.375 | II |
|     | 2813 | 0.429 | 1633.96 | -0.5   | II |
| 281 | 2816 | 4.667 | 1405.11 | 0      | II |
|     | 2819 | 0.505 | 317.84  | -0.353 | I  |
| 282 | 2829 | 3.5   | 886.41  | -0.333 | I  |
| 292 | 2920 | 0.804 | 920.49  | -0.5   | I  |
| 293 | 2930 | 0.632 | 563.31  | 0.412  | I  |
| 311 | 3110 | 0.531 | 219.11  | -0.382 | I  |
| 312 | 3120 | 0.099 | 1125.81 | -0.273 | II |
| 325 | 3250 | 0.256 | 887.84  | -0.714 | I  |
|     | 3290 | 0.066 | 1528.87 | -0.667 | II |

## Notes

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- <sup>1</sup> We shall find appropriability modes by the names of "conventional" and "non-conventional" protection mechanisms later on in this article.
  - <sup>2</sup> Firms that meet the sales requirement but not the employee requirement are also included in the census
  - <sup>3</sup> As an exception, ISIC codes 202 and 210 select specific four-digit industries within them
  - <sup>4</sup> According to Colombia's political-administrative partition, Bogotá is a first-order territory with its own administrative autonomy. Despite serving as the capital of Cundinamarca, its population size and administrative faculties necessitate distinction.
  - <sup>5</sup> Note that the map for metals does not specify the two-digit ISIC sector. This decision aligns with EDIT's methodology, which selects specific four-digit sectors, which can be found in Annex 1

## Challenges towards innovative knowledge-exchange: Examining the open-access publication and its impact on global south scholars

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### **Abstract:**

The paper analyses the challenges towards building an inclusive knowledge society with the novel approach of trying to minimise inequalities of opportunity. In doing so, it investigates the case of open access publication of scholarly articles in journals which has seemingly been celebrated as opening up knowledge. The paper questions some long drawn assumptions: are rich countries more innovative? Is open access really open? How location of scholars lead to hierarchisation and discrimination? The paper examines journal article publications in social sciences to probe the above questions. It explains open access and its impact on global south scholarship and how with the lack of institutional funding and infrastructural support, common in most countries of global south leads to scholars publishing in journals not listed in Web of Science or Scopus as most of these journals take an author publishing charge, which is beyond reach for academics of Global South having an adverse impact on research output and dissemination. These issues are addressed by using the de-colonial approach to understand the deep-seated disadvantages faced by academic, scholars and scientists of developing countries wherein they are often relegated to a silent partner or facilitator in large-scale international research projects. This in turn churns an 'academic colonialism' of sorts.

**Keywords:** Open access publication, knowledge economy, Global South, decoloniality, innovation

## 1. Introduction

What is open access? This is the primary question necessary to understand and initiate any debate on whether it is good or bad, advantageous, or like all other platforms and avenues for publication, have both pros and cons. "Open Access (OA) is when publications are freely available online to all at no cost and with limited restrictions regarding reuse. The Springer Publications website defines the fundamentals of OA as unrestricted distribution of research is important for authors (as their work gets seen by more people), readers (as they can access and build on the most recent work in the field) and funders (as the work they fund has broader impact by being able to reach a wider audience) (<https://www.springer.com/gp/authors-editors/authorandreviewertutorials/open-access/what-is-open-access/10286522>). OA, thus makes scholarly articles published online accessible to all without paying a fee or subscribing them. The Taylor and Francis website, describes OA as "accelerat[ing] research, enrich education, share the learning of the rich with the poor and the poor with the rich, make this literature as useful as it can be, and lay the foundation for uniting humanity in a common intellectual conversation and quest for knowledge." Peter Suber, the Director of Harvard Open Access Project, says OA is the convergence of tradition and a new technology, making possible an unprecedented public good" (Suber, 2002; Guedon, 2017). Here the 'old tradition' implies scientific ethos, and the 'new technology' is the internet.

While agreeing with Suber (2002) that, open access brings the old and new technology together, I cannot uncritically accept that OA has made knowledge a public-good. My reason for this disagreement is that the primary question to pose while discussing any knowledge discourse is: who is writing from where? (Mignolo, 1993). This essentially puts the pointer to the geographical, economic, social, political, gender positioning of the authors, which cannot be neglected in any discussion on OA, as location has a bearing on the opportunities available to authors. OA is a "development in the scientific publishing world has led to a state of neo-colonialism at the source, where what is being published [mostly] comes from that part of the World which can afford to pay the publication costs...opening up access may be equal to closing it at the other end" (Valsiner, 2006).

### Objective and research questions

The objective of this paper is to analyse the following research questions:

- What is Open Access Publication?
- Is Open access really 'open' as it claims?
- Are rich countries more innovative?
- Impact of OA on scholars of Global South. This will be conducted by analyzing the Social Science journals in Development Studies, their rankings and publication matrix.

### **Who is writing and from where? Location matters**

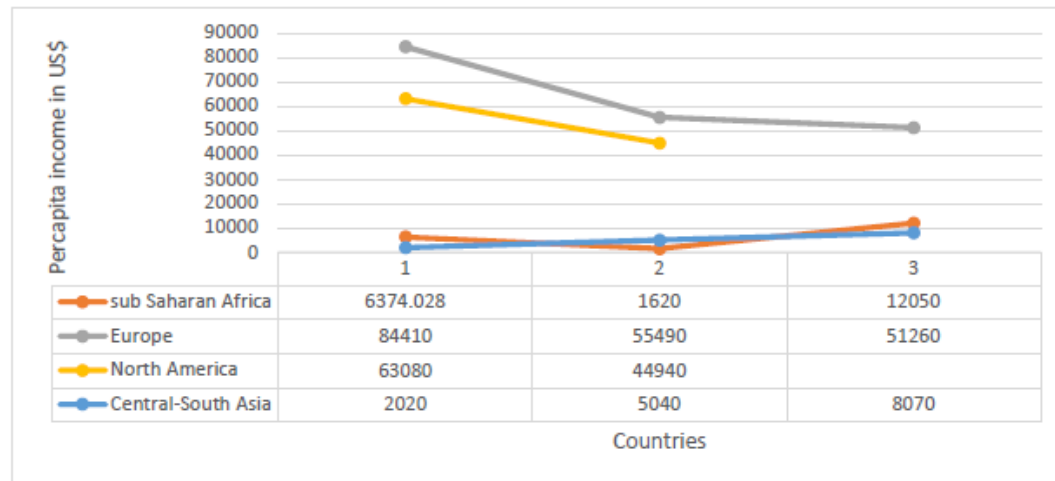
Scientific-academic research and hidden privileges. Let me elaborate the question who is writing from where further, to show how location of author impinges deeply on the arguments on OA and APC, more importantly on knowledge-generation and knowledge creation. The countries of the world designated earlier as the third world (during the cold war) and then the 'developing' world has come to be considered mostly as an area to be studied and not a place from which to speak. The countries and authors belonging to the so-called 'Global-South' have always been speaking and writing (Coronil, 1993; Wald, 1992 as referred by Mignolo, 1993), it is another matter that their work mostly goes unnoticed and often not considered 'scientific' enough by the commercial publishing houses of the North. An important factor is that most of these works are not written in English and even if they are, gets published in non-digital platforms, which are not accounted by the Web of Science. This process alone is exclusionary and discriminatory, howsoever unintentional; the upshot is the authors who cannot pay for their work to be published as OA. This adds to the existing hierarchy of knowledge generation and creation, considered as a prerogative of the rich and powerful developed world. The commercial publishers, all based in Europe and USA set the standards, rank journals, and assign impact-factor according to citations and downloads and then most charge APC for OA, claiming to make knowledge accessible and free of cost. In reality what it does is to rekindle a vicious circle of academic colonialism.

Academic colonialism, as developed by the Latin American scholar Walter Mignolo, connotes the implication that authors and academics from the developed powerful countries having better access to funding and institutional support due to their location and have better chances to get their works published. In contrast, authors writing on similar topics belonging to the Global South, lacking financial support end-up either not publishing their work or getting them published in 'substandard' journals, which are not indexed in Scopus etc. This keeps perpetuating and generating a new form of academic colonialism. The fallback becomes 'scientific knowledge', presumed to be

produced mainly in the Anglo-Saxon world, setting the rules and standards of the so-called game of what is publishable continues to be determined in the region: what is 'scientific' and is significant for publication, for instance. The fact that this also depends upon market-demands generated by private corporations in the name of research and development, resulting from industry-university collaboration and partnerships, get hidden from debate and view. Scientific knowledge can therefore be compared to a world system like Wallerstein's, wherein scientific publication is the market unit (Piron et al., 2017). The standard and measurements of these scientific publications are decided by the commercial publishers belonging to the center i.e., the countries of North like UK and USA, who along with universities dominate the measurement chart of articles and scholarly papers produced and published. The semi-periphery comprises of other countries of North and some from the Global-South, where writing is done in English, and the periphery are countries excluded from this world system of scientific publication, not that the periphery does not produce any scientific work, but these mostly go unnoticed and unrecognized (Piron et al., 2017). Similarly, knowledge produced in other languages fall further down the line, partly because the English-speaking world is not known for its ability to command other languages – a failure that it dare not reveal.

The United Nations Science Report towards 2030, indicated that science is universal, a language shared across regions and cultures and borders (UNESCO Science Report 2015). Further the UN report asserted, science literacy and capacity-building be promoted in low and middle-income countries, creating dependence on countries that are more scientifically literate and more industrialized (UNESCO, 2015, 10). A major problematic is the assumption in this statement, that the low and middle-income countries lack science education and no scientific innovations emanate from these countries. This can be challenged on two grounds: first who decides what constitutes 'science'? It is dictated by the high-income countries and the UNESCO is visibly biased as it accepts that definition as unproblematic. This is factually also incorrect because a look at the Global Innovation Index (GII) proves that countries of the Global-South show a higher rate of upward mobility. The most notable ones were China and Republic of Korea who continues to move upward in ranks of patents, industrial design, and trademarks by origin as well as High-tech and creative goods exports (GII, 2019, 6). Other notable countries moving upwards were United Arab Emirates (36th), Viet Nam (42nd) and Thailand (43rd), India (52nd), the Philippines (54th) and the Islamic Republic of Iran (61st) (GII, 2019,

6). India, Viet Nam, Kenya, and the Republic of Moldova have outperformed on innovation relative to GDP for the ninth consecutive year, setting a record (GII, 2019, 6).



Source: Constructed by author with data from World Bank <https://data.worldbank.org/country/>

Let us elaborate this further, comparing the three topmost innovative economies of sub-Saharan Africa, North America, Europe and Central-South Asia. According to the GII, South Africa, Kenya and Mauritius ranked top in sub-Saharan Africa. USA and Canada in North America. Switzerland, Sweden and Netherland and India, Iran and Kazakhstan from Europe and Central-Southern Asia respectively (GII, 2019, 6). Fig. 1 above. While comparing we notice marked variations between income and innovations, proving that the low-income countries are more innovative than the high-income ones even without as much income and funds. Innovation herein implies, “the process of translating an idea or invention into a good, service or policy that societies will adopt on a large scale (International Transport Forum, 2018). Secondly, better economic development is not necessarily proportional to knowledge-creation. Thus, maximum number of innovations originate from countries located in the continents of Africa, Asia and South America. (GII, 2019, 6). However, when it comes to copyrights of these innovations, rich-countries authors and researchers are in an advantageous position to benefit from these innovations by publishing them in scientific journals under their names, due to their awareness regarding copyright laws and intellectual property rights. (Rutenberg, 2013). According to Rutenberg, investigating Kenya, 50 percent of copyrights granted in Kenya are to foreign firms. (Rutenberg, 2013). This is because local innovators, innovate utilizing local resources for local use and scientific publication remains distant and mostly missing (Piron et al., 2017;



International Transport Forum, 2018).

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### **Journal rankings and OA: Advantaging the global-north?**

Out of a total of 5855 social sciences journals listed in SCImago journal ranking, only 28 are published from Africa, 198 from Asia, 230 from Latin America, whereas 1615 come from North America and 3218 from Western European countries. The impact factor for American Journal of Political Science, the top-ranking journal among social sciences in Western Europe and North America is 9.602, whereas the top ranking African equivalent journal called the South African Journal of Education has an impact factor of 0.422. Educational Technology and Society, the topmost journal from Asia published from Taiwan has an impact factor of 1.085 (Schimago journal ranking (<https://www.scimagojr.com/journalrank.php?area=3300&type=j>)). Authors in Asia and Africa outnumber their American and European counterparts still the number of journals published from the developing countries is much less with low impact factors. This means that even if an author publishes in the best journal of their respective country, given the gap in ranking and impact factor, they cannot compete with authors in North America and Western Europe. Whereas an average scholar located in the continents of Europe and North America will have better opportunities to get published than the best scholars in Asia and Africa. Second, many special series of journals with high global ranking are the outcome of international conferences. These conferences are organized by universities and scholars with sponsorship from publishing houses, research councils, non-governmental bodies, national governments and international agencies. These conferences provide a great platform for scholars and authors to

showcase their research actually works to the disadvantage of authors belonging to Global South, as they are most often unable to pay the high registration fee, visa and flight tickets as well as accommodation. This is coupled with another major limitation, i.e., mobility of people from Global South, especially the academics due to inability to show finances, immigration restrictions, non-availability of paid leave and institutional support paying for international conferences and stays. Third, the field of social sciences and humanities is the worst affected in relation to funding and publication as most countries from Global South are investing in the Science, Technology, Engineering and Mathematics (STEM) and Mathematics, Information (Computer science), Natural Sciences and Technology (MINT) disciplines, ignore the realm of social sciences and humanities. This implies that there are more publications and higher number of international collaborations in the natural science disciplines. The percentage of international collaborations is as high as 65 percent in life sciences, 27 percent in basic sciences and only 5 percent in Social and Human Sciences. Surprisingly still, some 70 percent articles published as the outcome of such collaborations were sole-authored from USA and UK without co-authors from Global South (Dahdouh-Guebas et al., 2003). It suggests that the only kind of international collaboration that gets credit is likely to be between peer countries in the Global North and rarely between the North and the South, despite the fact that scientists in Southern region may be contributing to knowledge production at multiple levels. In a research study undertaken to analyze the trend of publications in developmental journals only about 14.5 per cent of the 1894 articles were authored or coauthored by researchers based in developing countries (Piotrowski, 2014). Cummings and Hoebink (2016) analysis that looks at patterns of inequality in knowledge-production focused on the extent of academics from developing countries represented in editorial journal boards and participating as authors in journals in the field of development. They delineate that: a) Out of the 2112 articles from 10 development studies journal published between 2012 and 2014, 43 percent of authors belonged to USA and UK and the other 43 to other developed countries while only 14 percent to developing countries; b) out of 329 board members, 62 percent were located in USA and UK and merely 9 percent in developing economies.

### **Some alternatives to facilitate authors from global south and contribute to knowledge innovation**

We can infer from the above discussion that there is a disadvantage syndrome for

authors based in Global South wanting to publish OA in best scientific journals. This makes the prospect of OA, an otherwise noble initiative in principle, far from reaching its audience in Global South. The question then arises: Are there any viable alternatives? The answer is 'yes', there are.

1. If APCs become the norm, then differentiated varying rates of APC relative to the location of the author should be introduced. Such varied rates can have at least five categories- a) authors located in the Global North with funding pay the highest APC; b) authors in Global North without funding comes next; c) joint-papers from authors based in north and south with funding pay an average APC; d) authors based in Global South with funding also pay a minimal APC; e) authors based in Global South without funding pay no APC.
2. Co-authored articles with at least one belonging to the Global South must be encouraged, not only in the funding process appraisal and evaluation but also in terms of research outcome and joint publications.
3. More scientific journals should establish their headquarters in the Global South and get their journals registered from Global South. To elucidate what I mean by this is, for example: Sage Publications publishes 84 Political Science and International Relations journals, out of which 10 are published from India but these are registered under Sage UK and not Sage India ([journals.sagepub.com](http://journals.sagepub.com)). Similarly, Elsevier publishes 52 journals under Sociology and Political Science, with none specific to Asia and Africa ([Elsevier.com](http://Elsevier.com))

Lastly, there is a need to change the colonial attitude of the developed countries that by OA the authors are doing knowledge philanthropy, acknowledging that every society and culture generates and produces knowledge depending on the context, immediate issues facing them as well as taking cognizance of past history and future development. In the path of knowledge creation, Global North has had clear advantages, given histories of colonialism, appropriation and value extraction of the Global South by the countries of Global North. Furthermore, if authors of Global South are provided with even half the funding along with institutional- infrastructural support, they can excel and compete with authors belonging to colonizer economies – where neo-colonial dominances continue in varied ways.

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## 4

# International partnerships with foreign universities and RTOs: Their roles in centers of excellence in latin america.

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### **Abstract**

International collaboration in STI has been developed through a variety of mechanisms and some developing countries have recently promoted international partnerships with actors from the developed world. Under the scheme of centers of excellence (CoEs), Chile and Peru have promoted partnerships with foreign universities and research and technology organizations (RTOs), expecting them to support local actors in accessing global sources of knowledge, technology and innovation as well as to contribute to strengthen their capabilities. This study explores the role of international partners drawing on conceptual insights derived from two bodies of literature: the internationalization and the intermediary roles of universities and RTOs. Our findings show that foreign universities and RTOs have been fulfilling limited roles compared to what was expected and shed light on potential explanations for it. This study also provides a taxonomy that might guide further research on this contemporary issue.

**Keywords:** International partnerships, centers of excellence, innovation intermediaries, Latin America

## 1. Introduction

International collaboration in science, technology and innovation (STI) has been promoted and developed in different forms and pursuing a variety of aims. Some authors highlighted the importance of international flows of knowledge, technology and people in the catching up process of several countries (Freeman, 1995; Mazzoleni & Nelson, 2007; Patel & Pavitt, 1994). Studies on the internationalization of national systems of innovation (NSIs) have analyzed certain aspects of the internationalization of multi-national companies (MNCs), universities, researchers, research and technology organisations (RTOs), among others (Carlsson, 2006; Georghiou, 1998; Watkins et al., 2015; Youtie et al., 2017; Zacharewicz et al., 2017).

Moreover, international collaboration encompasses a variety of channels such as information exchange, laboratory sharing, joint research, researchers' mobility, international partnerships, the attraction of foreign organisations to setup subsidiaries and so on. Among the most well-known mechanisms to foster international technology transfer and innovation are trade and foreign direct investment (FDI), in which MNCs might play key roles through R&D and technology partnerships with local firms and spillovers (Economic Commission for Latin America and the Caribbean - ECLAC, 2022; Freeman & Hagedoorn, 1994; Majidpour, 2017; Saggi, 2002; Savona & Bontadini, 2016; Watkins et al., 2015). Limitations of these mechanisms, particularly for developing countries, have also been highlighted by this strand of literature.

Adopting a different mechanism, in the last decades some countries have promoted large-scaled international partnerships aimed at strengthening domestic STI capabilities with a range of structures (Pfothenhauer et al., 2016). In Latin America, Peru and Chile have been making efforts to strengthen their NSIs and launched centers of excellence (CoE) programs as a distinctive policy instrument to promote research, technology transfer and innovation through international collaborations and university-industry linkages (UILs). According to the calls for public funding, CoEs required the participation of international partners, expecting them to allow host-country actors to access new knowledge, technology, and global innovation networks.

To this respect, we found neither evidence on whether those expected benefits have been achieved and how this might have happened nor a suitable well-defined conceptual framework to analyze the roles of international actors in the context of CoEs in Latin American countries (LACs). To address this gap in the literature, therefore, we draw on insights derived from studies on the

internationalization of RTOS and universities and their intermediary roles as a reference.

Literature on the internationalization of RTOs and universities has been mostly focus on the experience of developed countries and shed some light on the motivations and potential benefits from international connections (Altbach & Knight, 2007; Cruz-Castro et al., 2015; Wahlers, 2018; Zacharewicz et al., 2017). This body of literature seems to have adopted a *home-country perspective*, i.e., the analysis of the motivation and benefits for organisations and their innovation systems from connection overseas. Complementing that approach, we adopt a *host-country perspective* to study experiences in which developing countries attract foreign organisations to work in partnerships with local actors. Moreover, given the lack of a clear conceptual framework to explore their roles in the context of CoEs, we turn to studies on innovation intermediaries as a point of reference to analyze the nature and roles of universities and RTOs.

Our results show that international partners have been fulfilling very limited roles compared to what was expected from them in Chile and Peru and provide some insights for explaining this phenomenon. Finally, we include a section with conclusions and discussion.

## **2. A brief background on CoEs in chile and peru**

NSIs in Latin America have been characterized for low scientific and technological capabilities in both universities and firms, a lack of experience in linking these two worlds, and a low level of private investment in R&D (Alcorta & Peres, 1998; Arocena & Sutz, 2000; Crespi et al., 2014). These features are shared by Chile and Peru, which have exhibited similar positive trajectories in terms of macro-economic performance but face certain challenges regarding STI that make them be characterised as weak NSIs. Among their several attempts to foster STI capabilities and UILs, they launched similar programs to set up CoEs.

These programs in Chile and Peru required the involvement of international partners expecting them to contribute to strengthen the host country capabilities through, for instance, access to and the generation of technology, technology transfer, the training of highly qualified human capital, and the promotion of entrepreneurship and new business opportunities. In Chile the program “Attraction of International Centers of Excellence” promoted the set up international centers of excellence, in liaison with local R&D organisations, in order to perform R&D, technology transfer and commercialization in forefront



areas of technology (Innova Chile 2012). In Perú, CoEs should constitute as strategic alliances formed by Peruvian renowned research entities, international research centers of excellence and Peruvian companies (FONDECYT 2015).

Peruvian and Chilean CoE programs meant unprecedented efforts not only because of their large scale (in terms of public funding and time horizon) but also because they promoted the attraction of international partners, which is new to the region according to Klerkx and Guimón (2017). In both countries, therefore, CoEs have configured as international partnerships for research and innovation (XXX). Their main international partners have been universities and RTOs from developed countries: the Fraunhofer Society - FhG (Germany), the Commonwealth Scientific and Industrial Research Organisation - CSIRO and Sustainable Minerals Institute of the University of Queensland - SMI (Australia), the Institut National de Recherche en Informatique et en Automatique - INRIA (France), the Fundación LEITAT (Spain), and the Wageningen UR (Netherlands) as well as the University of California Davis, the Washington University and the Pennsylvania State University (US).

### **3. Conceptual approach**

#### **3.1 Internationalization of RTOs and universities**

In this field, Carlsson (2006) surveyed the literature on the internationalization of NSIs and found that studies have focused on: the internationalization of innovation systems and the interdependencies among them, the internationalization of corporate R&D, and the barriers to internationalization. One conclusion of this body of literature is that internationalization of corporate R&D and international technology transfer are highly concentrated in the developed world (Carlsson, 2006; Hagedoorn, 2002; Mowery & Oxley, 1995). Moreover, some authors highlighted that the internationalization of corporate R&D differs substantially from the internationalization of research organisation (universities and RTOs) for the latter relies more *“on ‘soft’ measures such as joint research, publications and mobility than on ‘hard’ measures such as R&D-related FDI”* (Berger & Hofer, 2011, p: 110).

Previous work on the internationalization of RTOs and universities has focused on strategies, rationale (potential benefits), impacts and barriers (Altbach & Knight, 2007; Antelo, 2012; Frølich, 2006; Georghiou, 1998; Knight, 1999; Pfothenhauer et al., 2016; Youtie et al., 2017; Zacharewicz et al., 2017). For universities, studies pointed out the importance of their international connections as a means to support their local environment (their home country

or region) (Albuquerque et al., 2015; Bramwell & Wolfe, 2008; Qiu et al., 2017) and found that the main motivations for internationalization are financial/economic and academic benefits (Altbach & Knight, 2007; Bartell, 2003; Bennell & Pearce, 2003; Knight, 1999; Wahlers, 2018; Youtie et al., 2017).

To this respect, there are certain considerations. First, some authors stated that universities' internationalization has been a strategic concern in developed countries and less important in developing ones, a trend that might be changing recently (de Wit et al., 2019). Second, most studies approach this issue from a *home-country* perspective by exploring and explaining the motivations and benefits for both universities and their environment, with little attention to the effects on their counterparts. Finally, many studies have focused on the internationalizations of the first two missions of universities, i.e., education and research (branch campuses, franchised degree programs, foreign students, joint research, researchers and students mobility, and so forth). Meanwhile the internationalization of their third mission, that refers to linkages with social and industrial actors (technology transfer, innovation, linkages with global innovation networks, entrepreneurship, and so on) has been neglected to some extent.

Only a few studies have recently explored the international process of universities from a host- country perspective by analyzing programs promoting the attraction of foreign universities to build domestic capabilities (Pfotenhauer et al., 2016; Youtie et al., 2017). This body of literature has suggested that host-country organisations can obtain scientific, technological and reputational benefits, without exploring thoroughly how those benefits can be obtained.

Regarding RTOs' internationalization, motivations, benefits, costs, and risks have also been studied to some extent (e.g., Berger & Hofer, 2011; Jonkers & Cruz-Castro, 2010; Loikkanen et al., 2015; Zacharewicz et al., 2017). This body of literature highlighted that the main motivation of RTOs to collaborate internationally is to access funding and complementary academic assets (knowledge, facilities and so forth) to develop high-quality research (i.e., economic and academic motivations). Therefore, RTOs' international operations seem to depend on finding suitable partners in terms of their capabilities and resources as well as having market opportunities in case of RTOs closer to industry such as the German Fraunhofer institutes and the Finish VTT institutes.

Studies on this field have usually adopted a *home-country perspective*, save certain claims about potential benefits for host-country organisations. For example,

according to some authors, international counterparts of RTOs might obtain commitment of reputational capital, visibility, access to funding and the fostering of research (Cruz-Castro et al., 2015; Jonkers & Cruz-Castro, 2010). However, there is no evidence on how those benefits can be achieved and whether they have been actually realized, particularly when host countries are characterised by having weak NSIs.

From a different but complementary perspective, our study addresses the question about the roles foreign universities and RTOs have been performing in LACs within CoEs and, consequently, we analyze their contribution to local actors – i.e., adopting a *host-country perspective*.

### **3.2 Universities and RTOs as innovation intermediaries**

As argued earlier, we did not find a conceptual framework about the role of international partners in the context of research and innovation partnerships (CoEs in this case) in developing countries. As international partners analyzed in this study include universities and RTOs, we can draw on the intermediary functions these actors might fulfil.

The domain of innovation intermediaries is vast and complex, with several actors fulfilling a variety of roles. A general definition stands that an intermediary is “an organization or body that acts an agent or broker in any aspect of the innovation process between two or more parties. Such intermediary activities include: helping to provide information about potential collaborators; brokering a transaction between two or more parties; acting as a mediator, or go-between bodies or organizations that are already collaborating; and helping find advice, funding and support for the innovation outcomes of such collaborations” (Howells 2006: p. 720).

Given the diversity of actors that might fit into this broad definition, there have been various classifications by making distinctions between internal and external intermediaries (Mina et al., 2009) individuals and intermediary structures (Khan et al., 2015; Meyer, 2010; Wright et al., 2008) and individual and organizational intermediaries (Haas, 2015). A comprehensive classification is provided by Yusuf (2008), who considered four types: i) general purpose intermediaries such as universities; ii) specialised intermediaries such as TTOs within universities; iii) financial actors such as venture capitalists and angel investors, and iv) institutional intermediaries such as public agencies and RTOs. It is not our purpose here to analyze each type of intermediaries but to clarify whether RTOs and universities can be regarded as innovation intermediaries.

Regarding ‘general purpose’ universities and under a specific approach for

developing countries, some authors have argued that universities might play intermediary roles in the process of technology transfer from foreign firms and international knowledge sources towards local firms and local innovation systems (Albuquerque et al., 2015; Qiu et al., 2017; Schiller & Lee, 2015; Vaaland & Ishengoma, 2016). However, this approach is not exclusive to the developing world given that an intermediary function has been found, for example, for the University of Waterloo in Canada (Bramwell & Wolfe, 2008). Universities and their international connections, therefore, have been considered as a means to support the local environment in which they are embedded (their home country or region).

The second group of intermediaries includes RTOs, which are different from universities and companies, despite some overlap in terms of roles (Berger & Hofer, 2011; Giannopoulou et al., 2019). Even though the RTOs group is very heterogeneous, they share certain characteristics such as having significant public funding that is complemented by other sources, doing applied research and development, bridging the gap between basic science and market solutions, and delivering services to firms and other clients (Berger & Hofer, 2011; Giannopoulou et al., 2019; Mina et al., 2009; Sharif & Baark, 2011; Zacharewicz et al., 2017).

In summary, the partners of Peruvian and Chilean CoEs – foreign universities and RTOs – do fulfil the criteria to be considered as innovation intermediaries. The question is what roles they might be performing in the context of CoEs in two developing countries.

### ***3.3 Intermediary roles of universities and RTOs***

For our enquiry, we take as a reference the roles fulfilled by innovation intermediaries in general and RTOs and universities in particular, which complement the motivations for and benefits from their internationalization (developed earlier).

According to some studies, innovation intermediaries, RTOs in particular, can fulfill a range of functions that might evolve depending on the emergence of new needs from users and their strategies to diversify their operations (i.e., the context in which they work) (Howells, 2006; Intarakumnerd & Goto, 2018; Sharif & Baark, 2011; Shiu et al., 2014). In the UK, for instance, Howells (2006) identified 10 general roles: foresight and diagnostics, scanning and information processing, knowledge processing and combination, gatekeeping and brokering, testing and validation, accreditation, validation and regulation,

protection of results, commercialization, and evaluation of outcomes. In turn, Kodama (2008) studied TAMA association, which was created to promote the generation of new technologies and products in the Metropolitan Area of Tokyo through collaborations between product-developing SMEs, universities, and large firms. Regarding TAMA's functions, this author stated that besides UILs, inter-firm linkages are also important, especially in the phase of product creation and commercialization.

For the agriculture sector in Latin America, Dutrénit et al. (2012) identified four intermediary roles: the identification and integration of the offer of R&D and technology, the articulation of farmers' demands, the matching of demand with an offer of technology and R&D, and the management of innovation. Dutrénit and colleagues found that intermediary roles in the agriculture sector in Mexico differ from those in developed countries such as the Netherlands, which might be explained by differences in the agricultural system in each country. For example, there is private funding for the provision of R&D and extension services in the Netherlands (Klerkx & Leeuwis, 2008), while in Mexico those activities are still financed with public resources (Dutrénit et al., 2012).

Regarding RTOs, Mina et al. (2009) identified at least 11 functions: (i) development and application of technological know-how; (ii) linkages with the research base (universities and public research institutes); (iii) linkages with firms through the provision of contract research and joint R&D; (iv) dissemination of R&D results, directly via dedicated events or via universities; (v) brokering agreements; (vi) patenting and commercialization of technology as well as licensing of local technologies; (vii) facilitation of risk-sharing, support to new business creation; (viii) management of venture capital; (ix) screening, selection and incubation of innovative ideas; (x) formation of human capital at postgraduate level, and training of engineers and entrepreneurs; and (xi) participation in international standard setting.

In case of universities, the literature has highlighted their three fundamental missions: education, research and linkages with industrial and social actors (Martin, 2003; Martin & Etzkowitz, 2000). As Bramwell and Wolfe (2008) stated, besides generating knowledge to commercialize, universities engage in several channels of knowledge transfer and support to their local environment such as the attraction and retention of talent, linkages with industry in the formation of human capital, global linkages that facilitate access to global flows of knowledge, and support of entrepreneurship through education and business activities.

Summing up, this section identified the roles performed by universities and RTOs within their innovation systems (a *home-country perspective*). We wonder whether foreign universities and RTOs have been fulfilling similar intermediary roles in LACs within CoEs (a *host-country perspective*).

### 3. Methodology

This study adopts a qualitative approach that, according to some authors, is suitable for relatively new phenomenon on which there is limited evidence (Creswell, 2007; Eisenhardt & Graebner, 2007; Verschuren, 2003; Yin, 2013). To this respect, we did not find defined conceptual frameworks to study the roles international partners in the context of CoEs, particularly in countries with weak NSIs. Given the lack of clarity about these phenomena, what we identified in previous sections should be regarded as a set of conceptual insights that will serve as a point of reference. We prefer not to assume any specific type of roles as there is limited literature on this matter and, as argued by some authors, analytical frameworks used to understand certain issues in developed countries might not be suitable for the developing world (Albuquerque et al., 2015; Arza, 2010; Torres et al., 2011).

Therefore, we adopt a case study strategy taking CoEs as units of analysis to explore the role of international partners within them. Aware that patterns of collaboration might vary across sectors and technology fields, something highlighted by some authors (Britto et al., 2015; Meyer-Krahmer & Schmoch, 1998), we selected two CoEs by using the so-called theoretical sampling and chose the Fraunhofer Chile Research – Center for Biotechnology Systems (FCR-CBS) in Chile, and the Cocoa Innovation Center (CIC) in Peru. Their activities – research or business lines – are related to the same technological field (i.e., biotechnology) and are intended to respond to the needs of similar industries (i.e., agriculture and food industry).

Having CoEs configured as international partnerships, we designed fieldwork to obtain a comprehensive empirical approach by collecting perspectives from both local and foreign partners. International partners were foreign universities and RTOs, while local actors were universities, intermediaries, firms and civil servants from funding agencies. We interviewed 48 participants (20 in Peru, 17 in Chile and 11 from international actors - Germany, the US and the Netherlands), 33 of which have been involved in our two cases and the remaining ones have been related to other CoE initiatives.

Information was triangulated with secondary data, mainly administrative

reports, which proved to be quite limited. This situation was mitigated by integrating the perceptions of several types of actors involved in CoEs. Finally, being a case study, it has limitations in terms of generalization, while its conclusions and considerations can be analyzed at the theoretical level. The resulting taxonomy on the roles of international actors in large-scale international partnerships in developing countries might constitute a starting point for a new research avenue.

## 4. Results

### 5.1 *On the role of international partners: A new taxonomy*

This article studies the role international partners in the context of CoEs in Chile and Peru and the corresponding benefits for local actors (i.e., with a *host-country perspective*). As explained earlier, we take the internationalization and the intermediary roles of universities and RTOs as a referential conceptual approach. In what follows, we describe our main findings.

In Chile, CoEs have been led by subsidiaries of foreign RTOs, with foreign names but local capabilities, while the role of international partners in Peruvian centers was secondary, as they did not show too much involvement in neither the decision-making process nor the activities of the centers. Nonetheless, the roles of international actors with regard to local organizations seem to exhibit similar patterns in both countries. For instance, Chilean and Peruvian actors recognized that the main contribution of foreign partners has been their *names and prestige*.

In Chile, two senior managers of the CoE highlighted that international actors bring an illustrious reputation with them, which opened many doors. According to one of them, "*it was an amazing opportunity to work with such a well-recognized innovation brand.*"

<sup>1</sup> In Peru, interviewees highlighted that the prestige of the international partner helps to build a positive image of the initiative. As one senior manager of the Peruvian center stated, "*as a brand, it helps a lot ... if I wanted to deliver a service, it is like saying 'hey, these are the center partners, and we have one of the best universities from the US.'*" Therefore, international partners in both countries seem to allow local actors to signal their capabilities because they are working with prestigious foreign organisations.

However, that does not necessarily mean that they are playing important roles in *supporting dialogue between partners and building UILs*. In Chile, most

interviewees criticized international partners because they do not usually foster direct linkages between local actors. We found a couple of potential reasons for this: first, Chilean centers have organized in such a way that their internal teams have to be involved and lead all interactions between universities and firms (control of operations), so they do not perform the role of brokering transactions between these. Second, CoEs compete with universities for public funds to do research and connect with firms as well as for private funding coming from services provided to firms, so they do not have too much incentive to fulfill a brokering function between local universities and firms.

In Peru, most interviewees pointed out that international partners limit their roles to participation on the center's board and specific research activities. An international interviewee recognized that they do not play an important function in facilitating dialogue between actors. Expectations about international partners were well described by one civil servant, who complained saying *"they [international actors] are more focused on research projects; however, it [facilitation of interactions] would have been important because they have a lot of experience in this type of linkages and in negotiations on technology."*

Regarding other intermediary roles, the literature has identified activities such as supporting actors in several aspects of R&D, improving networking, laboratory sharing, finding specialist personnel and so forth. In terms of ***R&D and commercialization***, international partners were attracted to Chile to fill a gap in the system relating to capabilities in applied R&D, technology transfer and commercialization. Therefore, we might have expected international partners to strongly support local actors in these aspects but, according to most Chilean interviewees, that did not happen.

A senior manager of a Chilean center stated that there was not too much collaboration to strengthen universities' R&D capabilities. This interviewee stressed: *"to some extent, I was very sad they [universities] did not come to us to either work together or take our advice. (...) our involvement with universities was not as close as it should have been or could have been."* Moreover, a staff member of a university intermediary stated: *"whether they [international actors] brought technology or encouraged the participation of specialists with advanced knowledge from their headquarters, in projects developed in Chile, that did not happen"*.

In Peru, the participation of the international partner was limited to attending meetings of the center's board and supporting the scientific committee of this center. Several interviewees labelled its role as a 'consulting' or 'advisory' function. Such a role can fit into the broad concept of research collaboration



provided by Katz & Martin (1997), which include offering general advice and insights. This role could then be considered as a channel to support local partners R&D activities.

Regarding the strengthening of local actors' *capabilities in knowledge and technology transfer*, Chilean interviewees recognized that international partners brought some capabilities into the country through, for instance, procedures for laboratory management, confidentiality management, and technology transfer. However, this role seems to be still limited, for six interviewees complained that universities and their TTOs did not obtain benefits. Two persons from university intermediaries stated that in this aspect "there is a debt" and one of them added: "if I had to highlight a weak point of this program of centers of excellence, it would be that they did not install those capabilities sufficiently." In Peru, this role was almost negligible; as one civil servant pointed out, the international center focused on research, so "it was hard for us to incorporate other topics of interest such as technology transfer".

In this regard, interviewees from Germany claimed that the main objective of internationalization of intermediaries such as the Fraunhofer Society is to gain access to funding and knowledge, which has also been highlighted in previous studies (e.g. Berger and Hofer 2011; Jonkers and Cruz-Castro 2010). Considering the other side of international collaboration, German actors stated that they expect their counterparts to access knowledge and technology useful for their needs and to benefit from German organizations' experience in building UILs and carrying out technology transfer. However, based on our findings in Peru and Chile, those benefits seem to be still very limited.

Regarding other potential benefits, most Chilean interviewees stated that *accessing laboratories and equipment of the parent center* is possible, but its realization has been very limited for various reasons. First, Fraunhofer institutes are financially independent from each other and, therefore, using their facilities comes with associated costs. Second, one member of an intermediary unit stated that laboratory sharing is possible but did not happen because international actors do not have large equipment based in Chile, while there is little connection with their overseas headquarters. A few exceptions can be found in collaborative projects, where some activities are carried out in Germany and the results sent to Chile. A similar situation has been highlighted by Peruvian actors involved in the CoE.

In terms of *networking and mobility*, we found mixed perceptions. Some Chilean actors highlighted that there has been a lot of mobility (internships and visits)

between the internal team of the Chilean center and Fraunhofer institutes. However, Chilean university actors perceived that they did not benefit greatly from those international linkages. For instance, a person working for a university intermediary complained, *"they have not opened up opportunities for us, such as those of Horizon 2020<sup>2</sup> (...) there was not this kind of collaboration outside the established activities of the CoE"*.

In Peru, half of our interviewees stated that international actors did not promote those connections because either local partners did not ask for that or they have nothing to show internationally yet. The other half acknowledged that there had been some actions to broaden networks through, for instance, the participation of Peruvian actors in international academic events, internships and visits, but they are still relatively limited.

Finally, intermediary roles also refer to *supporting actors to create new firms, linking them with investors and incubators, to identify and hire specialist personnel as well as to promote internationally the products of local partners* (Kodama, 2008; Mina et al., 2009). Most interviewees in Chile and Peru did not identify these functions in international partners. For instance, a senior manager of the Chilean CoE highlighted that it did not play the role of linking firms with investors because *"the system has not been that much developed, and the center of excellence did not have that much experience to offer backing to start-up companies."*

Summarizing, we can conclude that international partners of CoEs in Chile and Peru have been performing certain roles, some of which are intermediary ones. As argued earlier, benefits from internationalization and intermediary roles were just a point of reference to analyze empirically the roles of international actors and were used with an open perspective. Therefore, the resulting taxonomy set out in Table 1 can be regarded as a new analytical framework suitable for studying their contribution in partnerships aimed at fostering developing countries' STI capabilities.

**Table 1.** Roles of international partners in the Chilean and Peruvian systems

| Activities                                                                                                | Chile<br>International RTO | Peru International<br>University |
|-----------------------------------------------------------------------------------------------------------|----------------------------|----------------------------------|
| Reputational benefits.<br>Opportunities to broaden networks.<br>Signalling of local actors' capabilities. | Yes                        | Yes                              |
| Facilitating dialogue and interactions between local actors.<br>Brokering function.                       | Very limited               | None                             |
| Support to universities and firms in R&D aspects.<br>Advisory function.                                   | None                       | limited                          |
| Support to universities in knowledge and technology transfer management.                                  | Very limited               | None                             |
| Accessing laboratories.                                                                                   | Very limited               | Very limited                     |
| Broadening networking and mobility.                                                                       | limited                    | limited                          |
| Support entrepreneurship. Linking with investors.<br>Identifying specialist personnel.                    | None                       | None                             |

*Author's own elaboration.*

## **5.2 On the reasons for the limited involvement of international partners in CoEs in developing countries**

Our results show that international partners in Chile and Peru do not seem to be fulfilling substantial intermediary roles between local partners and the international sphere, at least not at the degree expected by the CoE programs. This limited role can be explained by certain conditions and capabilities in the Chilean and Peruvian systems. Interviewees from Chile and Germany highlighted that one of the most important factors hampering international connections is the lack of resources. In the Peruvian case, an international partner stated: *"resources are very limited; even with the funding for the center of excellence, there is not enough money to do as much work as is needed (...) The size of the project is still very small."*

A second potential explanation, particularly for the lack of knowledge or technology brought from abroad, is that foreign technologies do not necessarily

fit the needs and capabilities of receiving countries, as highlighted by some German actors. A previous work found that Chilean and Peruvian actors, from both the academic and business sectors, face certain limitations regarding capacities in developing R&D, technology transfer and UILs (labelled as *capacity-related* barriers) (XXX). These weaknesses might have limited their international connections, which seems to be consistent with some studies on technical change that pointed out the mismatch between foreign technology and local capabilities and conditions in developing countries (e.g. Acemoglu 2002; Freeman 1995; Fu, Pietrobelli, and Soete 2011; Lundvall 2016).

These two potential explanations – lack of resources and limited capabilities – complement each other to some extent. According to one German interviewee, technology developed in Germany needs to be adapted to local conditions in other countries, and that requires financial resources, which are often missing in developing countries.

Finally, we found that the level of involvement of international partners in CoEs – a leading function in Chile and a secondary role in Peru – makes local actors perceive them differently. In Chile, for example, one staff member of an intermediary criticized international partners because these only collaborate with local organisations if they do not have another option and, unfortunately, they are actually more competitors in the system than collaborators. In Peru, nobody mentioned this tension, which could be explained by the ancillary role of international partners in Peruvian CoEs.

In the Chilean context, characterized by UILs mainly built upon public subsidies (XXX), it may be understandable for universities to perceive international actors as competitors for funding as they are new actors in the system, something that might be hampering cooperation between them. However, in some mature systems, different actors have specialised in different aspects, so they sometimes compete and sometimes cooperate (Frietsch and Schubert 2012). An example is the German system where, according to Harding (2001), there is competition between technology transfer institutes – including universities – for public and private money alongside cooperation and interdependence between them.

## **5. Conclusions and discussion**

Addressing a gap in the literature relating to the roles of foreign universities and RTOs in international partnerships in developing countries, we adopt a *host-country* perspective. The result of our empirical analysis is a new taxonomy

(Table 1) on the role of international partners in large-scale initiatives intended to foster local capabilities in terms of R&D, technology transfer and innovation.

In this regard, local and international actors involved in Chilean and Peruvian CoEs agreed that one of the main contributions of international partners is their names and reputation, which allowed the former to signal their capabilities to other actors in their local system and even internationally. A second contribution refers to international mobility of researchers and personnel of local centers and universities, which might bring certain advantages such as greater involvement in technology transfer and innovation activities in their home countries, something identified in other contexts (e.g., Edler et al., 2011). However, in areas such as fostering international networking and access to laboratories, the role of international actors was quite limited. Moreover, in terms of support to local actors in R&D aspects, technology transfer and UILs outside the centers, their role was almost negligible.

This study also identified certain local conditions that may help to understand why international partners fulfilled limited roles in Chile and Peru. For example, the lack of resources would have made foreign solutions, specialists and assets unaffordable for local actors. Moreover, limited capabilities in universities and firms may have made it difficult for them to adopt and master foreign technology. These findings are consistent with studies on internationalization of NSIs that stressed the concentration of internationalization of public R&D and technology transfer in the developed world (Berger & Hofer, 2011; Carlsson, 2006; Freeman & Hagedoorn, 1994; Mowery & Oxley, 1995) and with the literature on technical change that highlighted the mismatch between foreign technology and local capabilities and conditions in developing countries.

In particular, the main motivations of universities and RTOs to collaborate internationally is to gain access to funding and new and complementary knowledge, but local actors in developing countries show certain limitations in terms of resources and capabilities that make it unsurprising the limited involvement of foreign partners in CoEs in Chile and Peru. An example of this situation is the international revenue figures of the Fraunhofer Society (an RTO participating in two CoEs in Chile): *“some 30 percent of international revenue came from EU funds, 35 percent from customers and partners in Europe, and 35 percent from those outside Europe”* (Fraunhofer 2017: p. 30). Despite the geographical diversity of the international activities of FhG, one can see a relatively high concentration: for example, North and South America in 2017 generated revenue of €55 million, mainly concentrated on the US (€48 million), followed a

long way behind by Chile, which accounted for just €2.1 million (Fraunhofer, 2017).

An alternative explanation was given by Chen, Zhang, and Fu (2019), who argued that international technological collaboration would tend to be more limited by national boundaries as leading countries would make some effort to prevent developing countries from benefiting from their investment in R&D. In the same line, a study found that one of the most important deterrents for internationalization of German RTOs was that this might strengthen foreign scientific competitors (Edler 2007, cited by Berger and Hofer 2011). However, according to Ponds (2009), fears of 'unwanted knowledge spillovers' stemming from collaboration might be unfounded, something which might be the case in our study because the limited international R&D and technology collaboration seems to stem from different reasons: limited resources and capabilities.

Consequently, following the experiences of Asian countries such as South Korea, Singapore and Malaysia, centers and policy makers promoting this kind of initiatives should consider broadening the scope of CoEs to get them engaged in capability-building activities. They should also look for complementarity with other actors who may help carry out capability-building activities, so the centers do not need to do this on their own. In this context, the remaining question is what kind of roles international partners should play within schemes such as CoEs.

The main conclusion of this study is that there exist substantial differences between the expectations and the actual benefits from the participation of international partners in CoEs in Chile and Peru. Therefore, the role of international partners should be re-evaluated by considering the patterns in their internationalization process – focused on academic and economic interests – and certain limitations in developing countries. If the attraction of foreign personnel, equipment and technology is expected, the actual cost and the required capabilities should be considered. If that were not feasible, other collaborative activities could be promoted to strengthen local capabilities, particularly in terms of knowledge and technology transfer and innovation: visibility and reputation, personnel mobility, experience exchange activities, and advisory function.

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## Notes

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- <sup>1</sup> The general manager of another CoE stated that rather than financial backing, the international actor supported the initiative with its name and prestige.
- <sup>2</sup> Horizon 2020 is a European research and innovation programme that provides subsidies for projects that can involve the participation of non-EU partners.

## Blockchain for backcasting emerging technologies: Enhancing efficiency in review classification for R&D decision making process in emerging countries

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### **Abstract**

This paper presents an innovative approach utilizing private blockchain to enhance the efficiency of review classification for the optimization of decision-making process, since new technologies are attracting increasing interest in R&D of companies and academic institutions. In particular, backcasting approach in systematic and narrative review analysis aims to identify which emerging technologies is more convenient to invest.

This becomes a significant objective not only from a business point of view but also of interest to emerging countries that are usually weak in the implementation of new technologies and prefer to replicate and adapt current ones; therefore, an accessible and optimized research system is needed to assist R&D and innovation in rising countries in this field.

Blockchain system ensures transparency and reliability in sharing scientific material among experts by carrying out a kind of research tokenization through smart contracts in which “utility tokens” are represented by scientific papers and transaction object will be the intellectual property of papers with the evaluation report of each experts’ sub-team.

Methodology develops in the following steps: selection of sources to be subjected to anonymous analysis procedure; these scientific works are introduced into the blockchain so that the subsequent evaluation of the experts is not influenced by subjective aspects, according to the experimental SANSER scale for the Research Quality Assessment, combining SANRA and SCASST test.

Finally, two different output procedures are applied: NR4CASTING to produce a ranking of narrative review papers; SR4CASTING to generate a single literature review containing the references of selected papers to inform decision makers and optimize resource allocation in technological innovation projects.

**Keywords:** literature review, backcasting, technological innovations, smart contract, blockchain, emerging countries.

## **1. Introduction and preliminaries**

Procedures and methods that consistently monitor and identify emerging trends from scientific publications are required given the quickly evolving nature of scientific research.

Because of their significant potential for socio-economic effect, emerging technologies have recently attracted more attention from research and development departments, academic publishing organizations, and policy makers. The planning of scientific dissemination activities is another area where early trend detection is important.

Conference planners must have a comprehensive understanding of emerging trends to find hot themes for calls for papers and hire reviewers who are knowledgeable about these topics.

However, new technologies are characterized by uncertainty and ambiguity because their future influence is unknown and there is little agreement about their potential.

According to Kishita et al. (2017) back casting scenarios can be used to imagine desirable futures with discontinuous change from the present in mind, with particular attention to the concept of resilience which is crucial for creating visions of desirable futures designed to withstand the widest variety of shocks external to the system.

In fact, the authors proposed a method to design back casting scenarios to allow a systematic process of prediction of resilient futures; however, they also point out that there are still several open challenges with respect to the practical application of the proposed method.

By extending the back casting approach, in the design of desirable future scenarios in different sectors (including primarily the choice of investment on certain emerging technologies), the sharing of knowledge between experts and different stakeholders (including the industries themselves) would significantly increase the value of this decision-making process support tool to the point of being able to influence the most functional political choices with respect to what is identified as a desirable future.

Moreover, emergence of new technologies is a significant and intensively studied area. The research by Park et al. (2022) identifies the characteristics of the early stage of technological emergence by analyzing the early patents in five different technologies. The research's primary finding is that technological and scientific knowledge are strongly intertwined in the emerging stage, as early patents in all five technologies cite scientific papers more frequently than patents that support the continued development of technologies. Furthermore, most of the patents are granted to firms whereas the proportion of non-firm's patents in the early stage of technological domain is relatively higher than that of the other periods consistent with the larger role of scientific knowledge in the emerging stage.

Their results reveal crucial theories concerning the link between scientific accomplishments and technical innovation that were not previously offered and can be studied further as data sources improve.

Considering the limitations expressed by the authors of this research, the methodology exposed in the presentwork could, instead, provide a suitable tool for the upstream selection of the optimal scientific material for the subsequent scanning of the patent connections and their subsequent technological evolution in companies with respect to the literature considered and suitably filtered in advance.

To understand the application potential of an optimal model for the analysis and selection of the most advantageous emerging technologies, it is important to think also in terms of countries and not only of companies. The rate of



technological innovation is influenced by a number of variables and is significantly correlated with a country's income level. Huge technological disparities exist between developed, emergent, and developing nations, as well as between developed regions within a nation and their less developed counterparts. Since the Industrial Revolution, developed nations have dominated the technological frontier; they are the innovators and early adopters of new technologies. Emerging and developing countries approach technological innovation primarily through the adoption and adaptation of pre-existing and new-to-market or new-to-firm technologies, as opposed to the invention of new technologies. The technological disparity between income levels is also reflected within nations, particularly in developing nations. Some sectors in developed urban areas of China or India, for instance, may use world-class technology, but elsewhere in these countries, less advanced technology is still employed.

In the past two centuries, the rate of technological diffusion has accelerated on a global scale. The acceleration is especially pronounced in certain industries. However, the diffusion of technology in underdeveloped nations, particularly in developing nations, is relatively weak. (Tan, 2010)

In order to enhance the position of emerging countries in this field, the objective is to establish a supportive environment for R&D and innovation through an accessible and optimized research system.

Therefore, in the present research we will suggest a new method that combines the back casting approach for identifying the desirable future of emerging technologies as a systematic tool to support the related decision-making process and the analysis of the scientific literature corresponding to the emerging technologies under investigation.

Existing solutions, based on citation analysis, are less suitable for contemporary analysis of emerging trends because citation analysis cannot be applied until documents have sufficient circulation to be cited, i.e. not in the immediate time frame.

This is why it is preferable to resort to an analysis of the narrative and systematic literature, appropriately filtered as will be illustrated in the methodology, to identify the best path from a back casting point of view that can be adopted by the company to implement the technology that will be more effective and sustainable. Furthermore, to guarantee the desired sharing of scientific knowledge and that the network thus generated is valid and unalterable, it is proposed to introduce a block chain system in the company that integrates the intra- muros R&D function.

This paper is organized as follows: first, we discuss the related work on literature review and past/future-facing approaches evolution in Section 1. Then, in Section 2, we provide an overview of methodology used for the analysis as concern search strategies and data sources, the explanation related to the adoption of blind bias and expert elicitation, the application of smart contracts in a block chain approach and, finally, the Research Quality Assessment (RQA). In section 3 we discuss the block chain-based procedure, content validity and reliability and so the two output procedures: NR4CASTING and SR4CASTING. Then, we present limitation and future developments of our study in Section 4. Finally, we conclude the paper in Section 5.

### **1.1. Literature review as research methodology**

Prior, relevant literature should be considered for all research fields and projects. When reading an article, regardless of discipline, the author begins by discussing past research to map and appraise the research area to motivate the study's goal and justify the research question and hypotheses.

To become a proper research methodology, like with any other research, necessary procedures must be performed and action must be taken to ensure the review is exact, precise, and trustworthy.

The researcher can employ a variety of methodologies, standards, and guidelines designed specifically for performing a literature review, depending on the goal of the review. (Snyder, 2019)

For the purpose of developing the procedures and to achieve the results of this paper, we examine two reviews of the literature:

- Systematic review
- Narrative review

#### **1.1.1. Systematic review**

Systematic reviews may answer research questions, summarize issues and assess topic knowledge, as set research goals, find gaps and discuss a topic. (Tranfield et al., 2003).

Systematic reviews can also analyze data from an alternate present to a variety of plausible bifurcation sites and routes and findings from an alternative present. In these cases, a systematic review could create a new theoretical model and track a study problem.

We can determine if an effect is consistent and if more research is needed. Techniques can also reveal which study-level or sample characteristics affect the issue, such as whether research in one sociocultural environment gives

statistically diverse results from those in others (Davis et al., 2014).

A publishable review requires multiple steps and decisions (for specific considerations in respect to each phase).

1. Audience interest determines review topic. Thus, it's best to scan the topic first to evaluate previous literature reviews, estimate the number of research papers to be evaluated, and define the review's objective, scope, and study issue. After choosing the study question and general review technique, create a literature search plan.
2. Review the aim, research questions, and procedure. Pre-evaluate search phrases and inclusion criteria. Evaluation type and scope determine sample selection.
3. Analyzing the review: after systematic review and sample selection, article evaluation is crucial. Select a sample and consistently extract important information from each article. The review's purpose and topic determine this.
4. Writing up the review: justify the assessment first. The technique may require varied facts and depth in the review piece. PRISMA was developed for systematic literature reviews and meta-analyses; RAMSES was developed for systematic narrative reviews (Wong et al., 2013); and guidelines for integrative reviews were developed by Torrance (2005). These guidelines cover literature review reporting and structure. Then, discussing review progress and literature collection is crucial. Authors must describe how they found, studied, and created literature.

#### **1.1.2. Narrative review**

Most articles reporting empirical research, grant applications, and, of course, many articles and book chapters are devoted particularly to reviewing the literature on a particular topic, therefore narrative reviews are an essential component of all these types of writing.

Narrative reviews offer a conceptual overview of the topic. Such reports may be better suitable for certain questions and may give short useful guidance. This paragraph discusses the contemporary significance of narrative reviews. Narrative reviews are written from the perspective of the narrator, capable of providing an explanatory review of the current literature in the topic.

According to Sarkar and Bhatia the advantages of narrative reviews are (Sarkar and Bhatia, 2021):

- gives an expert's perspective on the subject, preventing information overload and focus attention on the most important facts and topics.
- the proof is presented in an understandable way. Such assessments try to convey the information in an accessible way, emphasizing the useful discoveries.
- it is useful to present a summary of the literature when the evidence is scarce, scattered, or clear objectives for the topic are difficult to formulate.

The following are the disadvantages, according to the same authors:

- may influence (bias) the selection of material.
- may miss out some relevant findings.

Literature reviews help when evidence is scant, fragmented, or issue objectives are unclear. So, experts can assess the evidence and point out flaws and clarify results.

A narrative review, like a systematic review, requires multiple steps to complete and, on the other hand, allows for far greater flexibility.

In this paper, we consider two standards while producing a narrative review:

- the simple collation of the selected articles (handout of selected research papers);
- the synthesis of the evidence that has been selected in a structured manner.

First, decide what questions the review will address, the criteria for the literature search, and the flexibility in choosing databases, search terms and combinations, identification criteria and thresholds, information extraction procedures, and data synthesis and implication methods.

Instead of summarizing literary findings, authors should highlight themes and compare and contrast. A trusted expert could review the manuscript. In-house evaluation and improvement may benefit.

Therefore, the process may lead to the following outcomes: a structured representation of the chosen articles or a simple collection of the chosen articles.

## **1.2. Past-facing and future-facing approaches**

Long-term planning requires a dependable way to predict and change future

events.

Operational environment dynamics and technology-induced changes—which are interrelated—present the biggest opportunities and threats to the organization's survival in both cases. Thus, a well-calibrated organization must be imagined.

Today's choices will last. Big decisions should regard the future and visionary states need future scenarios. Forecasting optimizes organizational and labor policy. A forewarned plan permits proactive response to near- to medium-term opportunities and risks. Forecasting helps companies stay ahead by managing risk and it can somewhat enable this, however validation and replication methods are becoming insufficient to validate forecasts in the near future. This contributed to the creation of the backcasting process (Dortmans, 2005).

Bendor et al. (Bendor et al., 2021) assess several ways and depict the future of landscape as a two-dimensional interaction of activity concentration on goals or paths and stakes.

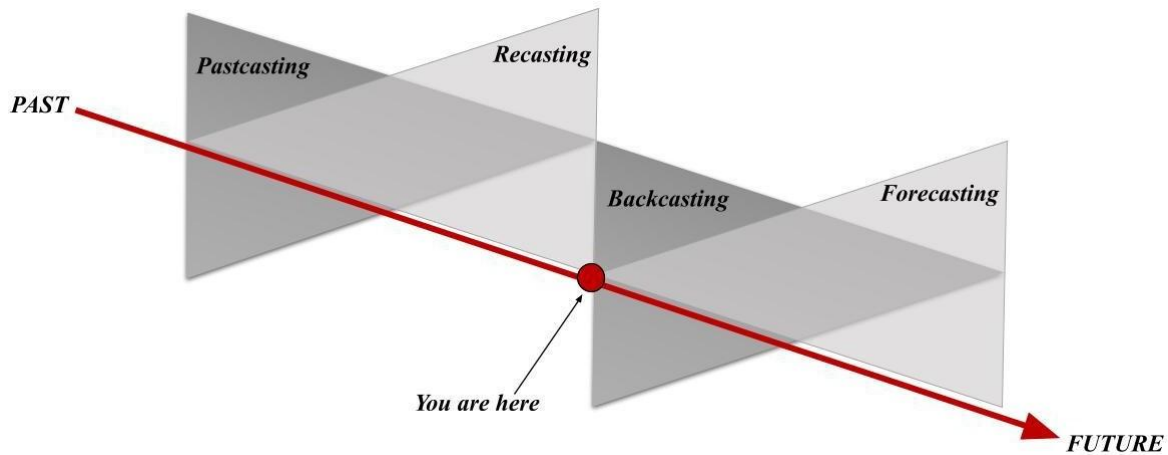
Future data—the building blocks of the future—comes from the past, making their task cliché. Few futuring procedures explicitly engage the past, but all do. Forecasting, backcasting, recasting, and pastcasting are foresight methods that shape futuring. Recasting imagines a new present, while forecasting predicts the future. Backcasting explores future possibilities to discover paths from the present to a preferred future, while pastcasting starts with a favored present and examines how past possibilities could have led to that present (see Fig. 1).

These four futuring methodologies can examine the activity's results and stakes. Back casting and past casting, the current study's symmetries, appear to be convergent and suited for examining numerous routes to a desirable future or present, pluralizing past and current stakeholders' voices.

Past and future methods have different stakes; prediction is riskier than recasting. The past is less changeable than the future, making it harder to modify.

So, while back casting can help futures researchers and practitioners gain a better understanding of future change levers, past casting can help them uncover the conditions, assumptions, barriers, and opportunities that influenced the I realization of past-futures, thereby informing, inspiring, and preparing future-facing actions (Bendor et al., 2021).

**Figure 1:** Schematic representation of Past-Facing and Future-Facing Approaches (Bendor et al., 2021).



### 1.2.1. First symmetry: Forecasting and recasting

*Forecasting:* a typical forecast begins with a (near) current state and projects to a future state, which typically refers to land-use changes that may occur during a specific period. All futuring tactics that aim to "systematically explore the possibilities that lie ahead" use forecasting as an example (Whiston, 1979). Forecasting multiplies a predicted future into several feasible options. Forecasting has lost its promise of scientific impartiality due to ideological, organizational, methodological, and human biases after its popularity after the Second World War (Cole, 1979). In addition to this, there is a growing realization that forecasting influences not only the present, but also the very futures that it aims to unfold (Mallard, 2011; van Lente, 2012). Forecasting helps us see the future as a growing set of options to explore, assess, and navigate, guiding technological and policy innovation.

*Recasting:* it refers, in its most fundamental sense, to the process of reconstructing the present. It makes use of methodologies for forecasting that begin with a condition that was established in the past and projects to the current state, typically for the purpose of comparison (from a projected current state to the actual state).

This kind of analysis is helpful for calibrating instruments and acquiring a comprehension of a condition that was unknown in the past but has become apparent in the current state.

Recasting, unlike anticipating, finds "tracks not taken" that could have changed the present. It involves testing simulation models using historical datasets,

interpreting their output in light of real events, and publishing the results. The use of recasting in some form has already been used by futurists in order to improve upon previously conducted exercises geared toward the future, but it has also been put to use in order to model and decrease risk (Woo, 2019). Recasting lets futuring activities explore hypothetical histories that (did not but could have) taken place to motivate them.

### **1.2.2. Second symmetry: Backcasting and pastcasting**

*Backcasting*: The backwards version of forecasting, in which the model begins from some point in the future and then plots a course of development leading up to the present status quo. This is helpful for mapping out a pathway that provides answers to questions such as “how do we get there?”.

Although projections are frequently used in scenario planning procedures, it is not necessary for analysis, modeling techniques, or mental processes to follow that timeline (moving forward in time) to design or effectively explain a scenario. *Backcasting*, the method of beginning an analysis from a desired future state and examining the route to get there, has been proven to be very helpful.

The objective of forecasting is to identify a set of probable or possible futures; the aim of backcasting is to have a clearer understanding of the range of possible developmental paths leading to an ideal future. “Generating a desirable future and then looking backwards from that future to the present in order to strategize and to plan how it could be achieved” (Vergragt and Quist, 2011).

Whereas forecasting attempts to pluralize the future, backcasting tries to pluralize paths to the future. As a result, where forecasting appears to be divergent, backcasting appears to be convergent, giving the cone representing it its distinctive shape and orientation.

Then, it is possible to define backcasting as the process of imagining a favorable future and then working backwards from that future to the present to formulate a strategy and arrange a plan for how it might be attained. Backcasting analyses are characterized primarily by their focus on how desirable futures can be achieved rather than plausible futures. It involves “going backwards” from a certain future end-point to the present to determine what measures would be necessary to achieve that future and is thus explicitly evaluative. Backcasting adds a focus on desirability to forecasting’s emphasis on plausibility (otherwise, it remains only fantasy or creative speculation). Concerns about probability are shifted away from the future and toward “the degree of freedom of action.” (Robinson, 1982).

*Pastcasting*: This study begins with a present time point (often a virtual, improved "now") and traces a developmental path backward.

Pastcasting creates fictional paths; each path represents a non-factual historical bifurcation that could have transformed the present. Pastcasting, unlike forecasting and recasting, works backwards from a chosen alternative present to various bifurcation points and trajectories.

Pastcasting, like recasting, enables planners compare projected and actual spatial planning outcomes.

It evaluates implementation, while recasting compares model predictions and results: "We journey from what planners envisioned for a present scenario to earlier time points to determine where the developmental pattern strayed from the planned path" (Deal et al., 2017). They found that pastcasting and recasting can assist planners and communities avoid mistakes. Reevaluating old goals can also help rank new tactics.

Backcasting is commonly used to forecast complicated long-term challenges encompassing many facets of society as well as technical advancements and developments. The focus of attention is on a perceived major social issue, such as technological advancement.

Given this starting point, the following characteristics favor backcasting:

- when the problem to be studied is complex, affecting many sectors and levels of society;
- when there is a need for major change, i.e. when marginal changes within the existing order will not suffice;
- when dominant trends are part of the problem—these trends are often the cornerstones of forecasts;
- when the problem is largely a matter of externalities, which the market cannot control.

As a result, the goal of the backcasting approach is to broaden perspectives of potential solutions among diverse players and to emphasize the societal effects of strategic choices (the opening or closing of future options).

Each alternative must look cohesive, and the implications analysis must be convincing. The data might then be used as scientific material in a process, allowing actors with varied values and purposes to establish an opinion and vision on the future. (Dreborg, 1996).



So, from a purely business point of view, backcasting allows companies to contain switching costs related to technological transitions and to maximize existing knowledge advantages and benefits by using all resources already integrated into companies.

Finally, Sandford (2019) distinguishes between the "instrumental future" which explores present untapped and abstract desires and the "lived future" which relies on society's imagination future and social interactions' material and emotive features. This last picture of the future is most like the backcasting approach we intend to use in this research, and Sandford suggests it to develop future research that aims to have a positive social impact by engaging with the past through linked interests and values.

To keep their earlier experiences relevant, future academics interested in understanding and developing care- related futures and context-specific interests should interact with these.

## **2. Methods and tools**

Here, the specific challenge is how to maximize the validity (i.e., trustworthiness) of qualitative systematic reviews that provide new information and theories. This viewpoint views literature searches as open-ended iterative processes that allow the topic or research question of interest to be refined over time as the nature of the evidence becomes more apparent. Most of the time, a select few pertinent documents are initially picked for inspection, and searching then begins with these important documents.

### **2.1 Search strategies and data sources**

It is crucial to consider the general nature of qualitative investigations prior to conducting a knowledge- building or theory-generating qualitative systematic review. Generally speaking, context-related research questions serve as the primary driving force behind single qualitative studies. As a result, the contextual characteristics of the subject under research are carefully shaped into each qualitative study throughout the stages of problem identification, data gathering, and analysis. These characteristics include elements related to gender, culture, class, geography, and other topics. Therefore, the goal is to provide qualitative findings that are firmly based on the opinions and experiences of the research subjects. Choosing a subject and a body of related research reports that support and justify a review is the responsibility of R&D area of each company. This means that to adequately support analysis, interpretation, and synthesis across studies, there must be enough topic-specific and contextually rich qualitative research reports. Sometimes there may not be enough studies to support thorough analysis. In other cases, several reports on the same issue might be accessible, but they

might not contain enough in-depth explanation to completely develop concepts and their links with one another. In conclusion, when data are being gathered for knowledge-building or theory-generating qualitative systematic reviews, there seem to be two significant risks to reliability. The first entails a complex collection of research reports that are not cohesively linked by carefully formulated research questions and subjects. The best course of action in this case might be to refine the sample so that it is in line with the original research topic and questions. The second issue, on the other hand, is when there aren't enough studies—or not enough descriptively rich studies—to produce findings that are saturated.

The process of searching the literature is a dynamic one that requires ongoing oversight and frequent recalibration. Bates described a broad technique to searching for literature that is consistent with thorough searching. As a result, the researcher browses as he or she catches glimpses, samples, evaluates, and obtains or discards information. Casual surfing may halt as phenomena of interest emerge, populations of importance become evident, contextual components take shape, and formative research questions are identified, and more focused searches may occur. Key search concepts arise as research questions become more logical, and foundational research reports begin to create the basic database for a systematic review. (Barroso et al., 2003; Bates, 2007, 1989; Boell & Cecez-Kecmanovic, 2010; Hannes & Lockwood, 2011; Hider, 2006; Johnson, 2009).

Searching the literature and building an impartial database provide several difficulties. Because publication procedures differ between the qualitative and quantitative research paradigms, there are distinctions in the kinds of biases that qualitative and quantitative systematic reviewers must strive to reduce (Finfgeld-Connett, 2010; Wilson, 2009). Researchers that carry out quantitative studies typically seek out outcomes that are statistically significant. The likelihood that their findings will be published in prestigious and widely accessible publications declines if this is not the case. Multiple interrelated reasons, including author dissatisfaction with or lack of interest in unfavorable findings, funding agency publication preferences, and editor and/or reviewer biases, all contribute to this publication bias. As a result, Wilson (2009), Booth (2010), Song *et al.* (2010), and others have found that positive quantitative findings are typically easier to access for systematic review than negative ones. Qualitative researchers are more extensively interested in learning about the contextual aspects that surround a scenario in addition to establishing whether an intervention is beneficial or not. Due in part to this change in emphasis, qualitative findings are no longer typically viewed as either good or negative, non-significant findings are no longer penalized, and these associated publication biases are frequently avoided (Finfgeld-Connett, 2010).

It is advised that qualitative systematic reviewers carefully consider whether to conduct literature searches using expert-designed optimal search algorithms. At the beginning of a literature search, researchers may choose to utilize such tactics, but if their findings are scant and data saturation seems unlikely, they may need to attempt alternative strategies. It could be essential to manually choose reports of qualitative research from this initial batch after searching for papers that are topically pertinent.

When it comes to building knowledge and creating theories through qualitative systematic reviews, “the more the better” isn’t always the best way to look at things from a methodological point of view. No matter what kind of systematic review is done, deciding when to stop the literature search is a matter of judgment, since it is impossible to know what information has not been collected (Barroso et al., 2003; Booth, 2006). Nevertheless, every effort should be made to make sure that decisions to stop looking are well thought out and supported in the context of each review (Booth, 2010).

Therefore, to start the research process according to the logic of backcasting, necessary to identify the relevant literature in the technological field on which the company has in mind to invest, we propose to the components of the R&D area to draw on one of the largest and most varied research databases, SCOPUS. Thanks to its filters it is possible to select the subject of interest and easily identify existing scientific research in this regard. In addition, it is possible to further refine the research by selecting a specific period of publication (particularly useful in the case of research related to emerging technologies), the source (preferably open source to avoid problems related to copyright and material availability of the research work) and the level of citations to select from the beginning the research considered most relevant in the scientific panorama.

This first step allows in fact to carry out an elementary clustering of all available resources by the same company without the need to incur additional costs for specialized human resources.

The next step involves the anonymization of the selected scientific papers to make the subsequent evaluation carried out by the team of experts as objective as possible, avoiding any personal bias as illustrated in the next paragraph.

This procedure can be carried out by adopting specialized software based on the format of the search file. In particular, considering the most popular formats, PDF Anonymizer is available for the automatic removal of identifiable information from PDF documents: by uploading the file into the software, you can select the desired anonymization options, such as removing author names, affiliations, addresses, contact information, etc. and start the anonymization process.

Alternatively, there is a LaTeX package called "anonymous" that can be used to anonymize the content of the document created by adopting this language. This package automatically replaces author names with generic placeholders, such as "Author 1", "Author 2", etc. ; removes other identifiable information such as affiliations and contact information; removes or replaces references to previous work by the authors themselves or other researchers that you do not want to identify; finally, you can identify and remove any other information, such as names of companies, organizations or places that may be related to the authors or their affiliations.

## **2.2 Blind bias**

As analyzed by Goues et al. (2018), peer review is a cornerstone of the academic publication process but can be subject to the flaws of the humans who perform it. Evidence suggests subconscious biases influence one's ability to objectively evaluate work; these biases can affect anyone, regardless of the evaluator's race and gender, therefore a double-blind review is usually adopted to mitigate these effects and reduce the perception of bias, both conscious and subconscious, making it a constructive step toward a review system that objectively evaluates papers based strictly on the quality of the work.

Any benefits attributed to double-blind peer review presuppose that the submitted paper has been successfully blinded and that reviewers cannot identify the authors or their institutions. Many have utilized the idea that an experienced referee may identify the author of a specific piece in a specialized publication to debunk the alleged benefit of double-blind review. Several research have explored the effectiveness of blinding. These interdisciplinary investigations found that blinding had success rates ranging from 53% to 79%. The practicality and success of blinding are contingent upon both the amount of work invested in the blinding procedure and journal-specific criteria. It is a common interest that the system be fair: favoritism, prejudice, and condescension bring dishonor on the entire operation and eventually work against the discipline, despite the occasional short-term benefits that may accrue to individuals. (Snodgrass, 2006).

So, scientific judgment should be based primarily on the content of publications, not on name recognition or standing within institutions. Editors are, at their core, people. When people recognize the author's name, his or her gender, country of origin, or institution, among other things, they may be subconsciously or intentionally predisposed in favor of or against an article. Like this, despite the possible quality of the provided content, an article may be rejected after first screening without further review if the editor has a preconceived notion about the author's name, gender, past work, nation, or linked institution. Furthermore, well-known scientists with track records who work at "prestigious institutions" or in wealthy nations would have a

significantly higher probability of having their papers approved for publication at the same level of content.

Thus, blind submission (submission without revealing the author's identity and contact information) would be a successful strategy to lessen biases in article rejection at the editorial levels and the initial stage of assessment. Articles submitted anonymously can be judged solely on their merit and content, free from any personal or organizational bias.

Blind submission would improve the scientific rigor and objectivity along with blind peer review. To improve the impartiality of the publication evaluation, the blind review system was implemented (Kmietowicz, 2008). Therefore, in identifying the most suitable literature review procedure to classify and select the emerging technologies that best meet business needs, we believe it is essential to provide a step that anonymizes the articles, as already discussed, before submitting them to expert analysis in the next step.

In addition, to further ensure the transparency and impartiality of this procedure, we introduce the application of the blockchain technique by carrying out a kind of research tokenization.

A "token" is the digital representation of an asset, a sort of security document, available on the blockchain (Weingärtner, 2019). The token is not necessarily related to a cryptocurrency like Bitcoin or Ether, but refers more to a smart contract on a blockchain (Kondrateva et al., 2022).

The development of blockchain technology and tokens could give entrepreneurs and innovators new ways to raise funds to finance their growth and compensate their core developers (Lerner et al., 2000).

Depending on their actual function, tokens are categorized into three main categories: the first type consists of Payment tokens, also known as currencies, with Bitcoin and Ethereum serving as typical examples. Moreover, they are all non-unique and non-divisible, contrary to the concept of fungible tokens (FTs), also known as non-fungible tokens (NFTs). The second variety of tokens is utility tokens, which are extensively employed and designed to grant digital access to an application or service. The emergence of NFT has significantly expanded the scope of asset tokens, the final type. A properly designed token offering could offer greater security, liquidity, and transparency than conventional financial instruments. Moreover, it has been developed a tractable dynamic equilibrium model of token pricing and platform adoption, demonstrating that the introduction of tokens reduces the effective transport cost of undertaking platform transactions, thereby accelerating the adoption of productive platforms. (Bao and Roubaud, 2022).

Blockchain technology fosters network confidence by assuring the verifiability of each transaction. Due to the decentralized nature of the technology, trust in a central authority is unnecessary (Ahluwalia et al., 2020).

In addition, tokenization can be utilized for intellectual property protection due to its function in transaction verification and its capacity to demonstrate the fluidity of the innovation process. Cost reductions, trust, and decentralization can be applied to all business functions through tokenization (Ahluwalia et al., 2020).

Therefore, the methodology proposed in this paper aims to apply blockchain technology for the advantages expressed considering scientific papers second type tokens, utility tokens.

### **2.3 Expert elicitation**

The judgment of experts is a way to describe through a number the level of knowledge of an uncertain quantity. In order to summarize these distributions and provide information about the degree of uncertainty, the sources of uncertainty, the degree of agreement/disagreement, and the reasons for any disagreement among the group of experts consulted, the method asks each of the various experts to provide a subjective probability distribution for the different aspects of interest.

The approach's main premise is that specialists, by using organized protocols, may define the current state of knowledge.

Analysts use different strategies for eliciting expert judgment, but they all involve a number of the same steps: framing the question, reviewing the evidence, identifying and recruiting experts, developing an elicitation protocol, informing experts about well-known biases in human judgment, summarization and presentation of the results.

What "expertise" one is seeking and how to identify it is a crucial subject that frequently lacks an obvious solution. Any procedure for choosing specialists must address the issue of "balancing," including disciplinary, institutional, and political considerations. It can be debatable whether or not to pursue balance and, if so, how to do it. Choosing the ideal or necessary number of experts is another problem.

According to the Theory of Expert Competence (Shanteau, 1992) skills and abilities that emerge or not in experts depend on five factors: domain knowledge, psychological traits, cognitive skills, decision strategies and task characteristics.

Therefore, a company that wants to identify a team of experts to entrust the

analysis procedure presented below should comply with all five parameters mentioned in the assessment of the degree of expertise and in the relative selection. In addition, it will be essential that each expert involved is not simultaneously the author of papers submitted to him for analysis.

Once a group of subject matter experts has been chosen, contacted and consented to participate, the team turns its focus to creating the elicitation process. Most protocols start with an informal discussion on the topic. The final protocol is typically developed in conjunction with the experts.

The project starts the elicitation phase after the final evaluation procedure has been defined.

In addition, to ensure the full reliability of the evaluation expressed by the experts, each scientific paper will be analyzed by sub-teams composed of three experts (both scientific and company researchers); the odd number will ensure the existence of a majority in the evaluation expressed.

The decision of whether and how to integrate the opinions of the participating experts is a crucial one in the reporting of results. No matter how the results are aggregated, it is crucial that any summary of the findings start by providing the report of each expert. Little needs to be done if the experts concur on the general trend. Instead, if the experts offer opinions that are significantly different from one another, it is crucial to talk about why. Here, meticulous documenting of each expert's reasoning is crucial. The issue of whether and how to integrate the experts' opinions emerges if there is significant disagreement among them.

The multidimensional nature of considered scientific papers raises the problem of aggregating results in simple indexes that can be accessed by stakeholders willing to compare different technologies based on their own preferences. In particular, for this research work it is possible to apply Choquet integral based Multi-Attribute Value Theory to elicit stakeholders' preferences on different attributes chosen by the same panel of experts to construct a robust index allowing to rank them. This tool can be used to support the decision-making process of the panel of experts looking for the emerging technologies with the highest probability of realization according to company context. In fact, this procedure can be straightforwardly adapted to much richer environments, such as the analysis of the reviews mentioned above. (Ferrara et al., 2016)

#### **2.4 Smart contract and block chain approach: new ideas into the frame of back casting method**

By including the terms of agreements between two or more parties, blockchain technology overlaps traditional contracts. However, smart contracts surpass them by automating the execution of agreements in a distributed environment

when certain conditions are met.

Smart contracts are executable codes that operate on the blockchain to facilitate, implement, and enforce an agreement between untrustworthy parties without a trusted third party. Smart contracts enabled the automation of the Internet and the transformation of paper contracts into digital ones. Smart contracts enabled users to codify their agreements and trust relationships without the oversight of a central authority, as compared to conventional contracts. To prevent contract manipulation, each node in the blockchain network copies smart contracts. To avoid disputes regarding such contracts, human error could be reduced by facilitating the execution of operations by computers and services provided by blockchain platforms. (Khan et al., 2021)

On-blockchain token systems have a wide range of applications, including sub-currencies representing assets such as USD or gold, company stocks, individual tokens representing smart property, secure unforgeable coupons, and even token systems with no ties to conventional value that are used as incentive point systems. A token system is essentially a database with a single operation: subtract X units from A and give X units to B, under the conditions that (i) X had at least X units prior to the transaction and (ii) A approves the transaction. To implement a token system, it is sufficient to incorporate this logic into a contract. (Buterin, 2014)

In our specific case, as anticipated, it is a complex of "utility tokens" represented by scientific papers and therefore the object of the transaction scheduled by the smart contract will be the intellectual property of papers together with the evaluation report of each sub-team by three experts.

Finally, they will be non-deterministic smart contract since they could include information (called oracles or data feeds) from an external party, outside the blockchain.

## **2.5 Research quality assessment (RQA)**

Good narrative and systematic reviews will likely remain crucial. In our study the following procedures have the potential to be the best grasp of possible developmental paths toward a desirable future.

To assess the quality of this, originally, our considered tool is a very similar version to the SANRA, the Scale for the Assessment of Narrative Review Articles, which is a concise critical appraisal tool for evaluating non-systematic pieces of literature.

Now, for the current study we apply the SANRA method as argued in Baethge et al. (2019) with findings from a field test examining its practicability, item-total correlation, internal consistency, reliability, and criterion validity.



The current version of SANRA is the result of a 2014 revision by the scale's creators, who aimed to streamline the survey while increasing its reliability. The language of the items was refined, and a question on a manuscript's writing and accessibility was removed since responses varied widely. The redesigned scale's six components are given numeric values between 0 (low standard) and 2 (high standard), with 1 representing a middle ground. The highest possible total is 12.

The SANRA scale's total score is meant to quantify the concept "quality of a narrative review article", which is comprised of the following sub-constructs: (1) an explanation of the review's significance; (2) a statement of the review's aims; (3) a description of the literature search; (4) a citation of relevant sources; (5) a demonstration of sound scientific reasoning; and (6) the presentation of relevant and appropriate endpoint data. We report anchor definitions and examples for each item on the instrument to help users fill it out correctly in Appendix.

Finally, we have generated a new scale, called SANSER, Scale for the Assessment of Narrative and Systematic Review, which includes SANRA score (max score 12), as already described, and the expert elicitation score (SCAST - Scenario CASTing) from 0 to 12, to obtain a unique value able to define the quality assessment of the analyzed review, considering future scenarios related to emerging, frontiering or dominant technologies. Therefore, the final highest possible total SANSER score is 24, as shown below in fig. 2.

This procedure of analysis and evaluation through the application of the aforementioned tests, will be carried out by each sub-team of three experts (specifically identified by the company according to its research needs using the available scientific indicators and the Scopus platform) within the blockchain procedure illustrated in the following sections.

**Figure 2:** Sanser scale

**Scale for the Assessment of Narrative and Systematic Review (SANSER)**

Please, in this first section, rate the quality of the narrative and systematic review article in question, using categories 0-2 for each of the following six aspects. So the first total score can be max 12.

|                                 | <b><i>QUALITY ITEMS (SANRA)</i></b>                                 | <b><i>SCORE<br/>(0-2)</i></b> |
|---------------------------------|---------------------------------------------------------------------|-------------------------------|
| 1.                              | <i>Justification of the article's importance for the readership</i> |                               |
| 2.                              | <i>Statement of concrete aims or formulation of questions</i>       |                               |
| 3.                              | <i>Description of the literature search</i>                         |                               |
| 4.                              | <i>Referencing</i>                                                  |                               |
| 5.                              | <i>Scientific reasoning</i>                                         |                               |
| 6.                              | <i>Appropriate presentation of data</i>                             |                               |
| <b><i>TOTAL SANRA SCORE</i></b> |                                                                     | <b><i>... / 12</i></b>        |

Please, in this second section, rate the quality assessment of the analyzed review, considering future scenarios related to emerging, frontiering or dominant technologies, using a 0-12 scale.

|    | <b><i>SCAST</i></b>                           | <b><i>SCORE<br/>(0-12)</i></b> |
|----|-----------------------------------------------|--------------------------------|
| 7. | <i>Expert Elicitation on future scenarios</i> |                                |

|                                                        |                          |
|--------------------------------------------------------|--------------------------|
| <b><i>TOTAL SCORE<br/>(SANSER = SANRA + SCAST)</i></b> | <b><i>..... / 24</i></b> |
|--------------------------------------------------------|--------------------------|

### 3. Procedures and results

Based on what was previously explained on the methodology adopted and on the reference classification of the reviews illustrated in the paragraph relating to the background, we proceed with illustrating the procedures adopted to subject both narrative review and systematic review to analysis to obtain an evaluation and therefore a scientific classification of the same.

### **3.1 Blockchain-based procedures**

A blockchain is a distributed database that documents every transaction that has ever taken place on the blockchain network. This database is replicated and made available to all network participants. The primary characteristic of blockchain is that it enables untrusted parties to communicate and transmit transactions securely without the need for a trusted third party. Each block is designated by its cryptographic hash in a blockchain, which is an ordered catalogue of blocks. Each block contains a reference to the block that preceded it, creating a chain of blocks. Each block is made up of a collection of transactions. Once a block has been created and added to the blockchain, its transactions cannot be altered or undone. This is to ensure the integrity of transactions and prevent the occurrence of double-spending.

Verification of network transactions is performed by specialized nodes (called miners). Verifying a transaction involves examining both the sender and the transaction's contents. After solving a mathematical conundrum (known as Proof of Work), miners generate a new block of transactions, which is then broadcast to the network. Other nodes in the network can validate the generated block's correctness and can only build upon it if it was generated correctly.

The second generation of blockchain enables the development of complex distributed applications beyond cryptocurrencies, such as smart contracts, which are regarded as the generation's defining characteristic.

There are two varieties of blockchain: public and private. In a public blockchain, any anonymous user can join the network, peruse the blockchain's content, transmit a new transaction, or verify the blocks' correctness.

In a private blockchain, only authorized users can join the network, write to the blockchain, or transmit transactions. Typically, a company or group of companies is accountable for granting these permissions to consumers before they join a network.

There are numerous applications for which smart contracts are applicable. One of these applications is associated with the Internet of Things and smart property: billions of devices are exchanging data via the Internet. A potential application of blockchain-based smart contracts is to enable nodes to share or access diverse digital assets without a trusted third party. (Alharby and Moorsel, 2017)

Therefore, by adapting this last type of blockchain application and choosing to make it private, we will allow companies and experts involved in a research project to share scientific material more efficiently and generate a transparent

and reliable screening of emerging technologies.

Outside the blockchain, as explained in paragraph 2.1, scientific papers related to the technological field for which the company is performing research are selected from the Scopus database. The selected papers are subjected to the anonymization procedure before being introduced into the blockchain so that the subsequent evaluation of the experts is based specifically on content and not influenced by subjective aspects.

Each block will consist of a sub-team of three experts and each sub-team will be subjected to a defined number of papers with respect to which it will start the analysis and evaluation procedures that we have defined NR4CASTING for the classification of scientific papers that make up a narrative review or SR4CASTING for the classification of scientific papers that make up a systematic review, based on the characteristics previously exposed.

### **3.2 Content validity and reliability**

The first step of both procedures is replication which is a way of confirming scientific research and is seen as an important condition for the adoption of new hypotheses and information. In the framework of empirical research, replication necessitates the repetition of “experiments” in such a way that we may be relatively assured that the results of two experiments are comparable and, thus, measure the same phenomenon.

The method relies heavily on repetition, however reiterating an entire action does not always entail doing so in its entirety each time. The end product will be comparable to the source material, but it will never be an exact replica in all respects. Considering the challenges that come with planning and carrying out precise replications, it could be good for us to adopt more practical modes of carrying out replication in our field.

If the data of the entire study are available, the results are validated following the procedure indicated in the research article. (Drost, 2011)

Regarding quantitative research, the availability of the data used in the study can be allowed both by the authors themselves and using the same datasets used by the authors.

Instead, as regards qualitative research, based on data made available by the authors (for example questionnaires), it is necessary to use the same data used in the research. (Golafshani, 2015)

If the original data are missing, the evaluation was carried out based on the impact factor of the journal in the reference sector.

However, the validity of the results is considered positively approved when the journal where the research article examined is published is placed in the Q1, Q2 or Q3 of the Thomson Reuter's Journal Citation Report(JCR).

### **3.3 NR4casting**

In this case, therefore, we consider N blinded narrative papers (B1, B2, B3, ... Bn), selected using the database and applying the search strategies set out in paragraph 2.1. Among these, those that pass the validation step illustrated in the previous paragraph, will be renamed keeping the same numerical reference, for example V1, V3, ... Vn, completely discarding those resulting unsatisfactory.

The sub-team of experts, in each block, will first proceed with the application of the SANRA test, assigning a score between 0 and 2 to each of the six evaluation criteria adopted by this method for a maximum total score of 12 points, as presented in paragraph 2.5.

After that, the same sub-team of experts will perform the Expert Elicitation procedure (SCAST) that assigns a score based on the probability that the technology described in the analyzed paper is to be considered emerging, frontier or dominant in future scenarios, so readapting the second of the previously exposed time symmetries, namely Backcasting – Pastcasting, in order to identify the optimal path that will allow the company to effectively implement the expected technological innovation scenario.

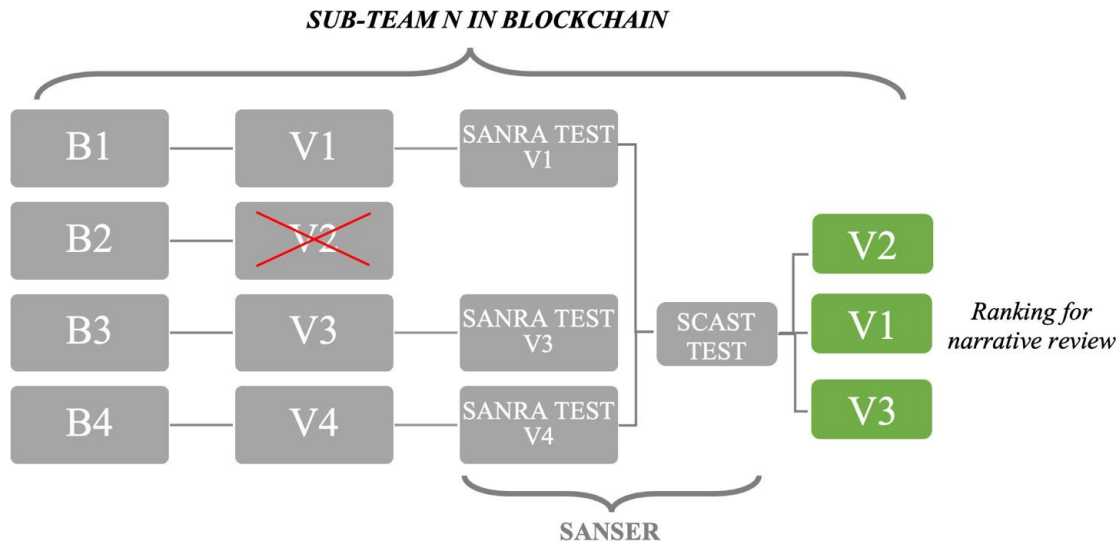
The maximum total score provided by SCAST is also 12.

The sum of the scores obtained by SANRA and SCAST generates the total one considered by the new SANSER methodology (maximum 24 points) through which it is possible to draw up a ranking of the papers thus analyzed.

In conclusion, each of these papers will be contained in the narrative review which is the final result of the NR4CASTING procedure.

The following figure 3 shows an application example of this procedure.

**Figure 3:** Schematic representation of NR4CASTING approach in blockchain



### 3.4 SR4casting

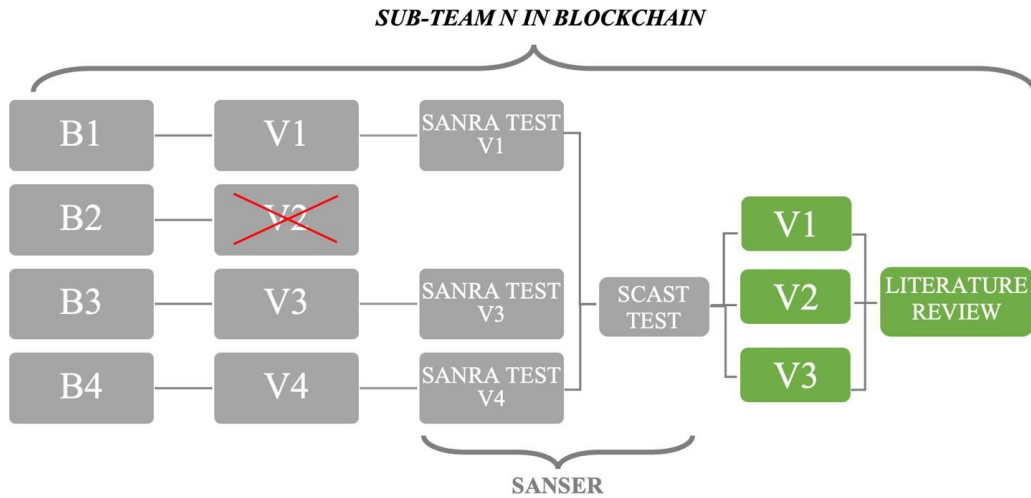
In this case we consider, as in the previous one,  $N$  blinded systematic papers ( $B1, B2, B3, \dots Bn$ ), always identified using database and applying the search strategies indicated in paragraph 2.1.

The first step of the procedure remains unchanged: papers that pass this verification will be renamed keeping the same numerical reference, for example  $V1, V3, \dots Vn$ , completely discarding those resulting unsatisfactory. Then, as for NR4CASTING procedure, sub-team of experts, in each block, will first proceed with the application of the SANRA test to validated papers and then the Expert Elicitation (SCAST) to obtain the final general score required by our SANSER method.

The final result of the SR4CASTING procedure is not the collection of all the papers selected and appropriately classified by the procedure as in the previous case, but the drafting of a single literature review containing references to the papers that have passed all the selection and evaluation steps.

The following figure 4 shows an application example of this procedure.

**Figure 4:** Schematic representation of SR4CASTING approach in blockchain



#### 4. Discussion and future developments

This study is limited to describing a research activity related to detect emerging and/or potentially dominant technology. We are aware that technological growth is not solely recorded by the state of the art on present research activity. However, one advantage of this strategy is that it may be merged into a larger one that includes other information sources as bibliometric data on research activities (Bildosola et al., 2017).

Scientists, corporate executives, and policymakers are increasingly interested in using new technology to address societal concerns and accomplish sustainable objectives. Aside from big data and AI-driven technologies, blockchain-based solutions are claimed to provide a plethora of prospective answers, especially in terms of anticipation and foresight. Because decision making and regulation should be based on both current knowledge and projections about upcoming changes, it is clear that futuring methodologies and foresight may offer enormous value to blockchain systems.

Now, they are still evolving in a dynamic interaction with other global trends such as socio-environmental change, and new applications for the technology are being investigated all over the world.

The technology as a whole certainly has a lot of promise, particularly in terms of community efforts to accomplish progress and so, even more, adopting blockchain is not just a method to reflect on and demand changes in different areas.

Furthermore, blockchain will be just one component of a broader multi-system architecture, the components of which must be understood in terms of their

complicated relationships. In an era of combining technical architectures based on artificial intelligence, distributed ledger technology, and cyber-physical systems, the future of “thinking” itself will demand our close attention. (Schulz et al., 2020)

However, for the above-mentioned approach to be formalized, each stage must adhere to particular standard characteristics.

These factors include, among others, the anonymity of the research’s authors, the journal of publication, bibliometrics information, as well as the panel of experts and the integrity of their judgment linked with non-repudiation. These ideas of research are going to be developed in the sequel of this ongoing study.

Finally, since the majority of technological advancement in emerging nations comes through the adoption and adaption of pre-existing technologies that are new to the market, as well as from the diffusion of technologies throughout enterprises, individuals, and the public sector within a country, it is essential to devise a model of innovation that is tailored to the specific conditions and requirements of developing countries.

To achieve this goal, the development of the model discussed above is not sufficient, but it is necessary to analyze in detail the specific needs of emerging countries and identify the gaps to be filled to allow them to implement the technological innovations identified through the described process. Moreover, in this circumstance, it may be more useful to have this research system adopted at the Government level to optimize their funds and investments rather than to the individual company.

## **5. Conclusions**

In this paper we present an innovative research approach based on literature review (both narrative and systematic) and on a future-facing approach which enhances backcasting to better support decision-making processes thinking about an actually feasible future.

If you can anticipate crucial decisions or occurrences in advance, then you can take measures to better inform decision-makers on the best course of action to adopt, especially as regards technological innovation opportunities, to contain costs and optimize the use of all kinds of resources, material, immaterial and human during such a transition.

As stated in the introduction, this study proposes a blockchain-based procedure with two different output methods - NR4CASTING and SR4CASTING - that considers numerous specific aims.

A private blockchain procedure, based on smart contract and the concept of



“research tokenization” which can enable nodes to share or access different digital assets without a trusted third party, could become a valid and organic tool for experts and R&D companies’ areas to share scientific works improving efficiency and transparent and reliable decision process as regard the investment choice in emerging technologies projects. Therefore, selected scientific papers related to the technological field for which the company is performing research will be introduced into the blockchain for the subsequent expert analysis and evaluation in each block, according to the new Research Quality Assessment which apply the experimental SANSER scale, obtained by SANRA and SCAST test.

Its primary objective was to collect (NR – narrative review) relevant scientific articles about promising technologies, validating the scientific results to identify emerging and/or dominant technologies without bias and to identify and resume (SR – systematic review) emerging and/or dominant technologies. These outputs will be useful to establish the preferential order of achievability of the technologies considered by the research subjected to each procedure.

Nevertheless, not all futuristic techniques are equally helpful. While each of the four approaches (forecasting, recasting, backcasting, pastcasting) can be utilized in a variety of ways, each is uniquely positioned to assist futurists in pursuing a certain line of research.

Backcasting provides a powerful framework for democratizing policymaking by opening up decision-making processes to a wide range of stakeholders, whereas pastcasting, although much more elusive than the other three approaches, appears useful for unfolding past decision-making processes and disclosing the types of biases that undermined and declined past possibilities and hopes.

Furthermore, the proposed methodology for studying emerging technologies, as well as its development and implementation, can be extremely advantageous to emerging countries. First of all, it enables to pool existing capabilities without paying additional fees for specialist human resources. This saves time and money, making the analysis process more efficient.

The strategy leverages blockchain technology to further improve transparency and impartiality. The blockchain guarantees verifiability and eliminates the need for trust in a central authority by tokenizing research which is a further guarantee of efficiency even more necessary at a governmental level of such emerging countries that cannot afford waste and errors in the policies adopted as they would generate other problems and instability. Blockchain technology promotes trust and decentralization, making it suitable for protecting intellectual property and bias reduction in a context of countries that are not yet fully structured and with limited resources.

In this regard, the inclusion of experts in the blockchain procedure plays a key and strategic role in overcoming uncertainties and conflicts, allowing the Government to take decisions already validated by subjects recognized as competent in the reference sector and thus increasing credibility and accelerating the effective implementation of the country's innovation process.

We encourage researchers to consider these approaches a critical tool for decision-making process to detect emerging and/or dominant new technologies, since we see them as providing the futures strategic planning environment with the vision, adaptability, and transparency essential to seizing opportunities.

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## Appendix

### Scale for the Assessment of Narrative Review Articles – SANRA

Please rate the quality of the narrative review article in question, using categories 0–2 on the following scale. For each aspect of quality, please choose the option which best fits your evaluation, using categories 0 and 2 freely to imply general low and high quality. These are not intended to imply the worst or best imaginable quality.

#### 1) Justification of the article's importance for the readership

- The importance is not justified. \_\_\_\_\_ 0  
The importance is alluded to, but not explicitly justified. \_\_\_\_\_ 1  
The importance is explicitly justified. \_\_\_\_\_ 2

#### 2) Statement of concrete aims or formulation of questions

- No aims or questions are formulated. \_\_\_\_\_ 0  
Aims are formulated generally but not concretely or in terms of clear questions. \_\_\_\_\_ 1  
One or more concrete aims or questions are formulated. \_\_\_\_\_ 2

#### 3) Description of the literature search

- The search strategy is not presented. \_\_\_\_\_ 0  
The literature search is described briefly. \_\_\_\_\_ 1  
The literature search is described in detail, including search terms and inclusion criteria. \_\_\_\_\_ 2

#### 4) Referencing

- Key statements are not supported by references. \_\_\_\_\_ 0  
The referencing of key statements is inconsistent. \_\_\_\_\_ 1  
Key statements are supported by references. \_\_\_\_\_ 2

#### 5) Scientific reasoning

(e.g., incorporation of appropriate evidence, such as RCTs in clinical medicine)

- The article's point is not based on appropriate arguments. \_\_\_\_\_ 0  
Appropriate evidence is introduced selectively. \_\_\_\_\_ 1  
Appropriate evidence is generally present. \_\_\_\_\_ 2

#### 6) Appropriate presentation of data

(e.g., absolute vs relative risk; effect sizes without confidence intervals)

- Data are presented inadequately. \_\_\_\_\_ 0  
Data are often not presented in the most appropriate way. \_\_\_\_\_ 1  
Relevant outcome data are generally presented appropriately. \_\_\_\_\_ 2

Sumscore

Fig. 1 SANRA - Scale

## SANRA – explanations and instructions

This scale is intended to help editors assess the quality of a narrative review article based on formal criteria accessible to the reader. It cannot cover other elements of editorial decision making such as degree of originality, topicality, conflicts of interest or the plausibility, correctness or completeness of the content itself. SANRA is an instrument for editors, authors, and reviewers evaluating individual manuscripts. It may also help editors to document average manuscript quality within their journal and researchers to document the manuscript quality, for example in peer review research. Using only three scoring options, 0, 1 and 2, SANRA is intended to provide a swift and pragmatic sum score for quality, for everyday use with real manuscripts, in a field where established quality standards have previously been lacking. It is not designed as an exact measurement of the quality of all theoretically possible manuscripts. For this reason, the extreme values (0 and 2) should be used relatively freely and not reserved only for perfect or hopeless articles.

We recommend that users test-rate a few manuscripts to familiarize themselves with the scale, before using it on the intended group of manuscripts. Ratings should assess the totality of a manuscript, including the abstract. The following comments clarify how each question is designed to be used.

### Item 1 – Justification of the article's importance for the readership

Justification of importance for the readership must be seen in the context of each journal's readership.

Consider how well the manuscript outlines the clinical problem and highlights unanswered questions or evidence gaps – thoroughly (2), superficially (1), or not at all (0).

### Item 2 – Statement of concrete/specific aims or formulation of questions

A good paper will propose one or more specific aims or questions which will be dealt with or topics which will be reviewed.

Please rate whether this has been done thoroughly and clearly (2), vaguely or unclearly (1), or not at all (0).

### Item 3 – Description of the literature search

A convincing narrative review will be transparent about the sources of information on which the text is based. Please rate the degree to which you think this has been achieved. To achieve a rating of 2, it is not necessary to describe the literature search in as much detail as for a systematic review (searching multiple databases, including exact descriptions of search history, flowcharts, etc.), but it is necessary to specify search terms, and the types of literature included. A manuscript which only refers briefly to its literature search would score 1, while one not mentioning its methods would score 0.

### Item 4 – Referencing

No manuscript references all statements. However, those that are essential for the arguments of the manuscript – “key statements” – should be backed by references in all or almost all cases. Exceptions could reasonably be made for rating purposes where a key statement has uncontroversial face-validity, such as “Diabetes is among the commonest causes of chronic morbidity worldwide.”

Please rate the completeness of referencing: for most or all relevant key statements (2), inconsistently (1), sporadically (0).

### Item 5 – Scientific reasoning

The item describes the quality of the scientific point made. A convincing narrative review presents evidence for key arguments. It should mention study design (randomized controlled trial, qualitative study, etc), and where available, levels of evidence.

Please rate whether you feel this has been done thoroughly (2), superficially (1), or hardly at all (0). Unlike item 6, which is concerned with the selection and presentation of concrete outcome data, this item relates to the use of evidence and of types of evidence in the manuscript's arguments.

### Item 6 – Appropriate presentation of data:

This item describes the correct presentation of data central to the article's argument. Which data are considered relevant varies from field to field. In some areas relevant data would be absolute rather than relative risks or clinical versus surrogate or intermediate endpoints. These outcomes must be presented correctly. For example, it is appropriate that effect sizes are accompanied by confidence intervals. Please rate how far the paper achieves this – thoroughly (2), partially (1), or hardly at all (0). Unlike item 5, which relates to the use of evidence and of types of evidence in the manuscript's arguments, this item is concerned with the selection and presentation of concrete outcome data.

Fig. 2 SANRA—explanations and instructions document



## Inter-linkages of actors, organizations and institutions in labour-intensive manufacturing cluster in a developing economy: Exploration of one of the oldest cluster

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### **Abstract:**

'System of Innovation' approach and 'Value Chains' literature has emerged with advancing technological waves of late 1980s. While the former literature focused on exploring the mechanism of accumulating 'capabilities' through 'continuous learning' with close inter-linkages between different actors, organizations and institutions; the later began exploring the dynamics of 'fragmented production chains' across and within regions. However, attempts were made to combine these two strands of literature to understand the relationship between the mechanism of learning, technological capability building, industrial advancements and changing participation in value chains. In this context, the paper aims to explore the linkages between the components of innovation systems and participation in value chains of an old industrial cluster from a developing country, with a case of Indian Jalandhar Sports goods manufacturing cluster. Sector specificities, geographical peculiarities, historical roots and technological complexities make each industrial cluster a special case. The birth and evolution of the cluster undoubtedly happened amidst numerous local, national and sectoral challenges and opportunities. Therefore, the paper focus on examining the mechanism of 'learning' with 'systems of innovation' framework at micro-level, meso-level and macro-level for upgrading within value chains, which is termed as 'Cluster innovation system'.

Primary data was collected from the units engaged in the production of various items related to sports. We interviewed the entrepreneurs, traders, trade associations, labour groups, industrial training institute and government officials to understand the 'cluster innovation system' with focus on transforming innovation policy

## 1. Introduction

The triumph of Indian Independence is accompanied with a blood-feed Redcliff line that ran across from northern Himalayan ranges to Kutch in the West and Bengal in the East that created a new country named Pakistan. On the Western side, province of Punjab was bifurcated that changed its socio-economic and political scenario. The peculiar geographical location and fertile land of undivided Punjab has remained a 'gateway' connecting Indian subcontinent with Central Asia (Chalana, 2016) was an attractive 'route' for both traders and invaders. Henceforth, the inhabitants of Punjab opted to become cultivators, traders, craftsman, entrepreneurs and soldiers leading to the growth of different sectors. With rich historical background of the region, the focus of the paper is upon an old sports goods manufacturing cluster, which has roots to undivided Punjab from the place called Sialkot, now in Pakistan. During 1880s, British army and officials used to play cricket, hockey and footballs with the imported sports goods and equipment. Successively, these sports also attracted the indigenous elites and middle-class people (UNIDO, 2001). Over time, the demand for sports equipment started increasing and moreover, the transportation from England used to take months. Therefore, a British army official asked a timber trader, Sardar Ganda Singh Oberoi to manufacture tennis racquets from mulberry wood, and hence lead the foundation of 'Oberoi Limited' (ibid). The company started exported to England in 1884

<sup>1</sup>. Therefore, the advise from Englishman to local timber trader acts as a '*window of opportunity*', that gave birth to the Sports Goods manufacturing cluster in undivided Punjab, which is growing with leaps and bounds over the years. The rest of the paper is structured as follows: Section II presents the framework of the analysis. Section III documents historical and foundational aspects of Jalandhar sports goods manufacturing cluster. Section IV presents the nature and structure of the Jalandhar's sports goods cluster. Section V focus upon the mechanism of learning. Section VI presents the opportunities and challenge the cluster is facing and Section VII finally concludes the paper.

## 2. Innovation systems and industrial cluster in developing countries

Geographical concentration<sup>2</sup> of firms with backward and forward nodes of suppliers, traders, clients along with enabling organizations and institutions constitute an industrial 'cluster'. The literature (Gordon and McCann, 2000)<sup>3</sup> on spatial organization of production emanates from the 'division of labour' argument of Adam Smith. Alfred Marshall (1920) has identified the benefits of 'externalities' like labour market, other enabling factors and availability of information for the geographical proximities of the firms within the local area. These factors were explored from different perspectives by scholars over time (Gordon and McCann, 2000) and the focus was on understanding the growth pattern of 'industrial cluster' in developed economies (Keeble, 1988; Saxenian,

1983; Dorfman, 1983), developing economies, (Pietrobelli and Rabellotti, 2006a; Nadvi and Schmitz, 1994) technology intensive sectors (Duran, 2006; Saxenian, 1983) and natural-resource based and traditional manufacturing sectors (Pietrobelli and Rabellotti, 2006b). There are some industrial clusters that are old and still competing with their 'first mover advantages', while there are some that become successful in short duration of times<sup>4</sup>. Sector specificities, geographical peculiarities, historical roots and technological complexities make each industrial cluster a special case (Gordon and McCann, 2000; Pietrobelli and Rabellotti, 2006a).

Therefore, we hypothesize that the birth and growth of an Industrial Cluster is caused by the structure of inter-linkages of varied actors, organizations and institutions that exist at three levels (3Ms)- micro (local), meso (national) and macro (global) levels, that lead the firms in the Cluster to participate simultaneously at (3VCs) -local value chains, regional value chains and global value chains. Therefore, the innovation at three levels (3Ms) and participation of firms from the cluster at three levels (3VC)- local, national and global value chains is termed as 'Cluster Upgrading System' (CUS). For empirical verification of the hypothesis, a case of Jalandhar's sports goods manufacturing cluster is taken. This is a contribution to the literature that combines the innovation system framework and global value chains aspects. Cluster Upgrading System: Synthesis of Systems of Innovation and value chains at Micro-level, Meso-Level and Macro-level:

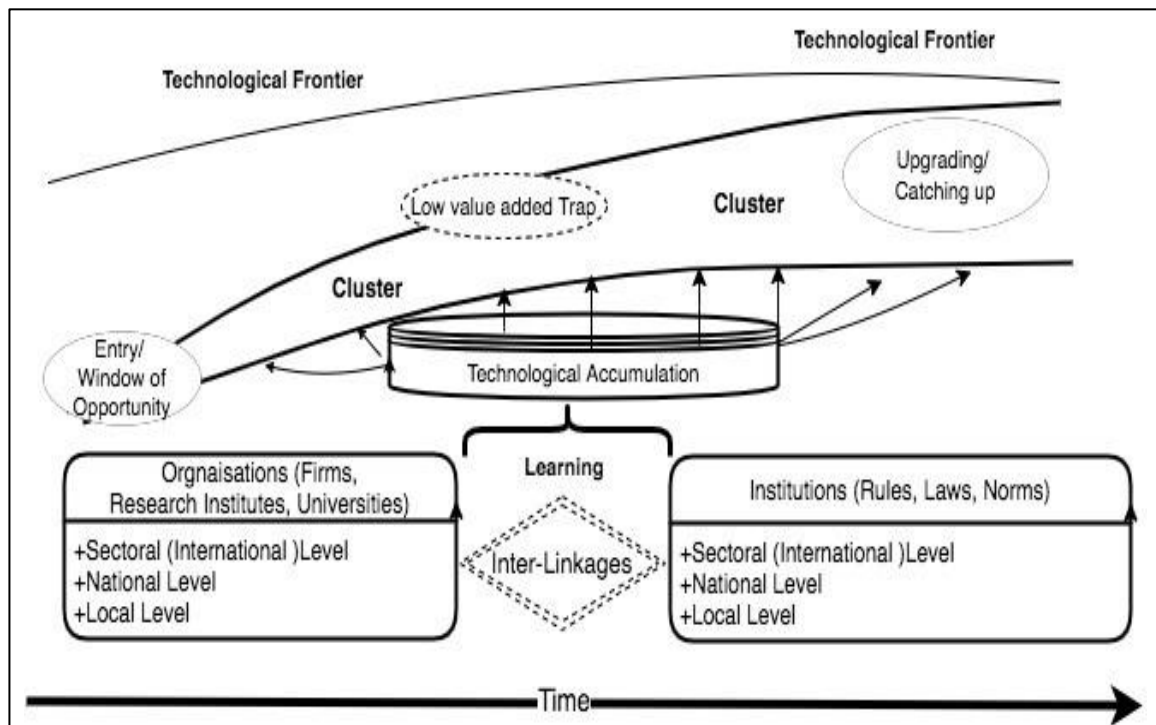
It is argued that success, sustainability, stagnation and failure of manufacturing cluster reflect an array of combinations of innovation systems at different levels- regional level (Cooke, 1992), national level (Lundvall, 1992), technological level (Carlsson and Stankiewicz, 1991) and sectoral level (Breschi and Malerba, 1997) along with participation in value chains and upgrading therein (Pietrobelli and Rabellotti, 2006a) over times, which is combined to understand the birth and growth of Industrial Cluster, termed as '*Cluster Upgrading System*' (CUS). Specifically, CUS combines the components of 'innovation systems' at (3Ms)- micro (local), meso (national) and macro (global) level paving the way for the firms in the cluster to 'participate in value chains' at (3VCs) - local value chains, regional value chains and global value chains. Industrial clusters are thus, composed of dynamic actors like producers, suppliers, customers, traders, various educational and training organizations, financial institutions and related public policies and their inter-relationships at different levels.

Figure 1 illustrates the phases from the inception of the industrial cluster to its growth and upgrading within value chains over years. Firm when finds a 'window of opportunity' enters the manufacturing sector, *which if lucrative enough*, attract individuals with entrepreneurial acumen to enter the same and/or similar production lines, that subsequently creates nodes of suppliers,

producers and customers to agglomerate which cooperate and compete to grow together over time, forming a *cluster*. But once enter; firms in the cluster strive hard to 'survive' the competitive markets while attempting to 'catch-up' with the incumbents and 'upgrade' within the value chains, through building 'technological capabilities' with continuous 'learning'. However, 'learning' and accumulating 'technological capabilities' (Lundvall, 2016) depends upon the inter-linkages of various organizations (firms, research institutions, trade associations, universities etc.) and institutions (rules, laws and norms) at local, national and global level constituting the 'Systems of Innovation' (Edquist, 2005) for the industrial 'Cluster'. Therefore, the clusters that were able to accumulate *technological capabilities* enough to *catch-up* with the incumbents and/or *upgrade* within value chains sustain over time, else fall in to the '*low value added trap*'.

This approach follows the initial breakthrough of evolutionary theory (Nelson and Winter, 1982) and 'systems' of 'innovations' framework (Freeman, 1987; Lundvall, 1992; Dosi et al., 1988). What initially took 'nation' (Lundvall (1992, 2016) as the dimension of 'learning' through interacting components of innovation systems, were expanded lately by the researchers who tried to focus on regions (Cooke and Morgan, 1990), technologies (Carlsson and Stankiewicz, 1991) and sectors (Breschi and Malerba, 1997). Therefore, the scope of inter-linkages between organizations and institutions took international character for the development of technologies and sectors. Subsequently, we argue that all the three levels (3M) – micro (local level), meso (national level) and macro (sectoral/ technological) are important for the development of industrial cluster and participate in value chains at (3VCs) -local value chains, regional value chains (national level) and global value chains. Therefore, the mechanism of inter-linking the organizations and institutions simultaneously at three levels (3Ms) for learning and participation in value chains at three levels (3VCs) defines 'Cluster Upgrading System' (CUS). This will be a contribution to the literature that combines the Innovation Systems approach and Global Value Chains literature (Jurowetzki et al, 2018).

**Figure 1:** Cluster upgrading system: micro-meso and macro-level synthesis



Source: Author illustration with adaption of concepts from the literature (Edquist, 1997; Pietrobelli and Rabellotti, 2006a, Lee, 2013)

### 3. Development of jalandhar's sports goods manufacturing cluster

**Inception and Relocation:** Indian sports goods manufacturing industry has its roots in pre-partition Punjab province at a place called Sialkot<sup>5</sup> with the establishment of the first sports goods manufacturing unit by a wood-trader Sardar Ganda Singh Oberoi in 1883. The documentary evidences (UNIDO, 2001) shows that British army personnel advised S. Ganda Singh Oberoi to start manufacturing wooden sports items like tennis racquet, cricket bats and hockey sticks. Local carpenters and artisans imitated the wood-based and leather-based sports equipment that lead to mushrooming of the units in Sialkot. At that time, the occupation and skills were largely caste, community and religion based as blacksmith-carpenter (*Lohars-Tarkhans in local language*) were largely composed of Muslims and non-Muslims Ramgarhia<sup>6</sup> community (Pandit, 1978; Nadvi, 1999 as cited Rose (1914)), while Ramdasias were largely dominated in leather-made goods (Sharma, 1978). Largely people from non-Muslim community and some Muslims (Shiekhs) were traders, financiers, and entrepreneurs (Nadvi, 1999). This community-based occupational structure leads to *informal training mechanisms*<sup>7</sup> and *on-the-job learning* through closely knit social network within the immediate family, extended family of closed relatives and friends (ibid). The lineage of craftsmanship, entrepreneurs, traders, financiers, availed the initial

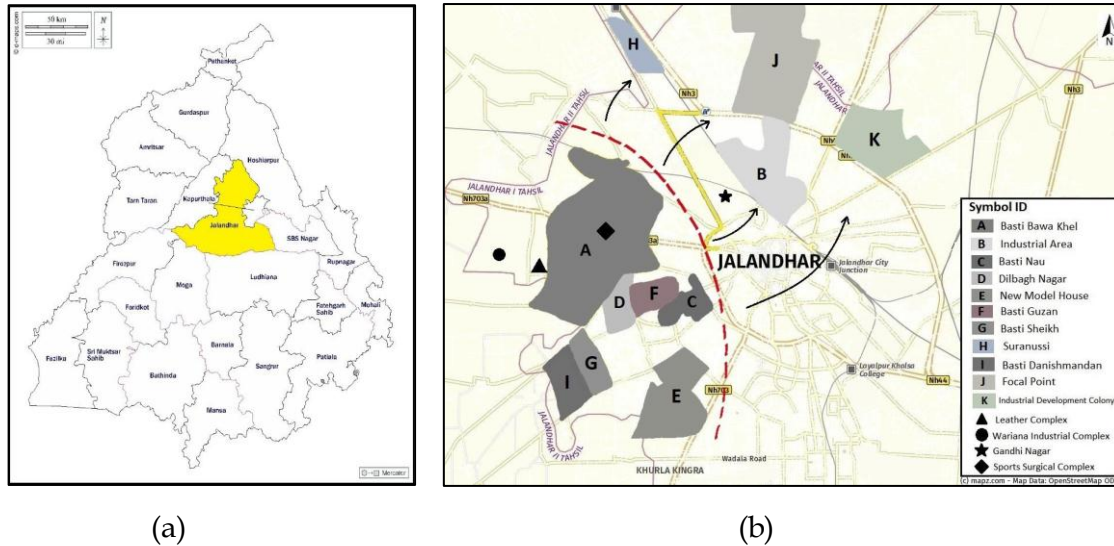
'window of opportunity' and laid the foundation of sports goods manufacturing cluster in undivided Punjab. The production of cricket bats, hockey sticks and balls that started first to meet the demands of the Englishmen (UNIDO, 2001) also created demand in the local Indian people leading to mushrooming of firms into a cluster. With the passage of time, the fight for India's independence intensified, so does the community-based scuffle; which culminated in the division of India leading to mass migrations of Muslims and non-Muslims (Bharadwaj et al, 2008) that changed the occupational structure of the industrial towns of undivided Punjab. Muslims craftsmen, workers and artisans were migrated to Pakistan, while the non-Muslims<sup>8</sup> entrepreneurs, financiers and traders migrated to India and get settled in Jalandhar (Pandit, 1978). This relocation of masses developed two separate sports goods manufacturing clusters in Sialkot and Jalandhar.

#### **4. Jalandhar sports goods manufacturing firms: Growth and expansion**

Punjab has been a predominantly an agricultural state that is transforming towards service sector economy with an almost stagnant manufacturing sector. For the year 2019-20<sup>9</sup>, the share of primary sector, secondary sector and tertiary sector is estimated as 28.7 percent, 24.11 percent and 47.18 percent, respectively. Amongst the tertiary sector, the share of trade, hotels, restaurants, repair services etc. is a whopping 21.26 percent, while the share of manufacturing sector is found to be only 13.23 percent. The issue of concern is that the share of manufacturing in Gross State value added (GSVA) has decreased over the past decade from 2011-12 to 2019-20 by around 1.5 percent. Sports goods<sup>10</sup> manufacturing sector is composed of some organized and large unorganized manufacturers. Annual Survey of Industries (ASI) data on organized manufacturing sector, as extracted from EPWRF shows that for the year 2019-20 there are 75 sports goods manufacturers in Punjab providing employment to 6428 persons<sup>11</sup>, while the data of NSS 73<sup>rd</sup> round for enterprises in unorganized sector shows that there are 882 sports goods manufacturers with 1765 employed therein in Punjab in 2015-16<sup>12</sup>. However, the data taken from the District Industrial Centre (DIC), Jalandhar has registered 483 sports goods manufacturers with employment of about 5774 persons and producing goods worth INR 6351.4 lakhs<sup>13</sup>. Therefore, given the different data sources having different methodology of collecting the data, gives a divergent picture of the size the industrial cluster. The data for organized and unorganized sector is collected by National Statistical Office (NSO) and National Sample Survey Office (NSSO), respectively through field surveys. District Industries Centres (DIC) maintains the data registered by the firms themselves at Udhog Aadhaar Memorandum (UAM) portal<sup>14</sup>. Conclusively, Punjab has about 40 percent of the total sports goods manufactures in India and provides employment to around 44 percent of those employed in the manufacturing of sports goods. Punjab contributes about 45.76 percent in Gross value added in 2019-20 (at constant prices 2010-11) of total

Indian sports goods production. The sports goods cluster<sup>15</sup> of Punjab is concentrated largely in the centre of Punjab in district Jalandhar (Map 1a).

*Map 1. Location of Jalandhar Sports goods Manufacturing Cluster*



*Source: Prepared by author based on map downloaded from d-maps.com.*

*Note: Map not to scale and does not represent authentic international boundaries. The arrows represent the shift of the sports goods industries from the traditional locations to the new locations as per government regulations.*

Initially, the entrepreneurs began establishing sports manufacturing units in (Figure 1b) areas like Basti Nau (Marked C), Basti Danishmandan (Marked I), and Basti Guzan (Marked F) and the adjoining areas, which is shown in the left side of the *red dotted line* in Map 1b. During the past three decades, the cluster started expanding towards the right side of the *dotted red line* of Map 1b. Table 1 shows that the traditional cluster has a larger allocated area. In the field survey, it was found that although Govt. is encouraging the industrialists to shift their manufacturing units out of congested traditional cluster areas, but the movement remained restricted as labour and traders are reluctant to travel across the traditional cluster area. Other than that, the entrepreneurs also found it expensive to establish new manufacturing units in new locations.

**Table 1.** Area of the locations of the traditional and new hubs within the sports manufacturing cluster in Jalandhar

| Jalandhar sports goods manufacturing cluster |             |                                 |                |
|----------------------------------------------|-------------|---------------------------------|----------------|
| Locations covered in Old area                |             | Locations covered in New Area   |                |
| Locations                                    | Area        | Locations                       | Area           |
| Basti Nau                                    | 173         | Industrial Area                 | 618            |
| Basti Sheikh                                 | 141         | Focal Point                     | 1327           |
| Basti Danishmanda                            | 109         | Industrial Development Colony   | 494            |
| Basti Bawa Khel                              | 1952        | Suranussi                       | 198            |
| Dilbagh Nagar                                | 168         | Sports & Surgical Goods Complex | 52.75          |
| Model House                                  | 684         | Leather Complex                 | 222.30         |
| Basti Guzan                                  | 151         | <b>Total</b>                    | <b>2912.05</b> |
| <b>Total</b>                                 | <b>3378</b> |                                 |                |

Notes: 1. The area is in acres for the year 2020.

2. The old area of the cluster is shown in the left side of the red dotted line in Map 1b with an exception of the Sports and Surgical Goods complex and Leather complex.

Source:

### 5. Technological accumulation in jalandhar sports goods manufacturing cluster: inter-linkages for learning?

Jalandhar sports goods manufacturing cluster has gained significant position in the sector. The local daily carries a report that Jalandhar football manufacturers received orders of around INR 60 million<sup>16</sup> during the FIFA world cup-2022<sup>17</sup>. A website of a leading bat manufacturing company states that a famous Indian batsman customized his 2.9 pound cricket bat with more pronounced curve from them, while Jamaican international cricketer, Chris Gayle got his 3.9 pound bat customized from a Jalandhar based bat manufacturer. Some Jalandhar based firms are found to be producing best helmets used in IPL teams. But, some dailies<sup>18</sup> are reporting about shifting of Jalandhar sports manufacturer to Meerut<sup>19</sup> in the neighboring state of Uttar Pradesh, which were seconded by industry-insiders during the interviews with the author. Specifically, sports goods manufacturing cluster is composed of manufacturing units producing about 130 different products based upon different inputs like wood (cricket bats, hockey sticks, cricket wickets), synthetic fabric (inflated balls), leather (cricket and hockey balls, gloves), rubber (bladders and tennis balls and other balls), metals (badminton and tennis racquets, fitness equipment), plastic (leg guard, shin guard and other protective equipment) cotton (sports nets, sports wear) and feather (shuttle cocks) (adapted from UNIDO, 2001 and field interviews). Therefore, this section presents the general overview of the Jalandhar sports goods manufacturing cluster, the next section present the methodology adopted for primary data collection, following by discussing the core aspects.



## 5.1 Sample and data collection:

The study is based on both secondary and primary data sources. Secondary resources, like reports and literature were explored to document the birth of Jalandhar sports goods cluster, along with to present the basic statistics of the cluster. Annual Survey of Industries (ASI) provides data for the organized manufacturing industries and it is found that for Punjab for the year 2017-18, there are around 71 firms engaged in the production of sports goods (NIC' 2008 code 323). District Industrial Centres (DIC) also collects industrial data at the district level. DIC, Jalandhar have the information of those manufacturing units that have registered with them as of March' 2020, which shows that there are only 5 medium unit registered with DIC, while there are 431 units that are micro and small units employing 179 and 7711 workers, and having investment of INR 4000 and INR 8946, respectively. DIC also maintains the record of the registered Industrial Associations and it shows that there are 6 sports goods associations, the largest being the 'Sports goods manufacturers and exporters association' with 43 members. There are also 12 traders registered with DIC office as of March' 2020.

For the second part of the paper, with a focus of validating the hypothesis of 'Cluster Upgrading system' composed of various firms, organizations and institutions that are influencing the 'learning' in the process of building 'technological capabilities', we conducted the field survey in the sports goods cluster in Jalandhar in August – September' 2022 for the sample of 45 firms<sup>20</sup> (Table 1), selected through purposive sampling technique. We gathered information from open-ended questionnaire in which the entrepreneurs were asked questions apart from raw facts and amounts, which provided a clear picture of the actual scenario prevailing at the ground level. The industrialists shared the information based on their memory and not the audited figures. For micro and small enterprises, the owners were the respondents; while for the medium units, the managers were the respondents. Some traders, leaders of the key sports goods associations and the officers at the DIC were also interviewed in order to have all parties viewpoint in order to make our research free from any kind of bias. The survey was conducted with a prior permission<sup>21</sup> from the concerned department and the selection of the firms was made on the basis of the references and area. It was assured that a major part of the cluster was covered by surveying different areas in the cluster instead of focusing on a single area. We collected data on various aspects of the firms in the sports goods industry in Jalandhar covering the entrepreneurship, historical background, aspects of backward and forward linkages, employment and skill intensity, learning mechanisms and obstacles to innovation, compliances done by the units etc. We also explored the role of associations, government institutions and institutional factors.

## II.I. Firms and entrepreneurship aspects:

Jalandhar sports goods manufacturing cluster is heterogeneous in nature. Table 1 presents the details of the sampled firms. We have collected the data from four medium size firms that are engaged in the production of different products. The founder of F1 firm started his career as an assistant storekeeper in Oberoi & Co. (started with Mr. Ganda Singh Oberoi) that gave him the idea to start a manufacturing firm. What began as the manufacturing of balls in small quantity, evolved as a successful brand from India in domestic and international market. The firm also signed partnership with BRICS Football Cup in 2015 and is competing with the leading brands like Adidas, Nike and Puma for the FIFA world cups. F2 firm is an Original Equipment Manufacturing (OEM) that has evolved over the years with annual turnover of around US\$35 million and are exporting to over 50 countries. The unit has 6 production units and sells with their own brand name with a trademark. Concerning the growth story of the firms, F4 depicted that in the pre- 1991, the firm was largely catering to the domestic demand that changed in the post 1991 era. However, the growth of F3 happened largely after 2005.

**Table 1.** Sample firms

| Size of the Firm | Name    | Est.       | Products Manufacturing                                                                                                                                                                                                                                                                                       |
|------------------|---------|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Medium           | F1      | 1934       | Balls (Football, Cricket balls, Shooting Ball, Handball, Throwball, korfball) Badminton Rackets, Shuttlecock, Cricket Bats, Sports Bags, Footwears, Sportswear, Track And Field Equipment, Insole Gel, Stopwatch, Nets, Goalkeeper Gloves, Netball, Skating, Tennis Equipment, Squash and Swimming Equipment |
|                  | F2      | 1976       | Balls (Soccer Balls, Futsal Balls, Basketballs, Volleyball, Handball, Rugby Ball, Netballs, Water Polo Ball, Indoor Ball, Medicine Ball) Soccer Shin Guard, Training Accessories, Fitness Accessories, Sports Bags and Soccer Shoes                                                                          |
|                  | F3      | 2000       | Balls (Soccer Balls, Basketballs, Volleyballs, Inflatable Balls, Leather Balls, Hand Stitched Sports Balls) Shin Guard, and Sports Bags                                                                                                                                                                      |
|                  | F4      | 1976       | Balls (Inflatable Balls, Volleyballs, Soccer Balls, Rugby Balls, Leather Balls, Training Balls, Handballs, Futsal Balls, Net Balls, Gaelic Balls) Boxing Gloves and Cricket Accessories                                                                                                                      |
| Small            | F5-F6   | Pre-1980s  | Cricket Equipment                                                                                                                                                                                                                                                                                            |
|                  | F7- F12 | Pre 1970s  | Cricket Bats and Hockey Sticks*                                                                                                                                                                                                                                                                              |
|                  | F13-F14 | Late 2000s | Gym Equipment, Boxing and Martial Art equipment                                                                                                                                                                                                                                                              |
|                  | F15-20  | Pre 1970s  | Inflatable Balls and Rubber/Cricket Balls                                                                                                                                                                                                                                                                    |
|                  | F21-F25 | Post 2000s | Sports Apparel and Sports Shoes                                                                                                                                                                                                                                                                              |

| Size of the Firm | Name    | Est.                       | Products Manufacturing                                                                       |
|------------------|---------|----------------------------|----------------------------------------------------------------------------------------------|
| Micro            | F26-F36 | 1970s, 1980s and Post 2000 | Inflatable Balls (Footballs) Cricket Balls<br>Other Sports Balls (Hockey, Tennis, Footballs) |
|                  | F37-F38 | 1952, 2010                 | Bats                                                                                         |
|                  | F39     | Post 2010                  | Leather Sports Goods                                                                         |
|                  | F40-F41 | Post 2010                  | Plastic Sports Goods                                                                         |
|                  | F42-F45 | Post 2000s                 | Sports Apparel and Sports Shoes                                                              |

Source: Field Survey

Notes: 1. F1...F45 are the firms, named so to respect confidentiality of the firms.

2. \* depicts that there are two firms that are manufacturing hockey sticks and cricket bats are established in post 2000s.

Apart from the few medium firms, the cluster has a relatively large number of small and micro units that are manufacturing one or more products, usually using the similar raw material and/ or techniques. It is important to highlight that in our survey there are five small and one micro firm, that although established before 1970s, still not able to upgrade the production and productivity to move to higher categories. It was found that the owners of the medium size firms are mostly graduates and have inherited the manufacturing unit from forefathers, migrated from Sialkot (now in Pakistan). In case of these small firms, the majority of owners are graduates with the equal number of 12<sup>th</sup> pass and having some technical/ vocational education. Similarly, in the case of micro sized firms, the majority owners are graduates. This shows that the majority of entrepreneurs are having formal high school and college education.

#### **Traders as intermediaries:**

The traders or middlemen or intermediary <sup>22</sup> act as a binding link between the Manufacturer and the ultimate buyers and supplier of raw materials, for which they charge a fee. It was also found that from our sample firms, there are few (around 17.8 percent) manufacturers who are also trading their goods themselves, while there are some (around 57.8 percent) of the manufacturers who are exporters<sup>23</sup>, while there was only one firm (F 13)<sup>24</sup> that has trading their main business in our sample firms. There are numerous traders that operate either as Wholesale traders or Retail Traders and do not involve in any kind of manufacturing activity. In some cases, the small manufacturers have additional trading business. Handful of these traders are also involve in a third-party exports. These selected traders do not maintain any kind of inventory of the goods, rather they maintains the samples of the goods manufactured by the firms in the sports industry. The traders not only bring orders to the manufacturers but also provide them with the market information. The wholesale and retail traders in some cases have a separate shop for displaying samples and maintaining the stock of the goods at backend. In our sample of

the traders collected from the DIC, Jalandhar, the traders are running a sole proprietary business. Majority of these traders have their units/offices in the Traditional (Basti's on the left side of red dotted line in Map 1) area of the sports goods cluster. This could be attributed to the fact that the trading business mostly concentrates in the regions involving high manufacturing activities. It was also found that mostly the trading firms were earlier engaged in manufacturing, that later set up trading as an additional business.

### **Backward linkages:**

Supplier and buyers plays an important role in determining the structure of any industrial cluster. Medium sized firms in our sample reported that they source plastic, rubber and cloth based raw materials mainly from *within Cluster*. They are also procuring these materials from *Taiwan and China*. These firms usually purchase Leather from other states like *Uttar Pradesh and Rajasthan*. During the interview, firm F2 reported that they have shifted from leather-based footballs<sup>25</sup> (which are difficult to stitch) to polyurethane (PU), polyvinyl chloride (PVC) based footballs for which the raw material is purchased from other places like *Bombay and Delhi*. The supplies of Cloth in some cases are met from the Ludhiana Cluster within Punjab. These medium sized firms are found to be purchasing polyester from Delhi based firms, whereas they are getting the natural rubber directly from Kerala, situated in South India.

In our sample, small firms engaged in the production of bats made of imported Willow wood from United Kingdom<sup>26</sup>, or it is purchased from Jammu & Kashmir. The bats are also being manufactured from Mulberry wood, which is purchased locally within Cluster from areas like Basti Nau. During the interviews, it was found that the sellers and exporters in Punjab are finding it difficult to procure Kashmir willow due to an official ban on selling Kashmir willow cleft to other states. The other product that is also facing shortages of necessary raw-material is the 'shuttlecocks' that are made by plucking feathers of live ducks<sup>27</sup>. In our sample, the firms purchase the raw materials used for manufacturing Inflatable ball from other states like Uttar Pradesh (Meerut) and Kerala. Assam and Kerala are also the major sources for the Latex and Natural Rubber used in manufacturing of Rubber Balls and Bladders, while Delhi is the biggest supplier of carbon fiber. The survey reported that approximately 13 per cent of the small firms totally depend on the local sources within the Cluster for the purchase of raw materials.

Survey of the micro units in our sample shows that they rely on other states like Uttar Pradesh (Meerut) for the supply of Cork wood and Leather. A firm (F25) in the sample imported the Leather and Corkwood from Portugal and South Africa. These firms are getting Plastic from Ludhiana and are purchasing the PV materials locally. Overall, 20 per cent of our sampled micro sized firms totally procure raw material locally from within the cluster. It was found that

there are suppliers of raw materials like PU, PVC, Cloth, Polyester, Rubber, Willow, Poplar wood, Leather Mesh in areas like Basti Nau, Leather Complex, Model House. On the other hand, the Split Leather used by firms is bought from Kanpur, Uttar Pradesh. Thus, it seems that there are some long-ranged backward linkages for procuring raw materials for the sports goods manufacturing firms based in Jalandhar.

**Exports and forward linkages:** The firms in the sample have local, national and international presence alike. It was found that our sampled medium size firms (F3, F4) are 100 percent export oriented and are exporting to the markets in USA, UK, Australia, Philippines, Japan and South Africa. However, some (F2) also caters to the national markets and supply the equipment to other Indian states like Haryana, Delhi, Punjab, Uttar Pradesh and Madhya Pradesh, apart from selling in the local market at Basti Nau, Jalandhar. From our sample of 21 small sized firms, approximately 45 per cent exports mainly to the international market and 15 percent firms sell their goods nationally to other states; while others majorly sell their goods locally. Many small and micro size firms also supply to the medium size firms to meet their demand of bulk order.

#### **Craftsman, workers and other facilitators:**

Given the nature of various sports goods manufactured in the Jalandhar cluster, the workers engaged therein can be classified broadly as skilled, unskilled and managerial staff. It is found that the number of employees engaged in the production of sports goods increased over the years from 5792 in 2010-11 to 12,383 in 2018-19, showing an increase of 113% (Statistical Abstract of Punjab)<sup>28</sup>. In our sample firms, we asked about the proportion of skilled, unskilled and managerial workers employed in the firms. Our respondents told us that employment of labour directly depends on the quantum of the order received by the firm, and hence the employment is highest during the peak business seasons<sup>29</sup>. Therefore, it is difficult to ascertain the exact employment statics of the sample firms in this cluster<sup>30</sup>. The average number of male workers employed in sample of 45 firms soared to 89.8 workers per unit in 2021-22 from 53.2 workers per unit in 2010-11 i.e., by 68.8%. The highest share in the increase was reportedly that of the male management staff (171%) followed by male unskilled workers (114%) and skilled workers (54.3%). Whilst the increment of 67.7% in the average number of female workers from 22 workers per unit to 36.7 workers per unit was observed during the period 2010-11 to 2020-21, with a maximum increase in female management staff (155.7%) succeeded by female unskilled (111.7%) and skilled workers (49.8%). The survey reported that an increase in the total number of male workers was more than the increase in the females workers employed in the Jalandhar sports goods industry.

The permanent labour is mostly employed on a salaried basis. The salaried labour is employed on a single shift for 8 hours and the labour also work

overtime during the peak time to meet the demand orders. The workers working on piece rate were found to be working beyond 8 hours to make their living. From the survey, 31 firms<sup>31</sup> responded that monthly salary paid by each firm to a skilled worker ranged between Rs 6,097 to Rs 7,903 in 2010-11 and Rs 9,800 to Rs 15,447 in 2021-22 (~ increase of INR 617 at constant prices at 2012=100). While the average monthly salary paid by each firm to an unskilled worker ranged between Rs 4,758 to Rs 6,048 in 2010-11 and Rs 8,192 to Rs 10,261 (~ increase of INR 305 at constant prices at 2012=100). From the survey responses of 19 firms<sup>32</sup>, the average monthly salary paid by each firm to the management staff ranged between Rs 8,684 to Rs 13,000 in 2010-11 and Rs 17,861 to Rs 41,676 in 2021-22 (~ increase of INR 4362 at constant prices at 2012=100). Clearly, the incomes and numbers of the workers have escalated in 2021-22 as compared to 2010-11 but the highest increase in the income and number of workers is experienced by the management staff because the industry has become more technically demanding and needs more technically trained and computer literate staff.

When asked about the training and learning of the labours in the firms, the respondent generally pointed to the lack of the institutional support for the development of the skill of the labour. Respondent from firm F15 opined, *“the workers generally learn by doing under the supervision of experienced employees. It takes about 10-15 days for a worker to learn the basic task to be done.”*<sup>33</sup> Another respondent (Firm F30) told that *“there is a gap between the skilled imparted for employment and the skills needed in the industry. Therefore, the newly employed workers require specific initial training.”* When asked about the impact on employment of advancing technologies, firms (F28, F29, F38 and F40) opined that *“their units witnessed a growth in production and productivity with adoption of new technology (advanced machines), leading to an increase in market share with increase in employment too”*. It was also found that there is a paucity of skilled craftsmen, specifically of producing cricket bats and stitching of cricket balls. Overall, the firms in the sector rely on the skilled craftsmen and workers who have been working with them for a long time (F22, F27, F37). Although, it was also found that high skilled craftsmen were of high demand in the industry. In nutshell, it was found that largely, the labour in the industry is semi-skilled, but with the cost of labour accelerating, the manufacturers are finding difficulty to compete with low cost products available from other clusters. Importantly, the labour engaged in the Jalandhar sports goods manufacturing cluster is migratory in nature and has moved to Punjab from Uttar Pradesh, Bihar, Jharkhand, and Chhattisgarh etc. and has partly inhabited in Jalandhar.

The skilled workers are mainly involved in different tasks required in the production of specific products, like wooden bats (machining a cleft, pressing, sanding etc.), wooden hockey sticks (shaping, sanding, fitting handles etc.), footballs (cover material, cutting, making bladder, stitching panels and bladder insertion), racquets (forming frame, drilling, sanding, tempering, stringing etc.),

cricket balls (polishing leather, cutting, stitching), inflatable balls (inflatable bladder and creating winding layer, injecting thermal air etc.) rubber balls (forming pellets, pressing, buffing, core formation etc.) basket balls (pressing, cutting, molding etc.). The unskilled tasks are the jobs performed by helpers, cleaning, dusting, organizing material, carrying material from one place to other, etc. The management staff is mainly involved with the task of auditing, record keeping, tracking materials and final goods, marketing, jobs requiring organizational skills, analyzing market trends, internal policy making, etc. The Chartered accountant (CA) facilitates the learning of the entrepreneurs by taking care of the external matters relating to credit financing, availing government schemes, registration of firm, etc. in case of the small and micro firms. The designers and the CAs are hired on the part-time basis.

### **Industry associations:**

There are nearly 8 to 9 associations in the sports goods industry in Jalandhar like SGEPC<sup>34</sup>, SGMEA<sup>35</sup>, Laghu Udyog Bharti, Khel Udyog Sangh, SAFASM<sup>36</sup>, SPORTTX<sup>37</sup> etc. We interviewed three industrial associations, namely SAFASM, SPORTXX and Laghu Udyog Bharti<sup>38</sup> to understand their role in the development of the cluster. The office-bearers were contacted and open-ended questionnaire was filled. It was found that Associations have a membership fee varying from about INR 4000 to INR 8000 depending upon the size of the association. These associations organise seminars and trade fairs that help the industrialists to gain the knowledge about the industry. The leaders of the association also facilitate the industrialists in the legal matters. It also helps in interlinking and networking of the members of association that improves their learning from their co-entrepreneurs. These association leaders also represent the sports goods industry in meetings with the government officials and put forth their problems and challenges so that a desired government policy can be framed in that regard. The association helps the industrialists to avail the benefit of the government schemes and encourages their regular participation in national and international level trade fairs and seminars. The regular meetings with the offices of DIC are organized for increasing the interaction between the industrialists and government. Most of the associations address the similar problems of the industrialists but they differ from each other in their areas of operation. Some of the associations deal at local level while others at National level. These associations represents the similar problems of the industrialist like raw material procurement, technology up-gradation and modernization, lack of skill development centers at the cluster level, competition from Chinese goods and heavy import duties on machinery and raw material. Majority of the associations have a well established website through which it shares important information.

To our sample of 45 firms, we asked: "Does your firm is a member of any industrial association?". It was found that all medium size firms, 81% small and

70% micro units of our sampled firms are members of industry associations. It was also found that small and micro sized units participate relatively less in the activities of associations as compared to medium size firms. We further asked the firms to mark on three stage likert scale of 'often, occasionally and never' the role of associations in legal matters, providing information about the latest policies, informing about the industrial changes, and availing Govt. policies. The owners of the medium size firms were of the opinion that the associations help the industrialists in legal matters; provide information about the industrial changes and latest policies more 'Often'. In 53 per cent of the small size firms the associations were more 'Often' helped in the legal matters while 20 per cent of small firms were 'Never' helped by associations in the legal matters. 60 per cent of the owners told that the associations provide the information about the latest Govt. policies. In case of the micro units the help extended by the associations was the minimum, as only 15 per cent of the firms were 'Often' helped in legal matters. 55 per cent of the micro units were given the information more 'Often' about the latest policies by the associations and 60 per cent of these units were passed on the information more 'Often' about the industrial changes through associations. The associations have also helped 60 per cent of the micro units to avail the benefits of the government policies more 'often'.

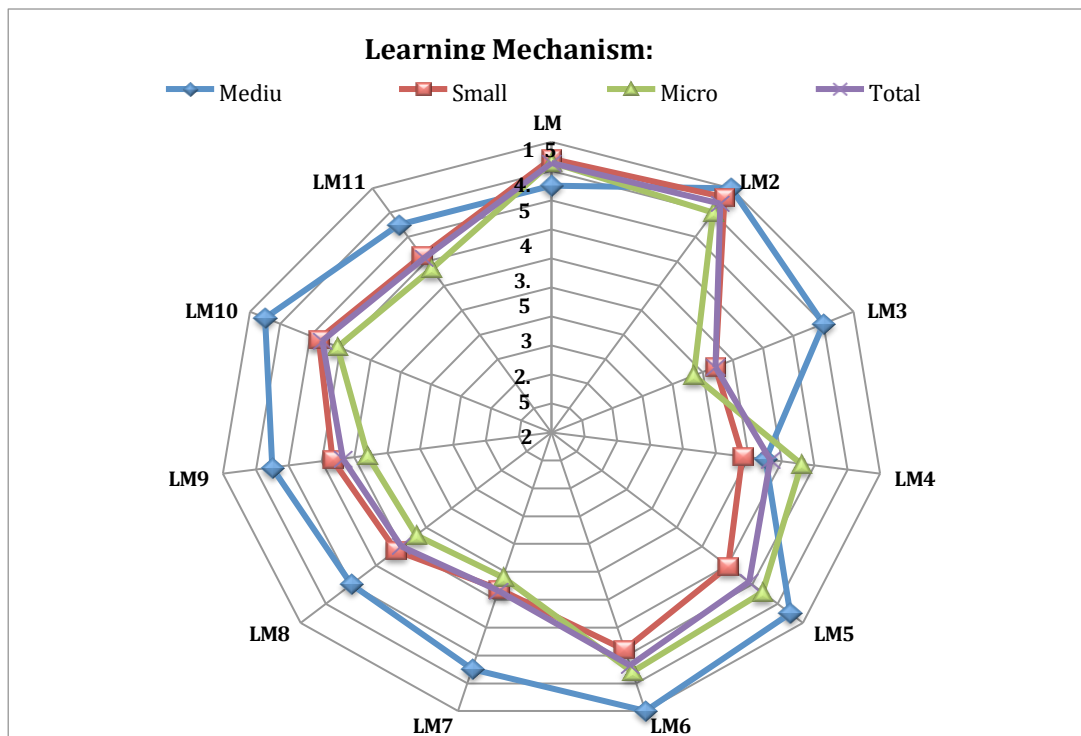
#### **Learning mechanism:**

Jensen et al. (2007) identified two modes of learning. One is experience based that involves learning by doing, using and interacting (DUI- mode) and another is Science based mode that rely on investment in research and development (R&D) and interaction with research institutions that links Science, Technology and Innovation (STI- mode). Different firms, industries at different level of technological ladder at different times use the combination of different modes of innovation. Based upon the nature of industry and initial observations while discussing the issues with industry-insiders, we identified 11 means of learning mechanism. For the means of learning by doing and using, we tried to understand these also during our focus on building 'skill intensity' of the workers in the firms. However, for specific learning mechanism of the firm, we tried to focus mainly upon "I" from DUI mode. Therefore, we asked the firms about the role of 'customers feedback', 'quality improvement by suppliers', 'learning from training institutions', 'learning through inter-linkages with co-entrepreneurs', 'learning through attending Trade Fares/ Seminars', 'learning through published materials/websites/social media', 'learning through higher educational institutions', 'govt. initiatives/ policies/ plans', 'learning through informal mechanisms like copying/ reverse engineering/ learning by doing', 'learning by information flows through financial institutions' and 'learning though any other means'. The respondents from 45 firms marked their response on a Likert scale of 'Never, Rarely, Sometimes, Often and Always'. Of



the data collected, we grouped the data on the basis of the size of the firm and the categorical variable was done using Cross-Tabulation analysis. The mean of the variables for medium, small and micro firms from our sample is presented in Figure 2.

**Figure 2.** Active learning mechanisms in jalandhar sports goods manufacturing cluster



Source: Author's compilation from Field Survey. The analysis is based on Cross-Tabulation method using SPSS.

Notes: 1. LM1 to LM11 are the means of 'Learning Mechanisms'.

2. LM1 is Product developments from **Customers** Feedback; LM2 is Quality improvement with advanced intermediates (like components, parts etc.) supplied by **Supplier**; LM3 is Learning about new products and process through **Institutions** like ITI, Technical Institutes NIFT, etc.; LM4 is Learning about new products and process through inter-linkages with **Co-entrepreneurs** within and outside Cluster; LM5 is Learning through attending **Trade Fares/ Seminars** etc.; LM6 is Learning through accessing **Published** material/ **Websites/ social media**; LM7 is Learning through linkages with **Higher Education institutions** (colleges/ universities/ research institutes); LM8 is Learning about market competitiveness and growth possibilities through **Government Initiatives/ Policies/ Plans**; LM9 is Learning through **Informal mechanisms** like Imitating (copying, reverse-engineering), Learning by Doing etc.; LM10 is Information flows (about new

products, expansion possibilities and advanced machines) through Financial Institutes (**Banks**); LM11 is Learning through Any Other means or source.

Figure 2 shows that medium firms in our sample show greater benefit of inter-linkages with training institutes (LM3), trade fairs and seminars (LM5), published materials and social media (LM6) and information flowing from financial institutions (LM10). These firms are found to be relatively more beneficial with the inter-linkages with higher educational institutes (LM7) and Govt. initiatives/ policies and plans (LM8) as compared with small and micro firms in our sample. However, the sampled small and micro firms were found to have more learning from the feedback of customers (LM1) and suppliers (LM2). But both small and micro firms have not reported much learning about product and process learning from technical institutes (LM3). Importantly, small firms have also reported about minimal learning from co-entrepreneurs (LM4) and through trade fairs/ seminars (LM5) and even through published materials. Micro firms in the sample were found to have greater learning from co-entrepreneurs as compared to other sub-groups of the firms.

### III. National and international institutional aspects

*Sports Goods Cluster in other parts of India:* Meerut district of Uttar Pradesh is also a prominent Sports Goods manufacturing cluster that too was born with the migration of craftsmen, artisans, and entrepreneurs from undivided Punjab during partition of India in 1947. Jointly, Jalandhar and Meerut produces two-third of the total sports goods in India (EXIM, 2021). District Anantnag in Kashmir region of Union Territory Jammu and Kashmir is famous for the production of wooden cricket bats with Kashmir willows, while Uluberia in West Bengal is a hub of production of Shuttlecock for Badminton. But, Meerut sports cluster produces similar products that have been producing in Jalandhar. Meerut also has a unique specific Common Facilitation Centre, under the Ministry of Micro, Small and Medium Enterprises named as Process cum Product Development Centre (MSME-PPDC) that has tool-room, testing centre and training centre. The facility is engaged in '*testing, inspection and consultancy of international standard*'<sup>39</sup>. During our interviews with member of industrial associations, entrepreneurs and even officials of DIC, we found that many sports goods manufacturers from Jalandhar have either shifted to Meerut<sup>40</sup> or created an additional production facility in Meerut. First the dark era of 1980s<sup>41</sup> created law and order adversities that forced the entrepreneurs to fled. Again in 2020, the rail and road blockage by farmers against the agriculture related laws<sup>42</sup> for almost a year put a dent on the manufacturers of Punjab. On the other hand, Meerut has a pool of skilled and unskilled labour, relative proximity to national traders in Delhi<sup>43</sup> and a shorter distance with port in Gujarat and Mumbai.

### **Global pattern of sports goods production hubs:**

Global sports goods manufacturing industries is very dynamic. It is showing some specific trends that are changing the organizational forms of the manufacturing industries in different countries owing to some institutional dynamics.

Literature shows that the production and sales of sports goods equipment's are rising in Asia (Manzenreiter, 2013; 2014) and over the years and Asia's production is no longer being confined to low-capital labor-intensive products. Some specific trends are also witnessed in the production of sports equipment's and sports wear industry. Sports goods industry is largely dominated with some global brand names like Asics, Nike, Adidas, Fila, Puma, and New Converse etc. that are outsourcing the manufacturing process to the cost-effective locations. There are also second tier sports brands, international retailers and non-branded traders, retailers that all source products from low-cost locations (Nadvi et al, 2014). Manzenreiter (2014) reported "*Adidas and Nike control 60 percent of the global athletic shoes market and one-fifth of the athletic apparel market, source most of their products through a vast network of subcontractors located in Asia.*" Adidas Annual report 2021 reported that "*as of 2021, they worked with 114 independent manufacturing partners that are producing in 234 manufacturing facilities, with majority (71%) are located in Asia*". It was further stated that for Adidas, Indonesia (36%), Vietnam (30%) and China (15%) were the largest source country for footwear; while for Apparel was sourced from Cambodia (21%), China (20%) and Vietnam (15%); while Accessories and Gear were sourced mainly from China (34%), Turkey (29%) and Pakistan (15%)<sup>44</sup>. For the inflatable balls (HS code 950662) (WITS database) for the year 2021, China is the biggest exporter (about 5 lakh thousand USD) followed by Pakistan (about 1 lakh thousand USD), Vietnam, Germany, Thailand, European Union and India (19 Lakh USD). Some big companies from South East Asia has become the biggest producers outsourcing to big global brands. For example, Hong Kong's companies Esquel and Yue Yeun Industrial Holding Limited<sup>45</sup> is the biggest producer to apparel and athletic shoes. A Chinese company Li Ning has become the most recognized brand name of China domestic market. Overall, the multinational sports companies, originating mainly from Global North (Americas, Europe and Japan and very recently from Asia) outsource the production to low-cost labour intensive locations, mainly to South East Asian and South Asian countries. The environmental and child labour and workers welfare compliances are to be met by the suppliers to enter and sustain in the value chains (Nadvi et al, 2011) These compliances also lead to the governance of supply chains by the global multinational.

## VII Discussion and conclusion

Industrial Clusters reflects varied historical, social, cultural and economic aspects, impacted thereof at local, national and global level. The agglomeration of different manufacturing units, suppliers, customers, traders etc. along with varied enabling organizations like research institutes, training and educational institutions, financial institutions etc. under the ambit of certain rules, laws, norms determines the participation of the cluster in the value chains. We argue that the growth of a Cluster can be impacted by the structure of inter-linkages of different actors, organizations and institutions that exist at three levels (3Ms) – micro (local), meso (national) and macro (global) levels, that can lead it to participate simultaneously at three levels (3VCs)- local value chains, regional value chains and global value chains. The 3Ms aspects of innovation systems and 3VCs participation in value chains is termed as ‘Cluster Upgrading Systems’ (CUS). It is argued that the birth, growth and sustainability of an industrial cluster depend upon the three levels of innovation systems that lead it to participate in value chains at three levels.

To present the argument, the case of Jalandhar sports goods manufacturing cluster is taken, which is an old cluster dating back to 1880s. Numerous socio-cultural and political factors gave birth to the cluster that remained largely labour –intensive with minimal transformation towards technology-intensive firms. The chosen cluster is very heterogeneous in nature and produces around 130 products including wooden bats, hockey sticks, racquet, inflated balls, gym equipment, sports wear and sports shoes, head gears, gloves etc. The firms in the cluster have both backward and forward linkages with local, national and global suppliers, traders and customers. There are few industrial associations, training institute, educational institutes and financial institutions within the cluster, which were expected to acts as a source of trade/ industrial knowledge and information. Using an exploratory approach, open-ended questionnaires were filled by representatives of manufacturing firms, traders, industrial organizations and training institutions. It was found that for large number of small and micro firms in the cluster, there is a lack of inter-linkages amongst co-entrepreneurs, educational and training institutions, financial institutions and even Govt. policy-making mechanism, reflecting a relatively weak Innovation System at the local level. On the other hand, the growth of the cluster is found to have an impact of similar industrial clusters of Meerut (Uttar Pradesh), Kashmir (wooden bats manufacturing cluster), Sialkot (Pakistan), and other New Industrializing Economies (NIE) like Taiwan, Hong Kong, Vietnam, Cambodia, Malaysia and some Latin American and African countries. The global sports goods manufacturing industry is largely brand-oriented sector and is dominated by few global brands from global North and East Asian economies, that procure the products from the production chains spreading across East and South-East Asia. In this broader context, the Jalandhar sports goods manufacturing cluster is feared of getting trap in ‘low value added trap’.

The low-cost, labour intensive production chains are spreading their web towards countries like Vietnam, Cambodia, Malaysia, Bangladesh and Pakistan; while the capital- technology intensive production chains are emanating from China, Taiwan and Hong Kong. Therefore, it is imperative that strategic policies should be framed and implemented for 'learning' advanced cost-effective production techniques to be adopted by different medium, small and micro (MSMEs) firms within the cluster. There is a need to build a stronger innovation system with increasing inter-linkages between co- entrepreneurs, firms and educational/ training institutions, financial institutions along with making provisions for greater learning through organizing trade fares, seminars etc.

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## Notes

- <sup>1</sup> [http://sgmea.org/sports\\_goods\\_industry\\_of\\_india](http://sgmea.org/sports_goods_industry_of_india)
- <sup>2</sup> It is not necessary that the industrial clusters are concentrated in small geographical local or one municipality. These may spread across municipalities and at times also regions. For example, the Silicon valley is the concentration of related firms in a certain small locality, while the dairy cluster in Nicaragua (Artola and Parrilli, 2006) is the case of a cluster spread across municipalities.
- <sup>3</sup> The paper presents the discussion of the extensive scholarly work in the growing field of 'economics of agglomeration', 'economic geography', 'industrial districts' and 'industrial clusters'.
- <sup>4</sup> In Mexico, two shoe clusters of Guadalajara and Leon (Rabellotti, 1997) has long histories, while the manufacturing clusters in South East Asia, mainly in and around China is of recent origin.
- <sup>5</sup> Sialkot was a major industrial center of undivided Punjab (Pandit, 1978) After partition Sialkot became the part of Pakistan. Wagah International border run between the Indian and Pakistan side of Punjab. The distance between Amritsar and Sialkot is 101 Kms.
- <sup>6</sup> These are the desendents of Jassa Singh Thoka, who freed a fort of Ram Rauni near Amritsar. The fort was renamed as Ramgarh and Jassa Singh Thoka became the governor of the fort, thus got the name as Jassa Singh Ramgarhia (McLeod, 1974).
- <sup>7</sup> Italics denote the emphasis as highlighted in the cited literature.
- <sup>8</sup> Pandit (1978) documented that non-Muslims in undivided India held dominant position with strong financial balances and urban non-movable property. It was stated "95 percent of the deposits of large joint stock banks, 92 percent of the insurance premium and 75 percent of the urban immovable property in terms of value was accounted by the non-Muslims" (p-1937).



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<sup>9</sup> Data is taken from Statistical Abstract of Punjab, 2020.

<sup>10</sup> Within the framework of Industrial Classification' 2008, Manufacturing of Sports goods with NIC code' 323 is kept under the broad group of 'Other Manufacturing' NIC code 32. However, under the NIC code 1410 'Manufacturing of wearing apparel, except fur apparel', the manufacturing of leather sports gloves and leather headgear is included. Likewise, under the NIC code 2219 'Manufacturing of other rubber products', 'manufacturing of rubber sports requisites' are included. NIC code' 2220 is 'manufacturing of plastic sports requisites', NIC code 2599 has 'manufacturing of sports goods' with other fabricated metal products.

<sup>11</sup> For the organized manufacturing sector, it was found that the production has increased three times to INR 30208 lakhs (in constant prices) over the last decade.

<sup>12</sup> Since 2010-11 (NSS 67th round) the percentage share of sports good units and employment in Punjab has declined substantially from around 4 % to 0.23 % and around 3 % to 0.34 % in 2015- 16 (NSS 73rd round), respectively.

<sup>13</sup> The author is thankful to the staff of the DIC, Jalandhar for providing the latest available data as of March' 2022.

<sup>14</sup> It is a single page registration form for MSME enterprises that collects information like type of ownership, employment, production, fixed investment, social category, address, telephone number and email

<sup>15</sup> Jalandhar also has a number of hand-tool and machine tool manufacturers, surgical instruments, automobile parts, and agricultural implements.

<sup>16</sup> Average exchange rate for 2022 was 1\$US = 78.6048.

<sup>17</sup> <https://www.youtube.com/watch?v=JPX3WSGsPWU>.

<sup>18</sup> <https://www.tribuneindia.com/news/archive/punjab/once-hub-of-sports-goods-in-country-jalandhar-in-crisis-165989>

<sup>19</sup> Along with Jalandhar, Meerut is also an old sports goods manufacturing cluster. After the partition, some craftsmen directly migrated to Meerut and started producing the sports equipments.

<sup>20</sup> The size of the sample is based on our initial collection of data from ASI for the year 2017-18, that reported that there are 71 organized firms in Punjab. Therefore, based upon the World Bank's Enterprise Survey (2009) methodology, sample size is calculated with level of precision of 7.5% for 90% confidence level.

<sup>21</sup> We took the reference letter from the govt. official bodies before conducting the interviews with the enterprises, that made them comfortable in giving their responses to our questionnaire and interviews.

<sup>22</sup> The term 'intermediary' is defined under section 2(13) of the (Integrated Goods and Services Tax) IGST Act, GOI as a broker, an agent, or any other person, by whatever name called, who arranges or facilitates the supply of goods or services or both, or securities, between two or more persons, but does not include a person who supplies such goods or services or both or securities on his own account.

<sup>23</sup> Amongst these, 30 percent firms are exporting their 100 percent output.

<sup>24</sup> The trader was a small-sized manufacturing unit that produces weight lifting and gym equipment.

<sup>25</sup> The Soccer ball is made from PV Micro Fibre and Leather 8 Panel Structure.

<sup>26</sup> The willow is lighter in shade and is considered 'best' for the production of customized bats. These clefts are light-weight and have more finishing. These are professionally grown in different parts of England.

<sup>27</sup> <https://economictimes.indiatimes.com/shortage-of-duck-feathers-has-put-shuttlecock-manufacturing-hubs-jeopardy/articleshow/17789059.cms?from=mdr>

<sup>28</sup> The data is collected from the District Industrial Centers.

<sup>29</sup> For footballs, there are international tournaments like FIFA World Cup, BRICS football Cup, NBAK tournaments, Olympic games, National Premier League, Champions League

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etc. Championship League Twenty 20IPLs etc. for Cricket Bats. The Rugby Championship and National Rugby League etc. for Rugby.

30 For aggregate data, we relied on data provided by DIC, Jalandhar, as for the year 2021-22 total employment in sports goods manufacturing cluster is 5774

31 These 31 Firms are: F1- F18, F23- F24, F29- F30, F33- F34, F36-F37, F39-F43

32 Only 19 firms from 45 firms responded to the question of 'salary to management staff'.

33 The views of the respondents were translated from Punjabi/ Hindi to English and presented in italics.

34 Founded in 1958, Sports Goods Exports Promotion Council is a Govt. of India sponsored organization working for the promotion of India's exports of sports goods.

35 Established in 1973, the Sports Goods Manufacturers and Exporters Association represents the leading manufactures and exporters of sports goods.

36 With 36 members as of Sep' 2021, the Sports and Fitness Welfare Association of SC-ST manufacturers was established in 2018.

37 Sports and Toys Exporters Association was founded by Sh. Sanjay Kohli in 2015, has 70 members as of Sep 2021.

38 This Association has 60 members in Jalandhar. At the time of interview, the President of the Association was Sh. Arvind Singh Rana. The association was formed in 1994

39 <http://ppdcmeerut.com/about-us.html>

40 The share of Punjab was 47 percent and Uttar Pradesh was 40 percent of the total production of Sports Goods in India for the year 2017-18 (EXIM, 2021).

41 Khalistani Movement in Punjab, Operation Blue Star and Anti-Sikh riots created serious law and order problem in Punjab: <https://www.indiatoday.in/fyi/story/1984-operation-blue-star-amritsar-1251681-2018-06-06>

42 <https://indianexpress.com/article/india/one-year-of-farm-laws-timeline-7511961/>; Goods, not protests, stopped on their tracks, The Hindu 14 Nov 2020.

43 The construction of Delhi-Meerut 14-lane Expressway for smooth and fast connectivity.

<https://www.sportzbusiness.com/meerut-outpaces-jalandhars-sports-industry/>

44 [https://report.adidas-group.com/2021/en/group-management-report-our-company/global-operations.html#:~:text=PRODUCTION%20THROUGH%20INDEPENDENT%20MANUFACTURING%20PARTNERS&text=In%202021%2C%20we%20worked%20with,facilities%20\(2020%3A%20277\).](https://report.adidas-group.com/2021/en/group-management-report-our-company/global-operations.html#:~:text=PRODUCTION%20THROUGH%20INDEPENDENT%20MANUFACTURING%20PARTNERS&text=In%202021%2C%20we%20worked%20with,facilities%20(2020%3A%20277).)

45 <https://www.yueyuen.com/en/manufacturing.html#manufacturingBusiness>. The company has the network of manufacturing facilities in China, Vietnam, Indonesia, Bangladesh, Cambodia, Myanmar etc.

## Development strategies in a context of world system disorder

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*"I'm a pessimist because of intelligence, but an optimist because of will." Antonio Gramsci in a Letter from Prison (December 1929)*

### 1. Introduction

The world has been through several major crises since the beginning of the new millennium such as the financial crisis 2009 and the Covid crisis 2019, and currently it faces, a risk of military conflict between great powers. The old-world order, with the US as hegemonic power, is challenged by the rise of China and there has been a reversal of, as well as directional change in, the globalization trend. A weakening of international collaboration is taking place against a backdrop of global challenges such as climate change and global inequality, challenges calling for coordinated action and transnational governance. This paper reflects on, and invites to a broader discussion of, what this means for innovation and development strategies in the South. What are the main threats and opportunities in the current era? Which lessons can be drawn from the rise of China? What are the implications for the research agendas of Globelics scholars?

This paper starts from the same assumptions as Lundvall (1992), where it was stated that we live in an era where knowledge has become the most important resource and learning the most important process. And it operates with the same broad definition of knowledge and learning as used in Lundvall and Johnson (1993) – knowledge is defined as including both explicit and tacit elements and learning as including searching/exploration as well as learning by doing, using, and interacting.<sup>1</sup> But, while Lundvall (1992) was focused on national systems of innovation in the North, this paper applies this perspective, first, to the world level and, second, to the challenges for countries in the South.

## **2. Combining Wallerstein's World System perspective with Freeman's Development Theory**

The paper combines Wallerstein's world system perspective (Wallerstein 1979; Wallerstein 2003) with Freeman's theory of world economic development (Freeman 1982/2004; Freeman 1987;

Freeman 1995/2004; Freeman 2004; Freeman 2008). Wallerstein's perspective has much in

common with Christopher Freeman's. Both refer to long cycles of the Kondratieff-type and both propose that social science/economics should be integrated with history. One major difference is that, while Wallerstein emphasizes the dependency of countries in the periphery, Freeman's analysis is focused on, changes in the world pecking order and on how knowledge-based strategies make it possible for developing countries to rise. While the world system perspective defines the shackles blocking development, Freeman's analysis gives inspiration for developing countries attempting to throw off the shackles.

I see the two perspectives as complementary. The world system perspective demonstrates, how systemic relationships make it difficult for poor countries to industrialize and create jobs and well-being. Freeman's approach demonstrates that the world capitalist system is not frozen once and for all – history never ends! With a clear understanding of the dependency, developmental states can design and implement strategies that break up the dependencies and exploit opportunities.<sup>2</sup>

In modern times, the single most important example of a rise of a periphery country is China, now seen by the US government as challenging its hegemony (Rikap and Lundvall, 2021; Lundvall and Rikap 2022). China's move from the periphery to the semi-periphery has wide implications for the constitution of the world system and at the same time it offers important insights in the potentials and limitations of knowledge-based development strategies in the current era.

Wallerstein's specific interpretation of the capitalist world system is outdated in important respects – not least the idea that industrial activities are concentrated in the core countries while periphery countries are specialized in natural resources. Nonetheless, I assume that it is useful to apply the world system perspective and to redefine it as constituted by national innovation systems in a context of learning economies and knowledge-based development.

### 3. The reversal of the globalization trend and the growing role of technonationalism

From the very beginning the conceptualization of national innovation systems, as developed by Freeman (1987), Lundvall (1992) and Nelson (1993) was challenged by alternative understandings raising doubts about the primacy of the national level (Niosi and Bellon 1994; Carlsson and Stankiewicz 1991). Is it meaningful to focus on national systems in a world with transnational enterprises and institutions? How to modify the concept so that it reflects that innovation processes involve interactions at the transnational level, some of them within multinational enterprises, others in transnational networks (Chaminade, Lundvall and Haneef, 2017, pp. 122-138)?<sup>3</sup>

These analytic discussions have counterparts in policy debates on development strategies. Liberal experts and international organizations propagating pro-market strategies presented the linking of domestic firms into global value chains as an alternative and more realistic strategy than one, where the state engages in building stronger national innovation system (Baldwin, 2013; World Bank 2020). This is in line with neoliberal ideas and the World Bank-view that 'the private sector agents should be in the driving seat'.

2015 Globelics organized a seminar in Copenhagen that brought together scholars working on global value chain analysis with scholars working on national innovation systems (see <https://www.eurolics.org/activities/eurolics-workshops/activity-1/>). One outcome was a special issue of European Journal of Development (see Lema, Rabelotti, and Gehl Sampath, 2018). There was no simple conclusion in relation to the policy issues in the contributions. But together they indicated that the two perspectives could and should be combined – to benefit from participation in global value chains required a strengthening of the national knowledge infrastructure. Joining global value chains should **not** be seen as an alternative to building a stronger national innovation system. Strategic management of the interface between local/nation and international/global interface should be at the core of development strategies (Lee, forthcoming).

But already at that time, the trend toward a globalized capitalism had been both broken and modified. There was a slow-down in value chain trade in tangible products while international trade in services and especially in digital services accelerated (Unctad 2019). There were different factors at play behind the reversal. The 2008 financial crisis triggered a weakening of the element of global value chain trade. This reflected a shift in China's economic strategy enhancing the role of domestic demand relative to exports which reduced its dependence on global value chains – the share of value content of imports in its exports started to fall as early as 2010. (Garcia Herrero 2020). The 2019 Covid-crisis resulted in a further disruption of supply chains (Hayakawa and Mukunoki

2021). It also gave rise to policies aiming at increased self-sufficiency. At the same time US-based tech giants expanded world-wide and as a result trade in digital services, spanning from e-commerce and use of search machines to social media, exploded (Rikap and Lundvall 2022).

The factor with the most lasting impact may nonetheless be geo-political. The economic rise of China and the challenging of US-leadership in strategic technologies has led to a 'technology war' with boycotts and embargos leading to further disruption of supply chains (Rikap and Lundvall 2021). While the first initiatives in 2018 by the Trump-administration defined the US-problem as one of bilateral trade deficit, and took the form of trade quotas, there is now a clear focus on limiting China's access to technology and China's access to markets for high technology products (Ciuriak 2019). Recently, the war in Ukraine and the unwillingness of China to join the West in isolating Russia have sharpened the conflict and we see the contours of a new world order where the US with allies confront China and its allies, while the protagonists in the two camps make efforts to strengthen their position through recruiting new allies in the rest of the world.

The weakening of trade in commodities went hand in hand with a move toward techno-nationalism in the US. While the US-administration has been among the most active in the world subsidizing science and technology (mainly through public programs related to the military and the health sector), the official doctrine has been neoliberal, anti-state and pro-market. This can be illustrated by the terminology used in the US, where the 'innovation eco-system' took the place of national innovation system (Jackson 2011). While the concept national innovation systems indicated an active role for the state, eco-systems are vague in this respect and the term indicates that the innovation system is the outcome of a 'natural' evolution. Over the last decade the illusion of the passive state has evaporated and now there are no ideological constraints for what the US-administration is ready to do to make sure that the US stays abreast of China in strategic technologies.

This change is reflected in a change in the world economic order, where US has moved from policing a rule-based world economy to systematically breaking the rules that it formerly imposed on others. The US aggressive industrial and trade policy, as reflected in the US Inflation Reduction Act, a USD 391 billion package of subsidies and tax credits, is officially aimed at driving the country's transition to clean energy but the main purpose is to respond to the rise of China. The shift in the US approach from a rule-based international order toward techno-nationalism is illustrated by the fact that in 2010 the US raised issues in WTO with China's support much more modest support to Wind Power (<https://www.reuters.com/article/us-usa-china-windpower-idUSTRE6BL3EU20101222>).

#### **4. Wallerstein and the world system perspective**

Current debates on global value chains have focused on, how participation might help development countries climb the ladder and secure a bigger share of value through upgrading. Earlier work by Marxist scholars studying the world economy saw them primarily as creating a dependency and structural relationships by which the rich countries exploited the poor countries.<sup>4</sup> They were thus seen as playing a key role in 'unequal exchange', where the rich countries harvest surplus value from international trade with countries in the South. They are important elements in Wallerstein world system theory.

The world system perspective, as developed by Immanuel Wallerstein, categorizes national systems as belonging to either the core, the periphery, or the semi-periphery. According to Wallerstein, they have different roles to play in the international division of labor and they are characterized by different forms of work organization. The core countries are specialized in manufacturing and produce high value products for the world market, and they are characterized by wage labor. The periphery countries are specialized in low value products and especially in raw materials based on natural resources. Historically, the periphery was dominated by slave labor while serfdom and tenancy were common in the semi-periphery. According to Wallerstein, the capitalist world system began to take form around the 15<sup>th</sup> century through colonization and it led to the integration of all countries in world-wide markets.

According to Wallerstein, the capitalist world system is poly-centric kept together primarily by economic interdependence. Historically, it followed upon a world order characterized by empires such as the Roman empire, which were ruled primarily by military force with one single center. There is nonetheless a hierarchy among the core countries in the capitalist world system and shifting nation states have taken on the role of hegemon. The Portugal, Netherlands, England and more recently the United States have in different historical epochs been hegemonic powers. Hegemony requires economic and military strength as well as cultural dominance.

Late in his career, Wallerstein (Wallerstein 2003) foresaw the demise of the US as the hegemon of the core. He recognized that it had by far the strongest military power in the world but saw a weakening of its economic power and its ideological dominance. The US debacle in Vietnam illustrated the limits of how far military dominance can be used to rule the rest of the world. Wallerstein refers to Japan as a rising economic power not mentioning China in this context.<sup>5</sup>

According to Wallerstein, one important mechanism reproducing the hierarchy in the world system and the distinction between core and periphery is unequal exchange. The exchange of commodities and services involves a premium to producers from the core countries while resource-based commodities are sold

below their value. Recent attempts to estimate the aggregate transfer of value taking place at the world level end up with astronomical figures (Hickel et al, 2022).

*Our results show that in 2015 the North net appropriated from the South 12 billion tons of embodied raw material equivalents, 822 million hectares of embodied land, 21 exajoules of embodied energy, and 188 million person-years of embodied labour, worth \$10.8 trillion in Northern prices – enough to end extreme poverty 70 times over. Over the whole period, drain from the South totalled \$242 trillion (constant 2010 USD). This drain represents a significant windfall for the global North, equivalent to a quarter of Northern GDP. For comparison, we also report drain in global average prices. Using this method, we find that the South's losses due to unequal exchange outstrip their total aid receipts over the period by a factor of 30. Our analysis confirms that unequal exchange is a significant driver of global inequality, uneven development, and ecological breakdown.*

The authors have little to say about the mechanisms that lie behind this gigantic value transfer, but they do refer to the role of global value chains, where lead firms in the north through their control of technology and market access seize most of the value created in the chain leaving little to the enterprises and workers in the periphery.

It is obvious that the world economy has gone through different important transformations since Wallerstein presented his world system analysis. The spread of manufacturing to the south has changed the patterns of the global division of labor. But according to the analysis of Basu and Vasudevan (2021) even with this new pattern, simultaneous productivity growth in the core and in the south may have a negative effect on employment and wages in the South.

This reflects the other and more recent development with a growing role for intangible capital and especially of intellectual capital. Market control and intellectual capital absorb a growing proportion of value. These activities are concentrated in the core countries, and it remains difficult for enterprises in the periphery countries to enter such activities. It is no longer enough for peripheral countries to industrialize; they need to establish market control through branding and technological strongholds.

This indicates that unequal exchange reflects, more than anything else, unequal access to knowledge (explicit as well as tacit, embodied as well as disembodied, individual as well as collective) and that the strength and weakness of the national innovation systems (knowledge infrastructure, education system) constitute a decisive factor explaining unequal exchange. Global value chain (GVC) analysis takes place at the enterprise level and considers, how lead firm may use monopoly power – both market control and control of technologies. To



explain unequal exchange and transfer of surplus value the GVC-perspective needs to be complemented by analysis at the level of national innovation systems.

As we shall see below, what constitutes a strong national innovation system might change from one historical era to the next reflecting the predominant techno-economic paradigm. In the current era, the acceleration of the development and application of artificial intelligence and digital services plays a major part in the transformation of the global order. At the same time, it calls for a critical reassessment of the value chain concept. While there has been a reversal in the global value chain trade in tangibles the tech giants have been main drivers in accelerating global trade in digital services. As argued in Rikap and Lundvall (2021) their mode of operation is not easily captured by the value chain figuration. They operate as spiders in a network where the most important flows are intangible (data, knowledge, algorithms). Rikap and Lundvall (2021) refer to these networks as Corporate Innovation Systems – defined as a world-wide network of subordinate suppliers – both enterprises and knowledge institutions – led and controlled by one major enterprise.

We see the kind unequal exchange taking place in these networks as characteristic for the current era. The tech giants harvest knowledge both from the knowledge commons and from subordinate enterprises and public knowledge institutions. They transform these elements of knowledge to private property, exploiting the other participants in the corporate innovation system. While some elements of knowledge remain as ‘public goods’, tech giants’ transformation of knowledge into private capital is their most important source of intellectual rent and profit. Some, but far from all, of this intellectual capital is protected by intellectual property rights (See Rikap and Lundvall 2021).

The current world system remains hierarchical and characterized by unequal exchange. The developing countries are handicapped under intellectual monopoly capitalism by the privatization of knowledge in the enterprise sector as well as by core states’ techno-nationalist strategies (Pagano 2014; Rikap 2018). The world system is characterized by a hierarchy of national innovation systems and by a hierarchy of corporate innovation systems. In the current era the transformation of the world system reflects co-evolution of corporate and national innovation systems. Mostly the state protects the interests of its own intellectual monopolies, but conflicts may emerge as when tech giants intrude on fundamental state functions as control of money and finance. Tech giants’ interests will not always coincide with their domestic state. But when world hegemony is at stake, we see a convergence where private actors join forces with the national state.<sup>6</sup>

Box 1:

### **A world system perspective on the production of social science**

An interesting specific example of how the world system hierarchy is reflected in the production and evaluation of knowledge has been presented by Demeter (2019). Demeter explains the global skewness of publishing, citation patterns and academic recognition in social science resulting in a systematic devaluation of research pursued in the South. He demonstrates that it reflects the specific institutional set up, where core countries, and especially the US and the UK, have monopolized the knowledge infrastructure (publishers, journals etc.). It is interesting to note that China is an exceptional case, where scientific publications have become more visible over the last decades and that it reflects that China has acquired specific elements of the knowledge infrastructure from core countries.

‘..China—through Baring Private Equity Asia—gained some control over the formally Thomson Reuters owned Web of Science, the most extensively used and most prestigious indexing service and scientific database. With this, the Chinese state and academy—at least theoretically—has some influence over citation indices, journal selection and assessing processes, which is an advantage one cannot overestimate.’ (Op cit. p. 134).

## **5. Freeman’s theory of world development**

At least since 1980 and until he passed away, Freeman pursued a research agenda with a double aim: to develop an alternative to neoclassical economic growth theory and to explain the evolution of the world order. Why do some countries catch-up while others fall behind? What is the basis of world hegemony and how to explain that latecomer countries can forge ahead and become world leaders?<sup>7</sup>

To simplify, Freeman’s theoretical framing is constituted by two basic elements, the uneven (but not completely irregular) development of technology and the national innovation system (NIS).<sup>8</sup> He uses the theory of shifting techno-economic paradigms, as developed by Carlota Perez, to establish the necessary link between the two concepts (Freeman & Pérez, 1988). In Freeman and Louçã (2002) and elsewhere, he combined historical analysis with attempts to quantify economic processes as characterized by long waves of growth and stagnation.<sup>9</sup>

The most coherent and ambitious presentations of his theory of economic development can be found in the newly published paper from 1995 (Freeman, 2019). Here Freeman argued that economic development will reflect the co-evolution of five semi-autonomous systems (science, technology, economics, politics, and culture). Societies where these systems match (systemic coherence)

will prosper. In his 1995-paper, he does not assign a dominant role to any of the sub- systems but in much of his work he refers to shifts in technology as the factor that disturbs systemic coherence and leads to a transition in the world order.

Freeman linked technological revolutions to shifts in global leadership. He explained that in the XVIII century. England's NIS had developed characteristics (and systemic coherence) contributing to explain why it became the homestead for the industrial revolution based upon steam power and textiles. As new technological systems dominated by electricity and chemistry emerged, Germany and the United States (US) forged ahead and left England behind. Freeman's (1987) analysis of Japan's emergence as a potential technological leader in an era of information technology illustrated this general hypothesis.

Freeman (1982/2004) is about science, technology, and international competitiveness. The article does not mention unequal exchange but the criticism of mainstream theory of international trade and the references to Friedrich List indicate a hierarchical world order, where some lead countries establish 'absolute advantage' based on technological leadership. Absolute advantage refers to situations where a country has taken a lead in general purpose technological systems with a wide set of applications across products and industries. This implies that a lead country simultaneously can harvest technological rents based on national technological monopolies from many industries. With the concept 'absolute advantage' Freeman gives a signpost for how to rethink unequal exchange in a knowledge-based world economy.

Rikap and Lundvall (2021) and Lundvall and Rikap (2022) use Freeman's framing of world development to study the rise of China in the era of artificial intelligence and how this has resulted in a geopolitical confrontation, where the US defines China's rise as a threat to its hegemony.

According to Rikap and Lundvall, governments both in the US and China act *as if* technological leadership in specific strategic technologies such as artificial intelligence is a prerequisite for world dominance (Webster et al 2017). China gives priority to strengthening the national innovation system in general and specifically to build strong AI-competences, while the US-sanctions against China are directed specifically to areas of importance for AI such as super-computers and advanced semi-conductors.<sup>10</sup> Recently it has combined these forms of protectionism with an ambitious industrial policy specifically designed to keep abreast of China in strategic technologies.

## **6. China's rise**

The reforms initiated by Deng Hsiao Peng in the middle of the 1980s were crucial for the subsequent rapid economic development. Increasingly the

success was built on investments in knowledge. China, like Japan 40 years earlier, invested heavily in knowledge through education and research.<sup>11</sup> but China was much more open to inward foreign direct investment than Japan. State owned enterprises engaged in joint ventures with some of the world's most powerful multinational enterprises entering fields, where China was far behind in technological terms. Some, including telecommunication and automobiles, were attractive because China offered a rapidly growing market. Other multinationals located activities in China primarily because of the abundant cheap labor. When the Chinese leaders offered foreign firms access to markets and to cheap labor, it had little choice. It did not have the financial strength needed to import technology and with the openness Chinese leaders expected that there would be 'spill-over' of knowledge from the multinationals to the state-owned enterprises.

Around 2005, the limitations of the strategy became obvious. Despite massive investments in education and research China's performance in terms of technology and innovation remained weak. China only had a handful of triad patents and almost all its high-tech exports came from foreign owned enterprises. Economic growth remained based, primarily, on quantitative expansion of capital and labor rather than on technological progress. This gave rise to strategy change under the heading 'independent innovation'.

A series of case and sector studies pursued by innovation scholars in the beginning of the new Millennium played an important role as inspiration for the new strategy. Lu Feng and his colleagues demonstrated that in sectors such as automobiles and telecommunication most of the state-owned enterprises engaged in joint ventures with multinational firms did not develop their own technological capabilities and that multinationals blocked technology transfer.<sup>12</sup> There were exceptions such as Geely in automobiles and Huawei in telecommunications and they were characterized by avoiding turn-key solutions and instead importing components and parts and taking on an active role in designing the final product. According to Feng (2019), the lack of success in building technological capabilities reflected the combination of unwillingness of foreign partners to share technology and the lack of incentives for SOEs management. Since there was no competition from indigenous producers, multinationals harvested huge profits from the Chinese market, often through the sales of products based upon outdated technologies.

The strategic shift from imitation to 'independent' (alternatively translated as indigenous) innovation was implemented with the 2006 – 2020 Plan for the Development of Science and Technology in the Medium and Long Term, where the term "indigenous innovation" became the keyword. A crucial ambition of this plan was to overcome the dependence of foreign firms in advanced technologies. This new direction towards indigenous innovation was confirmed in the Made in China 2025 (MiC) plan and again in China's 13th Five-Year

Science and Technology Plan and in its most recent five-year plan (2021-2025). This strategy implied that the openness of the economy should be managed differently.

The strategy change meant new emphasis on applying science and engineering in the production system and forthwith joint venture agreements became explicit in regard to technology transfer. Today China has taken the world lead in specific sectors and technologies such as in e-vehicles, green technologies (solar panels and wind power), and high-speed trains. This reflects a combination of state led initiatives at the central and province level and entrepreneurial initiatives. Huawei has become world leader in telecommunication. China has as the only country besides the US built its own tech giants such as Ali Baba, Tencent and Baidu. One factor behind the US struggle to arrest China's development is that China now aspires to become world leader in artificial intelligence.

There is little doubt that the combination of ambitious investments in education, research and development, the focused industrial policy and the scale of the market have been important for some of the success stories. The relative progress in artificial intelligence had as one specific prerequisite The Great Firewall which limited foreign access to digital services. While the US tech giants (Google, Amazon, Facebook, Apple, and Microsoft) established dominant market positions in the rest of the world, they could not penetrate the Chinese market for digital services.

## **7. China's move from the periphery to the semi-periphery has transformed the world system**

According to Wallerstein, most of the world population is living in the Periphery and Core with a minority in the semi-periphery. Given the size of China's population its rise has led to a change in this respect with a semi-periphery more populous than both the core and the periphery (Grell Brisk 2017). Wallerstein regards the semi-periphery as integrated part of the world capitalist system, and he assumes that it has a crucial role as a stabilizer of the world system. Those who subscribe to the world system perspective tend to regard China as participating in unequal exchange with countries in the periphery (Li 2019). According to this view, while China remains exploited through unequal exchange with the core countries its rise has reduced exploitation and it has opened for China's unequal exchange with countries from the periphery.

China has gradually strengthened its intellectual property regime and at the same time government has offered economic incentives linked to patenting. As a result, enterprises and knowledge institutions have become active in transforming technical knowledge into intellectual property. 2022 Chinese enterprises led the world and applied for 695,400 international patents followed

by the US (595,700) and Japan (502,600). This development confirms that Chinese enterprises now harvest intellectual rents online with, and at a scale corresponding to, what enterprises from the core countries do. Consequently, China has now got a strong stake in the current world regime of intellectual property.<sup>13</sup> According to a recent OECD study China is now number two, after the US, when it comes to harvesting intellectual rents from global value chains. India, the other major semi-periphery country on the rise, is number three (OECD???)

Another important change in the capitalist world system is the increasing role of geo-politics and geo-economics in organizing international relations. The capitalist world system has, according to Wallerstein, been kept together primarily by economic interdependence in contrast to earlier *époques* when empires were ruled primarily by military force. With the growing conflict between the US and China we see a movement back toward conflicting empires and to a world order where military power plays a major role.

The new trend toward geo-economics, where economic interests are subordinated to geo-politics, is reflected in the US weaponizing the dollar and the attempt by China and other semi-peripheral countries to establish an alternative world currency as well as in economic sanctions, including boycotts, embargos, and denial of market access. This politization of the economy impact all countries and the working of the capitalist world system.

## **8. Is de-coupling between China and the West a possible future scenario?**

Western critiques of China have raised the issue of isolating China through economic de-coupling. Given current patterns of trade and logistics such a strategy would have enormous economic costs for both parties. The West would probably carry the biggest costs, since China has reduced its dependence on imports of components and semi-manufactured goods, while the West has become more dependent on such imports from China.

What we have witnesses so far is technology-specific de-coupling, where the US, together with some Western allies, try to weaken China's advance through blocking exports to China of what they assume are strategic goods, especially advanced semi-conductors and the software and equipment necessary to manufacture them. At the same time the US has blocked access to the US-market for specific technologically advanced Chinese enterprises on the other hand.

This limited form of decoupling may slow down technological progress in specific areas, but it might also have the opposite effect. The focused efforts on winning the technological race related to artificial intelligence where the great power states and their giant corporations combine efforts may accelerate the development and use of AI technologies in the US, in China and world-wide.

However, the race may, when combined with great power techno-nationalism, leave the rest of the world further behind the two protagonists.

More important is that the growing bitterness of the conflict will impact on world politics in different dimensions. There is mutual suspicion which is reinforced by propaganda at both sides. The West tends to insist on the higher moral ground with reference to their defense of democracy. Chinese leaders regard the technology war as a systematic attempt to dwarf China's legitimate development ambitions. The worst problem is that the propaganda increases the risk for escalation and military conflict. In the long run, it becomes more difficult to cope with global challenges such as financial instability, inequality, climate change and health issues without some degree of co-operation between the great powers.

In the short term the lack of co-operation between China and Western countries has already worsened the situation for vulnerable countries risking sovereign default and now desperately in need of debt restructuring. For restructuring to take place, all creditors must agree. As Kristalina Georgieva, the head of the IMF, explained in early April, geopolitical fragmentation "will make it harder to resolve sovereign debt crises, especially if key official creditors are divided along geopolitical lines."

## **9. On the need to transform the world system**

Most countries in Africa and Latin America are not directly involved in the great power conflict outlined above. They will nonetheless experience the consequences of the conflict and they need to develop strategies to cope with them.

1. The UN is a global forum for international co-operation where China and the US meet in the presence of the rest of the world. China has been investing in building a stronger presence in the organization while the US has problems with recognizing the authority of the UN as framework for cooperation. In a more politized world the voice of 'third world' countries may be listened to, and they could help establish the UN as a platform for conflict solution.
2. The case of China as outlined in this paper and the transformation of the world capitalist system in the direction of intellectual capital exploitation point to the crucial role of access to knowledge as a prerequisite for economic and social development. A critical review of institutions (such as WIPO) and rules (WTO, UNCTAD) determining access should aim at a new global regime characterized by knowledge sharing.
3. Such a new regime could be combined with giving innovation clearer directions aiming explicitly at social and environmental sustainability. The

UN institutions could establish new ways of channeling knowledge resources from the core and semi-peripheral countries to the third world countries. This kind of knowledge transfer and capacity building would reduce current gaps in income between the core and the periphery.

4. It would require building new capabilities to absorb and develop green technologies and health technologies in those countries.

While the conflict hampers coordinated international action necessary to cope with global challenges threatening the most vulnerable countries, it also offers new opportunities for countries in the periphery. In connection with geopolitical conflicts Great Powers will attempt to mobilize political support from countries in Africa, Asia, and Latin America. They will try to impose their own standards and norms as well as establish infrastructure for communication and transport that establish links to the different countries. This implies that they will have incentives to listen to the voice of countries in the periphery.

In the 1970's peripheral countries called for a New International World Order and some of the Western countries responded to this call until the wave of neo-liberalism took the form of Washington Consensus which was, in its turn, undermined its negative impact on development. Now voices are raised to initiate a similar initiative. On 27 January 2023, 50 delegates from twenty- six countries gathered in Havana with the aim of launching a New International Economic Order (Selenica 2023).

A specific consequence when the West moves production out of China is that some peripheral countries will attract industries exploiting low wage labor. This process has already begun, because of the rise in Chinese wages and it might be re-enforced by the de-coupling process. These countries could learn from the China case that investing in knowledge is a prerequisite for upgrading production and for a move into more productive activities. But they could also learn from the China case that knowledge spill over and knowledge investments needs to be combined with industrial, technology and trade policy to lead to sustained development.

The move toward geo-economics in the world system reveals that it is no longer possible to regard economic exchange as separated from political power and the role of the state. For peripheral countries this implies that there is ample room for regulating the trade with natural resource-based products with the aim to usurp more of their value in exchange with the core countries. Individual countries, vulnerable to sanctions, might not have the political strength to do so but several countries may join forces. The OPEC coordination is an example of a co-operation forcing importers to pay a premium that can be used to build a more diverse and knowledge-based economy.

Moreira and Lee (2023) discuss how the leading producers of Coffee beans



(Brasilia, Colombia and Vietnam) could join forces to get a bigger share of value through forming a cartel – with the current trade policy in core countries brands from Switzerland, the Netherlands and Germany take most of the value. The long term goal would be to refine more of the beans and to establish strong brands at the world level.

Another field of special importance for Africa is the specific minerals playing key roles of electrification (batteries, e-vehicles, solar panels etc.). Africa produces more than 70% of the world's cobalt (DRC-Zambia), 60% of manganese (Gabon, South Africa), 25% of bauxite (Guinea), nearly 15% of copper ("copper belt" of the DRC-Zambia), a significant portion of graphite (Mozambique, Madagascar, Guinea). Resources crucial for batteries. The ideal for Africa would be to become able to master the end-to-end value chain – from battery construction to e-vehicles. China largely dominates the sector, from mining to end products. African countries should navigate the competition between the industrialized powers.

But single countries would be extremely vulnerable and weak in negotiating deals. There are several reasons why regional collaborations among peripheral countries may serve their interests better than going alone. Pooling resources may be useful for establishing a regional development bank of a certain strength and the new expansion of data-driven digital services offers opportunities primarily for big scale operators that operate beyond national borders. To counter the exploitation domestic and regional investments in education and knowledge, the formation of coalitions or federations of countries may be the most appropriate response.

One implication of the current world disorder is thus that countries in the periphery should join forces to mobilize the power necessary to change the current world system. One major aim should be to avoid war, and another would be to force core and semi-peripheral countries to share knowledge with and to transfer technologies to the south. But peripheral countries need to combine such efforts with building stronger innovation systems. Not to make efforts to do so would correspond to what Christopher Freeman has referred to as 'voluntary underdevelopment'.

## **10. Building stronger national innovation systems in the periphery**

To build stronger national innovation systems requires a combination of public and private investments in knowledge and infrastructure. Increasing the understanding of the importance of education and knowledge among citizens is crucial to mobilize the necessary resources through taxes and private initiative. It is equally important to train competent public servants who are accountable and respected among citizens.

Often 'knowledge' is narrowly defined in the context of peripheral countries as

codified scientific knowledge. There is more attention to universities and less to the training of skilled workers and technicians. Establishing technical institutes and professional training close to the sphere of production – to extraction of minerals, agriculture, manufacturing services is often more important for development than expanding universities.

Any innovation system strategy must take its point of departure in the current economic structure and the resources and infrastructures at hand. Establishing new industries might result in new jobs and incomes in a faraway future. In the short to medium term upgrading agriculture, services, and mining may give more direct results. Upgrading implies new methods as well as new products. Often infrastructural investments in relation to storage, transports and quality control will help.

Historically, there are many examples of, how poor countries that were depending on natural resource exports could become rich. They have in common that they invested in human resources and imported technology from abroad. On this basis they developed upstream, and downstream industries related to their natural resource specialization. It included machinery for agriculture, forestry mining as well as machinery for the process industries refining the resources. This is true for the Nordic countries which remained poor until the late 19<sup>th</sup> century.

Can countries in the periphery develop along a similar path today? Today the major barrier to development is the knowledge gap reflecting unequal access to knowledge. The combination of privatization of knowledge and technonationalism in core countries contributes to a new form of dependency and unequal exchange. It means that there is a risk of a perverse spill-over where the core countries harvest the fruits of the modest investments in knowledge made in peripheral countries (import of skilled workers, harvesting data etc.).

## **11. Implications for globelics research agenda**

Globelics was founded by scholars working in the field of economics of innovation and it has gradually broadened its research field to cover social and ecological issues. To contribute with research-based knowledge on how less developed countries may create better living and working conditions for their citizens through innovation remains one of its major missions.

One implication from our discussion is that to successfully pursue this mission, it is crucial to understand on-going changes in the world system. National innovation systems should be seen as elements of an evolving world system. This requires a historical perspective where we regard 'the present as history'.

One promising way to organize the co-evolution analysis of the world system and the national systems could be to apply Christopher Freeman's distinction

between sub-systems for science, technology, economy, politics, and culture to respectively the world system and the national system level.

It has never been a good idea to assume that the economy can be understood without reference to politics. Recent developments where it has become obvious that geo-politics tend to dominate over immediate economic benefits, requires that scholars working on innovation and development give more attention to the subsystem of politics, including the formation of international co-operations and alliances.

One specific issue is how the current tendencies toward de-coupling affect the global co-operation in science and what it means for future progress in science. The Covid crisis and the success of Pharma-giants to resist knowledge sharing of Vaccines illustrates the problems with a divided world system of science. This issue is crucial in a world plagued by global warming and threats to planetary survival.

Another major issue touched upon in this paper is how and to what degree the reproduction of global inequality reflects a world system where unequal exchange is rooted in private and state knowledge monopolies. This calls for research on the distribution of value in global value chains and in corporate innovation systems as well as on alternatives to current institutions regulating intellectual property right.

## **12. Conclusions**

To capture the ongoing transformation of the global order we combined two quite different perspectives: Wallerstein World System perspective and Freeman's theory of world development. We showed how the rise of China has changed the world system in fundamental respects and how the experience from the rise offers lessons for peripheral and semi-peripheral countries. The new world order is characterized by significant risks for war, and we pointed to the UN, as perhaps the only institutional framework that can bring the great power conflict under control. In the current era the most important mechanism reproducing dependence and unequal exchange is the knowledge divide. Knowledge sharing from core to periphery should therefore be at the very core of a New International Economic Order.

We proposed that peripheral countries may exploit a stronger negotiation position to make better deals when it comes to export natural resource-based products and scarce metals and that they need to establish alliances or regional federative collaboration to muster the necessary political clout.

Finally, we pointed to a combination of massive investments in knowledge and directional innovation and trade policy as necessary elements in a strategy to reduce dependence and establish sustained development.

We ended with some preliminary ideas on how Globelics research might contribute to the understanding the co-evolution of the world system and the national innovation systems.

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## Notes

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- <sup>1</sup> The focus on knowledge is grounded both in history and theory. First, attempts to measure intellectual and intangible capital as share of total capital indicate its growing importance and studies show that it is fundamental for growth and development (OECD 2008, WIPO 2017, Unctad 2019). Second, as resource, knowledge has unique characteristics. It can be shared without losing value and its value grows by use. It is not a scarce resource – it requires specific state interventions to transform it into private commodity. In a world characterized by absolute and irreversible scarcity (a world threatened by climate change, exhaustion of natural resources and accelerating extinction of species) this unique trait is of principle importance.
- <sup>2</sup> The global value chain perspective gives an illustration of the dialectics between dependency and development. While there, under specific circumstances, is room for learning and upgrading for enterprises participating in global value chains, at a certain stage in the development process there is a need to ‘break the chains’ to avoid the poverty and the middle-income traps (Lee, Szapiro, and Zhuqing 2017).
- <sup>3</sup> A similar discussion can be found among scholars ascribing to the world system view. While Wallerstein regarded ‘globalization’ as nothing new, Robinson (2011) and others adhering to the world system perspective argued that it represented a new stage characterized by transnational corporations and institutions, with a weakening of nation states.
- <sup>4</sup> The early work of Gary Gereffi, one of the key contributors to the modern literature on global value chains, pioneered his work by a critical study in the dependency school tradition showing how multinational firms allied themselves with capitalists in Mexico to overtake its promising attempts to establish exports of steroid hormones (Gereffi, 1978).
- <sup>5</sup> One of the few who recognized early on the possibility that China might become a challenge for the US-hegemony was Arrighi and Silver (see Arrighi and Silver, 2001; Arrighi, Silver, and Brewer, 2003). Arrighi and Silver saw China as a market economy but not as capitalist.
- <sup>6</sup> Miller (2022) illustrates how the tech giants and the US state have joined forces to defend a US-lead in semi- conductors and it shows the important role of military in the promotion of the technology.
- <sup>7</sup> The most coherent and ambitious presentations of his theory of economic development can be found in the newly published paper from 1995 (Freeman, 2019) and in his book co-authored with Frederico Louçã (Freeman & Louçã, 2002).
- <sup>8</sup> .....
- <sup>9</sup> .....
- <sup>10</sup> Miller (2022) gives a historical overview of what he refers to as the ‘Chip war’. The book takes a US-view on history, but it demonstrates how the US state and US big business join forces in protecting technology-based hegemony when the hegemony comes under threat.
- <sup>11</sup> The literacy rate increased from 66% 1982 to 97% 2022 (<https://www.statista.com/statistics>). Between 1996 and 2020 the enrolment rate in higher education increased from 3.4% to 57.6%. The R&D expenditure as share of GNP increased from 0.2 to 2.5% between 1982 and 2023.
- <sup>12</sup> Lu Fung’s 2005 book, *The Policy Choice to Develop China's Automobile Industry with Independent Intellectual Property Rights*, profoundly influenced the national policy transition toward emphasizing in-house innovation.
- <sup>13</sup> Interestingly, 2020, most countries turned down a Chinese candidate for the Presidency of WIPO, the UN organisation in charge of intellectual property protection after diplomatic pressure from the US.



## How the substantive innovation and strategic innovation impact firm performance<sup>1</sup>

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### **Abstract:**

Recent studies on substantive and strategic innovation have concentrated on the theoretical response to the adverse selection of enterprise innovation behavior behind the phenomenon of "patent bubble". However, existing studies have mainly addressed the motivational factors behind substantive-strategic innovation behavior from the perspective of access to policy resources. They failed to discuss robustly the micro-level mechanisms of how strategic innovation behavior affects firm performance. Most of the existing studies on the influence of innovation activities on enterprise performance follow the "competitive logic". This research offers an integrated framework of "competitive logic and signaling logic" based on resource dependence theory and signaling theory to investigate the effects of substantive and strategic innovation on firm performance using fixed-effects panel data regressions. The study also investigates the moderating impact of property rights' inherent characteristics. The findings demonstrate that substantive innovation can enhance both short-term and long-term performance, while strategic innovation can only enhance short-term performance. The results also establish that, when the firm's property rights are owned by the state, substantive innovation's ability to promote long-term performance is diminished while strategic innovation's ability to promote short-term performance is strengthened. The conclusion of the study provides certain reference values and enlightenment for the government to further improve the industrial policy related to innovation and the macroeconomic policy related to the reform of state-owned enterprises.

**Keywords:** substantive innovation; strategic innovation; firm performance; property rights; state- owned enterprises.

## 1 Introduction

The Chinese "patent bubble" problem has received a lot of scholarly attention recently (Long and Wang, 2015; Zheng, Chen and Ren, 2016; Zhang and Zheng, 2018). Scholars have investigated this phenomenon's motivational reasons and how they affect the caliber of corporate innovation from a variety of angles, including political ties and industrial policy (Shen, Hang and Zhao, 2018). Widespread academic interest has been given to the "patent bubble" phenomenon. As An et al. (2009) contend, businesses will selectively engage in strategic innovation activities to pursue the existing amount or greater of the government subsidies. The following are some examples of the activities: sending false "innovation type" signals to the government (Han and Chen, 2020), and manipulating the amount and proportion of R&D investment of enterprises (Han and Chen, 2020). To satisfy the local government criteria, the corporation may also engage in commercial bribery, rent-seeking, mindlessly chasing quantity at the expense of quality, and use of its innovation behavior as a tool to manage government-business relations (Mao and Xu, 2015). To differentiate the level of innovation activities, Li Wenjing (2016) initially suggested the concepts of substantive innovation and strategic innovation to distinguish the quality of innovation activities. Substantive innovation is the reorganization of factors of production by firms, which requires significant resources and substantial effort, and helps businesses acquire a competitive edge in the product or factor markets (Jiang, He and Lu, 2019). Strategic innovation is a signaling activity that requires less resources and effort, because it does not seek to encourage substantial technology or product upgrading (Jiang et al., 2019). Studies that have already been conducted on substantive and strategic innovation focus mostly on the antecedents of the two inventive behaviors and the effects they have from the perspective of policy resource acquisition. However, the micro-mechanisms by which strategic innovation impacts the performance of firms are not sufficiently discussed. On the other hand, the existing studies on the impact of innovation activities on firm performance follow the "competitive logic", i.e., "innovation is the key for firms to gain competitive advantage in product and factor markets" (Jiang, He and Lu, 2019). Fewer scholars have explored the impact of the strategic innovation on firm performance. Therefore, based on resource dependence theory and signaling theory, this paper proposes an integrated framework of "competitive logic and signaling logic" to explore the common and differentiated effects of substantive innovation and strategic innovation on firm performance. For this, this study set out to investigate the following research questions: 1. Are there any variations between the consequences of substantive innovation targeted at acquiring a competitive advantage and strategic innovation on company performance? 2. Does the heterogeneity in

the nature of corporate property rights in the context of equity division reform have a different impact on the connection between the two types of innovative behaviors (substantive and strategic) and firm performance?

## **2 Theoretical analysis and research hypothesis**

### **2.1 The relationship between substantive innovation and firm performance**

Innovation helps businesses acquire a competitive edge in the product or factor markets (Jiang, He and Lu, 2019). Such innovation is the reorganization of factors of production by firms, which requires significant resources and substantial effort (called substantive innovation). However, substantive innovation may not result in innovation advantages in the short term because of the high risk and lengthy cycle features that innovation has by its very nature. A company's high investment worth, however, might be indicated to the outside world by its active innovation activities (Chang, Chen and Huang, 2012). The fact that businesses carry out top-notch R&D and innovation operations also make it simpler for them to get government subsidies. In addition to the direct provision of resources, government subsidies, as an invisible government guarantee mechanism for enterprises, can release the double favorable message of technology certification and regulatory certification to society, which helps enterprises obtain external financing such as bank loans or venture capital (Wang, Xie and Jia, 2017). Shen (2014) found that the government subsidy can reduce the risk assessment level of the bank, and the debt financing cost of the enterprise is also lowered. With the increase of external funds, the resource constraints faced by enterprises will be alleviated, which will hedge the diminishing marginal income effect in the production and operation activities of enterprises, and then promote the short-term performance of enterprises. Based on the above analysis, following is the research hypothesis, H1:

**Hypothesis 1.** *Substantial innovative behavior of the firm is beneficial to enhance the short-term performance of the firm.*

In the long run, substantial innovation aims at promoting technological change and developing new market opportunities which not only reduce costs and increase added value, but also drive product upgrades and business expansion, thereby enhancing the sustainability of a company's competitive advantage (Li and Zheng, 2016). According to Griliches (1981), businesses can lower production costs and increase operational effectiveness by engaging in a high-quality innovative activity. Su and Sun (2014) highlighted that technological innovation can boost production efficiency, streamline the product-processing flow, raise product quality, and tightly regulate costs, all of which will promote the firm's performance. Additionally, the firm's ability to establish its own technological barriers in the product market rivalry,

contend with rivals, and ultimately triumph might benefit from high-quality innovation output as a private asset. Li et al. (2010), found that technological innovation can considerably enhance the operational performance of Chinese creative firms. Li and Zheng (2016), discovered that significant innovation driven by technological advancement can raise an enterprise's value. Drawing from this analysis, we propose the following research hypothesis H2:

**Hypothesis 2.** *Substantial innovative behavior of the firm is beneficial to enhance the long-term performance of the firm.*

## **2.2 The relationship between strategic innovation and firm performance**

According to the resource dependence theory, companies can modify themselves, pick their environment, and adapt to it through strategic action. Outsiders frequently lack complete knowledge of the true technical evolution and development of enterprises due to the prevalence of information asymmetry, therefore they typically rely their investment decisions on the innovation signals they receive from firms (Yu, Hui and Fan, 2010). Information asymmetry is widespread. When the costs of strategic innovation are lower than the benefits, firms have a strong incentive to implement strategic innovation (John, 2005). The business has a strong motivation to put strategic innovation into practice. Strategic innovation is a signaling activity even though it does not seek to encourage technology or product upgrading. However, the signaling theory claims that this behavior can draw the attention of the government and secure government subsidies by sending out positive innovation signals and demonstrating a strong willingness to innovate to external stakeholders. This behavior can also further influence potential investors' assessments of the firm's development prospects so that they are more willing to provide financing, which will ease the firm's financing constraints and facilitate its internal operation and development. Based on this, the research hypothesis H3 is suggested.

**Hypothesis 3.** *Strategic innovation behavior of the firm is beneficial to enhance the short-term performance of the firm.*

While strategic innovation can alleviate a firm's resource woes, some studies have shown that firms spend significant resources and effort on rent-seeking or commercial bribery in order to label themselves as active innovators, which crowd out resources that would otherwise be spent on research and development and undermine the motivation and initiative of firms to engage in quality innovation (Mao and Xu, 2015). These actions divert resources away from R&D and can reduce the drive and initiative of businesses to carry out high-quality innovation. Yu et al. (2010), found that the rent-seeking behavior of enterprises is not conducive to the improvement of enterprise performance and it undermines the overall allocation efficiency of scarce resources in society. Cheng and Ding (2021) think that in the long run, the rent-seeking

arbitrage behavior of "emphasizing innovation quantity but neglecting innovation quality" will inevitably lead to low innovation efficiency of enterprises. Li and Zheng (2016) show that the strategic innovation of firms can bring some other benefits to the firms but not the improvement of the firms' performance. Long and Zhang (2021) discovered that companies' strategic patent management practices resulted in improper resource allocation within the organization, which in turn reduced the organization's productivity. Based on these, the research hypothesis H4 is suggested.

**Hypothesis 4.** *Strategic innovation behavior of firms is not conducive to improving long-term firm performance.*

### **2.3 The effect of the nature of property rights on the relationship between firm innovation behavior and firm performance**

The nature of property rights has been a significant consideration in the analysis of enterprises' innovative activities in the context of China's transition economy (Wei, Xie and Zhang, 2017). According to the "competitive logic" of innovation, firms will solve their resource problem by acquiring resources and promote substantive innovation activities by making up for a lack of investment motivation in R&D. On the other hand, the effectiveness of R&D activities is a significant factor affecting the relationship between innovation behavior and firm performance. Additionally, State-owned enterprises (SOEs) and private enterprises differ in following ways: Firstly, SOEs experience less pressure from resource limits and are more likely to receive outside financial help from the government, banks, venture capitalists, and other institutions. Secondly, compared to aggressive private businesses, SOEs tend to have more conservative and vigorous innovation activities since they are responsible for more societal obligations including social security, stable employment, and economic progress. Thirdly, compared to private businesses, state-owned companies are experiencing more severe principal-agent issues, which has led to their lack of incentive for ongoing innovation, awareness of active innovation (Chen, Yang and Zhu, 2020), and substantial challenges with the transformation of innovative successes (JIN B, 2010). It is hypothesized that SOEs will weaken the contribution of substantive R&D innovation activities to firm performance, and from that view the research hypotheses H5a and H5b are proposed.

**Hypothesis 5a.** *The nature of property rights in SOEs can weaken the contribution of substantive innovation to firms' short-term performance.*

**Hypothesis 5b.** *The nature of property rights in SOEs can weaken the contribution of substantive innovation to long-term firm performance.*

In terms of the "signal logic" of innovation, SOEs are more easily able to secure

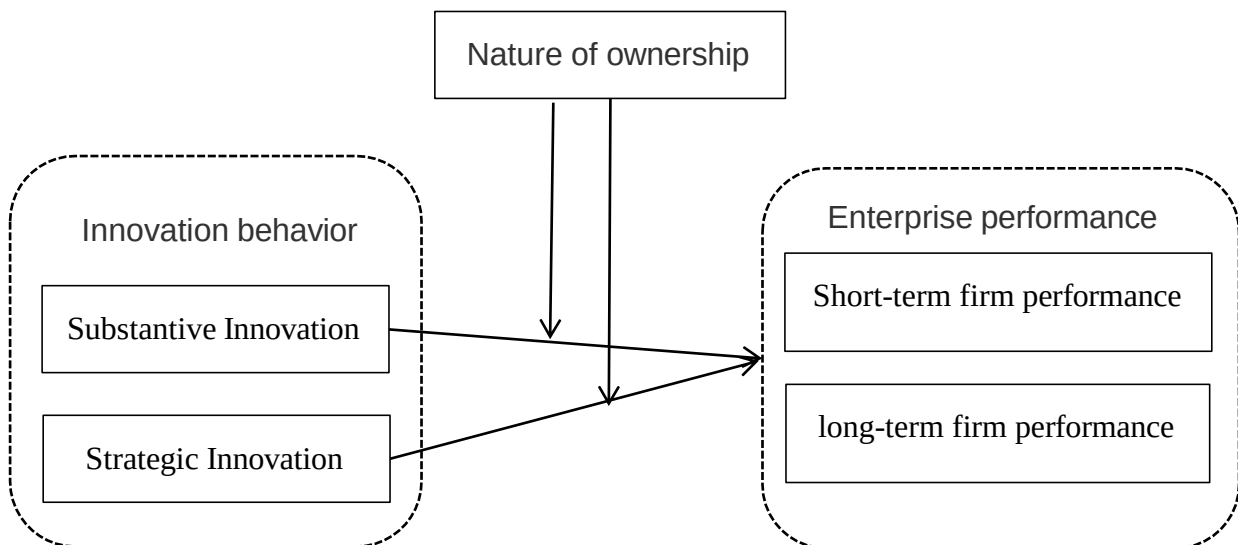
external funding such as bank loans or venture capital because of the credit backing and covert support of government agencies (Kleer, 2010). Therefore, this paper holds that the property right nature of state-owned enterprises can promote the short-term performance of enterprises by strategic innovation behavior. However, over time, the strategic innovation practices of SOEs may divert resources that were initially allocated for significant technological innovation, resulting in a serious mismatch of resources within the company and lowering innovation efficiency, which is not advantageous for the long-term growth and development of the firm's performance. In addition, most of the management of SOEs are directly hired by the government and lack both market competition experience and a willingness to take risks (Shen, 2001). Instead of taking risks with innovative projects, they are more inclined and willing to seek policy assistance by participating in rent-seeking conduct (Dong, Zhao and Yuan, 2014). Therefore, the nature of SOEs' property rights may further exacerbate the weakening effect of strategic innovation activities on firms' long-term performance. This leads to the research hypotheses H5c and H5d.

**Hypothesis 5c.** *The nature of property rights of SOEs enhances the contribution of strategic innovation to the short-term performance of firms.*

**Hypothesis 5d.** *The nature of property rights of SOEs enhances the dampening effect of strategic innovation on the long-run performance of firms.*

## 2.4 Research model

Figure 1 Research model



### 3 Method and data

#### 3.1 Sample selection and data sources

This paper takes manufacturing companies listed on A-shares in Shanghai and Shenzhen in China from 2011 to 2020 as the research object and obtains 14,189 observation samples from 2008 companies. The financial data is gathered from the WIND and CSMAR databases, while the patent data is gathered from the Incopat database. This study uses one-by-one matching in the patent database based on the firm names of the sample companies to retrieve their patent information. This paper eliminates and improves the samples with obvious deviation from normal values, suspension or discontinuation of listing, suspension of trading, ST, ST\*, and PT categories to ensure the reliability of the data. As a result, 9591 observations with an unbalanced panel data structure are obtained from 1616 samples.

#### 3.2 Variable Selection and Measurement

(1) Explanatory variable-firm performance: This study divides firm performance into short-term performance and long-term performance and mostly uses financial metrics to measure firm performance. This paper selects the current return on total assets (ROA), one of the core indicators of the DuPont analysis system, as a measure of corporate short-term performance, also selects ROA with a lag of 3 periods as a measure of corporate long-term performance.

(2) Explanatory variables-substantial/strategic innovation: This paper draws on the studies of Li et al (2016) and Guo (2018) to measure the substantive innovation behavior of firms by using the number of invention patent applications in the year and the number of non-invention patent (utility model patents and design patents) applications in the year to measure the strategic innovation behavior of firms. In the natural state, the number of patent applications of enterprises is obviously distributed to the right. This paper adds 1 to the number of patent applications of enterprises in the current year and takes the natural logarithm.

(3) Moderating variable nature of property rights: According to the type of property rights (the type of the beneficial owner disclosed in the enterprises' annual financial reports), this paper divides the entire sample into state-owned and private businesses and examines the moderating effects of various property rights on the relationship between innovation behavior and business performance.

(4) Control variables: The following indicators that could affect firm performance are chosen as control variables in this study. Firm size, firm age, equity concentration, capital structure, fixed asset ratio, incentive structures for compensation, R&D investment intensity, industry and year dummy

variables are specifically included. Table 1 provides definition of main variables.

**Table 1** Definition of main variables

| Variable Type         | Variable Name               | Variable Code | Variable Definition                                                                                          |
|-----------------------|-----------------------------|---------------|--------------------------------------------------------------------------------------------------------------|
| Explained variables   | Short-term performance      | SRoa          | 2 x net income / (total assets at the beginning of the period + total assets at the end of the period) x 100 |
|                       | Long-term performance       | LRoa          | Return on total assets with a lag of 3 periods ROA × 100                                                     |
| Explanatory variables | Substantive Innovation      | Spt           | ln (total number of annual company invention patent applications + 1)                                        |
|                       | Strategic Innovation        | Cpt           | ln (total number of non-invention patent applications in the company for the year + 1)                       |
| Adjustment variables  | Nature of ownership         | State         | The actual controller is the country takes the value of 1, the rest is 0                                     |
|                       | Enterprise size             | Size          | ln (Total book assets at the end of the period)                                                              |
|                       | Enterprise Age              | Age           | ln (year of statement - year of company establishment + 1)                                                   |
|                       | Shareholding Concentration  | Share         | Total shareholding of the top ten shareholders of the enterprise                                             |
|                       | Equity ratio                | Equ           | Total liabilities at end of period/total owner's equity at end of period                                     |
| Control Variables     | Fixed assets ratio          | Ppe           | Ending fixed assets / Ending total assets                                                                    |
|                       | Compensation Incentives R&D | Pay           | ln (Total annual remuneration for directors, supervisors and executives)                                     |
|                       | investment intensity        | Rd            | Current R&D investment as a percentage of operating revenue                                                  |
|                       | Industry                    | Ind           | Industry dummy variables                                                                                     |
|                       | Year                        | Year          | Year dummy variable                                                                                          |

### 3.3 Model construction

To examine the relationship between the effect of substantive and strategic innovation of firms on their short-term and long-term performance, regression models were constructed as follows.

$$Roa_{i,(t,t+3)} = \alpha_0 + \alpha_1 Spt_{i,t} + \alpha_2 Cpt_{i,t} + \alpha_n Control_{i,t} + \varepsilon_{i,t}$$



Among them,  $i$  and  $t$  represent enterprise and year respectively,  $\alpha$  is a constant term,  $a_0$  Control represents various control variables, and  $\varepsilon$  is a residual term. In the regression analysis, the dummy variables of industry and year are controlled, and the standard error is adjusted by Robust. To further verify the moderating role of the nature of ownership in the relationship between innovation behavior and firm performance, the paper divides the entire sample into state-owned enterprises and non-state-owned enterprises according to the nature of the ultimate controllers of the sample firms and performs group regressions.

## 4 Results

### 4.1 Descriptive statistics and correlation analysis

The descriptive statistical analysis and correlation analysis of the variables of interest are shown in Table 2. About corporate performance, the highest value of ROA of total assets of the sample firms was 21% and the lowest value was -24%, with a mean value of 4% and a standard deviation of 0.06. This indicates that there is a large difference in profitability levels between different sample firms. About innovation activities, the highest score of substantive innovation activities of the sample enterprises is 5.960, the lowest score is 0, the median is 2.080, and the standard deviation is 1.380; the highest score of strategic innovation activities is 6.250, the lowest score is 0, the median is 2.400, and the standard deviation is 1.490. This demonstrates the very clear polarization of China's industrial businesses' capacity for innovation. The correlation coefficients between the variables were found to be between -0.375 and 0.572, and the absolute values were generally low, and the correlation between the variables was known to be low. The maximum value of variance inflation factor VIF is 2.88, which is far below the generally accepted critical value of 10 in the academic community, indicating that the tolerance level of each model is high and the problem of multicollinearity among variables is negligible.

**Table 2** Descriptive statistics and correlation analysis

|       | SRoa      | LRoa      | Spt       | Cpt       | State     | Size     |
|-------|-----------|-----------|-----------|-----------|-----------|----------|
| SRoa  | 1.000     |           |           |           |           |          |
| LRoa  | 0.411***  | 1.000     |           |           |           |          |
| Spt   | 0.050***  | 0.040***  | 1.000     |           |           |          |
| Cpt   | 0.017*    | -0.030**  | 0.572***  | 1.000     |           |          |
| State | -0.168*** | -0.065*** | 0.164***  | 0.083***  | 1.000     |          |
| Size  | -0.025**  | -0.016    | 0.436***  | 0.336***  | 0.290***  | 1.000    |
| Age   | -0.054*** | -0.028**  | 0.039***  | -0.007    | 0.208***  | 0.143*** |
| Share | 0.269***  | 0.153***  | -0.001    | 0.065***  | -0.155*** | 0.026**  |
| Equ   | -0.375*** | -0.198*** | 0.133***  | 0.135***  | 0.289***  | 0.357*** |
| Ppe   | -0.202*** | -0.030**  | -0.084*** | -0.122*** | 0.129***  | 0.117*** |
| Pay   | 0.224***  | 0.163***  | 0.316***  | 0.226***  | 0.043***  | 0.491*** |

|      | SRoa   | LRoa   | Spt      | Cpt      | State     | Size      |
|------|--------|--------|----------|----------|-----------|-----------|
| Rd   | 0.013  | 0.016  | 0.176*** | 0.072*** | -0.127*** | -0.132*** |
| Mean | 0.040  | 0.030  | 2.140    | 2.420    | 0.320     | 21.95     |
| SD   | 0.060  | 0.060  | 1.380    | 1.490    | 0.470     | 1.070     |
| Min  | -0.240 | -0.240 | 0        | 0        | 0         | 19.22     |
| Max  | 0.210  | 0.210  | 5.960    | 6.250    | 1         | 24.96     |

**Table 2** Descriptive statistics and correlation analysis(continued)

|       | Age       | Share     | Equ       | Ppe       | Pay      | Rd    |
|-------|-----------|-----------|-----------|-----------|----------|-------|
| Age   | 1.000     |           |           |           |          |       |
| Share | -0.196*** | 1.000     |           |           |          |       |
| Equ   | 0.096***  | -0.153*** | 1.000     |           |          |       |
| Ppe   | 0.066***  | -0.095*** | 0.139***  | 1.000     |          |       |
| Pay   | 0.123***  | 0.046***  | 0.030***  | -0.057*** | 1.000    |       |
| Rd    | -0.052*** | 0.004     | -0.181*** | -0.190*** | 0.104*** | 1.000 |
| Mean  | 16.72     | 58.94     | 0.960     | 0.240     | 15.31    | 3.770 |
| SD    | 5.550     | 15.20     | 1.030     | 0.130     | 0.700    | 2.870 |
| Min   | 2         | 23.33     | 0.030     | 0.010     | 12.39    | 0     |
| Max   | 61        | 89.80     | 7.200     | 0.660     | 17.12    | 16.36 |

Note: \*, \*\*, \*\*\* represent significant at the 0.1, 0.05, and 0.01 levels, respectively.

## 4.2 Model regression analysis

To avoid the phenomenon of pseudo-regression, the unit root test and cointegration test were conducted in turns. The results showed that the variables used in this paper are all smooth series, and there is a stable equilibrium relationship between the variables, and there is a panel cointegration relationship, which can be further analyzed by regression. After that, the F-test and Hausman test were conducted in turns, and the p-values were less than 0.01, indicating that the fixed-effects model was better than the mixed-effects and random-effects models. Therefore, this paper uses the fixed-effects model for regression analysis of each variable, and the regression results are shown in Table 3 and Table 4.

The regression results in Table 3 show that substantive innovative behavior is significantly and positively related to the short-term performance of the firm at the 1% level ( $\beta=0.196$ ,  $p<0.01$ ), and hypothesis H1 is supported, which means that the substantive innovative behavior of the firm is conducive to enhancing the short-term performance of the firm. Substantial innovative behavior is significantly and positively related to long-term firm performance at the 1% level ( $\beta=0.294$ ,  $p<0.01$ ), and hypothesis H2 is supported, which means that firms' substantive innovative behavior is conducive to enhancing firms' long-term performance. This indicates that substantive innovative behavior aimed

at promoting technological progress and gaining competitive advantage can enhance the core competitive ability of firms and improve their business performance in a lasting way. Strategic innovation behavior is significantly and positively related to the short-term performance of firms at the 1% level ( $\beta=0.145$ ,  $p<0.01$ ), and hypothesis H3 is supported, which means that strategic innovation behavior of firms is beneficial to enhance the short-term performance of firms. There is no significant correlation between strategic innovation behavior and long-term corporate performance ( $\beta=-0.019$ ,  $p>0.10$ ), and hypothesis H4 is not supported, i.e., the strategic innovation behavior of firms is not conducive to enhancing long-term corporate performance is not tested. This indicates that strategic innovation aimed at non-technological innovation such as seeking government subsidies does not bring lasting benefits to firms.

**Table 3** Regression results (1)

| Variables               | SRoa                   | SRoa                   | LRoa                  | LRoa                  |
|-------------------------|------------------------|------------------------|-----------------------|-----------------------|
| Spt                     |                        | 0.196***<br>(3.94)     |                       | 0.294***<br>(4.11)    |
| Cpt                     |                        | 0.145***<br>(3.10)     |                       | -0.019<br>(-0.29)     |
| Size                    | -0.055<br>(-0.90)      | -0.231***<br>(-3.46)   | -0.368***<br>(-4.16)  | -0.522***<br>(-5.47)  |
| Age                     | 0.081<br>(0.49)        | 0.052<br>(0.32)        | 0.055<br>(0.25)       | 0.018<br>(0.08)       |
| Share                   | 0.072***<br>(20.66)    | 0.072***<br>(20.57)    | 0.050***<br>(10.16)   | 0.050***<br>(10.13)   |
| Equ                     | -1.814***<br>(-33.49)  | -1.813***<br>(-33.55)  | -0.921***<br>(-12.40) | -0.921***<br>(-12.41) |
| Ppe                     | -7.495***<br>(-17.65)  | -7.283***<br>(-17.14)  | -0.475<br>(-0.79)     | -0.258<br>(-0.43)     |
| Pay                     | 1.912***<br>(21.77)    | 1.844***<br>(20.91)    | 1.674***<br>(13.64)   | 1.611***<br>(13.06)   |
| Rd                      | -0.123***<br>(-6.06)   | -0.139***<br>(-6.76)   | -0.007<br>(-0.25)     | -0.030<br>(-1.01)     |
| Constant                | -24.187***<br>(-17.51) | -19.948***<br>(-13.18) | -15.942***<br>(-8.20) | -12.048***<br>(-5.65) |
| F-value                 | 445.27***              | 353.39***              | 84.01***              | 67.81***              |
| N                       | 9,591                  | 9,591                  | 7,181                 | 7,181                 |
| R <sup>2</sup>          | 0.2981                 | 0.3016                 | 0.1246                | 0.1272                |
| Adjusted R <sup>2</sup> | 0.2949                 | 0.2983                 | 0.1196                | 0.1219                |
| Year                    | YES                    | YES                    | YES                   | YES                   |
| Industry                | YES                    | YES                    | YES                   | YES                   |

Note: \*, \*\*, \*\*\* represent significant correlation at 0.1, 0.05, 0.01 levels (bilateral), respectively

The regression results in Table 4 shows that substantive innovative behavior of SOEs is not significantly related to their short-term performance ( $\beta=0.067$ ,  $p>0.10$ ), while substantive innovative behavior of non-SOEs is significantly positively related to their short-term performance ( $\beta=0.340$ ,  $p<0.01$ ). In order to test whether the regression coefficients of substantive innovative behavior on firms' short-term performance in these two groups are significantly different from each other, Fisher's Permutation test (FPT) was conducted, and the p-value was obtained by repeating the sampling 1000 times, and the results showed that  $p<0.001$ , indicating that the significance test was passed. That is, in the two groups of substantive innovative behavior there is a significant difference between the regression coefficients. Therefore, it is reasonable to assume that the nature of property rights of SOEs weakens the contribution of substantive innovative behavior to the short-term performance of firms, i.e., hypothesis H5a is supported. Strategic innovative behavior of SOEs is significantly and positively related to their short-term performance ( $\beta=0.223$ ,  $p<0.01$ ), while there is no significant relationship between strategic innovative behavior of non-SOEs and their short-term performance ( $\beta=0.075$ ,  $p>0.10$ ). The results of Fisher's Permutation test showed  $p<0.001$ , which means that there is a significant difference between the regression coefficients of the two groups of strategic innovative behavior and hypothesis H5c is supported. Substantial innovative behavior of state-owned firms is not significantly related to their long-term performance ( $\beta=0.152$ ,  $p>0.10$ ), while substantial innovative behavior of non-state-owned firms is significantly and positively related to their short-term performance ( $\beta=0.407$ ,  $p<0.01$ ). The results of Fisher's portfolio test showed  $p<0.001$  and hypothesis H5b was supported. There is no significant correlation between strategic innovation behavior of SOEs and their long-term performance ( $\beta=0.050$ ,  $p>0.10$ ), and there is no significant correlation between strategic innovation behavior of non-SOEs and their long-term performance ( $\beta=-0.102$ ,  $p>0.10$ ), and hypothesis H5d is not supported.

**Table 4** Regression results (2)

| Group                   | State-owned enterprises | Non-State-Owned Enterprises | State-owned enterprises | Non-State-Owned Enterprises |
|-------------------------|-------------------------|-----------------------------|-------------------------|-----------------------------|
| Variables               | SRoa                    | SRoa                        | LRoa                    | LRoa                        |
| Spt                     | 0.076                   | 0.340***                    | 0.152                   | 0.407***                    |
|                         | (0.85)                  | (5.66)                      | (1.37)                  | (4.37)                      |
| Cpt                     | 0.223***                | 0.075                       | 0.050                   | -0.102                      |
|                         | (2.58)                  | (1.36)                      | (0.47)                  | (-1.20)                     |
| Size                    | -0.209*                 | 0.118                       | -0.435***               | -0.304**                    |
|                         | (-1.85)                 | (1.36)                      | (-3.19)                 | (-2.24)                     |
| Age                     | -0.002                  | 0.152                       | 0.303                   | -0.155                      |
|                         | (-0.00)                 | (0.83)                      | (0.66)                  | (-0.58)                     |
| Share                   | 0.037***                | 0.083***                    | 0.033***                | 0.055***                    |
|                         | (5.40)                  | (19.98)                     | (4.01)                  | (8.63)                      |
| Equ                     | -1.208***               | -2.561***                   | -0.506***               | -1.618***                   |
|                         | (-16.89)                | (-29.22)                    | (-5.94)                 | (-12.38)                    |
| Ppe                     | -9.286***               | -5.838***                   | -2.256**                | 1.449*                      |
|                         | (-12.39)                | (-11.06)                    | (-2.49)                 | (1.79)                      |
| Pay                     | 2.063***                | 1.687***                    | 1.341***                | 1.697***                    |
|                         | (12.76)                 | (15.89)                     | (6.96)                  | (10.56)                     |
| Rd                      | -0.075*                 | -0.196***                   | 0.073                   | -0.104***                   |
|                         | (-1.88)                 | (-8.03)                     | (1.51)                  | (-2.73)                     |
| Constant                | -22.465***              | -25.596***                  | -9.937***               | -17.533***                  |
|                         | (-8.31)                 | (-13.26)                    | (-3.06)                 | (-5.93)                     |
| F-value                 | 99.93 ***               | 246.45 ***                  | 18.49 ***               | 50.48 ***                   |
| N                       | 3,022                   | 6,416                       | 2,405                   | 4,668                       |
| R <sup>2</sup>          | 0.3288                  | 0.2995                      | 0.1756                  | 0.1356                      |
| Adjusted R <sup>2</sup> | 0.3196                  | 0.2945                      | 0.1620                  | 0.1276                      |
| Year                    | YES                     | YES                         | YES                     | YES                         |
| Industry                | YES                     | YES                         | YES                     | YES                         |

Note: \*, \*\*, \*\*\* represent significant correlation at 0.1, 0.05, 0.01 levels (bilateral), respectively

### 4.3 Robustness tests

In order to ensure the reliability of the above empirical findings, this paper uses the method of replacing the proxies of the explanatory variables for robustness testing. In this paper, ROE, the return on net assets, is chosen as a proxy variable for corporate performance ROA (Pan and Yu, 2014; Zhang, Shi and Liu, 2015). The regression results are shown in Tables 5 and 6. It can be seen that the regression results of each model are basically consistent with the previous papers after the robustness test by replacing the proxies of the explanatory variables. It indicates that the empirical findings of this paper have good robustness and the conclusions are highly convincing.

**Table 5** Robustness tests (1)

| Variables   | SRoe                   | SRoe                   | LRoe                  | LRoe                  |
|-------------|------------------------|------------------------|-----------------------|-----------------------|
| Spt         |                        | 0.491***               |                       | 0.667***              |
|             |                        | -4.49                  |                       | -4.09                 |
| Cpt         |                        | 0.273***<br>(2.66)     |                       | 0.092<br>(0.61)       |
| Size        | 0.811***<br>(5.97)     | 0.412*** (2.81)        | -0.630***<br>(-3.13)  | -1.042***<br>(-4.79)  |
| Age         | 0.888**                | 0.816**                | 0.617                 | 0.527                 |
|             | -2.46                  | -2.27                  | -1.21                 | -1.03                 |
| Share       | 0.091***               | 0.090***               | 0.075***              | 0.074***              |
|             | -11.87                 | -11.79                 | -6.64                 | -6.59                 |
| Equ         | -4 254***              | -4 251***              | -0.681***             | -0.683***             |
|             | (-35.76)               | (-35.82)               | (-4.02)               | (-4.04)               |
| Ppe         | -10.975***             | -10.480***             | -1.129                | -0.581                |
|             | (-11.77)               | (-11.23)               | (-0.83)               | (-0.43)               |
| Pay         | 3.495***               | 3.341***               | 3.167***              | 3.003***              |
|             | -18.13                 | -17.26                 | -11.33                | -10.69                |
| Rd          | -0.412***              | -0.451***              | -0.041                | -0.093                |
|             | (-9.22)                | (-9.96)                | (-0.62)               | (-1.38)               |
| Constant    | -64.349***<br>(-21.22) | -54.655***<br>(-16.44) | -33.926***<br>(-7.67) | -23.750***<br>(-4.89) |
| F-value     | 347.86***              | 277.60***              | 32.92***              | 28.54***              |
| N           | 9,591                  | 9,591                  | 7,181                 | 7,181                 |
| R2          | 0.2339                 | 0.2379                 | 0.0632                | 0.0666                |
| Adjusted R2 | 0.2304                 | 0.2343                 | 0.0578                | 0.0609                |
| Year        | YES                    | YES                    | YES                   | YES                   |
| Industry    | YES                    | YES                    | YES                   | YES                   |

Note: \*, \*\*, \*\*\* represent significant correlation at 0.1, 0.05, 0.01 levels (bilateral), respectively.

**Table 6** Robustness test (2)

| Group       | State-owned enterprises | Non-State-Owned Enterprises | State-owned enterprises | Non-State-Owned Enterprises |
|-------------|-------------------------|-----------------------------|-------------------------|-----------------------------|
| Variables   | ROE                     | ROE                         | lag3_ROE                | lag3_ROE                    |
| Spt         | 0.171                   | 0.681***                    | 0.462*                  | 0.817***                    |
|             | -0.74                   | -5.66                       | -1.66                   | -3.99                       |
| Cpt         | 0.393*                  | 0.155                       | 0.216                   | -0.085                      |
|             | -1.76                   | -1.4                        | -0.81                   | (-0.46)                     |
| Size        | 0.047<br>(0.16)         | 0.965***<br>(5.54)          | -1.214***<br>(-3.57)    | -0.642**<br>(-2.15)         |
| Age         | 0.208                   | 0.821**                     | 1.274                   | 0.126                       |
|             | -0.21                   | -2.23                       | -1.11                   | -0.21                       |
| Share       | 0.047***                | 0.116***                    | 0.060***                | 0.084***                    |
|             | -2.62                   | -13.99                      | -2.88                   | -6.03                       |
| Equ         | -3.969***               | -4.329***                   | -0.223                  | -1.382***                   |
|             | (-21.43)                | (-24.67)                    | (-1.05)                 | (-4.81)                     |
| Ppe         | -14.351***              | -8.240***                   | -2.938                  | 1.46                        |
|             | (-7.39)                 | (-7.80)                     | (-1.30)                 | -0.82                       |
| Pay         | 4.137***                | 2.856***                    | 2.938***                | 2.959***                    |
|             | -9.87                   | -13.44                      | -6.09                   | -8.38                       |
| Rd          | -0.501***               | -0.433***                   | 0.032                   | -0.183**                    |
|             | (-4.87)                 | (-8.85)                     | -0.27                   | (-2.19)                     |
| Constant    | -53.432***              | -61.327***                  | -20.387**               | -30.768***                  |
|             | (-7.63)                 | (-15.87)                    | (-2.51)                 | (-4.74)                     |
| F-value     | 90.70***                | 166.18***                   | 8.22***                 | 20.76***                    |
| N           | 3,022                   | 6,416                       | 2,405                   | 4,668                       |
| R2          | 0.2696                  | 0.2172                      | 0.0925                  | 0.0745                      |
| Adjusted R2 | 0.2596                  | 0.2117                      | 0.0775                  | 0.0659                      |
| Year        | YES                     | YES                         | YES                     | YES                         |
| Industry    | YES                     | YES                         | YES                     | YES                         |

Note: \*, \*\*, \*\*\* represent significant correlation at 0.1, 0.05, 0.01 levels (bilateral), respectively.

## 5 Conclusion and Discussion

This paper examines the effects of substantive and strategic innovation on firm performance using the perspectives of resource dependence theory and signaling theory. It also attempts to investigate the relationship between the innovation behavior of Chinese manufacturing firms and their financial performance from the perspective of various innovation motives. On this basis, we further investigate the moderating role played by different property rights in the relationship between the two in the context of China's economic

system transformation and the reality of equity division reform. The main findings of this paper are as follows: (1) Substantial innovation can improve an organization's long-term performance in addition to its short-term performance. However, strategic innovation can only promote the short-term performance of a firm and has no significant contribution to the performance of a firm in the later period. (2) The promotion effect of substantive innovative behavior on enterprise performance is reduced when enterprise ownership is state-owned, whereas the promotion effect of strategic innovation on short-term enterprise performance is strengthened.

This study offers the following management lessons and suggestions for future research based on the findings.

(1) The Chinese government should progressively strengthen the pertinent innovation subsidy programs, correct the mistaken perspective of "emphasizing quantity over quality," and gradually raise the significance of high quality and high-level innovative achievements. Future research can explore the evaluation method of patent quality and, on this basis, the impact of different quality patents on enterprises' access to policy subsidies. The negative effects of the current information asymmetry can be offset by research on patent quality assessment and government innovation subsidies based on patent quality, and the goal of preventing the development of unfavorable selection behavior of firms can be accomplished.

(2) Due to the signaling effect of strategic innovation behavior and the possible erosion effect on the substantive innovation of enterprises, capital market investors should improve their ability to identify patent signals, so that the capital market can allocate resources more effectively and creatively to promote the efficiency of enterprises' innovation activities. External investors should gradually improve their own level of identification and conduct appropriate and reasonable evaluations of the actual innovation level of enterprises in order to increase investment effectiveness and efficiency, reduce resource mismatch, and maintain the normal operation of the capital market. Further research can be conducted in the future on how substantive and strategic innovations can be efficient in terms of capital market innovation resources.

(3) From the perspective of corporate governance, the findings of this study pose new challenges to existing corporate governance research. In the context of innovation-driven strategy, innovation signals will likely further increase the scope and intensity of influence on stakeholders, and how to avoid the adverse effects of strategic innovation behaviors is a new issue facing corporate governance and an important direction for future research on the relationship between corporate governance and innovation. In the context of innovation-driven strategy, innovation signals will likely further increase the scope and intensity of influence on stakeholders, and how to avoid the adverse



effects of strategic innovation behaviors is a new issue facing corporate governance and an important direction for future research on the relationship between corporate governance and innovation.

The research on strategic innovation behavior at the micro enterprise level is still in its initial stage, and the research in this paper is an exploratory empirical study, which still has some shortcomings: First, this paper chooses the number of invention and non-invention patent applications in the current year to measure the substantive and strategic innovation of enterprises, and future research can choose more reasonable and comprehensive measurement indicators to further distinguish the different innovation behaviors of enterprises. Secondly, this paper mainly explores the direct effect of different innovation behaviors on enterprise performance and the moderating effect of property rights but does not include more potential moderating mechanisms and mediating mechanisms in the research framework. Despite these limitations, the findings make significant contribution towards understanding the impact of substantive innovation and strategic innovation on firm performance.

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## Note

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## Intellectual property rights and firm performance. Evidence from sub-Saharan Africa

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### Abstract

Intellectual Property Rights-protected innovations are commonly ignored in firm-level innovation studies in developing economies. We explore whether patents, copyrights, and trademarks carry explanatory power for firm performance above and beyond that of subjective self-reported innovation measures. We use four measures of firm performance: the scale of innovation, total factor productivity, export, and employment growth. We analyze data of 6811 firms in 11 countries in sub-Saharan Africa and distinguish three relevant sub-samples: SMEs versus large firms, low-corrupt versus high-corrupt countries, and The African Regional Intellectual Property Organisation (ARIPO) versus Non-ARIPO members. Our findings show that the explanatory power of IPR-protected inventions for firm performance is relatively small but with interesting nuances. For example, IPRs positively predict the scale of innovation, whereas firm-level productivity is positively related to trademarks for SMEs. On the other hand, IPR negatively affects various firm performance measures in high-corruption countries, emphasising the interaction between institutions and firm-level innovation dynamics.

**Keywords:** intellectual property, TFP, innovation, export, firm growth  
JEL code: O12; O30; O34; O55

## Introduction

Innovation is essential for economic development and long-run firm success in both developed and developing economies. Innovation is often the primary source of sustainable competitive advantages in developed economies. In developing economies, innovation helps firms overcome internal and external resource constraints (Ploeg et al., 2021) and helps them gain access to international markets (Barasa et al., 2021). Whereas firm-level innovation in developed economies is widely studied, research regarding this phenomenon in emerging/developing economies, particularly sub-Saharan Africa (SSA), is much scarcer (Lundvall et al., 2011; Ramadani et al., 2017; Crowley & McCann, 2018).

Given the importance of understanding firm-level innovation in developing countries, having reliable measures of this phenomenon is crucial. In many studies conducted in developed countries, intellectual property right (IPR) based innovation measures, such as patents, are used to measure firm innovativeness (Candelin-Palmqvist et al., 2012; Blind et al., 2017; Fritsch et al., 2021). Furthermore, perception-based measures, in which firms self-report the (degree of) innovativeness of their products and services, are widely used (e.g., see Gunday et al., 2011; Hall & Sena, 2017; Rajapathirana & Hui, 2018; Lee et al., 2019; Audretsch et al., 2020; Hervas-Oliver et al., 2022). Studies comparing both measures of firm-innovativeness in developed economies find that they are strongly correlated and associated with the same set of firm characteristics (Athreye & Fassio, 2019), such as R&D expenditures and exporting (Frenz & Ietto-Gillies, 2007).

However, in studies in developing countries, IPR-protected innovations are commonly ignored (Anderson, 2006; Wang et al., 2012). Their quality control is deemed low, and their protection mostly unenforceable (Blakeney & Mengistie, 2011; Schneider, 2005; Deardorff, 2011; Helpman, 1993). As a result, studies on firm-level innovation in developing economies settings almost exclusively rely on perception-based measures of firm innovativeness (Barros, 2015). This is problematic as there are good reasons to assume that perception-based measures are systematically biased in exactly those settings (Cirera & Muzi, 2020). For example, the self-reported innovation rates in many African countries, especially the SSA region, are extremely high compared to other countries. To illustrate, the percentage of firms in the European Union that self-report product innovations is 33%, whereas this figure is close to 50% for SSA firms in the World Enterprise Survey using identical question-wording.

Therefore, only relying on perception-based measures of innovativeness could result in a biased and incomplete understanding of firm-level innovation. By ignoring all IPR-based measures, we might throw out the baby with the bathwater.

In this study, we therefore re-examine the role of IPR-based innovation measures in the context of developing countries. Specifically, we assess whether they carry additional explanatory power for various dimensions of firm performance above and beyond self-reported perception-based innovation measures. In doing so, we utilise a broad range of IPR-based measures. However, most research has focused exclusively on patents with less attention to other IPRs, such as trademarks and copyrights (Castaldi, 2020). This is puzzling because the other types of IP instruments provide firms with a wide arsenal to protect the outcomes of their innovative efforts (Brem et al., 2017; Fikkema et al., 2019; Athreye & Fassio, 2019). For instance, Thomä & Bizer (2013) and Audretsch et al. (2020) find that small German firms employ other protective tools (e.g., utility model, industrial design, secrecy, the complexity of design, copyrights, trademark, and lead time) apart from patents to attribute returns to their innovative propensity.

To determine the added explanatory power of IPRs for firm performance in SSA, we analyse World Bank Enterprise and Innovation Capability Surveys from 8285 firms from 11 countries in SSA. Firm performance is measured through *innovation counts* (i.e. the degree of innovativeness); *firm-level total factor productivity (TFP)*, *exports*, and *employment growth*. To isolate the additional effect of IPR-protected innovations on firm performance as best as possible, we use propensity score matching to match firms with IPR-protected innovations to similar firms without IPR-protected innovations. In addition, we distinguish between firms that apply for patents, trademarks, and copyrights. Finally, we perform these analyses for various relevant sub-samples, such as SMEs versus large firms, low-corrupt versus high-corrupt countries, and ARIPO

<sup>1</sup> versus Non-ARIPO members. We do so because all three concepts have been shown to influence the value firms can extract from IPR and could therefore influence the magnitude of the effect of IPR on firm performance. SMEs, for example, not only often refrain from using IPR but are also at a disadvantage to extra value from IPR due to having a smaller and less diverse product/service portfolio (Czarnitzki & Hottenrott, 2010; Veugelers & Schneider, 2018) and their larger vulnerability to patent litigation (Blind et al., 2006). In consequence, in countries that suffer from high levels of corruption with weaker IPR regimes, firms are also likely to face challenges to extracting value from their IPR as the protection regime might be very limited, and the legal means to challenge infringement of their IPR are hampered (Barasa et al., 2017).

To the best of our knowledge, this is the first study to examine how SSA firms'

IPR-protected innovations relate to firm performance indicators other than self-reported perception-based innovativeness. Foreshadowing our main results, our findings show that except for the degree of innovativeness, IP-protected innovations have little explanatory power for firm performance, with some interesting exceptions and nuances. First, IP-protected innovations do matter for local development because they explain the *degree* of innovativeness better than just the perception-based measures. Second, the African IPRs may also be of interest to international business scholars precisely because they negatively influence export and employment growth. This implies that engaging with African IPR could be used as a signal for weak capabilities and lack of integration with international markets and supply chains. Last, our finding that IPR particularly has negative effects in high-corruption countries, further emphasising the need to study the interaction between institutions and firm-level innovation.

This paper is structured as follows: section two summarises the relevant literature, while section three illustrates the empirical framework of the analysis. We describe the data and variables in the same section. Section four reports the results and interpretations. We discuss our findings in the subsequent section and draw important policy implications. We conclude in the last section by documenting the limitations of the study and outlining the potential areas future scholars can build on.

## **Theoretical background**

### ***IPR and firm performance***

While the implementation of firms' innovation relies on diverse mechanisms, such as the quality of human capital and absorptive capacity (Teece, 2000; Cohen & Levinthal, 1990; Leiponen & Byma, 2009; Pradana et al., 2020), IPR is considered quintessential to firms' incentives and abilities to innovate (Athreye & Fassio, 2019; Teixeira & Ferreira, 2019). The standard justification for granting IPRs is that developing new knowledge brings positive externalities in the form of knowledge spillovers. IPR, in this reasoning, promotes inducements to produce such positive externalities, thereby mitigating the impacts of innovation market failure (Wang, 2021; Greenhalgh & Rogers, 2007; Guellec & van Pottelsberghe de la Potterie, 2007). Based on this logic, promoting IP usage by firms is an integral part of innovation policy (Athreye & Fassio, 2019; Kay et al., 2014).

In discussing its effects on firm performance, it is crucial to distinguish between various kinds of IPR. Even though traditionally, the focus has been on patents, trademarks, and copyrights have also started gaining attention more recently. Together, trademarks, copyrights, and patents cover various features of firms' intangible assets (Athreye & Fassio, 2019). For example, patents are only granted



to inventions that solve an existing technical problem and are granted when the invention is novel and non-trivial (Blind et al., 2022).

Unlike patents, trademarks do not require novelty. They are granted on any words or symbols that identify products and firms (Flikkema et al., 2019; Athreye & Fassio, 2019; Schautschick & Greenhalgh, 2016). A trademark is granted so far that it is not similar to any mark on the national trademark register. By granting sole rights to use a distinguishable sign, the trademark system primarily aims to decrease consumer search costs (Castaldi & Giarratana, 2018). Trademarks allow businesses to protect their strong brands and establish a competitive advantage by creating services and products of consistent quality that cannot be copied (Hall & Sena, 2017; Fisher, 2001). Because of the functional impact of trademarks on a much broader range of companies, they are relevant to firms without engaging in technologically innovative activities. Evidence also shows that trademarking is highly correlated with other types of innovation (Athreye & Fassio, 2019; Schautschick & Greenhalgh, 2016), including copyright (Park, 2010; Suh & Hwang, 2010; Power & Reid, 2021). In this way, all types of IP could improve firm performance and encourage investments in intangible assets. However, an open question is whether they have such an effect on firm performance in developing countries and sub-Saharan Africa specifically.

### *IPR in developing countries*

The existing evidence suggests that adopting IP systems similar to those in developed economies would be unfavourable to developing countries (Schneider, 2005; Deardorff, 2011; Helpman, 1993). Even though stronger patent protection is believed to promote technology transfer and foreign direct investment (FDI) in emerging economies, mixed evidence exists regarding the stronger patent protection impact on domestic innovation in emerging economies (Watkins & Taylor, 2010; Branstetter, 2004; Schneider, 2005; Sharma et al., 2022). For example, Chen & Puttitanun (2005) show that stronger patent protection effects varied by development level, with high-income countries responding more positively (Falvey et al., 2006; Chen & Puttitanun, 2005). There are trade-offs between copying or replicating existing innovations and spurring innovation by providing adequate IP protection based on the economy's development level (Falvey et al., 2006; Nguyen et al., 2023).

Based on a global sample, Sweet & Maggio (2015) find that the more IP laws a country has, the greater its level of innovation as measured by export complexity. Again, however, the positive impact is limited to countries with high levels of development. Their results further indicate that IPs have no significant effect on economic complexity in developing countries and are often negatively impacted. Cimoli et al. (2011) and Odagiri et al. (2010) demonstrate that technologies emerge from relatively loose IPR regimes in developed and

developing countries, proving that IPRs do not significantly drive technology advancement.

Based on these findings, almost all firm-level studies in the context of developing countries ignore IPR measures, which hold for patents, trademarks, and copyrights. However, doing so ignores the fact that IPR-protected innovations exist in developing countries and that firms use those. We, therefore, propose a nuanced view on the role of IP-based innovation by considering various factors that could influence its effects on firm performance. Specifically, we consider the specific IPR institutions, the size of the firm, and the level of corruption in the firm's environment.

### *IPR Institutions in SSA*

SSA countries are confronted with many IP issues, including the development of IP policy and implementation and enforcement burdens (Blakeney & Mengistie, 2011; Andrés et al., 2015). The enforcement of IPRs, especially copyrights and patents, in emerging economies generates significant controversies, for instance, in the area of pharmaceuticals, where IPRs often stand in the way of access to essential medicines and vaccines for large parts of the population (Jain, 1996; Archibugi & Filippetti, 2010; Goldberg, 2010). Moreover, domestic interests in enforcing IP protection are highly debated (Dosso et al., 2021; Asongu & Nwachukwu, 2017). Products such as software, video films and music are often only accessible when (illegally) copied. Because of this, copyright becomes a focus of conflict in less developed regions. The global IPRs standards are significantly covered in the agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS); however, SSA countries struggle to implement these standards.

The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) and other international IP instruments place significant implementation burdens on countries in SSA, illustrating the necessity for regional IP cooperation among those countries. In addition to the African Common Market (COMESA), the South African Development Community (SADC) and the African Union (AU), African Regional Intellectual Property Organisation (ARIPO) and Organisation Africaine de la Propriété Intellectuelle (OAPI) provide cooperation in protecting IP in their member states. Furthermore, by promoting greater public awareness of the role played by intellectual property in asset creation and building human resources and institutions relating to IP, SSA countries can be enabled to accelerate the pace and scope of IP asset creation and commercialisation. Developing national IP offices' capacity to provide business development services to assist entrepreneurial firms in selecting appropriate technologies at reasonable prices is crucial. Extending and strengthening technological capacity is vital to encouraging firms to integrate IP issues into their business strategy and plan.

This, particularly, contributes to one of the reasons countries in SSA have decided to identify with some IPR institutions, like the African Regional Intellectual Property Organisation (ARIPO), for the Anglophone countries and Organisation Africaine de la Propriete Intellectuelle (OAPI), for the Francophone countries in the region. As an intergovernmental organisation aimed at facilitating cooperation among its twenty-two members in the intellectual property arena, the African Regional Intellectual Property Organization (ARIPO) improves member states' economic, social, technical, scientific, and industrial development through financial and human resources management. Furthermore, by implementing an operational IP structure, the organisation promotes ingenuity and innovation amongst its members. One would therefore expect that the added value of IPR-protected innovations for firm performance is larger in ARIPO versus non-ARIPO countries.

### *IPR and Firm size*

The innovation literature commonly argues that bigger firms have more innovation capabilities than SMEs, especially with IP-protected innovations (Schumpeter, 1934; Candelin-Palmqvist et al., 2012). Empirical findings often confirm this argument. For example, European SMEs tend to patent their inventive activities at a lower rate compared to large firms (Arundel & Kabla, 1998). Even when firms of different sizes have the same innovative ability, financial constraints often lead smaller firms to opt for other protection mechanisms than IP protection (Jenssen & Webster, 2006). Studies also confirm that the appropriation channels pursued by large and small firms differ significantly (Leiponen & Byma, 2009). There are also contradictory views on the suitability of informal IP for large and small firms. While Hall et al. (2014) consider informal IP, such as lead time or secrecy, more suitable for large firms, Leiponen & Byma (2009) thought otherwise.

Nonetheless, despite the hurdles SMEs need to overcome to utilise IP, one crucial advantage of IP usage for SMEs is recognising and exploring the global market. Additionally, SMEs typically use patents to stop competitors from replicating their innovative ideas instead of assessing and capitalising on the success of successful innovation to the stage that SMEs do not benefit reliably from patents, according to McDonald (2004). While Hall et al. (2014) assume formal IP to be more prevalent in large firms, it also appears that SMEs have the potential to apply and utilise IP mechanisms, such as copyrights, patents, and trademarks. Interestingly, Hall et al. (2014) conclude that (in)formal IPRs are more beneficial to productivity increase in large firms than in smaller ones. What this translates to is that SMEs can only benefit, especially from formal IP, by protecting their internal capabilities while trying to explore knowledge or materials externally. Lastly, Brem & Hitchen (2017) find that trademarking positively impacts the turnover of small firms.

Regarding productivity, Hall & Sena (2017) find a positive impact of formal IP on SMEs and large firms through product innovations. A significant positive link exists between superior innovation introduction, productivity, and choice of IP by large and SMEs, respectively. Evidence points to SMEs patent activities, even if large enterprises are usually more disposed to use patents (Blind et al., 2022). There is considerable support that small businesses are much more committed to obtaining IP properties than large businesses in British companies (Schautschick & Greenhalgh, 2016; Hanel, 2006). By employees, it is also more likely for small enterprises in the US to file patents than bigger ones (Audretsch, 2002). Studies generally find formal IP protection to matter for higher productivity as firms choose their innovation trajectories. Despite the inconclusiveness of the direction of the effect, the literature strongly suggests that firm size influences the relation between IPR-protected innovations and various dimensions of firm performance.

### ***IPR and Corruption***

Formal and informal institutions, and the degree of corruption present in those countries, in particular, are fundamental to applying and utilising IPR (Barasa et al., 2017). Moreover, corruption can increase the cost of gaining IP rights in different ways, including imposing additional fees or reducing the processing time. Similarly, innovation is likely to be discouraged by corruption, which will hamper growth prospects by raising the cost of investing in innovation (Goel, 2020). As well as reducing investments in innovation, corruption may raise social demands for redistributive measures depending on social preferences concerning inequality (Rothstein & Uslaner, 2005). Therefore, innovation activities can be fostered by the IP system, which provides an essential public service to innovators and manufacturers (Pisano & Teece, 2007; OECD, 2018). However, firms will often invest in routine production activities than innovative activities if corruption is pervasive (Paunov, 2016; Anokhin & Schulze, 2009; Murphy et al., 1993). Against this backdrop, it is important to distinguish between low- and high-corruption countries when assessing the firm-level effects of IPR on firm performance.

### **Data**

We use the World Bank Enterprise (WBES) Survey and Innovation Follow-up Survey (IFS) to explore the added value of incorporating IPR-protected inventions for firm performance. The WBES is an extensive, multi-country standardised survey that collects representative firm-level data, particularly in emerging and developing countries. The data includes manufacturing and service firms but excludes primary and public sectors. Since the WBES does not contain sufficiently detailed innovation information, adding the IFS is instrumental in capturing firms' innovation activities. In addition, the IFS collect more detailed information regarding the innovation-related activities and

outcomes of a subsample of the firms in the WBES. The IFS is available for 11 countries in SSA. The surveys are conducted in different years in different countries, and all data we use is from the 2012- 2015 waves. All in all, we have complete data for 6811 firms from 11 countries (see Table 1).

**Table 1:** Tabulation of sample by country and main sector

| Country     | Sector        |        |          |       |
|-------------|---------------|--------|----------|-------|
|             | Manufacturing | Retail | Services | Total |
| Nigeria     | 832           | 427    | 769      | 2028  |
| Namibia     | 75            | 102    | 140      | 317   |
| South Sudan | 66            | 358    | 229      | 653   |
| Sudan       | 34            | 49     | 133      | 216   |
| Ghana       | 292           | 88     | 165      | 545   |
| DR Congo    | 226           | 128    | 125      | 479   |
| Malawi      | 123           | 98     | 129      | 350   |
| Tanzania    | 277           | 72     | 112      | 461   |
| Uganda      | 265           | 92     | 126      | 483   |
| Zambia      | 322           | 103    | 200      | 625   |
| Kenya       | 357           | 128    | 169      | 654   |
| Total       | 2869          | 1645   | 2297     | 6811  |

***Variable description and measurement****Independent Variables: IPR-protected inventions*

We use three IPR indicators in our analyses: patents, copyrights, and trademarks. The IFS respondents are asked separately whether the firm has applied for patents, copyrights, or trademarks. If the response is 'yes', the corresponding variable takes the value "1" and "0" otherwise.

*Dependent variables: Firm performance*

We assess the effects of a firm holding IPR-protected inventions on a range of firm-performance indicators. First, we measure innovations relating to the degree of innovation (Rodríguez et al., 2022; Chatterji & Fabrizio, 2014; Díaz-García et al., 2013). Specifically, the IFS survey asks respondents how many innovative products or services they have developed in the last three years. This count variable has been log-transformed before use in our analyses.

Second, we measure firm-level *total factor productivity*. To do so, we follow the approach of Hall & Sena (2017) and Fink et al. (2021) with slightly different indicators. Specifically, we regress the log of sales on the logs of total materials, capital, and labour inputs, all of which are measures in the WBES, and use the residual of this regression as an estimation of the firm-level total factor productivity.

Exporting is considered an essential gauge of firm performance and is often related to innovation (both as a cause and as an effect of exporting) (Aw, Roberts, & Winston, 2005; Aw, Roberts, & Xu, 2008; Eaton & Kortum, 2001; Mairesse & Wu, 2019). Therefore, we measure the degree of *exporting* of a firm using the percentage of their annual sales obtained from exporting in WBES.

The number of employees has been used consistently in the innovation literature to measure how much firms benefit from their innovation activities (Avenyo, Konte, & Mohnen, 2019; Crespi, Tacsir, & Pereira, 2019). We, therefore, include *employment growth* as a measure of firm performance which is calculated by taking the difference between the total number of full-time employees of the establishment over three years and dividing it by the level of employment in the initial period (e.g.  $emp_{2015} - emp_{2012} / emp_{2012}$ ).

#### *Control/matching variables*

Given that our research assesses whether IPR-based innovation measures have added explanatory power for various dimensions of firm performance beyond that of perception-based innovation measures, we need to control for those perception-based measures. To do so, we measure whether a firm has self-reported 1) *process*, 2) *product*, 3) *marketing*, 4) *organisational*, or 5) *radical innovations*. These measures conform with the Oslo Manual definition of innovation and innovation activities (OECD & Eurostat, 2018). Perception-based innovation is common in the innovation literature (see, Avenyo et al., 2019; Medase & Abdul- Basit, 2020; Medase & Barasa, 2019; Okumu et al., 2019; Van Uden et al., 2017). It takes '1' if firms have introduced or significantly improved any of these innovation types and '0' otherwise. Beyond perception-based innovation measures, we also match firms on other relevant features. First, scholars highlight the importance of *managerial expertise* to both innovation performance and firm growth (see Custódio et al., 2019; Barasa et al., 2017; Medase & Abdul- Basit, 2020; Ploeg et al., 2020; Van Uden et al., 2017). This variable is measured in the enterprise survey as the years of top managers' experience working in the establishment. Second, we include *employees' education* as the percentage of employees with at least high school certificates. Third, we also matched on an indicator capturing whether permanent staff received training or not (0, 1), whether the firm performed internal or external R&D (0, 1), participated in technology transfer (0, 1) and quality certification (0, 1). Finally, we match on the % of foreign ownership of firms, the degree of capacity utilisation, the reliance on credits or loans (0, 1), the percentage of senior managers' time dealing with government regulations, and on for *location*, *country*, *sector*, and *period* dummies. Detailed measurements of all variables are reported in Table 2, whereas their pairwise correlations are depicted in Table 3.

**Table 2: Descriptive Statistics of Estimation Variables**

| Variable Description                                                                                                                | Mean   | SD    |
|-------------------------------------------------------------------------------------------------------------------------------------|--------|-------|
| <b><i>Outcome variables</i></b>                                                                                                     |        |       |
| Degree of innovation (logged): Originally measured as the number of innovative products/services introduced in the last three years | 1.67   | 2.91  |
| Total factor productivity (TFP)                                                                                                     | -0.002 | 3.02  |
| Export: percentage of sales from direct export (%)                                                                                  | 4.80   | 15.05 |
| Employment growth – log difference between full-time employees in 2012 & 2015                                                       | 0.02   | 2.75  |
| <b><i>IP Measures</i></b>                                                                                                           |        |       |
| Copyright: Did firm: Apply for a copyright                                                                                          | 0.05   | 0.21  |
| Patent: Did firms apply for a patent concerning a product and process innovation                                                    | 0.05   | 0.21  |
| Trademark: Introduced/Significantly changed: Branding, logo, name, or trademark in a firm: Apply for a trademark                    | 0.17   | 0.38  |
| <b><i>Perception-based innovation</i></b>                                                                                           |        |       |
| Product Innovation (incremental): New or significantly improved products introduced in the last 3 years (new to firms' market 0/1)  | 0.55   | 0.50  |
| Process Innovation: New or significantly improved method of manufacturing products or offering services in the last 3 years         | 0.49   | 0.50  |
| Radical innovation: New or significantly improved product also new to the establishment's main market? (0,1)                        | 0.37   | 0.48  |
| Marketing Innovation: New or significantly improved marketing techniques introduced in the last 3 years (0/1)                       | 0.52   | 0.50  |
| Organisational Innovation: New or significantly improved organisational structure introduced in the last 3 years (0/1)              | 0.41   | 0.49  |
| <b><i>Matching Variables</i></b>                                                                                                    |        |       |
| Internal R&D – conducted by firms in the last 3 years (0/1)                                                                         | 0.12   | 0.32  |
| External R&D: Did firm conduct external R&D (0, 1)                                                                                  | 0.04   | 0.20  |
| Trained Staff                                                                                                                       | 0.28   | 0.45  |
| Managerial experience (absolute value)                                                                                              | 0.18   | 9.70  |
| Schooling: % of full-time workers completed High School                                                                             | 53.08  | 0.38  |
| Capacity Utilisation: percentage of used up space by firms in the last fiscal year (%)                                              | 24.81  | 37.12 |
| Foreign ownership: % owned by private foreign individuals, companies, or organisations                                              | 10.85  | 28.21 |
| Private ownership: % owned by private domestic individuals, companies, or organisations                                             | 77.46  | 38.61 |
| Technology transfer: Do You Use Technology Licensed from a Foreign-Owned Company? (0,1)                                             | 0.07   | 0.25  |
| Quality certification: Does Establishment Have an Internationally-Recognized Quality Certification? (0, 1)                          | 0.13   | 0.33  |
| Manager time: % of senior management time spent in dealing with government regulations                                              | 8.68   | 18.18 |
| Manufacturing                                                                                                                       | 0.42   | 0.49  |
| Services                                                                                                                            | 0.34   | 0.47  |
| Cities with over a million inhabitants & City over 250 to 1m (0,1)                                                                  | 0.89   | 0.31  |



**Table 3:** Pairwise correlation of estimation variables[illegible]

## Empirical strategy

Our empirical approach examines the impact of using copyrights, patents, and trademarks on firm performance. The major challenge for this empirical method is assessing the counterfactual condition—the firm's performance had it not applied for any of the IP indicators. As factors impacting the IPR probability also affect the potential firm performance, the treatment (holding copyrights, patents, or trademarks) is an endogenous variable in assessing firm performance. We use a propensity score matching approach to deal with this issue. This technique extracts 'treatment effects' from observational data (Guo et al., 2020). In our case, the treatment is a firm with a specific IPR-protected invention. Every firm receiving this 'treatment' is matched to 4 other firms as similar to it as possible on all observed covariates (including subjective innovation measures) but that did not receive the 'treatment' (Caliendo & Kopeinig, 2008). In doing so the maximum tolerated difference between matched firms was set at 0.2 standard deviations (as suggested by Austin (2011) and Lunt (2014)).

A key issue in matching approaches is how well firms can be matched, i.e. do firms that only differ on holding IPR-protected innovation exist? To assess this, we first evaluate the area of common support, which reflects the extent to which the densities of the estimated propensity scores for 'treated' and for 'non-treated' overlap (Figure 1). Figure 1 shows that for all types of IPR-protected innovations, the area of common support covers the entire range of the estimated propensities. After matching, the density functions fully overlap. We also assessed the ability of the matching procedure to reduce differences between 'treated' and 'non-treated' firms for individual covariates (see Table 4). Table 4 shows that, unsurprisingly, for all three types of IPR, there are substantial differences between the two groups, especially on R&D (both internal and external) and the self-reported perception-based innovation measures. These differences are reduced to almost 0 after matching, however. All in all, these assessments indicate that our matching procedure is able to create suitable comparison groups that are nearly identical in all aspects except the holding of IPR-protected innovations.

As outlined in our theoretical arguments, we perform three split-sample analyses in addition to our full-sample analysis. In all analyses, we gradually build up the number of characteristics that firms are matched on. In the first step, we only match on the control variables, and we add the various perception-based innovation measures as matching criteria in the four subsequent steps (the matching information for all sub-samples and sub-steps is available from the authors on request). Doing so allows us to make a fine-grained assessment of the added value of IPR-based measures over perception-based innovation measures.

**Figure 1.** Areas of common support

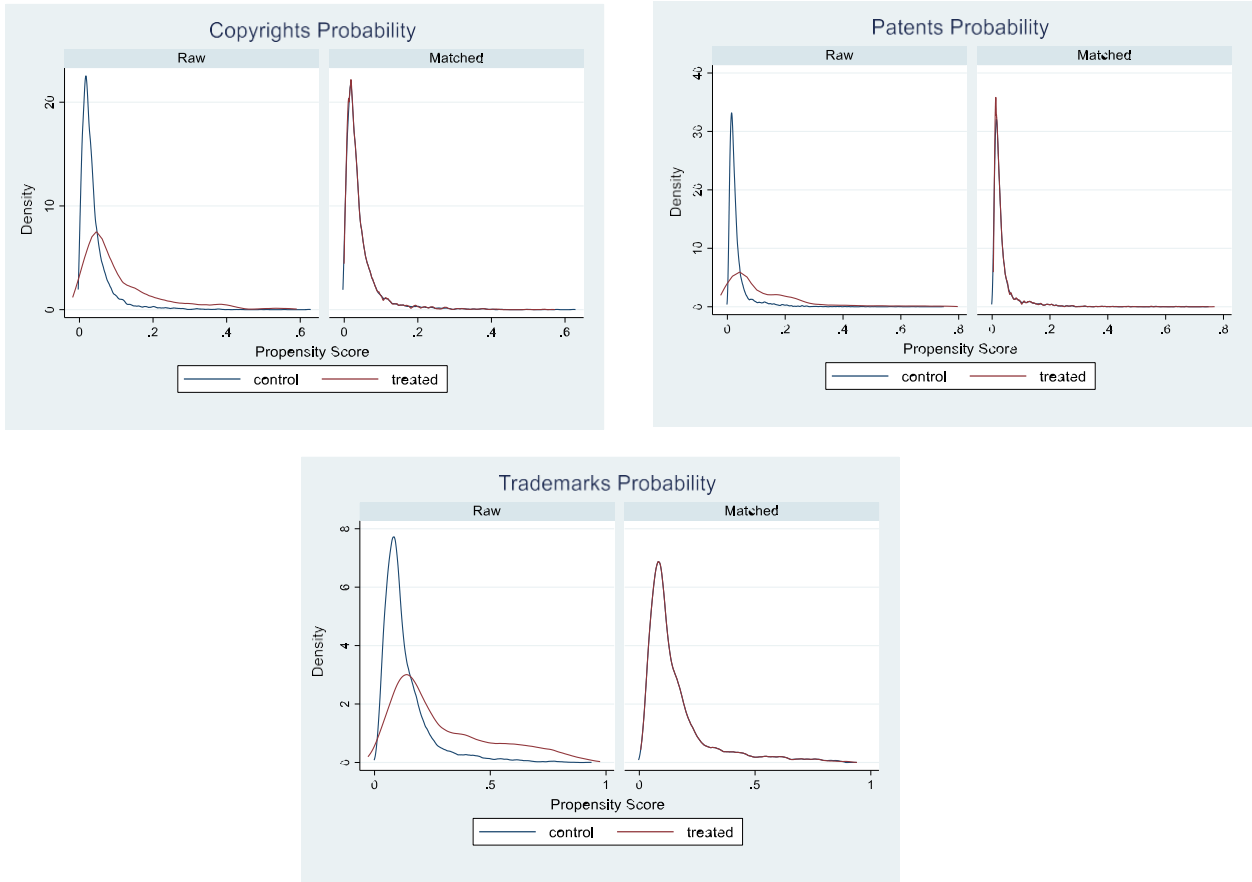


**Table 4:** Balance before and after propensity score matching

|                              | Copyrights     |                    | Patents        |                    | Trademarks     |                    |
|------------------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|
|                              | Raw difference | Matched difference | Raw difference | Matched difference | Raw difference | Matched difference |
| Product innovation           | 0.317          | 0.05               | 0.29           | 0.092              | 0.32           | 0.032              |
| Process Innovation           | 0.477          | 0.009              | 0.443          | -0.189             | 0.305          | -0.005             |
| Marketing Innovation         | 0.443          | 0.007              | 0.463          | 0                  | 0.417          | -0.005             |
| Organizational Innovation    | 0.466          | 0.067              | 0.329          | -0.06              | 0.328          | 0.045              |
| Radical Innovation           | 0.45           | -0.022             | 0.47           | -0.036             | 0.366          | 0.002              |
| Innovation combined          | 0.394          | 0.034              | 0.381          | 0.059              | 0.424          | 0.013              |
| Firm size (log of employees) | 0.192          | -0.035             | 0.216          | -0.05              | 0.115          | -0.059             |
| Firm age (logged)            | -0.265         | 0.14               | -0.183         | -0.114             | -0.218         | 0.025              |
| Internal R&D                 | 0.544          | 0.093              | 0.702          | 0.04               | 0.688          | 0.025              |
| External R&D                 | 0.422          | 0.099              | 0.482          | 0.03               | 0.426          | 0.049              |

|                           | Copyrights     |                    | Patents        |                    | Trademarks     |                    |
|---------------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|
|                           | Raw difference | Matched difference | Raw difference | Matched difference | Raw difference | Matched difference |
| Trained Staff             | 0.142          | 0.095              | 0.045          | -0.091             | 0.153          | 0.01               |
| Managerial Experience     | 0.013          | 0.014              | -0.009         | -0.023             | 0.022          | 0.012              |
| Staff Education           | 0.164          | 0.099              | 0.042          | -0.039             | 0.13           | -0.027             |
| Private ownership         | -0.023         | -0.028             | 0.039          | 0.111              | -0.055         | 0.036              |
| Foreign ownership         | 0.074          | 0.023              | -0.07          | -0.073             | 0.141          | -0.018             |
| Line of credit from banks | 0.099          | 0.015              | 0.23           | -0.073             | 0.161          | -0.026             |
| Export                    | -0.064         | -0.026             | -0.051         | -0.098             | -0.013         | -0.038             |
| Technology transfer       | 0.092          | 0.036              | 0.068          | -0.033             | 0.129          | 0.022              |
| Quality certification     | 0.288          | 0.006              | 0.155          | -0.014             | 0.12           | 0.049              |
| Capacity utilization      | 0.228          | -0.078             | 0.041          | 0.011              | 0.065          | 0.012              |
| Managerial time           | 0.231          | 0.009              | 0.009          | -0.137             | 0.11           | 0                  |

## Results

Table 5 reports the results of our full sample analyses. The results clearly show that all types of IPR indicators positively affect the degree of innovativeness under all matching conditions. In addition, trademarks positively affect TFP under all matching conditions, whereas patents negatively affect firm exports in most matching conditions. Finally, in quite a few matching conditions, the effect of copyrights on employment growth is negative.

The fact that these findings are consistent quite across matching conditions illustrates that the IPR-based measures indeed capture variance in firm performance beyond the perception-based innovation measures.

**Table 5: IP and firm performance for all firms**

| Matching forms for all firms                                            | Indicators | Degree of innovation | TFP                 | Export               | Employment growth    |
|-------------------------------------------------------------------------|------------|----------------------|---------------------|----------------------|----------------------|
| Matching on controls                                                    | Copyrights | 1.542***<br>(0.240)  | -0.010<br>(0.152)   | 0.063<br>(0.382)     | -0.307*<br>(0.185)   |
|                                                                         | Patent     | 2.363***<br>(0.288)  | 0.262<br>(0.255)    | -0.675*<br>(0.368)   | 0.042<br>(0.203)     |
|                                                                         | Trademarks | 1.775***<br>(0.115)  | 0.219***<br>(0.082) | -0.317<br>(0.273)    | -0.083<br>(0.223)    |
| Matching on controls + product innovation                               | Copyrights | 1.508***<br>(0.243)  | 0.234*<br>(0.134)   | 1.170<br>(1.316)     | -0.406***<br>(0.153) |
|                                                                         | Patent     | 2.199***<br>(0.195)  | 0.141<br>(0.145)    | -1.093***<br>(0.400) | -0.090<br>(0.182)    |
|                                                                         | Trademarks | 1.671***<br>(0.127)  | 0.183**<br>(0.091)  | -0.284<br>(0.326)    | -0.030<br>(0.141)    |
| Matching on controls + process, marketing and organizational innovation | Copyrights | 1.396***<br>(0.212)  | 0.050<br>(0.188)    | -0.633<br>(1.024)    | -0.354*<br>(0.195)   |
|                                                                         | Patent     | 2.519***<br>(0.201)  | 0.266<br>(0.281)    | -1.173**<br>(0.508)  | -0.267<br>(0.180)    |
|                                                                         | Trademarks | 1.589***<br>(0.130)  | 0.210**<br>(0.084)  | -0.421<br>(0.295)    | -0.146<br>(0.220)    |
| Matching on controls + radical innovation                               | Copyrights | 1.432***<br>(0.240)  | 0.272<br>(0.200)    | 0.581<br>(0.989)     | -0.355*<br>(0.201)   |
|                                                                         | Patent     | 2.359***<br>(0.334)  | 0.433**<br>(0.206)  | -0.074<br>(0.570)    | -0.299*<br>(0.168)   |
|                                                                         | Trademarks | 1.725***<br>(0.125)  | 0.225**<br>(0.090)  | -0.186<br>(0.385)    | -0.064<br>(0.166)    |
| Matching on controls + all innovation indicators                        | Copyrights | 1.657***<br>(0.289)  | 0.053<br>(0.328)    | 0.679<br>(1.471)     | -0.121<br>(0.141)    |
|                                                                         | Patent     | 2.527***<br>(0.342)  | 0.019<br>(0.252)    | -1.279***<br>(0.321) | -0.311<br>(0.193)    |
|                                                                         | Trademarks | 1.680***<br>(0.129)  | 0.219**<br>(0.093)  | -0.104<br>(0.370)    | -0.075<br>(0.204)    |

Tables 6 and 7 report the split-sample analyses for SMEs (Table 6) and large firms (Table 7). We find effects similar to those of the full sample for SMEs and large firms for the degree of innovation. Regarding TFP, several positive effects are found as well. For SMEs, TFP is positively influenced by the possession of trademarks, whereas for large firms, patents are found to have an effect in most matching conditions. The effects on export and employment growth are mostly insignificant. Whenever effects are found, they are predominantly negative, which aligns with the full sample analysis.

In the subgroup analysis (Tables 8 and 9), where we split ARIPO (*Ghana, Kenya, Sudan, Uganda, Tanzania, Zambia, Namibia, and Malawi*) and non-ARIPO members

(Nigeria, DR Congo, and South Sudan), we find that the effects of IPR types differ quite starkly across the two groups. For example, the positive effect of trademarks on TFP only manifests in non-ARIPO countries, and the same holds for the negative effects of various IPR variables on export and employment growth.

**Table 6:** IP and firm performance for SMEs

| Matching forms for SMEs                                                 | Indicators | Degree of innovation | TFP                 | Export               | Employment growth   |
|-------------------------------------------------------------------------|------------|----------------------|---------------------|----------------------|---------------------|
| Matching on controls                                                    | Copyrights | 1.669***<br>(0.255)  | 0.099<br>(0.117)    | -0.245<br>(1.185)    | -0.029<br>(0.180)   |
|                                                                         | Patent     | 2.438***<br>(0.274)  | -0.087<br>(0.171)   | -0.770<br>(0.620)    | 0.016<br>(0.137)    |
|                                                                         | Trademarks | 1.793***<br>(0.156)  | 0.221**<br>(0.099)  | -0.917***<br>(0.250) | 0.150<br>(0.111)    |
| Matching on controls + product innovation                               | Copyrights | 1.513***<br>(0.254)  | 0.204<br>(0.221)    | 0.177<br>(1.394)     | -0.296**<br>(0.138) |
|                                                                         | Patent     | 2.308***<br>(0.309)  | -0.152<br>(0.269)   | -1.147**<br>(0.483)  | -0.037<br>(0.109)   |
|                                                                         | Trademarks | 1.582***<br>(0.132)  | 0.266***<br>(0.092) | -0.581<br>(0.389)    | 0.206<br>(0.136)    |
| Matching on controls + process, marketing and organizational innovation | Copyrights | 1.453***<br>(0.243)  | 0.024<br>(0.184)    | -1.034<br>(1.071)    | -0.003<br>(0.163)   |
|                                                                         | Patent     | 2.230***<br>(0.318)  | -0.013<br>(0.266)   | -1.122<br>(0.812)    | -0.118<br>(0.140)   |
|                                                                         | Trademarks | 1.503***<br>(0.147)  | 0.218*<br>(0.119)   | -0.429<br>(0.465)    | 0.196<br>(0.152)    |
| Matching on controls + radical innovation                               | Copyrights | 1.601***<br>(0.233)  | 0.287<br>(0.193)    | 1.082**<br>(0.467)   | -0.113<br>(0.198)   |
|                                                                         | Patent     | 2.261***<br>(0.318)  | -0.166<br>(0.221)   | -1.201**<br>(0.551)  | -0.056<br>(0.101)   |
|                                                                         | Trademarks | 1.609***<br>(0.140)  | 0.250**<br>(0.111)  | -0.399<br>(0.371)    | 0.177*<br>(0.097)   |
| Matching on controls + all innovation indicators                        | Copyrights | 1.505***<br>(0.278)  | 0.114<br>(0.107)    | 0.151<br>(1.659)     | 0.070<br>(0.190)    |
|                                                                         | Patent     | 2.305***<br>(0.348)  | -0.080<br>(0.264)   | -1.082<br>(0.728)    | -0.103<br>(0.142)   |
|                                                                         | Trademarks | 1.660***<br>(0.146)  | 0.248**<br>(0.102)  | -0.569**<br>(0.248)  | 0.148<br>(0.109)    |

**Table 7:** IP and firm performance for large firms

| Matching forms for large firms                                          | Indicators | Degree of innovation | TFP                 | Export              | Employment growth    |
|-------------------------------------------------------------------------|------------|----------------------|---------------------|---------------------|----------------------|
| Matching on controls                                                    | Copyrights | 2.465**<br>(0.981)   | 0.008<br>(0.643)    | 0.673<br>(7.849)    | -0.879<br>(0.719)    |
|                                                                         | Patent     | 3.121***<br>(0.567)  | 1.612**<br>(0.644)  | -3.958<br>(3.766)   | -0.096<br>(0.292)    |
|                                                                         | Trademarks | 2.572***<br>(0.310)  | 0.400**<br>(0.165)  | 2.379<br>(2.788)    | -0.124<br>(2.257)    |
| Matching on controls + product innovation                               | Copyrights | 2.314***<br>(0.727)  | -0.538<br>(0.494)   | 1.845<br>(5.109)    | -0.657<br>(0.593)    |
|                                                                         | Patent     | 2.244***<br>(0.470)  | 1.086<br>(1.116)    | -4.703<br>(3.101)   | -0.052<br>(0.268)    |
|                                                                         | Trademarks | 2.372***<br>(0.233)  | 0.431<br>(0.369)    | 0.070<br>(2.798)    | -0.577<br>(1.021)    |
| Matching on controls + process, marketing and organizational innovation | Copyrights | 2.327***<br>(0.234)  | -0.090<br>(0.566)   | 1.652***<br>(0.376) | -1.426***<br>(0.400) |
|                                                                         | Patent     | 3.488***<br>(0.533)  | 1.881***<br>(0.260) | -4.514*<br>(2.732)  | -0.120<br>(0.229)    |
|                                                                         | Trademarks | 1.972***<br>(0.488)  | 0.730*<br>(0.428)   | -1.380<br>(1.766)   | -1.466**<br>(0.656)  |
| Matching on controls + radical innovation                               | Copyrights | 2.417**<br>(1.067)   | 0.081<br>(0.598)    | 1.079<br>(8.365)    | -1.168***<br>(0.426) |
|                                                                         | Patent     | 3.136***<br>(0.528)  | 1.762**<br>(0.734)  | -4.058<br>(3.415)   | -0.083<br>(0.294)    |
|                                                                         | Trademarks | 2.423***<br>(0.405)  | 0.257<br>(0.374)    | -0.945<br>(2.728)   | -0.013<br>(1.741)    |
| Matching on controls + all innovation indicators                        | Copyrights | 2.608***<br>(0.932)  | -0.438<br>(0.634)   | 2.004<br>(8.685)    | -0.995<br>(0.920)    |
|                                                                         | Patent     | 2.545***<br>(0.819)  | 1.209<br>(1.032)    | -2.638<br>(4.388)   | -0.145<br>(0.395)    |
|                                                                         | Trademarks | 2.168***<br>(0.569)  | 0.328<br>(0.408)    | -2.830**<br>(1.231) | -1.466<br>(1.740)    |

**Table 8:** IP and firm performance for ARIPO member countries

| Matching forms for ARIPO                                                | Indicators | Degree of innovation | TFP                 | Export             | Employment growth   |
|-------------------------------------------------------------------------|------------|----------------------|---------------------|--------------------|---------------------|
| Matching on controls                                                    | Copyrights | 1.438***<br>(0.303)  | -0.301**<br>(0.137) | 1.998<br>(1.499)   | 0.222<br>(0.170)    |
|                                                                         | Patent     | 2.253***<br>(0.317)  | 0.349<br>(0.355)    | -0.052<br>(0.228)  | 0.141<br>(0.143)    |
|                                                                         | Trademarks | 1.892***<br>(0.208)  | 0.156<br>(0.124)    | -0.103<br>(0.319)  | -0.458<br>(0.387)   |
| Matching on controls + product innovation                               | Copyrights | 1.511***<br>(0.285)  | -0.327**<br>(0.165) | 1.667<br>(1.141)   | 0.279***<br>(0.105) |
|                                                                         | Patent     | 2.299***<br>(0.391)  | 0.256<br>(0.161)    | 1.125<br>(1.226)   | 0.092<br>(0.318)    |
|                                                                         | Trademarks | 1.706***<br>(0.170)  | 0.090<br>(0.161)    | -0.017<br>(0.424)  | -0.215<br>(0.260)   |
| Matching on controls + process, marketing and organisational innovation | Copyrights | 1.709***<br>(0.242)  | 0.041<br>(0.277)    | 0.626<br>(0.823)   | 0.096<br>(0.216)    |
|                                                                         | Patent     | 2.105***<br>(0.220)  | 0.396*<br>(0.222)   | -0.076<br>(0.303)  | -0.033<br>(0.197)   |
|                                                                         | Trademarks | 1.771***<br>(0.191)  | 0.064<br>(0.103)    | -0.429<br>(0.274)  | -0.367<br>(0.332)   |
| Matching on controls + radical innovation                               | Copyrights | 1.489***<br>(0.350)  | -0.131<br>(0.186)   | 2.039**<br>(0.865) | 0.106<br>(0.147)    |
|                                                                         | Patent     | 1.972***<br>(0.313)  | 0.077<br>(0.329)    | 0.373<br>(0.850)   | 0.078<br>(0.168)    |
|                                                                         | Trademarks | 1.749***<br>(0.164)  | 0.093<br>(0.135)    | -0.463<br>(0.365)  | -0.148<br>(0.191)   |
| Matching on controls + all innovation indicators                        | Copyrights | 1.432***<br>(0.382)  | -0.066<br>(0.213)   | 0.674<br>(2.283)   | 0.458<br>(0.503)    |
|                                                                         | Patent     | 1.948***<br>(0.325)  | 0.219<br>(0.218)    | 0.043<br>(1.128)   | -0.157<br>(0.504)   |
|                                                                         | Trademarks | 1.732***<br>(0.163)  | -0.006<br>(0.141)   | -0.608*<br>(0.335) | -0.236<br>(0.345)   |



**Table 9:** IP and firm performance for Non-ARIPO member countries

| Matching forms for Non-ARIPO                                            | Indicators | Degree of innovation | TFP                 | Export               | Employment growth    |
|-------------------------------------------------------------------------|------------|----------------------|---------------------|----------------------|----------------------|
| Matching on controls                                                    | Copyrights | 1.523***<br>(0.145)  | 0.100<br>(0.515)    | -2.282***<br>(0.378) | -0.605**<br>(0.307)  |
|                                                                         | Patent     | 2.441***<br>(0.509)  | -0.353<br>(0.226)   | -1.079<br>(2.621)    | -0.309*<br>(0.159)   |
|                                                                         | Trademarks | 1.878***<br>(0.224)  | 0.451***<br>(0.167) | -0.244<br>(0.526)    | 0.236<br>(0.244)     |
| Matching on controls + product innovation                               | Copyrights | 1.267***<br>(0.118)  | 0.043<br>(0.497)    | -0.874<br>(1.133)    | -1.122<br>(0.721)    |
|                                                                         | Patent     | 2.128***<br>(0.391)  | -0.144<br>(0.246)   | -1.385<br>(1.331)    | -0.292**<br>(0.145)  |
|                                                                         | Trademarks | 1.608***<br>(0.192)  | 0.331**<br>(0.167)  | -0.720<br>(0.581)    | 0.482<br>(0.317)     |
| Matching on controls + process, marketing and organisational innovation | Copyrights | 1.027***<br>(0.341)  | 0.111<br>(0.399)    | -1.148<br>(1.747)    | -0.871<br>(0.747)    |
|                                                                         | Patent     | 2.672***<br>(0.789)  | -0.492<br>(0.454)   | -2.290<br>(1.922)    | -0.281***<br>(0.084) |
|                                                                         | Trademarks | 1.622***<br>(0.150)  | 0.309*<br>(0.172)   | 0.018<br>(0.788)     | 0.174<br>(0.252)     |
| Matching on controls + radical innovation                               | Copyrights | 1.291***<br>(0.291)  | 0.125<br>(0.502)    | 1.888<br>(2.285)     | -1.784***<br>(0.604) |
|                                                                         | Patent     | 2.454***<br>(0.451)  | -0.472*<br>(0.278)  | -1.521<br>(1.162)    | -0.255<br>(0.174)    |
|                                                                         | Trademarks | 1.657***<br>(0.176)  | 0.422***<br>(0.157) | 0.342<br>(0.729)     | 0.278<br>(0.214)     |
| Matching on controls + all innovation indicators                        | Copyrights | 1.154**<br>(0.505)   | 0.387<br>(0.441)    | 0.997<br>(0.901)     | -1.470*<br>(0.868)   |
|                                                                         | Patent     | 2.655***<br>(0.510)  | -0.316<br>(0.673)   | -2.543*<br>(1.392)   | -0.183*<br>(0.100)   |
|                                                                         | Trademarks | 1.661***<br>(0.199)  | 0.441**<br>(0.174)  | 0.070<br>(0.705)     | 0.132<br>(0.197)     |

In the last subgroup analysis, we split our sample into two categories by using the corruption perception index of *Transparency International* to classify countries into low- corrupt and high-corrupt nations. We benchmark the distribution by using a nine-year corruption index for all countries (2012-2020). The benchmark is that when a country's score is less than 30, we categorise it as high corruption (i.e. *South Sudan, Sudan, Nigeria, Uganda, and DR Congo*). If the score exceeds or equals 30 (i.e. *Malawi, Kenya, Zambia, Tanzania, Namibia, and Ghana*), we categorise the country as having low corruption. Given that all low-corruption countries are ARIPO members, the findings for this subsample are highly similar to those based on the ARIPO subsample. That is, beyond the effects of IPR on the degree of innovation, the effects are very limited (Table 10).

For the high-corruption sub-sample (which consists of ARIPO and non-ARIPO countries), the effects are more pronounced (Table 11). With regard to TFP, the relationship with trademarks is positive and significant in all matching conditions. However, several negative and significant effects are found on exporting and employment growth for patents and copyrights.

**Table 10:** IP and firm performance for low-corrupt countries

| Matching forms for low-corrupt nations                                  | Indicators | Degree of innovation | TFP               | Export               | Employment growth   |
|-------------------------------------------------------------------------|------------|----------------------|-------------------|----------------------|---------------------|
| Matching on controls                                                    | Copyrights | 1.387***<br>(0.320)  | -0.174<br>(0.125) | 1.111<br>(0.959)     | 0.151<br>(0.262)    |
|                                                                         | Patent     | 2.478***<br>(0.339)  | 0.704*** (0.082)  | 0.663**<br>(0.298)   | 0.078<br>(0.351)    |
|                                                                         | Trademarks | 2.118***<br>(0.225)  | 0.028<br>(0.100)  | -0.470<br>(0.784)    | -0.339<br>(0.273)   |
| Matching on controls + product innovation                               | Copyrights | 1.360***<br>(0.334)  | -0.076<br>(0.099) | 0.545<br>(0.807)     | 0.319***<br>(0.095) |
|                                                                         | Patent     | 2.448***<br>(0.278)  | 0.620<br>(0.412)  | 1.036<br>(0.881)     | 0.016<br>(0.318)    |
|                                                                         | Trademarks | 1.643***<br>(0.171)  | 0.136* (0.076)    | -0.685**<br>(0.281)  | -0.255*<br>(0.145)  |
| Matching on controls + process, marketing and organisational innovation | Copyrights | 2.066***<br>(0.254)  | 0.014<br>(0.273)  | -0.157<br>(0.760)    | 0.107<br>(0.326)    |
|                                                                         | Patent     | 2.163***<br>(0.440)  | 0.257<br>(0.203)  | -0.162<br>(1.135)    | 0.049<br>(0.296)    |
|                                                                         | Trademarks | 1.713***<br>(0.235)  | 0.025<br>(0.126)  | -0.594***<br>(0.130) | -0.391*<br>(0.235)  |
| Matching on controls + radical innovation                               | Copyrights | 1.364***<br>(0.337)  | 0.050<br>(0.283)  | 2.761*<br>(1.503)    | 0.188<br>(0.238)    |
|                                                                         | Patent     | 2.296***<br>(0.226)  | 0.622*** (0.194)  | 0.439<br>(0.986)     | 0.048<br>(0.322)    |
|                                                                         | Trademarks | 1.780***<br>(0.213)  | 0.048<br>(0.126)  | -0.063<br>(0.378)    | -0.242<br>(0.173)   |
| Matching on controls + all innovation indicators                        | Copyrights | 1.470***<br>(0.242)  | -0.097<br>(0.097) | 1.304<br>(2.611)     | 0.591<br>(0.631)    |
|                                                                         | Patent     | 2.421***<br>(0.563)  | 0.124<br>(0.223)  | 1.122<br>(1.482)     | -0.103<br>(0.236)   |
|                                                                         | Trademarks | 1.756***<br>(0.204)  | -0.013<br>(0.105) | -0.576<br>(0.416)    | -0.339<br>(0.315)   |

**Table 11: IP and firm performance for high-corrupt countries**

| Matching forms for high-corrupt nations                                 | Indicators | Degree of innovation | TFP                 | Export              | Employment growth    |
|-------------------------------------------------------------------------|------------|----------------------|---------------------|---------------------|----------------------|
| Matching on controls                                                    | Copyrights | 1.714***<br>(0.239)  | 0.346<br>(0.480)    | 0.493<br>(2.552)    | -0.813***<br>(0.282) |
|                                                                         | Patent     | 2.402***<br>(0.354)  | 0.339<br>(0.335)    | 0.431<br>(1.560)    | -0.232*<br>(0.125)   |
|                                                                         | Trademarks | 1.770***<br>(0.178)  | 0.413***<br>(0.133) | -0.180<br>(0.468)   | 0.282<br>(0.316)     |
| Matching on controls + product innovation                               | Copyrights | 1.822***<br>(0.170)  | 0.313<br>(0.320)    | -0.343<br>(0.792)   | -0.966***<br>(0.363) |
|                                                                         | Patent     | 2.203***<br>(0.332)  | 0.576<br>(0.431)    | -0.344<br>(0.521)   | -0.172<br>(0.163)    |
|                                                                         | Trademarks | 1.679***<br>(0.174)  | 0.427***<br>(0.127) | -0.830**<br>(0.392) | 0.190<br>(0.240)     |
| Matching on controls + process, marketing and organisational innovation | Copyrights | 1.458***<br>(0.343)  | 0.300<br>(0.364)    | -0.030<br>(1.019)   | -0.645<br>(0.482)    |
|                                                                         | Patent     | 2.550***<br>(0.417)  | 0.436<br>(0.342)    | -1.210<br>(1.490)   | -0.183<br>(0.137)    |
|                                                                         | Trademarks | 1.828***<br>(0.146)  | 0.524***<br>(0.140) | -0.426<br>(0.437)   | 0.059<br>(0.175)     |
| Matching on controls + radical innovation                               | Copyrights | 1.834***<br>(0.354)  | 0.260<br>(0.349)    | 0.028<br>(2.312)    | -0.998**<br>(0.444)  |
|                                                                         | Patent     | 2.293***<br>(0.330)  | 0.516<br>(0.394)    | -0.776**<br>(0.327) | -0.138<br>(0.157)    |
|                                                                         | Trademarks | 1.668***<br>(0.183)  | 0.434***<br>(0.140) | -0.424<br>(0.586)   | 0.125<br>(0.167)     |
| Matching on controls + all innovation indicators                        | Copyrights | 1.659***<br>(0.182)  | 0.375<br>(0.424)    | -1.000<br>(1.558)   | -0.745*<br>(0.407)   |
|                                                                         | Patent     | 2.486***<br>(0.390)  | 0.350<br>(0.302)    | -1.254<br>(1.029)   | -0.188<br>(0.174)    |
|                                                                         | Trademarks | 1.731***<br>(0.156)  | 0.599***<br>(0.147) | -0.512<br>(0.634)   | 0.157<br>(0.187)     |

In summary, IPRs have a strong positive effect on the degree of innovativeness. Also, we observe some positive impacts on TFP, but only from trademarks and particularly for SMEs. On the other hand, there are negative effects on exports and employment growth, particularly for non-ARIPO and high-corruption countries.

## Discussion

In this study, we re-examined the role of IPR-based innovation measures in a developing country context. We then assessed whether they carry additional explanatory power for various dimensions of firm performance beyond perception-based innovation measures. Overall, our results paint a picture of

African IPR mattering mostly for development-oriented studies interested on how firms in these contexts innovate and grow. This conclusion is rooted in our finding that IPR does help to distinguish the more innovative from, the less innovative firms beyond their distinction based on perception-based innovation measures.

Subsequently, IP-based innovations have a divergent effect on SMEs as opposed to large firms. We find some, albeit relatively weak, positive effects of trademarks on TFP for SMEs. This suggests that IP protection offers these small firms the protection they require to extract value from the innovations. However, for larger firms that also have more other instruments at their disposal, patents positively influence TFP. Beyond that, the effects of IP protection for large firms are mostly negative, especially when considering employment growth and exporting. This suggests that large firms engaging in African IPR could be interpreted as a sign of weak capabilities.

The interpretation of engaging with African IPR as a sign of weak capabilities also points to an interesting use for African IPR for economic growth and international business studies. The extent to which larger firms engage in this type of protection of their innovations could be used as an indicator of disengagement from international market quality standards. Many firms engaging in this innovation protection strategy in an ecosystem could similarly be seen as evidence of isolation from global trade networks and a lack of potential for future development.

With regard to the types of IPR, our work supports the recent trend to broaden the perspective beyond 'just' patents. Our results suggest it seems especially worthwhile to focus on trademarks as a source of protection that helps firms extract value from their innovative activities. Trademarks are especially interesting as they affect firm performance even in environments with weaker IPR protection and/or high corruption. This makes it an instrument that could help stimulate firm growth and, local economic development in areas where this is traditionally most difficult to achieve. This finding notwithstanding, the effects of the other types of IPR are more beneficial in context with better IPR protection and/or less corruption underlies the general importance attached to the quality of local institutions for firms to benefit from their innovative efforts (Barasa et al., 2021).

Overall, we conclude that ignoring all IPR-based measures studies on firm-level innovation in developing contexts implies throwing out the baby with the bathwater. At the same time, the effect of IPR-based innovations on firm performance is by no means straightforward and uniformly positive. The effects of African IPR are nuanced; in some cases, it even seems to operate as a negative quality signal. Because of these nuances, further disentangling the role and effect of IPR in developing countries is a very fruitful avenue for further

research. Also, some countries in SSA have improved significantly regarding regional institutions, especially those in East Africa. Future research could explore the link between regional institutional quality and its impact on IPR-protected innovation of firms.

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## Note

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<sup>1</sup> The African Regional Intellectual Property Organization ([www.aripo.org](http://www.aripo.org))

## Dynamics of technology, ICT and employment in India: Need for industrial policy in a knowledge driven economy

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India has been witnessing jobless growth, even during a period of high economic growth. While there are countries that have been witnessing labour shortages, India has an immense labour surplus. But what we see today is a historic high level of unemployment, with a low level of labour force participation rate. India also has the largest youth population in the world, with a high percentage of youth that are neither in education nor in employment. While the share of youth in education has increased in the last decade and a half, youth with higher levels of education would be seeking decent non-agricultural employment with higher wages. Thus, there is an imminent need for generating employment for mainly the following reasons. India's demographic window would be closing in the next decade and a half. India's median age of the population would be around 29 by 2021, just on the threshold of transition out of the youthful stage. Meanwhile, India is expected to surpass China in terms of population by 2027.

The need for an Industrial Policy for India is reiterated by the need to prepare for Industry 4.0, as the labour market and industrial production would be directly affected. The first sector to be impacted would be manufacturing. Manufacturing is essential for increased productivity, better opportunities for attaining economies of scale, and most importantly to embody and further technological progress and innovations. The backward and forward linkages of manufacturing with the rest of the economy may then be expected to gradually result in positive spill-over effects throughout other sectors. Productivity gains across sectors are fuelled by the spread effects of technological change. Mehrotra (2020) states that "the growth in services after manufacturing growth

is very different in nature – it is in research and development (R&D) and high-end services – while without manufacturing, they are in low-end and fragile services. This is because manufacturing provides a strong technological base in the country.”

The main objectives of this paper are thus: 1. To analyse the trends and patterns of capital stock, growth, returns to capital & gross capital formation in India; 2. To estimate the incremental capital-output ratio and employment elasticity with respect to capital investment; 3. Overview of firms in India based on the technological classification of the output; and 4. Trends and Patterns of ICT Investment in India across sectors, its inter-linkages with the economy, along with international trade in ICT goods from the perspective of self-sufficiency. This analysis pertains to a long-term trend since 1990s till the pre-pandemic phase (until 2017).

Capital formation in India and other related aspects are analysed using data from various sources such as Reserve Bank of India- KLEMS database, National Accounts Statistics, and unit-level data from the Annual Survey of Industries. The paper begins with an aggregate analysis of capital followed by sectoral analysis, which includes an aggregate view of the economy and capital stock and capital growth. This section also looks at the incremental capital-output ratio (ICOR) and employment elasticity with respect to capital. Section 2 discusses Capital Formation and its Constituents, along with savings and investment trends in the economy. Section 3 provides Firm-Level Analysis based on Technology intensity of output. Section 4 pertains to ICT investment across sectors and Firms, as a key technology parameter. Section 5 provides for the inter-linkages of ICT and Research & Development Sector (R&D) with respect to other sectors in the Indian economy. The final section discusses international trade in capital goods with special emphasis on ICT capital goods from the perspective of self-sufficiency.

With the advent of industry 4.0, it becomes imperative to have a relook at our industry from the perspective of changing technology and capital intensity. The sectors that have high-level capital efficiency should ideally be incorporating capital intensive mode of production, while sectors with low capital efficiency should be promoting a labour-intensive mode of production. Capital intensive mode of production may not be an efficient choice always. However, India has been indulging in the capital intensive mode of production, even though it is a labour surplus country. The outcome of such a mode of production has resulted in a scenario where returns to capital have been increasing over time, at the cost of decreasing return to labour. Also, there has been a skewed spread of capital across industries, which needs to be relooked in terms of employment. High capital intensive industries also at times provide for low employment elasticity.

Thus for employment generation, it is imperative to allocate capital to such

industries that generate the highest employment. We need a manufacturing policy that looks into the forward and backward inter-linkages of the economy and provides a policy that maximizes output growth along with employment generation. ICT investment is a crucial aspect of technology. While employment elasticity of ICT is very low, it has high capital efficiency. With the advent of Industry 4.0, ICT investment would be increasing, employment generation would be insignificant. Automation and Industry 4.0 may prove detrimental for many functional areas and would disrupt not only the industry but also the labour market. There would be a need for acquiring new skills and re-skilling in the light of technological change.

India should also aspire to be technologically self-reliant. There is high incidence of import in case of ICT goods, most of the import being used for consumption rather than capital goods. India could develop its competency along a wide range of ICT goods with varying level of R&D intensity, and make a holistic approach for not only reducing import but also promoting export of ICT goods. This would not only revive the manufacturing sector but would also be instrumental in employment generation along with reducing import dependency. India needs a comprehensive Industrial as well as Employment Policy focusing on generating employment, providing economies of scale, embodying technological progress and correspondingly upgrading human capabilities by skilling and re-skilling with changing technologies.

### **Technological interface in India**

The major concern is that, the percentage of an ageing population in India would be almost doubling in the intervening period of 2011-2036. India would start its journey being an ageing society. It is pertinent that India realizes its demographic dividend in the time that is available. Youth are increasingly preferring industry and services sector, moving out from agriculture. Industry and service sectors have higher productivity and higher incomes, which also translates to higher savings, thereby higher investment and higher economic growth. Industry 4.0 may increase the productivity of machines by automation and boost economic growth, but in the process displace labour. This becomes relevant because the new forms of jobs created by automation would require a different set of skills. In this context, a more detailed understanding of technological change and labour paradigms is required, especially in terms of preparedness of industry for such change.

Autor and Dorn (2013) argued that low-skill service jobs have been on the rise essentially due to 'preference of variety over-specialization', while falling cost of automating routine and codifiable job tasks were witnessed. According to them, this meant that local labour markets reallocated low-skill labour into service occupations (employment polarization), experienced earnings growth at the tails of the distribution (wage polarization), and received inflows of skilled

labour. Thus, the implications of technology for skilled as well as less-skilled workers are important to be seen, as the demand for jobs may shift to other sectors and/ or change in form.

Recent research also focuses on the expected challenges of automation on human capital in future, especially stressing on the need for identification of firms' strategies towards automation and corresponding labour demand as well as skills expected from labour. Preparedness of manufacturing in particular towards Industry 4.0 remains a significant issue (Ahmad et al, 2018). In fact, Industry 4.0 is also expected to create some technological unemployment, essentially by creating new structural changes and new forms of jobs, and the most affected would be unskilled labour and youth (Kurt, 2019).

Industry 4.0 is expected to directly impact the manufacturing sector initially, and through forward-backwards linkages within industries. Aspects such as new jobs based on information technology, training in technology, automation and digitization etc. will necessitate the need for youth in the labour force to adapt to new skills (Sima et al, 2020).

It has been documented that different countries are showing different responses in preparing for Industry 4.0. Kuo et al (2019) suggest that industrial economies such as the USA, Germany and China are focusing on demand-side policies coupled with public service policies and with emphasized focus on training. A PWC survey of manufacturing, engineering, electrical and ICT companies had also found that such companies generally expected increased levels of investment required to be prepared for Industry 4.0. The survey further found estimated that expected share of investments towards solutions for Industry 4.0 and automation could reach round as high as 50% of overall capita investments over the next few years, especially in case of industrial economies like Germany. This immediately raises questions on India's level of preparedness.

### **Need for an industrial policy for India**

In case of India, Mehrotra (2020) has argued that despite Indian GDP's steadily increasing growth rate over the decades post-Independence, the contribution of industry in GDP (including construction and utilities along with manufacturing) only reached 25% in 2017 from 8% in 1950, while that of manufacturing specifically was only 16%. Given the advent of Industry 4.0, the expected impact on the industry as well as labour market discussed above may well hit India harder in such a situation. This is why, as in the case of industrial economies like Germany and China as mentioned above, India needs to focus first on a manufacturing policy (Mehrotra, 2019 and Mehrotra, 2020) with special focus on capital investment shares as well as policies towards preparing for Industry 4.0.

Failing this, it may well be expected that deficiencies in capital markets and inadequate investments resulting in non-optimal performance and failure to achieve economies of scale, coupled with insufficient focus on firm-level investment in training towards new skills will only hamper manufacturing and by extension the other sectors of Indian economy further. This would also have a cascading effect on labour demand. To prepare for Industry 4.0 therefore, India will need to look at its investment patterns, capital and skill scenario, for which a comprehensive industrial policy would prove necessary (see Mehrotra, 2019).

### **Section 1: Trends and patterns of capital distribution across industries**

To initiate the analysis, an aggregate view of the economy and different aspects of capital are given with broad sectoral insights. This is to understand the demand side of the labour market and how it may ultimately impact labour through the KLEMS data, which makes use of National Accounts Statistics (NAS), Annual Survey of Industries and National Sample Surveys (NSS- for unorganised manufacturing) to give an overview of the economy.

#### **Capital stock across industries**

Figure 1 and 2 present capital stock within manufacturing and non-manufacturing industries. Within the manufacturing sector, Wood, Plastic, Paper and Electricals have been the industries with relatively low capital stock. On the other hand, Mining, Chemicals, Textiles, Food and Metals industry have had a higher combined capital stock. Non-Metals, Transport and Equipment and Petroleum were some of the industries belonging to the middle category based on total capital stock amongst manufacturing industries.

Within the non-manufacturing sector, the lowest share of capital stock is seen in the case of Hotels while the highest was in administration and other Non-classified services combined. Construction, Trade, Transport, Electricity and Business services have also had a relatively higher level of capital stock. These are also the sectors with a relatively higher share of non- agricultural employment.



## Capital stock at constant 2011-12 prices [Rs. 000'Crore]

**Figure 1: Manufacturing**

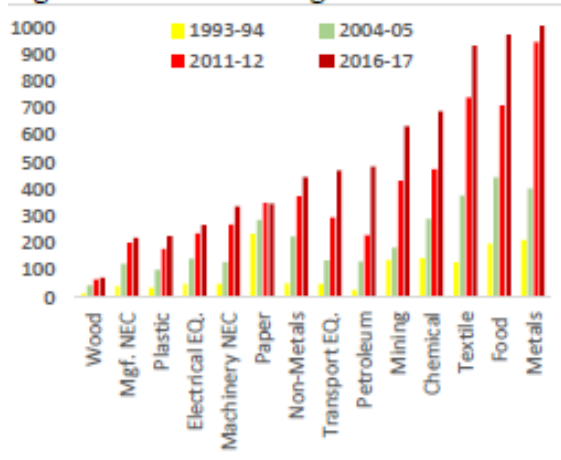
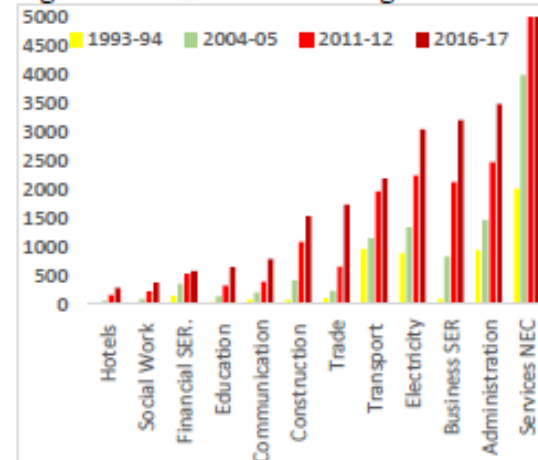


**Figure 2: Non-Manufacturing**



Source: Estimation from RBI-KLEMS data

There is a consistency across various time periods in the distribution of capital stock across different industries. The important aspect is that in most of the industries, capital accumulation has been robust in both the time periods from 1993-94 to 2004-05 and 2004-05 to 2016-17. While those industries with higher capital stock had a higher addition, those with lower capital stock had only a marginal increase. Thus, those industries that were already having a higher concentration of capital had a further addition. However, the phenomenon seen is concentration rather than diversification of capital across industries. If capital investment and accumulation are seen across a broad spectrum of industries in different sectors, it would also lead to higher product diversification and innovation.

### Changes in capital stock across industries

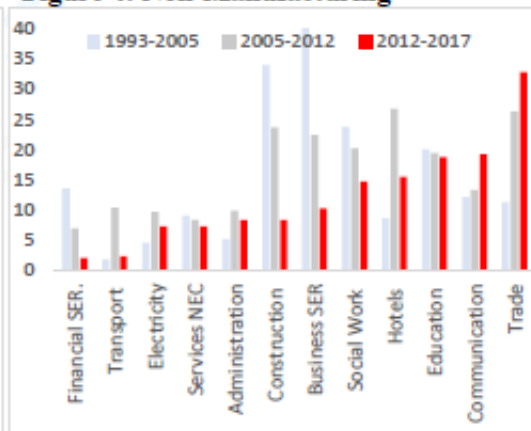
Figures 3 and 4 depict average percentage increment of capital stock for the time periods 1993- 2005, 2005-2012 and 2012-2017. In the period 1993-2005, Non-Metals, Petroleum, Construction, and Business Services showed a higher average annual percentage change in capital stock. In the period 2005-12, Metals, Mining, Construction, Business Services, Hotels and Trade showed a higher average annual percentage change in capital. In the last period, Mining, Transport Equipment, Petroleum, Communication and Trade showed higher average annual percentage change in capital stock.

## Average annual percentage change in capital stock

**Figure 3: Manufacturing**



**Figure 4: Non-Manufacturing**



Source: Estimation from RBI-KLEMS data

One of the important aspects here is that there was a higher annual percentage change in capital stock during 2005-12, but in the last period the average percentage of capital additions has come down. Increase in capital stock in terms of investment in capital goods or R&D is necessary for innovation and for product diversification as well as labour productivity. Many sectors such as Paper, Wood, Electrical equipment, Plastic and Food showed a consistently lower average annual change in capital stock in each of the successive periods. In the non-manufacturing sector, Construction, Business Services and Social work were some of the sectors which had been witnessing a successive decline in the average annual percentage change in capital stock.

### Incremental capital output ratio

The incremental capital-output ratio (ICOR) gives a representation of marginal investment that would generate another unit of output. Therefore, a lower ICOR would imply that production is more efficient. The aggregate ICOR of the economy, for manufacturing and services, are given in the following figures.

**Figure 5: ICOR of the Indian economy**

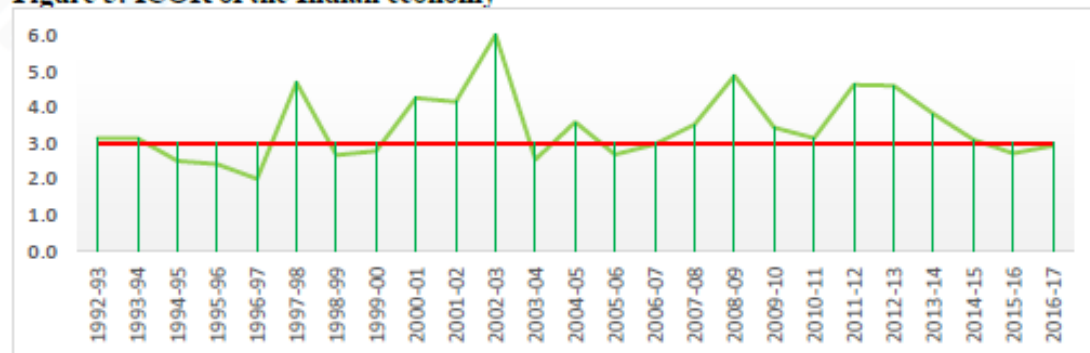


**Figure 6: ICOR- Services**

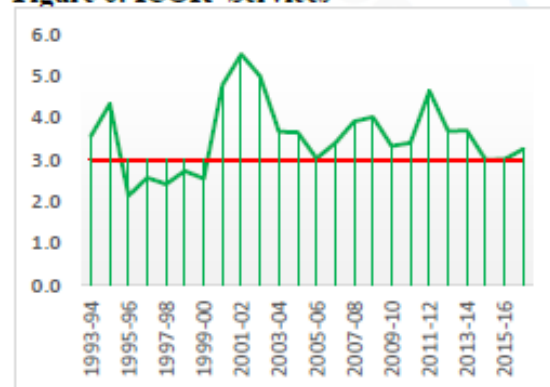
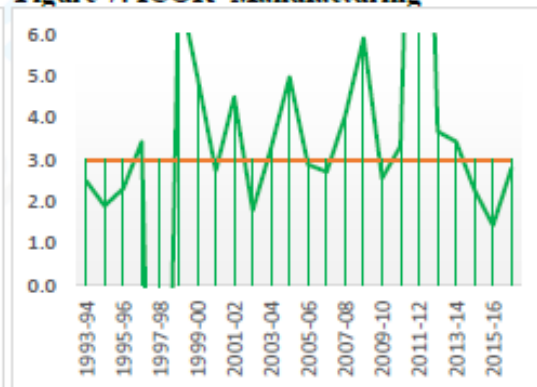


**Figure 7: ICOR- Manufacturing**



*Source: Estimation from RBI-KLEMS data*

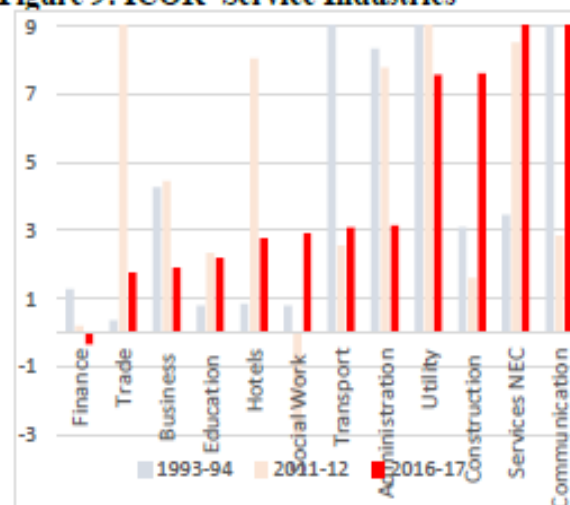
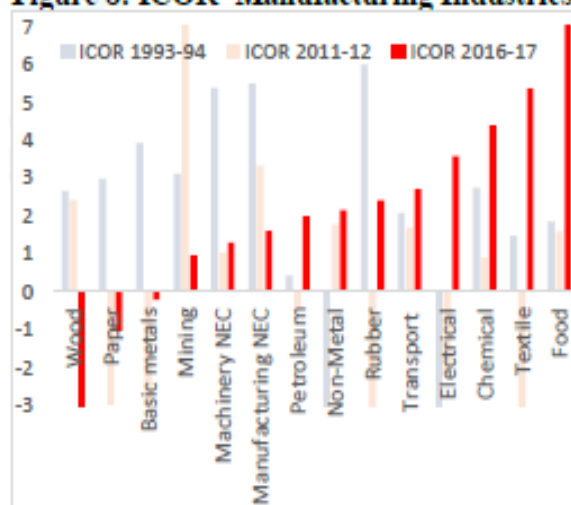
With respect to the Indian economy, ICOR has been showing cyclical trends. Although it has marginally gone down below 3 only during select few years, it has not substantially declined. ICOR had gone up to 6 in 2002-03, and was around 4 in 2008-09, 2011-12 and 2012-13. However, post that it has been around 3.

In case of ICOR for manufacturing, it was negative during 1997-98 and very high during 1998-99. It is also important to note another instance of extremely high ICOR in 2011-12. These outliers are exceptions. Post 2013-14, there was a decline in ICOR which came down below 3 but again came up to 3 in 2016-17.

In case of services, ICOR increased post 1999-00, which came back to 3 in 2005-06. However, it again started to increase gradually through with fluctuations, again coming back to 3 in 2013-14. It is important to note that the movement of services ICOR has been more stable than manufacturing ICOR.

Figures 8 and 9 plot the ICOR for different industries and sectors within manufacturing and services to give a much clearer picture

**Sectoral ICOR [Capital Constant 2011-12 & Value Added Constant 2011-12 Prices]**  
**Figure 8: ICOR- Manufacturing Industries**      **Figure 9: ICOR- Service Industries**



*Source: Estimation from RBI-KLEMS data*

Initially, there was a higher ICOR (1993-94) in manufacturing industries such as Rubber, Machinery, Basic Metals and Manufacturing. While there was higher ICOR (2011-12) in Mining, for most other industries there was a decline in ICOR, suggesting an improvement in production efficiency with respect to the marginal efficiency of capital. In the last phase, there has been an increase in ICOR (2016-17) for most of the manufacturing industries such as Rubber, Transport, Electrical, Chemical, Textile and Food. At the same time, there has also been an improvement in ICOR consistently for Mining, Machinery and manufacturing.

There have been mixed trends in ICOR for the non-manufacturing sector from 1993-94 to 2011-12 and 2016-17. In 1993-94, there was a high ICOR for Transport, Administration, Utilities and Services. In 2011-12, there was a high ICOR for Trade, Hotels Administration, Utilities and Construction. But in 2016-17, high ICOR was seen in Utilities, Construction Services and Communications.

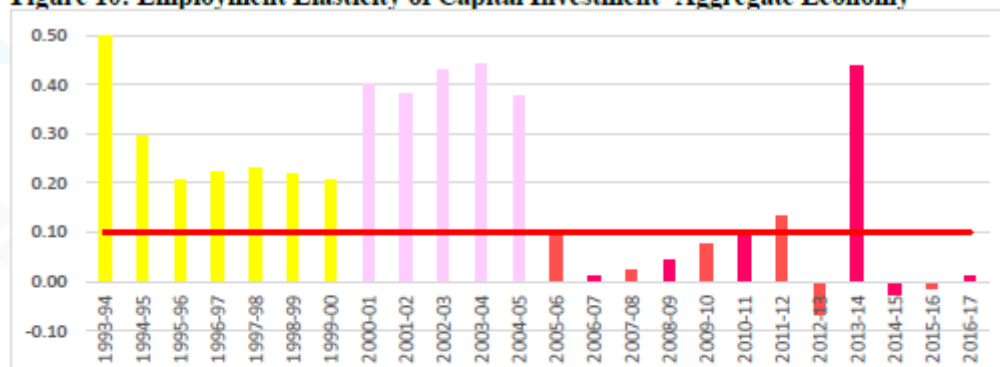
ICOR in essence is a representation of marginal investment required to generate another unit of output. This means that a lower ICOR would imply a more efficient production. Therefore, the high ICOR seen in Trade, Hotels and Restaurants, Utilities and Construction which are major employers, is a worrisome trend. The declining ICOR in mining and machinery is a positive trend with regard to productive efficiency.

### **Employment elasticity of capital investment**

Having looked at capital stock, returns to capital and ICOR for different industries in manufacturing as well as services, this section addresses the

important issue of employment elasticity of capital investment, in aggregate as well as for industries within manufacturing and services.

**Figure 10: Employment Elasticity of Capital Investment- Aggregate Economy**



**Employment Elasticity of Capital Investment**

**Figure 11: Manufacturing**

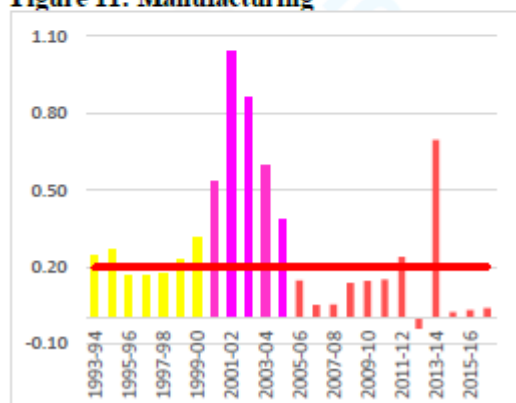
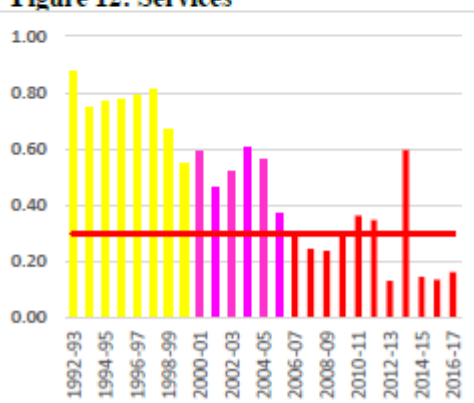


**Figure 12: Services**

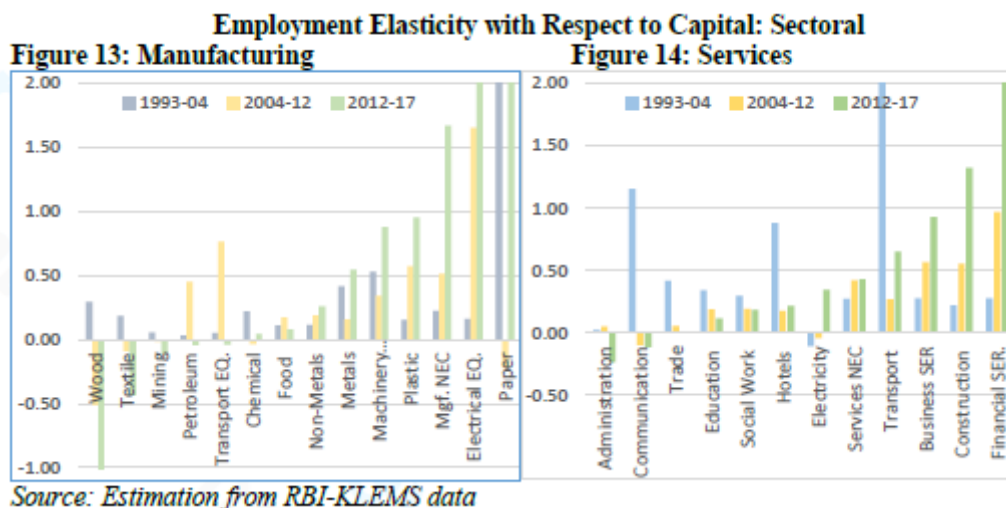


Source: Estimation from RBI-KLEMS data

In the overall economy (Figure 10), the period from 2000-01 to 2004-05 showed higher average employment elasticity. But in the period between 2005-06 and 2016-17, there has been very low employment elasticity with the exception of 2013-14, coming close to zero, which may even become negative with the current economic and global scenario.

Manufacturing sector had a lower employment elasticity even in the first phase from 1993-94 to 1999-00. But in the second period, there was high employment elasticity although for a very short duration. In the period after 2006-07 with the exception of 2013-14, employment elasticity has been very low.

The major feature for employment elasticity of services was that in the first phase (1992-93 to 1999-00) there was high employment elasticity with respect to capital. This was followed by a period of medium employment elasticity in 2000-01 to 2005-06. As expected, the employment elasticity in the last phase from 2006-07 has been low. Especially in the periods since 2014-15 employment elasticity of services with respect to capital has been extremely low.



Employment elasticity for manufacturing industries such as Textile, Mining, Petroleum, Transport Equipment, Chemicals, Food and Non-Metals remained low. There was an increase in employment elasticity in 2012-17 for Metals, Machinery, Plastic, Manufacturing, Electrical Equipment and Paper. There was negative employment elasticity in 2012-17 in case of Wood, Textile and Mining.

Within the non-manufacturing sector, there was higher employment elasticity in 1993-04 in case of Communications, Hotels and Transport industries, which declined in successive periods. Employment elasticity has increased for most of the non-manufacturing industries in 2012-17 as compared to 2004-12. There has been a consistent increase in employment elasticity for Business services, Constructions and Financial Services. There was negative employment elasticity for the period 2012-17 in Administration and Communications, and a declining employment elasticity in Education and Social Works and Hotels.

The abysmal trends in employment elasticity in manufacturing as well as non-manufacturing only go to further prove the fears of increasing unemployment in future with the advent of automation and Industry 4.0. High ICOR in general witnessed in the previous section also proves that the economy is less productive and efficient. Technology may be poised to improve productivity, which it also has the potential of impacting labour adversely.

## Section 2: Capital formation in Indian economy gross capital formation in the economy

This section tries to see the preparedness of Indian industry to face any exogenous shocks, (either positive or negative) and how it will ultimately impact labour demand. It is clear from Figures 15 and 16 that both Gross Capital Formation and Gross Fixed Capital Formation have been declining over time. Gross Capital Formation was relatively higher during the period of 2007-08 and 2012-13, even though it was the period just after the financial crisis. In the post-crisis period, having a higher Gross Capital Formation would have



helped the economy and would also have been a signalling effect that shows the positive sentiments of the market economy. But since 2012-13, there has been a declining trend although gradual.

**Figure 15: GCF as a percentage of GDP**

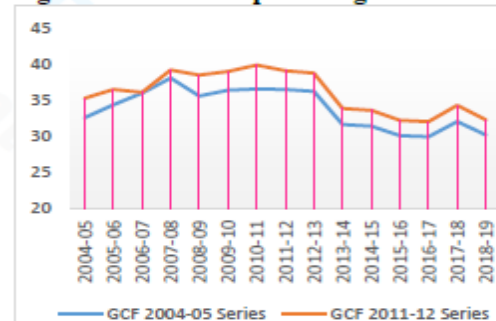
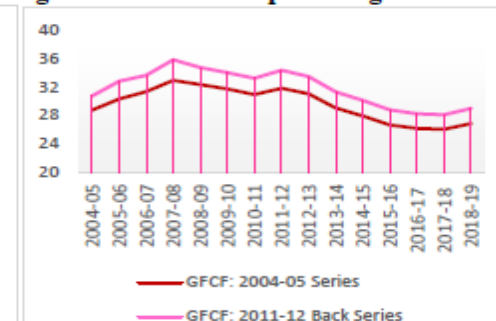


**Figure 16: GFCF as a percentage of GDP**



Note: GCF= Gross Capital Formation, GFCF= Gross Fixed Capital Formation  
Source: Author's estimation from CSO data

*In the post-COVID period, efforts may be needed to accelerate capital formation in the form of stimulant packages for economic recovery.* There is also a similar case with respect to Gross Fixed Capital Formation. Fixed capital investment during the recessionary period would be low due to weak demand, but on a positive note these times are also associated with lower market borrowing rates, cheap monetary policy, and by promoting investment there would be demand creation by way of multiplier effect (with a time lag).

### Composition of gross capital formation

For further analysis, we consider GFCF excluding dwelling, buildings and other fixed structure components, and exclusively taken up Machinery and Equipment, IPR and Bio Resources. There has been a declining trend in the percentage of Machinery and Equipment in GFCF (Table 1). While Bio Resources<sup>1</sup> remained constant, the percentage of Intellectual Property Rights has been increasing from 17% in 2011-12 to 21% in 2018-19.

**Table 1: Composition of GFCF**

| Year    | Machinery & Equipment | Bio Resources | IPR  |     |
|---------|-----------------------|---------------|------|-----|
| 2011-12 | 82.4                  | 0.6           | 17.0 | 100 |
| 2012-13 | 78.9                  | 0.5           | 20.6 | 100 |
| 2013-14 | 75.1                  | 0.5           | 24.4 | 100 |
| 2014-15 | 78.2                  | 0.5           | 21.3 | 100 |
| 2015-16 | 76.0                  | 0.5           | 23.5 | 100 |
| 2016-17 | 74.6                  | 0.5           | 24.9 | 100 |
| 2017-18 | 77.1                  | 0.5           | 22.4 | 100 |
| 2018-19 | 77.9                  | 0.5           | 21.6 | 100 |

Source: Estimation from CSO data

In recent years, there has been a significant change in the percentage share of Private NFC in the GFCF in Machinery & Equipment (Figure 17). The share of Private NFC in total GFCF Equipment did increase from 53% in 2011-12 to 60% in 2013-14 but again declined to 45% in 2018-19. This, in turn, has initially decreased the share of households' investment in Equipment and Machinery in total GFCF Equipment from 24% in 2011-12 to 13% in 2013-14, when Private NFC was increasing. In the period post-2013-14, there has been a steep rise in the percentage share of households in GFCF equipment from 13% in 2013-14 to 36% in 2018-19. Even though GFCF has been increasing over time, it has done so at a decreasing rate and unless the Private NFC GFCF picks up the momentum the overall GFCF cannot pick up.

### Gross fixed capital formation: Components

**Figure 17: Equipment**

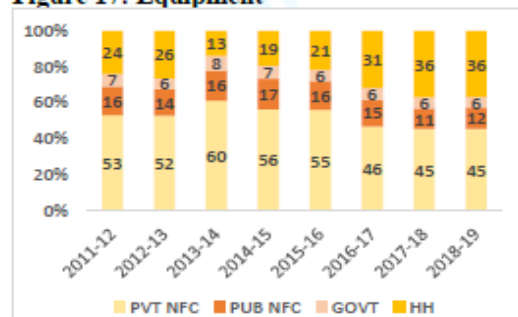
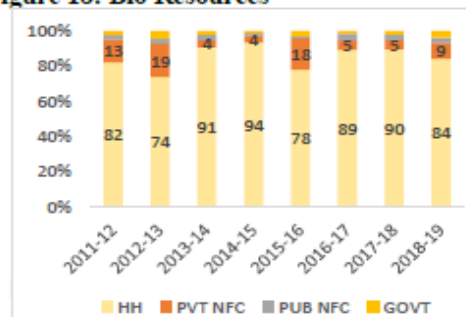


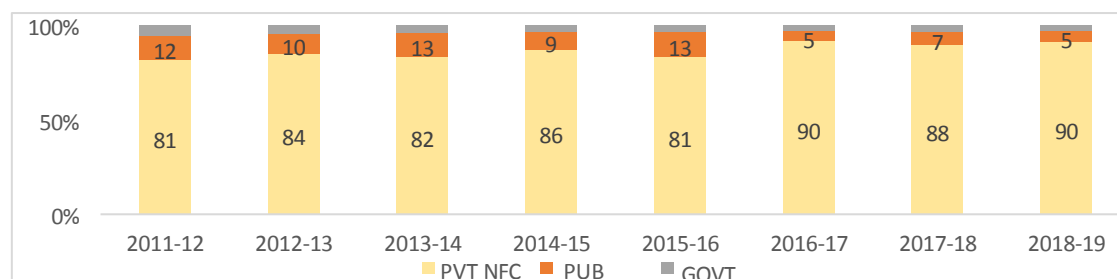
**Figure 18: Bio Resources**



*Note: Pvt= Private, PUB= Public, NFC=Non-Financial Corporations, HH= Households*  
*Source: Estimation from CSO data*

GFCF BioResources (Figure 18) is mainly invested by households as it mostly comes under agriculture. There are marginal GFCF BioResources that are taken up in the private sector. The government should be taking a proactive stand in spurring up GFCF of BioResources and should also create an ecosystem where there are research and development in Bioresources and harness the vast biological resources of India. Increasing GFCF will, by boosting industrial growth and output will increase employment in the long run.

**Figure 19: Gross fixed capital: IPR**



*Note: Pvt= Private, PUB= Public, NFC=Non-Financial Corporations*  
*Source: Estimation from CSO data*



GFCF in IPR has been dominated by private NFC, while the share of Public NFC has come down from 13% in 2015-16 to 6% in 2018-19. It is worth noting that government share in GFCF IPR was 5% in 2018-19. There is an imminent need to develop IPR investment culture in the public sector that has only a marginal share in GFCF in IPR currently. The government needs to have a dedicated IPR development policy so as to promote research and development. This is important if the industry is to be technology ready.

### Detailed analysis of investment in machinery and equipment

**Table 2:** Percentage Distribution of Investment in Equipment and Machinery across Industry: Public Sector

|         | AGR | MIN | MGF | UTL | CNS | THR | TSC | FIN | REP | PAD | * |     |
|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|-----|
| 2011-12 | 0   | 7   | 15  | 37  | 0   | 0   | 10  | 3   | 0   | 26  | 3 | 100 |
| 2012-13 | 0   | 6   | 14  | 36  | 1   | 0   | 11  | 3   | 0   | 25  | 3 | 100 |
| 2013-14 | 0   | 7   | 14  | 35  | 1   | 0   | 8   | 3   | 0   | 28  | 3 | 100 |
| 2014-15 | 0   | 4   | 14  | 41  | 0   | 0   | 8   | 3   | 0   | 26  | 3 | 100 |
| 2015-16 | 1   |     | 21  | 47  | 0   | 0   | 8   | 3   | 0   | 24  | 3 | 100 |
| 2016-17 | 0   | 3   | 16  | 40  | 0   | 0   | 9   | 2   | 0   | 26  | 3 | 100 |
| 2017-18 | 0   | 2   | 14  | 38  | 0   | 0   | 11  | 3   | 0   | 27  | 4 | 100 |

**Table 3:** Percentage Distribution of Investment in Equipment and Machinery across Industry: Private Sector

| AGR     |   | MIN | MGF | UTL | CNS | THR | TSC | FIN | REP | PAD | * |     |
|---------|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|-----|
| 2011-12 | 0 | 2   | 46  | 23  | 5   | 4   | 10  | 2   | 6   | 0   | 3 | 100 |
| 2012-13 | 0 | 2   | 50  | 19  | 3   | 5   | 9   | 2   | 6   | 0   | 3 | 100 |
| 2013-14 | 1 | 7   | 42  | 16  | 3   | 4   | 11  | 2   | 10  | 0   | 3 | 100 |
| 2014-15 | 1 | 1   | 53  | 13  | 3   | 5   | 9   | 2   | 11  | 0   | 3 | 100 |
| 2015-16 | 1 | 1   | 47  | 10  | 3   | 4   | 17  | 2   | 12  | 0   | 3 | 100 |
| 2016-17 | 0 | 0   | 47  | 13  | 2   | 5   | 9   | 2   | 17  | 0   | 4 | 100 |
| 2017-18 | 0 | 0   | 47  | 13  | 2   | 5   | 9   | 1   | 17  | 0   | 5 | 100 |

Note: AGR= Agriculture MIN= Mining MGF= Manufacturing UTL= Utilities CNS= Construction, THR=Trade Hotels & Restaurant TSC= Transport, Storage & Communication FIN= Financial Services REP= Real Estate & Professional Services PAD= Public Administration. \* Other Sector; Source: Estimation from CSO Data

The maximum investment in equipment and machinery by the public sector is undertaken in the Utilities sector (Table 2). Investment in the utilities sector has been more or less constant over recent years. In 2017-18, 38% of investment in equipment and machinery by the public sector has been in the utilities sector, followed by 27% in Public Administration and Defence Services (PAD), and 11% in Transport Storage and Communications (TSC).

*Private sector investment in equipment and machinery has been mostly concentrated in manufacturing and utilities industry (Table 3).* Percentage of investment in machinery and equipment in manufacturing has more or less remained at the same level since 2011-12 but increased in case of Real Estate, Business and Professional Services (REP), from 6% in 2011-12 to 17% in 2017-18. In 2011-12, 46% of machinery and equipment investment by the private sector was in the manufacturing industry and 23% in the utilities industry, and in 2017-18 it was 47% and 13% respectively.

Such abysmally low trends further stress on the need for investment in equipment as well as IPR (following section) to prepare the industry for exogenous shocks, at the same time helping in employment generation by increasing the number of enterprises by raising returns.

### Detailed analysis of investment in intellectual property rights (IPR)

**Table 4:** Percentage Distribution of Investment in IPR across Industry: Public Sector

| AGR     |   | MIN | MGF | UTL | CNS | THR | TSC | FIN | REP | PAD | * |     |
|---------|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|-----|
| 2011-12 | 0 | 65  | 2   | 2   | 0   | 0   | 0   | 0   | 0   | 29  | 1 | 100 |
| 2012-13 | 0 | 68  | 2   | 1   | 0   | 0   | 0   | 1   | 0   | 27  | 1 | 100 |
| 2013-14 | 0 | 74  | 1   | 2   | 0   | 0   | 0   | 1   | 0   | 21  | 1 | 100 |
| 2014-15 | 0 | 67  | 1   | 4   | 0   | 0   | 0   | 1   | 0   | 25  | 1 | 100 |
| 2015-16 | 0 | 78  | 1   | 3   | 1   | 0   | 0   | 0   | 0   | 17  | 1 | 100 |
| 2016-17 | 0 | 63  | 0   | 1   | 1   | 0   | 0   | 1   | 0   | 33  | 2 | 100 |
| 2017-18 | 0 | 59  | 1   | 5   | 2   | 0   | 1   | 1   | 0   | 30  | 1 | 100 |

**Table 5:** Percentage distribution of investment in IPR across industry: Private sector

| AGR     |   | MIN | MGF | UTL | CNS | THR | TSC | FIN | REP | PAD | * |     |
|---------|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|-----|
| 2011-12 | 0 | 1   | 35  | 5   | 15  | 2   | 15  | 1   | 18  | 0   | 7 | 100 |
| 2012-13 | 0 | 2   | 14  | 6   | 30  | 1   | 13  | 2   | 28  | 0   | 3 | 100 |
| 2013-14 | 0 | 1   | 15  | 5   | 10  | 1   | 45  | 1   | 18  | 0   | 3 | 100 |
| 2014-15 | 0 | 2   | 9   | 3   | 3   | 2   | 11  | 1   | 67  | 0   | 2 | 100 |
| 2015-16 | 0 | 1   | 22  | 4   | 3   | 4   | 15  | 3   | 42  | 0   | 7 | 100 |
| 2016-17 | 0 | 2   | 21  | 4   | 10  | 2   | 20  | 2   | 35  | 0   | 4 | 100 |
| 2017-18 | 0 | 2   | 21  | 4   | 10  | 2   | 20  | 2   | 35  | 0   | 4 | 100 |

Note: AGR= Agriculture MIN= Mining MGF= Manufacturing UTL= Utilities CNS= Construction, THR=Trade Hotels & Restaurant TSC= Transport, Storage & Communication FIN= Financial Services REP= Real Estate & Professional Services PAD= Public Administration. \* Other Sector; Source: Estimation from CSO Data

In the case of **Public Sector investment in IPR** (Table 4), highest investment has been undertaken in Mining followed by Public Administration and Defence. In 2011-12, 65% of total IPR investment was undertaken in Mining followed by 29% in

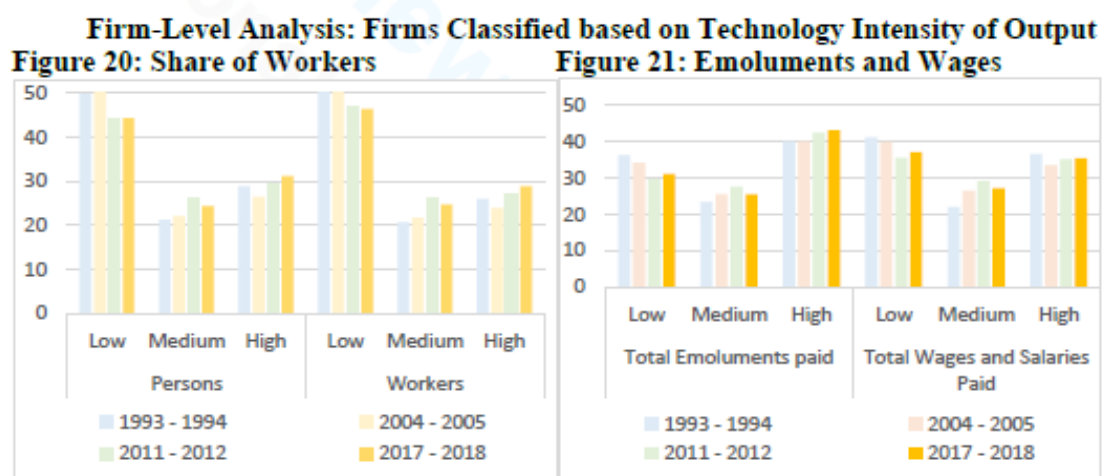
Public Administration and Defence. Percentage of IPR investment in Mining increased to 78% in 2015-16 but came down to 59% in 2017-18. At the same time, the percentage of IPR investment in Public Administration and Defence decreased to 17% in 2015-16 but increased to 30% in 2017-18.

In case of distribution of **private IPR investment** (Table 5), *manufacturing* industry constituted 35% of total private IPR investment in 2011-12, which declined to just 9% in 2014-15, but again increased to 22% in 2015-16 and was 21% in 2017-18. In 2011-12 percentage of IPR investment in Real Estate, Business and Financial Services was 18%, which increased to 35% in 2017-18.

As the saving rate in the economy is declining, which may be attributed to the declining income level, it would negatively impact capital formation on the economy. There is wide disparity in the extent of the capital formation across sector, with respect to both equipment and IPR, as well as by the source of investment, i.e. private as well as public. These disparities are need to be bridged and the extent of capital formation in manufacturing need to be emphasized and channeled so as to make it the driving force of the economy.

### Section 3: Firm-level analysis: Firms classified on technology intensity of output

This section further delves into the demand-side analysis of the labour market by looking at the firm-level. To begin with, using classifications based on Annual Survey of Industries (ASI) 2 digit concordance as per OECD, returns to capital and share of workers in industries are plotted based on their technology levels, which have been classified into Low, Medium and High Tech. **The classification of High Tech, Medium Tech, and Low Tech in India is based on OECD ISIC Rev.3 Classification.** *This in essence captures the labour demand in firms with different technology levels, to provide basic insights into how firms may react to Industry 4.0 in terms of labour demand in future.*



Source: Calculations using ASI unit-level data

**Share of Workers:** Share of persons employed in Low Tech firms declined from 51% in 2004-05 to 44% in 2017-18. In the Medium Tech firms, the share of persons employed was 24% in 2017- 18 declining marginally from 26% in 2011-12. High Tech firms were found to be employing 31% of the total persons engaged. In terms of distribution of workers across firms based on technological classification, it is seen that in 1993-94, 53% of the workers were engaged in Low Technology firms, which marginally decreased to 46% in 2017-18. Again, Medium technology firms employed 25% of the workers whereas High technology firms employed 29% of the workers. Low tech firms employ more persons and workers as compared to Medium and High tech firms.

**Emoluments and Wages:** In 2017-18, the share of low technology firms in total emoluments paid was 31% which had declined from 36% in 1993-94, while there was a marginal increase in medium technology firms' share from 23% in 1993-94 to 26% in 2017-18. In the case of high technology firms, it increased from 40% in 1993-94 to just 43% in 2017-18. Share of low technology firms in total wage and salaries paid was 37% in 2017-18, while it was 27% for medium tech firms and 36% for high tech firms.

**Figure 22: % of Factories by Tech Level**

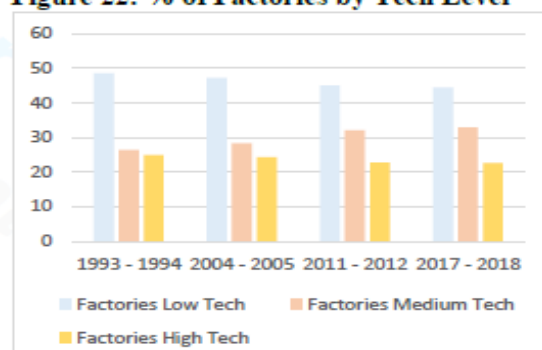
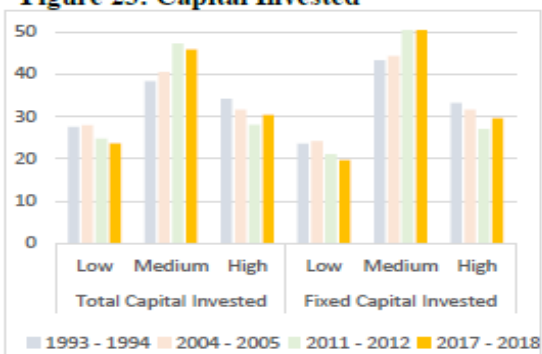


**Figure 23: Capital Invested**



Source: Calculations using ASI unit-level data

**Percentage of Factories by Tech Level:** The number of factories in firms with different levels of technology is shown in Figure 22. The percentage of low technology firms was 49% in 1993-94 which declined to 44% in 2017-18. Medium technology firms' share was 26% in 1993-94 which increased to 33% in 2017-18. The most important aspect is that the percentage of high technology firms was 25% in 1993-94 which marginally declined to 2017-18. There is a constant decline in the percentage of low technology firms while there was a marginal increase in the percentage of medium technology firms in the period from 1993-94 to 2017-18.

**Capital Invested:** In terms of total capital invested (Figure 23), low technology firms had 24% share, while the medium technology firms had a share of 46% and high technology firms had 30% share in 2017-18. There has been a significant increase in the percentage share of capital invested in the medium-tech firms from 38% in 1993-94 to 46% in 2017-18. Also, in terms of Fixed capital

Investment, the share of low technology firms was 20%, medium technology firms were 51%, and high technology firms was 30% in 2017-18.

**Figure 24: Gross Capital Formation**

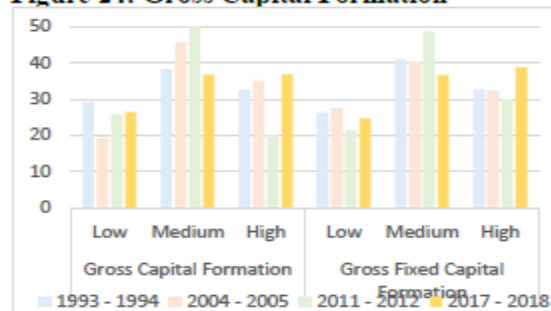
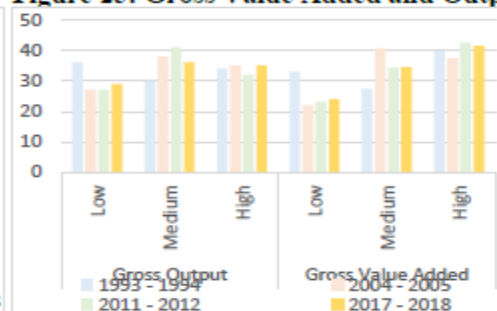


**Figure 25: Gross Value Added and Output**



Source: Calculations using ASI unit-level data

**Gross Capital Formation:** Low technology firms accounted for only 29% of the Gross Capital Formation in 1993-94 which declined marginally to 26% in 2011-12 (Figure 24). Medium and High technology firms had a share of 37% in 2017-18. It is to note that the Gross Value Added share for medium technology firms was 54% in 2011-12 and was 20% in the case of high technology firms. Share of Gross Fixed Capital Formation in 2017-18 was 25% for low tech firms, 37% for medium technology firms and 39% for high technology firms. In 2011-12, the share of Gross Fixed Capital Formation for medium technology firms was 49% while for high technology firms it was 30%.

**Gross Value Added:** In terms of gross output produced (Figure 25) Low tech firms used to produce 36% of total gross output which declined to 29% in 2017-18. Medium tech firms produced 36% of gross output in 2017-18 and High tech firms produced 35% of gross output in 2017-18. But in terms of Gross Value Added, High tech firms' share was 41% in 2017-18 given that it was 40% in 1993-94. Similarly, the share of low tech firms in Gross Value Added was 24% in 2017-18 which declined from 33% in 1993-94. In the Medium tech firms, share in Gross Value Added was 27% in 1993-94 which increased to 34% in 2017-18.

Firm-level analysis by technology classification highlights the following points. Most of the capital invested is in medium-tech firms contrary to belief. There is indeed concentration of low tech firms in India but they are decreasing and there has been a very gradual but definite rise in medium-tech firms. This suggests that a gradual progression from low to high tech firms is possible and middle tech firms are filling the void. Interestingly, medium-tech firms do not seem to create employment as much as high tech firms, which is again contrary to the belief that high tech firms employ less labour. However, India's aspirations of becoming a tech superpower may not come to fruition, as high tech firms are not growing.

## Section 4: Information and communication technology (ICT)

From all the above analyses, it is clear that the situation of Indian industry (manufacturing as well as services) seems to be lagging far behind and although India's role in IT is undoubtedly important, its future and its impact on the labour demand (for the aggregate economy but especially in Technology Domain) will be decided by how India responds to Industry 4.0. Following from the above discussion, this paper henceforth focuses on ICT in particular.

**ICT Investment in Industry [Amount in Rs Lakh Crore at 2011-12 Prices]**  
**Figure 26: Aggregate Total**

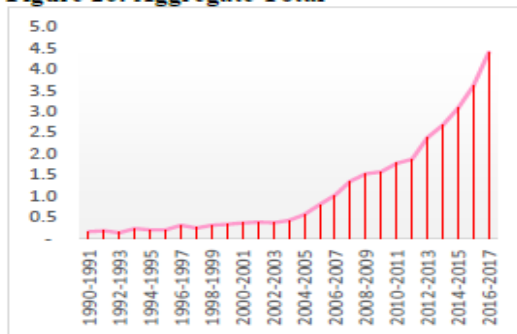


**Figure 27: Aggregate Annual**

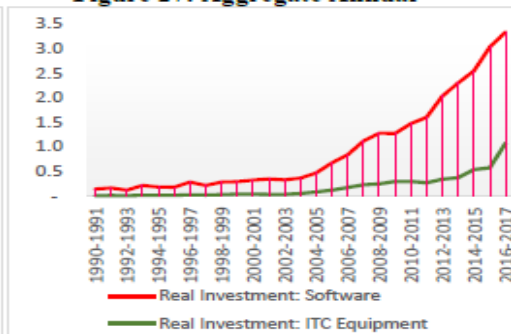
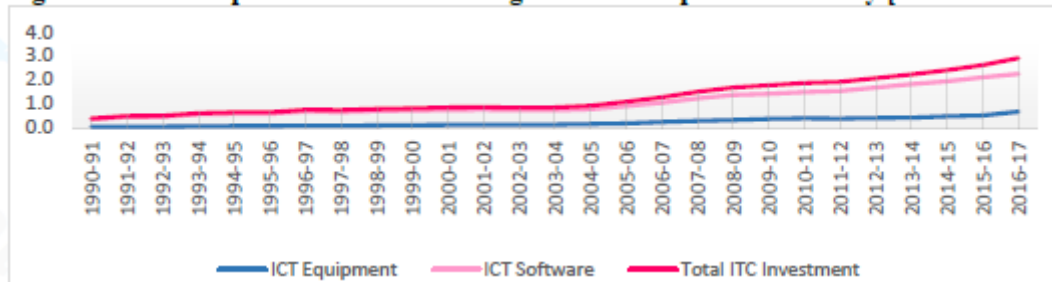


**Figure 28: ITC Capital Stock as Percentage of Total Capital in Industry [2011-12 Prices]**

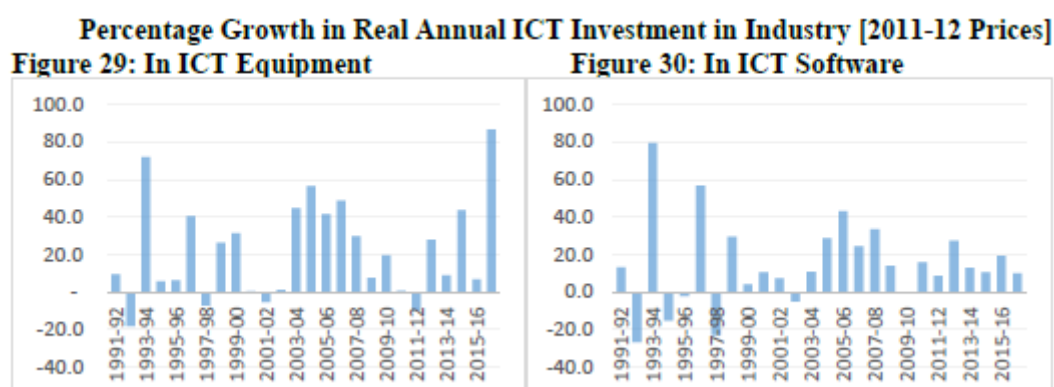


Source: Estimations using RBI-KLEMS data

aggregate ICT investment in the industry remained almost at a flat curve with negligible increment until 2004 (Figure 26), the period from 2004-05 to 2011-12 being a period of moderate ICT investment, while in the period from 2011-12 onwards a high growth in investment is witnessed. Thus there are two structural breaks in terms of aggregate total ICT investment in Indian industry at constant 2011-12 prices.

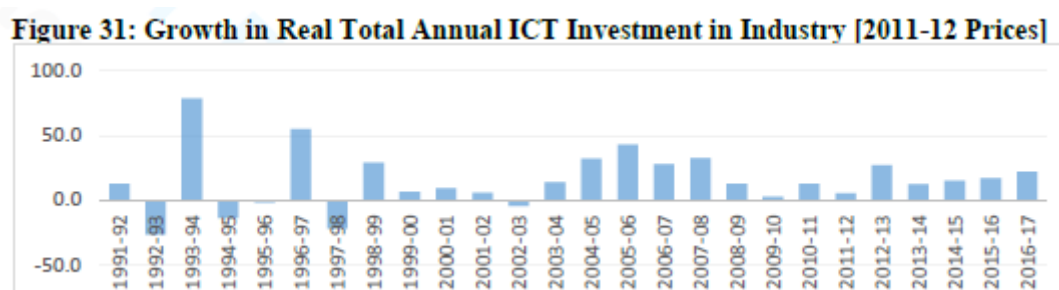
When it comes to annual ICT investment in the industry, investment in software exceeds that of hardware (Figure 27). Again, a structural break is seen in 2004-05, and a second structural break in 2011-12, with moderate, medium and high investment in software respectively. When it comes to annual investment in hardware, the period before 2004-05 witnessed negligible annual investment in ICT equipment. The annual investment in equipment increased to more than 1 lakh crore only in 2015-16, a level of investment which already existed for software way back in 2006-07.

Further, in Figure 28, ICT capital stock has been presented as a percentage of total capital stock. Even by 2016-17, the capital stock of ITC equipment was less than 1 percent of total capital stock in the industry. Since the majority of the investment is made in software, there is not much difference between total ICT capital and ICT software capital. In 2004-05 total ICT capital stock increased to more than 1% and by 2016-17 it increased to nearly 3%. The software capital stock was 2.25% of the total capital stock in the industry in 2016-17. Thus it is seen that there is *limited investment in ICT, especially in equipment* as a percentage of total capital stock which must be increased so as to prepare for the fourth industrial revolution.



Source: Estimations using RBI-KLEMS data

Annual growth in investment in Industry was not consistent (Figures 29 and 30), with high fluctuations and some years even recording negative growth. On an average, the period of 2003-04 to 2007-08 had a high level of growth in ICT Equipment investment, but after 2008-09 annual growth seems to have become cyclical in nature. Although the average investment in software is very high as compared to average investment in ITC equipment, the average growth rate of software investment has been low but consistent since 2004-05 onwards. In the earlier period between 1991-92 and 2003-04, software investment growth rate varied to a large extent and was cyclical. From 2010-11, the annual growth rate of software investment has been more than 10%.



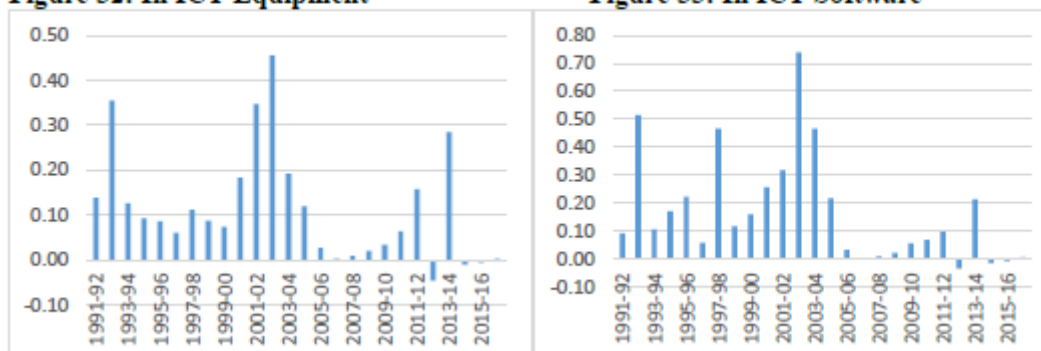
Source: Estimations using RBI-KLEMS data

Similar to software investment growth, the total ICT investment has been cyclical in the earlier period until 2003-04 (Figure 31). While in the period after



2003-04 annual ICT investment was high until 2007-08, the recession period of 2008-09 to 2011-12 also had a positive annual investment growth but to a lesser extent than the previous period. Growth has been consistently increasing since 2013-14 and crossed 20% in 2016-17.

**Employment Elasticity of Real Annual ICT Capital in Industry [2011-12 Prices]**  
**Figure 32: In ICT Equipment** **Figure 33: In ICT Software**

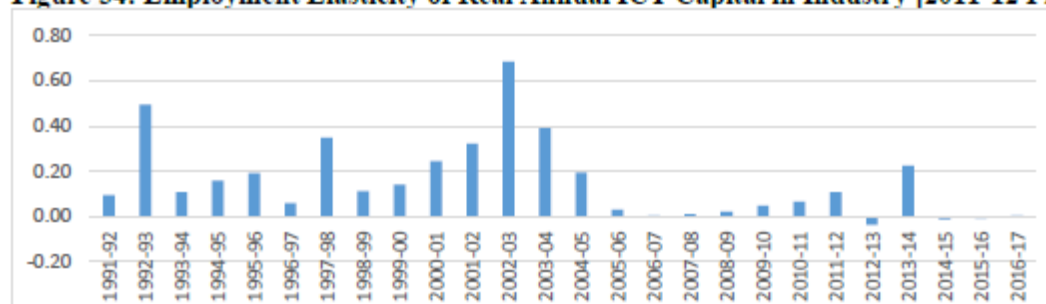


Source: Estimations using RBI-KLEMS data

The *employment elasticity with respect to annual investment in ICT equipment was for most of the years less than 0.10* (Figure 32). It is seen that employment elasticity was high during the 2000-01 and 2004-05 phase, while in the post-2004-05 phase, with the exception of 2011-12 and 2013-14 it was nearly zero. In the later periods, there has been negligible or negative employment elasticity. Thus in the earlier period even though the investment in ITC equipment was low as discussed earlier, but it was associated with high employment elasticity. But in the second phase after 2004-05 even though there was higher ICT equipment investment it was associated with lower employment elasticity.

In the first phase employment elasticity with respect to annual investment in ICT software was moderately increasing and fluctuating till 1997-98 (Figure 33). Since 1998-99 it was increasing at a very high rate until 2004-05. In the period from 2005-06 onwards with the exception of 2013-14, the employment elasticity was almost zero and in the recent years, it became negative. *As it is usually believed that with the addition of technology and automation there would be complimentary employment growth too, that has not been seen.*

**Figure 34: Employment Elasticity of Real Annual ICT Capital in Industry [2011-12 Prices]**

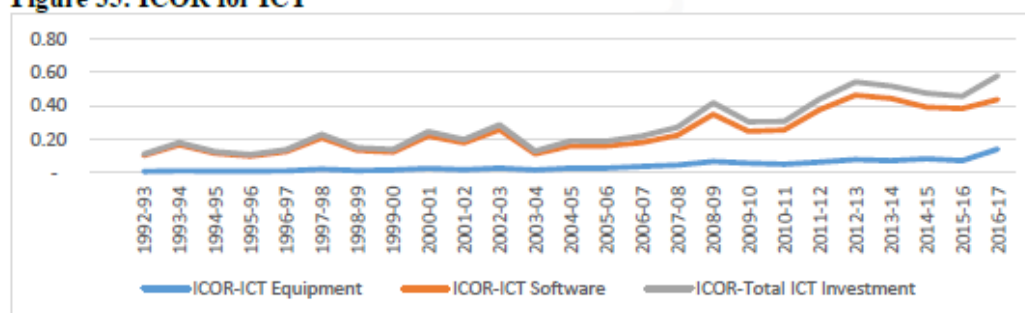


Source: Estimations using RBI-KLEMS data



Employment elasticity prior to 2004-05 was high, but in the period from 2005-06 to 2016-17 employment elasticity was nearly zero for most of the years (Figure 34). The highest elasticity was seen in 2002-03, and earlier in 1992-93. In the period since 2005-06 highest elasticity was seen in the year 2013-14, which was 0.22. Since 2014-15, employment elasticity was marginally negative or zero, which is worrisome.

**Figure 35: ICOR for ICT**



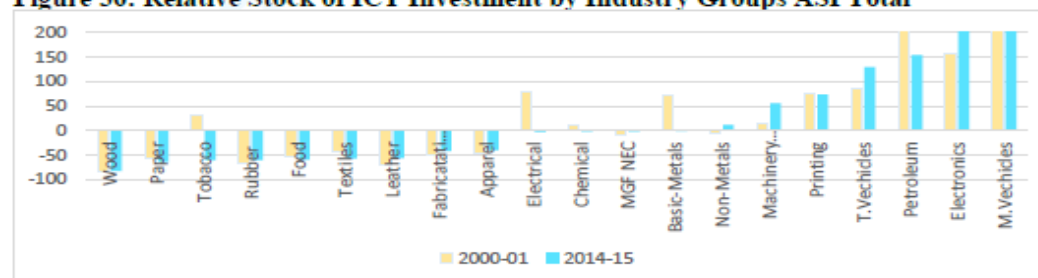
*Note: ICOR= Incremental Capital-Output Ratio; Source: Estimations using RBI-KLEMS data*

ICOR with respect to Investment in ICT and Output has been increasing, thereby suggesting that the marginal efficiency of investment of Capital has been decreasing (Figure 35). But the ICOR is still below one (at constant 2011 Prices), which signifies high efficiency of ICT investment. But the bottom line is that the investment in ICT with respect to total capital investment is extremely low, and the drawback of ICOR is that it just shows the efficiency but does not enable us to infer that to what extent production increase has been due to specifically due ICT Investment. But one positive aspect is that as ICOR is extremely low, it would enable high- efficiency gains with the addition of ICT investment.

## Sector Analysis/ Firm-level analysis of investment of ICT

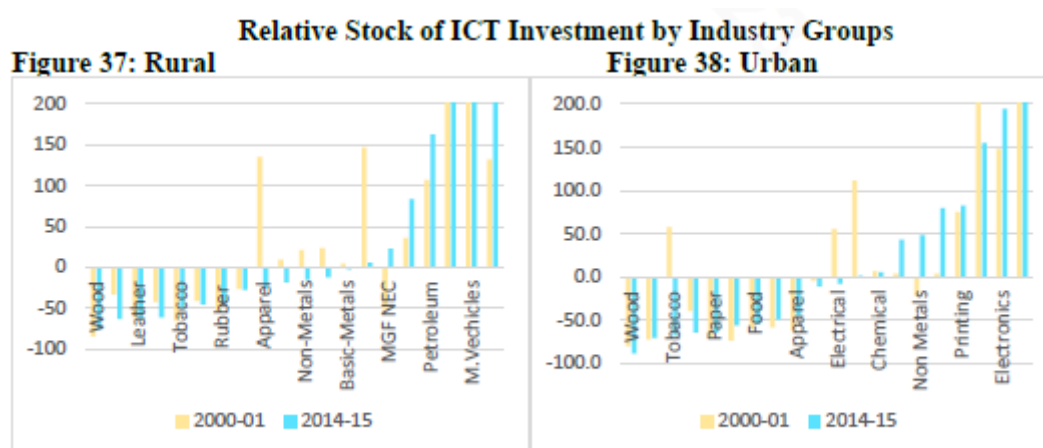
It is evident from previous analysis that average level of ICT investment differs across industries. The following section presents relative level of ICT capital stock with reference to average ICT capital across all industries. In essence, the ICT investment stock in industry is analysed below

**Figure 36: Relative Stock of ICT Investment by Industry Groups ASI Total**



*Source: Estimations using ASI unit-level data*

As per Figure 36, Wood, Paper, Tobacco, Rubber, Food, Textiles, Leather, Fabrication, and Apparels are the industries that have ICT capital stock below the overall industry average of ICT capital stock. On the other hand, industries such as Electricals, Chemicals, Other Manufacturing, Basic Metals and Non-Metals that have the same level of ICT investment as that of overall ICT investment across all industry groups. Also, Machinery, Industry, Transport Vehicles, Motor Vehicles, Petroleum and Electronics are the sectors that have a very high level of ICT Investment. As per ASI 2014-15 data, the ICT capital stock in Electronics and Motor Vehicles is around 270% higher than the average level of ICT capital stock of Industry (combined).



In **rural enterprises** as per ASI 2014-15 (Figure 37), most of the industries were having ICT capital stock below the average, and most of the ICT capital stock was in select industries such as Transport Vehicles, Motor Vehicles, Petroleum and Electronics, all of which had around 250% more ICT investment than the average of all the industries combined. Industries such as Wood, Paper, Leather, Food, Tobacco, Textiles, Rubber, Fabrication, and Apparels have substantially below the average stock of capital. It is also seen that in 2001 Apparels industry was having nearly 150% of the average ICT capital of all industries combined, while in 2014-05 the apparels industry has less than the average stock of capital.

In the **urban industries** (Figure 38), there are a larger number of industries having ICT investment higher than average level of ICT stock. Industries such as Wood, Rubber Plastics, Tobacco, Paper, Leather, Food, Fabrication and Apparels were having a stock of ICT capital below that of average ICT capital stock of all the industries combined. Industries which had a significantly higher level of ICT capital stock included Petroleum, Electronics and Motor Vehicles, while other industries such as Machinery Non-Metals, Transport Vehicles and Printing also had a higher level of average ICT capital.

It is seen that Electricals industry had a significant decline in relative annual

ICT investment between 2000-01 and 2014-15 (Figure 39). Relative annual investment in 2001 was low for Basic Metal, Petroleum and Electronics, while in 2014-15 it was just around the average for Basic Metals and higher than average for Petroleum. As per ASI 2014-15, Printing, Petroleum, Transport Vehicles and Motor Vehicles had a higher level of annual investment than the average level. On the other hand, Electronics, Paper, Wood, Textiles, Leather, Tobacco, Rubber, Plastic, Fabrications, Apparels and Food were having a lower than average annual ICT investment.

**Figure 39: Relative level of Annual Investment in ICT by Industry Groups ASI Total**

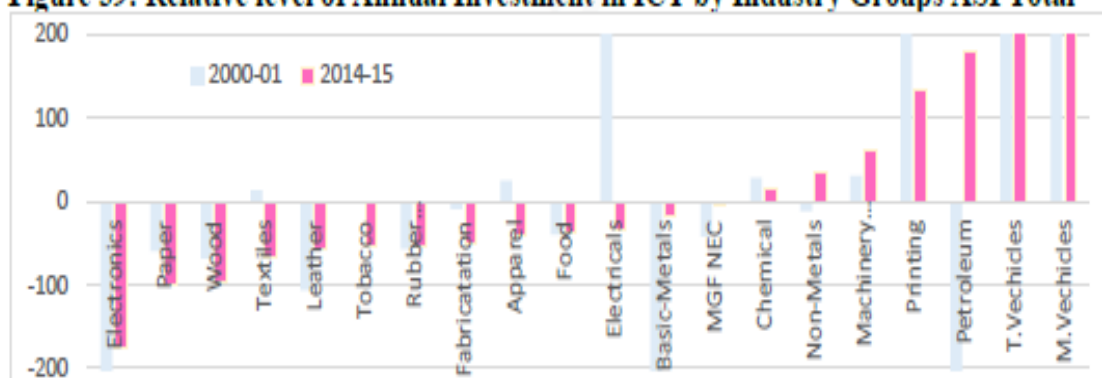
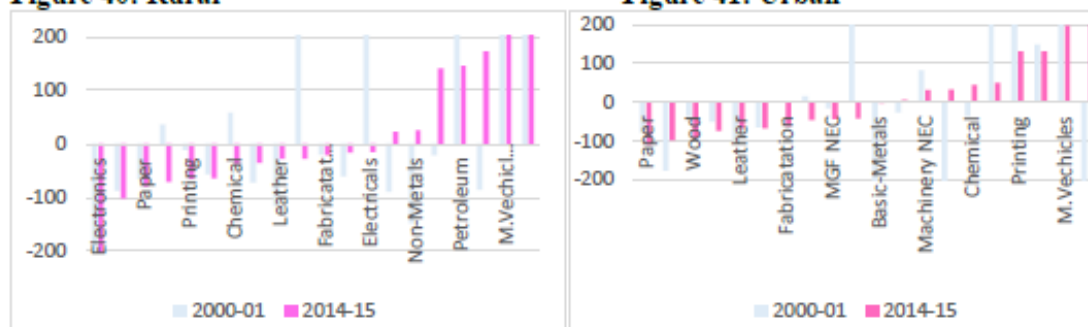


**Figure 40: Rural** **Figure 41: Urban**



*Source: Estimations using ASI unit-level data*

In the **rural** areas (Figure 40) most of the industries have a lower annual investment than the average ICT investment except for select industries such as Machinery, Petroleum, Manufacturing, Motor Vehicles and Transport Vehicles. As per ASI 2014-15, the Electronics sector had the least relative investment in ICT. Also, Apparels industry and Electrical industry had a higher level of relative annual investment in ICT in 2000-01, but in 2014-15, it was just around the average level of ICT investment. Industries such as Tobacco and Non-Metals were having lower than average investment in ICT in 2000-01, while in 2014-15 they were having a higher than the average level of investment in ICT.

On the other hand, relative annual investment in ICT for **urban** enterprises (Figure 41) of more than 100% of the average was seen in case of Printing, Transport Vehicles, Motor Vehicles and Petroleum as per ASI 2014-15. Also, the

annual investment in ICT for Paper and Tobacco was less than half of the average. It was also seen that Petroleum, Basic Metals and Electricals had more had a significantly lower level of ICT investment in 2000-01, but as per ASI 2014-15, ICT investment was highest in case of Petroleum, and just average in case of Basic Metals, and marginally higher for Electronics.

The ICT investment in India has only picked up in the period after 2004-05. The majority of the ICT investment is driven on the software front while the investment in hardware's remains muted with respect to the software's. Given the comparatively low level of ICT investment, the incremental output with respect to a unit increase in ICT investment remains very high, but given the capital intensive mode of production, the employment elasticity is very low. Above all, ICT investment remains concentrated in the select sectors that are also highly capital intensive.

## **Section 5: Inter-Linkages of ICT sector and R&D sector to economy**

This section analyses the forward and backward linkages of ICT and R&D with other sectors and vice versa. This is especially relevant at the current juncture, because given the advent of Industry 4.0 the role of ICT and R&D will be very significant. IT is pertinent as when the economy would grow, industries would also grow, along with employment and demand for labour will also grow. ICT and R&D industry growth will have a positive impact on other industries with respect to output. Increased use of ICT and R&D, there would be productivity gain across industries, raising investible resources and potential for firms to grow and expand, thus generating jobs as they grow and expand. *Input and Output Tables of the Economy have been used so as to understand the forward and backward inter-linkages, and key sectors with highest inter-linkages have been presented.*

### **Input-Output leontief inverse: Forward inter-linkages**

Leontief Inverse Input-Output analysis helps in estimating how one successive unit increase in production of ICT and R&D entail a higher production in successive rounds in another sector. A unit increase in ICT production (Table 6) would have 1.1 unit increase in production for successive rounds. The industries with highest forward inter-linkages were *Paper, Printing & Publishing, Machinery & Equipment, NEC, Textiles, Leather & Footwear, Other Transport Equipment, Fabricated Metal Products, Electrical Machinery & Apparatus, NEC, and R&D & Business Activities*. These are some of the industries that are expected to higher output growth, with the increase in the ICT sector. It is expected that there would be higher growth in ICT industry over time with the advent of Industry 4.0, under these circumstances; industries with higher inter-linkages with ICT would be witnessing higher output, productivity gain and higher employment.

**Table 6: ICT Spillovers to other sectors (Forward Linkages) in India**

|                                       | ICT 2011 |
|---------------------------------------|----------|
| Computer & Related Activities         | 1.1      |
| Paper, Printing & Publishing          | 0.043    |
| Machinery & Equipment, NEC            | 0.036    |
| Textiles, Leather & Footwear          | 0.029    |
| Other Transport Equipment             | 0.032    |
| Fabricated Metal Products             | 0.046    |
| Electrical Machinery & Apparatus, NEC | 0.036    |
| R&D & Business Activities             | 0.014    |
| Manufacturing NEC; Recycling          | 0.032    |
| Computer, & Electronic Equipment      | 0.026    |
| Chemicals & Chemical Products         | 0.018    |
| Rubber & Plastics Products            | 0.018    |
| Motor Vehicles & Trailers             | 0.021    |
| Wood & Products Of Wood               | 0.018    |
| Community, Social & Personal Services | 0.007    |
| Food Products, Beverages & Tobacco    | 0.018    |
| Transport & Storage                   | 0.011    |
| Public Administration & Defence       | 0.008    |

*Source: Calculations using OECD data*

Similarly, if the R&D sector were increasing it would lead to 1.17 unit increase in output of the R&D sector in the successive round. Other industries with positive forward inter-linkages were *Community, Social & Personal Services, ICT Computer & Related Activities, Transport & Storage, Machinery & Equipment, NEC, and Computer & Electronic Equipment* are some of the sectors with highest positive inter-linkages with R&D sector.

**Table 7: R&D Spill-over to other industries (Forward Linkages)**

|                                       | R&D 2011 |
|---------------------------------------|----------|
| R&D & Business Activities             | 1.174    |
| Community, Social & Personal Services | 0.041    |
| ICT Computer & Related Activities     | 0.044    |
| Transport & Storage                   | 0.034    |
| Machinery & Equipment, NEC            | 0.042    |
| Computer & Electronic Equipment       | 0.035    |
| Textiles, Leather & Footwear          | 0.03     |
| Manufacturing NEC; Recycling          | 0.053    |
| Motor Vehicles & Trailers             | 0.027    |
| Electrical Machinery & Apparatus, NEC | 0.025    |

*Source: Calculations using OECD data*

### **Input-Output Leontief inverse: Backward inter-linkages**

In the backward inter-linkages, the output growth of other sectors would in

turn positively affect the output growth of ICT and R& D sector. In Table 8, how 1 unit of output increment in sectors would positively impact the ICT industry has been mapped. The highest backward inter-linkages of ICT sector is with the financial intermediation, one unit of output increment in Financial Intermediation would have 0.04 unit increase in the output of ICT industry. Other industries having a significant impact on the ICT industry were *Construction, Basic Metals, Computer & Electronic Equipment, Wholesale & Retail Trade; Repairs, Hotels & Restaurants, Transport & Storage and R&D & Other Business Activities*.

**Table 8:** Other Industries' Growth in Output Spill-over to ICT (Backward Linkages)

|                                   | ICT 2011 |
|-----------------------------------|----------|
| Financial Intermediation          | 0.04     |
| Construction                      | 0.03     |
| Basic Metals                      | 0.01     |
| Computer & Electronic Equipment   | 0.01     |
| Wholesale & Retail Trade; Repairs | 0.02     |
| Hotels & Restaurants              | 0.02     |
| Transport & Storage               | 0.02     |
| R&D & Other Business Activities   | 0.04     |

**Table 9:** Other Industries' Growth in Output Spill-over to R&D (Backward Linkages)

|                                   | R&D 2011 |
|-----------------------------------|----------|
| Construction                      | 0.04     |
| Financial Intermediation          | 0.06     |
| Computer & Electronic Equipment   | 0.04     |
| Wholesale & Retail Trade          | 0.05     |
| Transport & Storage               | 0.04     |
| Basic Metals                      | 0.03     |
| Coke & Refined Petroleum Products | 0.03     |
| Motor Vehicles & Trailers         | 0.01     |
| Electricity, Gas & Water Supply   | 0.04     |
| Hotels & Restaurants              | 0.07     |
| Post & Telecommunications         | 0.03     |
| Mining & Quarrying                | 0.03     |
| Chemicals & Chemical Products     | 0.02     |
| ICT Computer & Related Activities | 0.01     |

*Source: Calculations using OECD data*

Similarly, in Table 9, R&D backward inter-linkages has been presented. The higher output in the following industry would positively impact the R&D sector. Some of the key sectors having positive association with R&D sectors

were *Construction, Financial Intermediation, Computer & Electronic Equipment, Wholesale & Retail Trade, Transport & Storage and Basic Metals*.

The forward and backward linkages, as well as spill-over effects, suggest that with automation and Industry 4.0, the role of ICT and R&D will impact as well as be impacted by the above-mentioned industries, which in turn will impact labour demand in these industries. We have to develop ICT and R&D sector so as to make the best use of Industry 4.0. It is essential that major thrust is laid on the sectors that have the highest backward and forward inter-linkages. With the increase in output, these sectors are also expected to generate employment. Thus it is necessary to have a manufacturing policy in the backdrop of Industry 4.0 along with an employment policy and a vision encompassing backwards and forward inter-linkages.

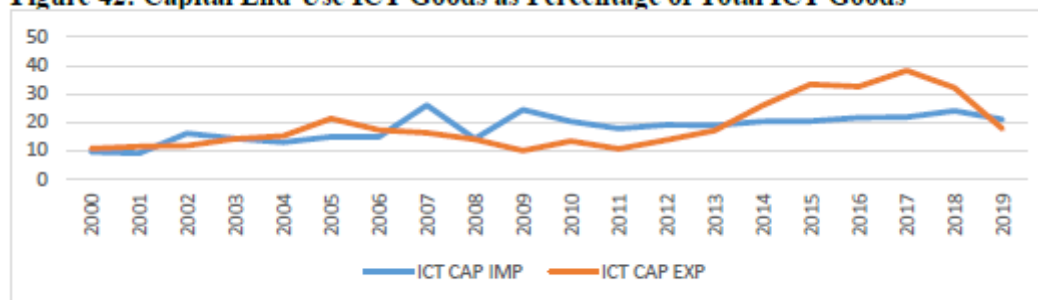
### **Section 6: ICT technology and international trade by India**

In the above sections, capital investment, especially ICT investment has been discussed in greater detail. It is also expected that in the coming years, the demand for ICT goods would be increasing, given the impending Industry 4.0. ICT goods are required for both consumptions as well as an investment as capital goods. From the perspective of self-sufficiency, it is necessary that India should be self-sufficient to some degree in ICT consumption goods such as Computers, Communication and Electronics. These goods demand are by individuals, households as well as by firms. Also, as the economy grows the demand for ICT goods would also be growing. With the advent of automation in the backdrop of industry 4.0, the ICT demand is expected to rise; India needs to be self-reliant in domestic ICT production.

Augmenting domestic production in these segments would not only give a boost to the manufacturing sector, but also be instrumental in generating employment. The demand for ICT goods exists in India, and India has been resorting to importing in order to meet the demand. So under these circumstances, domestic production can be encouraged to meet domestic demand. If goods imported are capital goods then it would only add to capital growth and augment domestic production capacity.

In the section below, ICT export and Import by India has been divided into capital goods and consumption goods using OECD data in order to understand the preparedness of India for Industry 4.0. For India to prepare for Industry 4.0, it needs to shoot up its domestic production of ICT goods so as not only be self-reliant in meeting domestic demand but also be a leading exporter of ICT goods. Both import and export of ICT goods has been divided into end-use, consumption demand or used as capital goods.

**Figure 42: Capital End-Use ICT Goods as Percentage of Total ICT Goods**



*Source: Calculations using OECD data*

Percentage of Capital ICT goods export out of total ICT goods export and percentage of Capital ITC goods import out of total ITC goods import has been presented in Figure 42. The *basic rationale* is that if the goods are imported for capital use then it would be used as an investment and will add to the productive capacity of the Indian economy and eventually would raise the level of production in the economy. When it comes to export both the final consumption of end- use goods and capital end-use goods should be taken up so as to holistically develop the export market. It is seen that just over 10% of total ITC goods import were designated as end-use capital goods in 2000 which increased to just over 20% in 2019. Percentage of total ITC goods export designated as end-use capital goods increased to 20% in 2005 which came down to 10% in 2009, but again increasing to nearly 40% in 2017 and decreasing to below 20% in 2019. Thus there was a brief period where the percentage of total ITC goods export designated as end-use capital goods was greater than the percentage of ITC goods import designated as end-use capital goods.

**Capital End-Use ICT Goods as Percentage of Total ITC Goods: Import & Export**  
**Figure 43: ICT Computers and Peripherals**      **Figure 44: ICT Communication Goods**

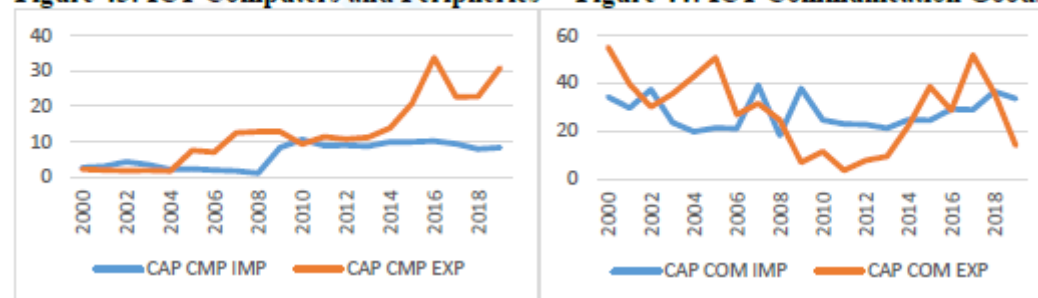
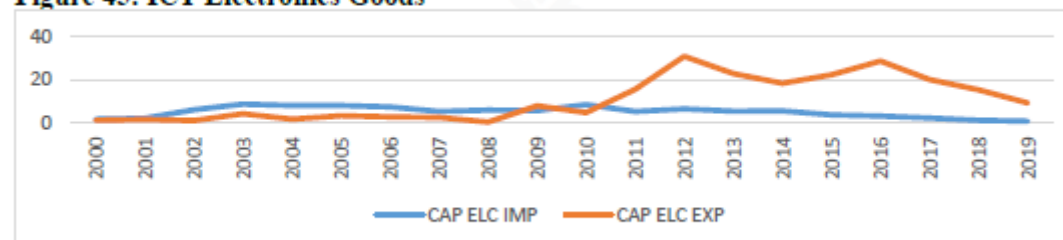


**Figure 45: ICT Electronics Goods**



*Source: Calculations using OECD data*



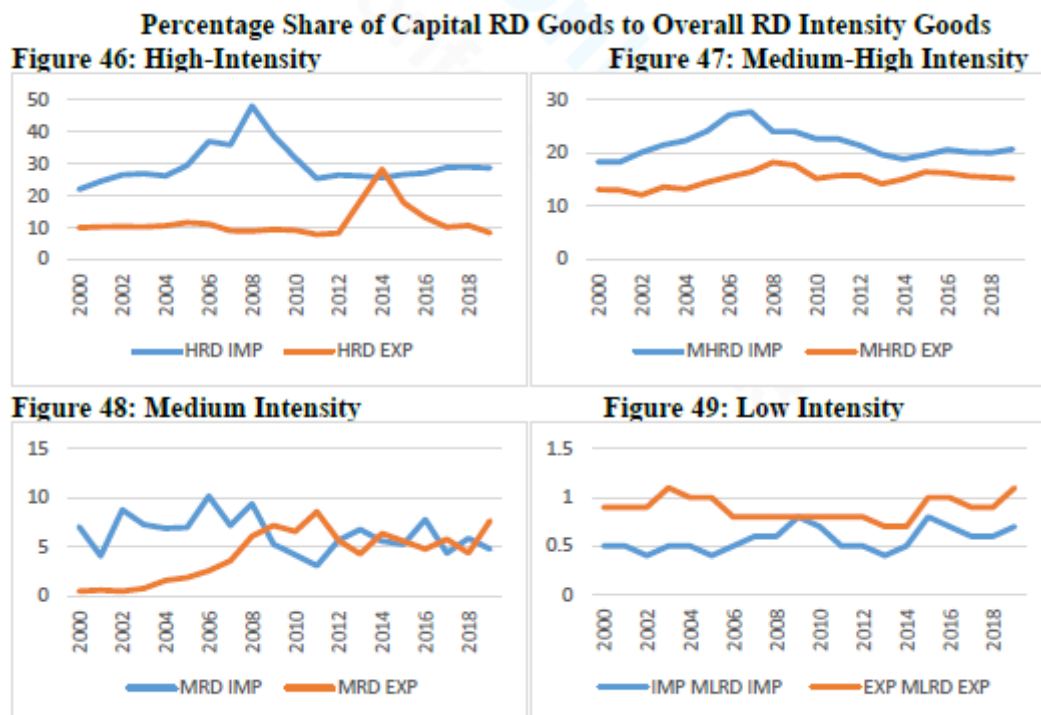
Although there has been a significant increase in the percentage of capital use computers out of total ITC computers and Peripheral goods, it is still less than 10% (Figure 43). Thus most of the computer and other allied goods imported are for final consumption, not used as an investment as capital goods. Ideally, domestic capacity should have been augmented so that domestic computer manufacturing meets domestic demand so as not having to resort to importing goods. On the other hand, nearly one-third of India's computer and peripheries exports now constitute as capital end-use, which was less than 5% in 2004.

Capital use content of imported communication goods declined from over 50% in 2000 to less than 5% in 2011 again increasing to over 50% in 2017, only to decline to nearly 10% in 2019 (Figure 44). Thus there has been a cyclic pattern over time. But with respect to the percentage of capital end-use communication out of total communication goods remained in the range of 40% to 20%. Currently, over 30% of communication goods import consists of capital end-use goods.

Almost all of the electronics imports are for consumption use, while a maximum of nearly 10% of electronics import was designated use as capital goods in India in 2003 which decreased to less than 1% in 2019 (Figure 45). Thus it is pertinent to develop electronics industry in India so that consumption goods are met by the domestic production and not having to resort to importing. With respect to electronics export, in 2008 almost all the export was for consumption use while in 2012, 30% of electronics export was designated as capital end-use which declined to 10% in 2019. Indian export of electronic goods should also be diversified so as to address the global requirement of capital and consumption requirement. The important aspect is to develop our domestic capacity and domestic competitive advantage so as to meet the domestic consumption requirement by way of domestic production.

### **ICT goods import & export based on the R&D intensity of the goods**

In this section, ICT goods have been classified into high R&D intensity goods, Medium High R&D intensity goods, Medium R&D intensity goods and Low R&D intensity goods. The classification is based on OECD ISIC Rev. 3. India's import and export across R&D intensity segment has been presented below.



*Source: Calculations using OECD data*

It is important to note that less than one-third of import of high Technology goods is used as capital goods. This means that **nearly two-thirds of domestic demand for high technology goods is met through imports**. India's export of high technology goods are mostly designated as consumption goods. In case of import of medium and high technology goods, around 20% were designated as capital goods in 2000, which increased to over 25% in 2006-08, again stabilizing at around 20% in the 2013-19 period. In other words, 80% of medium and high technology goods imported in India are used for consumption purpose, which could have been supplied through domestic production if such production capacity or Technology was available domestically. As far as exports are concerned only 15% of our medium and high technology goods for export are designated as capital goods.

**Less than 10% of India's imports of medium technology good are used as capital goods.** At the same time, less than 10% of our medium Technology goods export is constituted as capital goods. Less than 1% of our export of medium technology good was capital goods which increased to 8% in 2011, again decreasing to around 4% in 2013, and in recent period increasing to around 8% in 2019. Similarly in recent periods just around 5% of our Import of medium technology goods are designated as capital goods. India has a huge potential in developing protection base for consumer goods in medium technology segment since, **most of our import of medium Technology goods are used for consumption purpose, which can readily be developed within India.**

There has been a consistent rise in ICT goods import. The surge in the import of ICT capital goods can be attributed to a lack of domestic capability in producing

ICT goods. ICT hardware sector requires capital investment, a higher gestation time and a higher degree of risk. India's Software Industry was able to take off, given its young and dynamic workforce and foresight by the government. However, China not only developed its competency in software development in the last decade but also overtook India. China is not only a major exporter in ICT hardware sector but also in ICT software sector. If India had put forth a plan in developing its ICT hardware sector in the early post-reform era, India could have emerged as a global leader in ICT. However, India needs to prepare for Industry 4.0, and a high reliance on import is detrimental to the goal of self-reliant India. India could develop its competency across various ICT, R&D segments not only to boost domestic production and generate employment but also to be a world leader in ICT export.

### **Concluding remarks:**

To understand the industry side, a structured analysis at the firm level has been carried out in this study in order to draw reasonable conclusions from available data for a holistic picture of 'job creation' in the labour market. Therefore, this study tries to analyse capital investment patterns and their impact on output (ICOR), returns to capital and employment.

**Capital Stock:** When looking at the capital stock in the Indian economy, the major industries in manufacturing include metals, chemicals, textiles and food, while those in non-manufacturing include utilities, business, professional and administrative services. Interestingly, the ICOR of investment in manufacturing in India has been more volatile as compared to non-manufacturing. Industries with high ICOR include chemicals, textiles and food within the manufacturing sector, and utilities, construction and communication within non-manufacturing. It is important that capital be invested in output efficient areas; case in point, utilities have the highest capital investment but a high ICOR which means a lower output.

**Employment Elasticity of Capital Investment:** In terms of employment elasticity, it is higher for services than manufacturing. To increase jobs, more capital should be invested in plastics, electrical and paper industries within the manufacturing sector, and in business, transport, construction and financial services within non-manufacturing. Similarly, when looking at returns to capital, when the profit appropriation is more, capital is preferred over labour, reducing the demand for labour. Such industries include chemicals, non-metals and machinery within manufacturing, and financial services, trade and business within non-manufacturing.

**ICOR and ICT:** When it comes to technology, a lot of stress is laid on the ICT sector in India, especially as it is the most sought after trade-in VET. India's ICT investment in firms is high only in motor vehicles, electronics, and petroleum and transport vehicles as per ASI unit-level data. However, technology in India

has a major focus on software rather than hardware and ICT equipment (which is also very volatile). Investment in software though less volatile, has been growing very slowly over time. It is interesting to note that the employment elasticity of ICT (both software and hardware) is very low, almost negligible. Investment in ICT on the other hand shows that ICOR is also very low, which implies that lower investment is sufficient for higher output, which should ideally lead to an increase in employment. This is contradicted by the fact that automation and Industry 4.0 have an adverse impact on labour demand in ICT.

**Inter-Linkages of ICT with the Rest of the Economy:** It is clear that if the output of ICT increases, the maximum increase in output is seen in paper, printing, machinery, textiles, transport equipment, electrical and R&D. Increase in output is expected to increase demand for labour in these industries. At the same time, increase in R&D is expected to have a positive impact on ICT, Community, Social and Personal Services (CSP), machinery, textiles, and Transport, Storage and Communication (TSC).

At the same time, an analysis of patents and Intellectual Property Rights (IPR) in India shows that investment by private non-financial corporations has been increasing, while that of public non-financial corporations has been decreasing. The shares of investment by such private corporations are high in real estate, business and professional services, TSC and manufacturing. Share of investment by such public corporations is high in mining and public administration.

**Competitive Edge in Technology:** It may be argued that industrial development in India and ultimately the generation of demand for labour can be pursued through import substitution. On the one hand, India imports extensively capital goods, and this in itself can have a positive impact through an increase in productive capacity resulting in an increase in output and thus increase in employment. On the other hand, import substitution of goods meant for consumption can lead to the creation of jobs domestically. Therefore for a deeper understanding, capital goods under ICT have been divided into here categories- computers, communication and electronic goods. India's imports in these have increased in the recent period, but exports have not increased proportionately. It is interesting to note that under the import of computers, only one- third is used as capital goods and the rest is for consumption. Similarly, for communication and electronic goods, only 10 per cent is used as capital and the rest is for consumption. These large shares of imports which are simply only for consumption may be domestically produced to increase demand for labour. There is a similar case for capital goods across different categories based on R&D. The major takeaway is that India should at least have a competitive edge in low-tech and low-medium tech so as to reduce imports and increase jobs through domestic production.

### **Is India ready for Industry 4.0?**

This study set out to have an overview of the labour market for youth with a focus on skills and technology. Given the advent of Industry 4.0, the preparedness of the Indian economy and labour market to automation remains an important question. The main highlights with regard to the same are summed up as follows.

The demographic 'dividend' in India is at risk of becoming a demographic disaster if employment trends continue at the current trajectory. For instance, the share of youth not in education, training or employment (NEET) continues to remain high, though a section of youth has gradually started moving towards education. Share of youth in NEET remains high despite the declining share of youth in casual work and an increase in regular salaried work due to declining preference in agriculture and NREGA. Generation of employment also remains slow.

On the industry side, this paper looks at firm-level analysis, which clearly suggests that employment elasticity is higher for service sector as compared to the manufacturing sector (overall it is highest for sectors such as plastics, electrical and paper industries, and business, transport, construction and financial services). Although ICT is a very important sector for the Indian economy, its low ICOR implies less investment is needed for more output which should ideally increase employment, but employment elasticity of the ICT sector is very low. This suggests that automation and Industry 4.0 may prove detrimental for employment generation. In addition, trading patterns of technology and capital goods suggest that by import substitution of a portion of such goods meant solely for consumption and not capital generation, labour demand can be generated to a certain extent.

All said and done, for Indian manufacturing to be prepared for productivity gains from Industry 4.0 as well as for labour market to be protected from the negative impact of automation, a manufacturing policy and a corresponding employment policy focussed on the provision of new skills will be imperative.

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## Note

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<sup>1</sup> Bio Resources-Cultivated Biological Resources which consist of Tree, Crop & Plant Resource

## The nexus between labour mobility and innovation: An empirical analysis

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### **Abstract**

Labour mobility is a crucial feature of human nature and an effective medium of knowledge transfer. As the workers shift from one region to another, their embodied skills travel with them, and the diversities of skills make complementarities of ideas that encourage new methods of production or innovation in the destination. Further innovation boosts economic growth and smoothen the mobility path. In this way, an endogenous phenomenon continues, and knowledge diffusion occurs. In other words, a virtuous cycle takes place between migration and innovation, which has not been comprehensively explored in the existing literature. Especially in developing nations, such studies are a handful in number and are not at a consensus to derive the normative conclusion. And as the relationship between the two has remained inconclusive due to the variation of skills and endowments, the study aims to investigate the migration-innovation nexus critically. The migration and innovation data are extracted from the World Development Indicators (WDI) dataset for the empirical analysis from 1980 to 2020. We constructed a panel dataset across countries for 40 years. Patenting by residents and non-resident data are taken as the proxy of innovation. In the study, we find a strengthening and positive trend of migration and innovation in the developed nations while there is a relatively weaker relation in developing countries. We also observe the regional variation of migration and patenting trends over the period. The system GMM model identifies the endogenous phenomenon of the two aspects across the developed and developing nations. Further, the study suggests a virtuous cycle between migration and



innovation which is appreciable for economic growth and development. So, the importance of labour migration (mainly skilled labour) is operative to encourage innovation in receiving firms as well as sourcing firms. The study provides a relevant path for the researchers to study further migration-innovation relations.

**Keywords:** Migration, Innovation, Patenting, Knowledge Diffusion

## Introduction

Labour migration significantly influences wage, labour supply, population growth, skill composition, income composition, taxes and cultural diversity. But while those labours are skilled, they play a sine-qua-non role in transfer of skills, diffusion of knowledge, and spread of technology. Movement of labour transfers skills and knowledge from one organization to another, one region to another, and one country to another (Ozgen, 2014; Bosetti, Cattaneo & Verdolini, 2015). The labour migration (mainly skilled labour) also operates innovation activities in receiving and outsourcing regions. So, the linkage between skilled labour mobility and innovation has been recognised as an operator of economic growth (Braunerhjelm, 2011). As experienced workers directly contribute to the production and diffusion of knowledge (Vandenbussche et al., 2006; Miguelez, & Temgoua, 2020), people having science, technology, engineering, and mathematics (STEM) degree puts positive externalities in the workplace by encouraging new method of production (Winters, 2014). That is why the spread of knowledge occur due to the mobility of skilled workers, further accentuating innovation. Evidently, after globalisation policies, the trend of migration has been changed, and that helps to generate positive externalities both in the destinations (Kerr and Lincoln, 2010; Hunt and Gauthier- Loisel, 2010) and origin (Agrawal et al., 2011; Breschi et al., 2017).

In such cases, the connection between migration and innovation is virtuous for economic growth and development. Triple and Maier (2010) investigated the role of human capital and regional development and found that skill migrants carry knowledge from the employees and spill over to another receiving firm. Peri (2005) studied knowledge transfer among the firms and interpreted that the knowledge flow reaches much farther relative to trade flow. The research analysis of Lewis (2011) on the effect of skilled and unskilled labour mobility on patent applications in US documented that emigrant from Mexico in the US lead to slower growth and capital-output ratio. Regarding mobility and

innovation, the study of Kim and Marschke (2005) and Castilo et al. (2016) expresses that patent application rises when scientists or high-skilled mobility occurs compared to low-skilled mobility. Braunerhlem et al. (2014) conducted an empirical study in Sweden, reflecting that innovation's effect rises when worker collaboration exists in the region. Specifically, the firm requires relevant knowledge for more patent application.

On the contrary, the adverse picture also arises due to migration. The brain-drain issue is also one of the major challenges in destinations that appear with emigration. Similarly, cultural and language barrier issues are seen in destinations, which obstruct the virtuous cycles of migration and innovation. Besides, the dynamics of knowledge diffusion and innovation vary across regions and circumstances due to distinguished characteristics such as availability of capital, technological obtainability, and accessibility of skilled labour.

Despite the research mentioned above on migration and innovation, a gap is still visualised in the study of the relationship between migration and innovation. So, the study aims to analyse the association between migration and innovation. Again, few research studies discuss the positive relationship, while others suggest an inconclusive relationship. Bove & Elia (2017) point out that skilled migration leads to economic growth and development via the diffusion of knowledge and remittance (Ratha, et al., 2016), which directly and indirectly contribute to economic growth. But in several cases, brain drain issues arise, especially in developing countries, because of outsourcing skilled workers (Cattaneo, 2009). Poor coordination and collaboration also occur in the workplace due to cultural diversity that acts as a barrier (Belot & Ederveen, 2012). So, the relationship between the two has remained as unsettled and inconclusive.

As we know, several studies have been explored the migration and innovation aspects separately. But the survey of simultaneous analysis of the two aspects is a dearth. Additionally, the study on migration-innovation is sparse in developing nations. In such contexts, the question of the connection between the two is an open debate. Here, the paper attempts to seek the answer and analyze its rationale. Again, several studies have been attempted that talk about the theoretical perspective, but those are not at a consensus to derive a normative conclusion, although it provides guidance. The paper figure out a migration-innovation nexus phenomenon that analyses theoretical and empirical perspectives.

The paper organizes the discussion systematically as follows. To begin with section 2, we discuss the literature review, which includes theoretical and empirical aspects of migration and innovation framework. Section 3 talks about the nexus between migration and innovation. In section 4, we discuss the data

and methodology for the analysis. Section 4 comprises results and discussion. Section 5 incorporates concluding remarks and a way forward to future research.

## **2. Literature review**

To understand the phenomenon of migration and innovation, we categorize the literature study into three parts: 1) Role of Migration Versus Innovation, 2).Theoretical Perspective of Migration and Innovation, 3). Empirical Evidence of Migration and Innovation.

### **2.1. Migration versus innovation**

Before investigating the association between migration and innovation, a separate study of the two concepts is essential for better understanding. So far as migration is concerned, it has a mixed-bagged impact on economic activities concerning region, population, and labour efficiency. In general, migration has a positive effect on economic growth and development. Firstly, it helps in filling labour market gap where shortages are seen in industries like healthcare, construction, and agriculture (Castles, 2011). Further, it helps to make remittances for outsourcing countries where remittance money is transferred by migrants to their relatives back in their own countries (Li & Zhou, 2013). Families receiving these remittances may rely on them as a major source of income, and they may also help the host nations' economies to flourish. Then it also aids in entrepreneurship (Light, Bhachu, & Karageorgis, 2017). Migrants establish firms in their new countries, which can create jobs and economic expansion. In several nations, it has been discovered that immigrant entrepreneurs are more likely to launch enterprises than people born there.

Most importantly, it encourages innovation and knowledge transfer. As highlighted earlier, migrants provide their host nations with fresh perspectives and new information. Again, it contributes to increased productivity and production by encouraging innovation and boosting productivity, which both support economic expansion. Finally, it helps to boost consumer demand by opening new markets and driving up demand for products and services. These migrants help to enhance consumer demand in the nations where they eventually settle (Walsh, 2012).

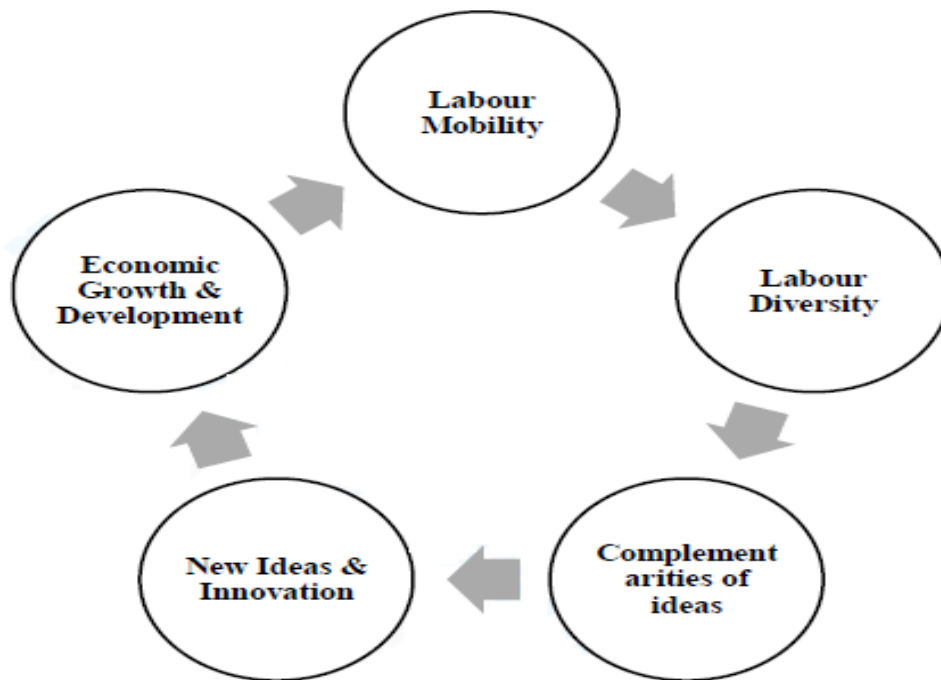
On the other hand, innovation is essential for progress and growth across a range of industries and sectors, which is about introducing novel concepts, techniques, or goods that significantly enhance or transform current procedures or systems. Some of the main functions of innovation include innovation is a major factor in economic growth (Cameron, 1996; Rosenberg, 2006) since it develops new goods, services, and markets, all of which lead to the creation of new employment and sources of income. Secondly, productivity and efficiency can be improved through innovation, which can assist organizations in

streamlining their procedures and improving overall performance (Zhang, & Vigne, 2021). Thirdly, by increasing the quality of life of people and communities with improved access to services and goods, innovations in healthcare, education, and other sectors can raise the quality of life for both individuals and entire communities (Lämsä, 2006; Serdyukov, 2017). Fourthly, innovation can assist in addressing some of the severe issues, including healthcare access, climate change, etc. (Heltberg, Siegel, & Jorgensen, 2009). Fifthly, by creating new products or services that better match consumer wants, innovation assists organizations in staying ahead of the competition (Kim & Mauborgne, 1997). The above considerations indicate that innovation is critical for developing and expanding various industries. It is crucial that people, organizations, and society at large embrace and encourage innovation to effect positive change.

So, migration (mostly skilled) and innovation, individually, have a virtuous effect on the economy for higher productivity growth, larger production, and mass distribution. Both are requisite for the nation to prosper the growth. That is why the connection between the two undoubtedly leads to double-bang growth and development.

## **2.2. Virtuous cycle of migration and innovation**

Several studies on labour migration and innovation denote a positive association as well as cause and effect relation between them, indicating a virtuous cycle of migration-innovation nexus. The process can be elaborated as such. When the workers shift from one region to another, their embodied skills travel with them (Argote, 2000, Bove & Elia, 2017). And at the same time, the cultural diversities among different regions make complementarities of ideas that promote new production methods (Ozen et al., 2013), which is also regarded as innovation. The movement of labour leads to knowledge diffusion with subsequent technological innovation and ensures economic growth (Bove & Elia, 2017). Therefore, it is crucial to ensure progression by strengthening such nexus in all the countries for economic growth and development.



*Source: Authors' elaboration from literature*

### **2.3. Theoretical evidence of migration and innovation**

Diffusion of knowledge is one of the important drivers of innovation, which directly and indirectly aids economic growth (Archibugi & Filippetti, 2010). Various theories and models are related to the theoretical attribute of knowledge flow, skilled migration, innovation, and economic growth, which spotlight the migration innovation traits. To begin with, endogenous growth theory (Romer, 1990), a larger population prospers economic growth, and immigration of labor aid innovation activities and economic dynamism. The semi-endogenous growth theory also suggests that as the population increases in a place, economic growth prospers there because of higher production with a positive return to scale. Solow (1956) also mentioned that population growth replaces a higher return to scale of production in place of a lower return to scale via creative destruction.

As the innovation activities associated with the creative destruction aspect, several seminal contributions related to creative destruction also discussed the same aspects. Generally, the inflow of migrants increases population growth and leads to creative destruction with diversified knowledge and ideas (Grossman and Helpman, 1991; Aghion and Howitt, 1992). The receiving countries take advantage of such creative destruction activities as the new methods and mode of production replaces the old ones. The methods basically target the cost- effective process to achieve economies of scale and scope.

The theory of knowledge transfer posits that migration frequently entails the

migration of people from various origins, expertise, and skills. When migrants arrive at a destination, they bring their own experiences, knowledge, and opinions. This transfer of information and skills can help the host country's innovation capability by bringing new ideas, technologies, and techniques (Krugman, 1979; Williams, 2007; Lissoni, 2018). Migrants, for example, may have specialized expertise in science, technology, engineering, and mathematics (STEM), which can boost innovation in such industries. These theories spotlight skilled immigration, which positively affects the production of host economies.

Similarly, migration network theories highlight the diaspora effect, which generally means the residents of individuals from the same origin grouped in foreign countries, which are formulated because of migration (Beine, Docquier, & Ozden, 2011; Kilduff, & Corley, 1999). These diaspora populations can activate innovation activities and entrepreneurial conduits. They construct networks that connect individuals and businesses in the host country to those in the home country. These networks foster innovation in both countries by promoting information interchange, business, investment, and cooperation (Agrawal et al., 2011; Naghavi & Strozzi, 2011; Naghavi & Strozzi, 2015). Diaspora entrepreneurs, for example, may provide financial resources, experience, and market relationships to encourage innovative enterprises in their home countries.

Besides, the theory of the triple-helix model posits that the diversities of ideas among the institution, government, and university leads to complementarities of idea which requisite collaborative work and further leads to new method of production and innovation. In other words, migration directly and indirectly affects the innovation activities within the triple helix model (Etzkowitz & Zhou, 2017; Burgos-Mascarell, Ribeiro-Soriano & Martínez-López, 2016).

## **2.4. Empirical evidence of migration-innovation**

The empirical evidence of migration innovation framework shows a diversified relationship between migration and innovation. Different studies find distinguished results concerning nature, region, and other characteristics. Here, we analyze the evidence of both internal and international migration and its association with innovation (especially patenting and research & development expenditure).

### ***Internal migration***

So far as internal migration is concerned, Gray, Montresor, Wright (2020) reported with firm-level analysis in the United Kingdom that low-skilled workforce mobility stimulates and inhibits process innovation. However, regarding net effect, the gain from process innovation outweighs the loss from product innovation. Zhao & Li (2021) found out the positive influence of migration on local innovation and significantly rising urbanization encourages

innovation. In addition, regional innovation is also influenced by internal migration. Similarly, Doehne & Rost (2021) unfolded the social network perspective and mentioned that due to diverse local compositions, areas close to hub characterised by diversified experience led to radical innovation. Because of these high levels of creativity and knowledge stock increase extensively although such innovation and inventiveness are transitory and temporary.

### *International migration*

Concerning international migration, the firm-level study of Fassio, Montobbio & Venturini (2019) posits a beneficial impact on innovation because of highly educated immigrants in European counties. However, the influence differs with respect to industries. The results reveal that a 1% increase in educated residents generates a 0.3% increase in citation-weighted patents, but a 1% increase in highly educated migrants causes a 0.1% increase in patents. The study of D'Ambrosio et al. (2019) concludes that immigrants serve as a worldwide knowledge bridge between their home areas and their destination countries. Skilled migrants are found to be more influential over non-Spanish-speaking nations, emphasizing migrants' language-bridging function. Kazakis (2019) examines the United States' university graduates and patenting phenomenon. The study illustrates that STEM graduates and entrepreneurial education significantly impact regional innovation. In addition, the immigration of highly skilled graduates and innovation has a positive and advantageous relationship.

Bahar, Choudhury & Rapoport (2020) focused on knowledge inflows to destination countries and knowledge feedback to source countries. According to them, migrant inventors contribute significantly to economic outcomes through innovation and technology in destination and source nations. A doubling of inventor migrants results in a 25-60% increase in technical superiority. Fackler, Giesing & Laurensyeva (2020) investigated the industrial patenting of 32 European nations. Their regression analysis shows that a one percent rise in emigrants upsurge patent applications by 0.67 percent of innovation. 2SLS regression analysis also denotes that the elasticity of knowledge transfers concerning emigration is 0.40. The citation data also noticed the knowledge flow due to the cross-border migration. Drivas et al. (2020) studied the local production of technological knowledge in OECD countries, where they found that geographical proximity stimulates local innovation. Individuals with high levels of expertise are more effective in improving local innovation. It encourages the integration of these inflows into the local economy. Caviggioli, Jensen, and Scellato (2020) found different results in the study of European nations. The outcome indicates an inverse link between migration and technical specialization.

The study of Ozgen (2021) posits a direct and advantageous link between the level of regional or personal innovation and the knowledge transfer of

international students. International students favourably impact locals who work with foreigners, particularly in knowledge- intensive high-technology areas. The economic benefits increase by boosting production as variety develops in European regions. Sinoi (2021) viewed that tertiary-educated workers immigrants stimulate the number of patent applications relative to foreign doctoral students. The assessments indicate that highly educated immigrants, both employed and PhD scholars, significantly advance patents. Sequeira, Nunn & Qian (2021) estimated that an increase in immigration to the 50th percentile (0.049) results in a 41% increase in foreign patenting. It means immigration has a favourable and considerable impact on foreign patents. The author also discovered that German-Jewish immigration significantly impacted the innovation rate among native innovators in the United States. Miguelez, Noumedem & Temgoua (2020) focused on the migrant inventors who are important carriers of knowledge for the host country and their homeland. Due to migration, even low-middle-income countries also obtain technological benefits from the developed countries. So, the study suggests that policymakers should focus on the connection between migrants and knowledge instead of concentrating on the brain drain debate.



**Table-1.** Relationship between migration and innovation

| Authors                              | Year |                | Data & Methodology                                                                                              | Objectives                                                                                   | Findings                                                                                                                                                                                                                                                                       |
|--------------------------------------|------|----------------|-----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Internal Migration</b>            |      |                |                                                                                                                 |                                                                                              |                                                                                                                                                                                                                                                                                |
| Gray, Montresor, Wright (2020)       | 2020 | United Kingdom | The source of data is the firm-level panel data on product and process innovation in UK.                        | To evaluate the effects of labour mobility on local innovation activity.                     | The study reported that the low skilled labour mobility triggers process innovation and lessens process innovation. But so far as net impact is concerned the gain from process innovation is higher than the loss from product innovation.                                    |
| Zhao & Li (2021)                     | 2021 | China          | Data extracted from the China statistical yearbook on Science and Technology from the period 2002 to 2017.      | The objective of the study is to explore the spatial spillover effect on local innovation.   | Migrants have significant effect on local innovation. Increasing urbanization also foster innovation. Besides internal migration also causes regional innovation.                                                                                                              |
| Doehne & Rost (2021)                 | 2021 | Europe         | Geocoded residences and birth & death year of 124,860 individuals who lived in Europe between 1000 and 1900 CE. | The objective is to explore the local creative clusters from a social network perspective.   | Due to diverse local compositions, areas close to hub characterised by diversified experience led to radical innovation. High levels of creativity and knowledge stock both occur extensively. However, this kind of innovation and inventiveness is transitory and temporary. |
| Fassio, Montobbio & Venturini (2019) | 2019 | Europe         | The data of the study is related to patent citations of European industries for the period 1994 and 2005        | The study aims to measure the effect of skilled immigration on innovation at industry level. | The study posits that very well-educated immigrants have a positive effect on innovation. A 1% rise in highly educated migrants tend to increase patents by less than 0.1%.                                                                                                    |

|                                         |      |                                             |                                                                                                                                                                                                                                          |                                                                                                                  |                                                                                                                                                                                                                                                 |
|-----------------------------------------|------|---------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| D'Ambrosio et al. (2019)                | 2019 | Spanish                                     | Patent data and national data on people of Spanish province and electors abroad has been analysed. The gravity model is applied to understand the knowledge flow of two locations which are measured not by their GDP and R&D intensity. | It evaluates the impact of migration on novelty networks between the nation and foreign countries.               | Immigrants play a global knowledge bridge between the outsourcing nations and destination nations. The skilled migrants put stronger effect with respect to non-Spanish-speaking countries which points out language-bridging role of migrants. |
| Kazakis (2019)                          | 2019 | United States                               | Patent information were extracted from the US Patent and Trademark Office (USPTO) website.                                                                                                                                               | The study indicates the association between patenting and movement of university graduates.                      | STEM graduates and entrepreneurial education play a prominent role in regional innovation. A positive association exists between the immigration of highly skilled graduates and innovation.                                                    |
| Bahar, Choudhury & Rapoport (2020)      | 2020 | Dataset of 121 countries were investigated. | Patenting activity from the United States Patenting Office (USPTO) is considered where about 651 technology sub classes specified by the International Patenting Classification (IPC) for the period 1976 to 2011.                       | The study examines knowledge inflows to destination countries as well as knowledge feedback to source countries. | A doubling number of inventor migrants leads to a gain in technological advantage by 25- 60%. Migrants inventors play an important role in generating economic outcomes through innovation and technology in destination and source countries.  |
| Fackler, Giesing & Laurentsye va (2020) | 2020 | European countries                          | Industry-level patenting data and migration data of 32 European nations have been considered.                                                                                                                                            | To find out the link between migration, knowledge flows and innovation.                                          | The regression analysis shows that 1% rise in emigrants upsurge patent application by 0.67 percent of innovation.                                                                                                                               |
| Migueluez, Noumedem & Temgoua (2020)    | 2020 | OECD nations                                | Patent data extracted from the World International Patent Office (WIPO). Citing and cited patents on inventors and their countries of habitation are chosen for the phase 1990-2010.                                                     | It investigates the association between international knowledge flow and migration of inventors at global scale. | Migrant inventors are important carriers of knowledge for the host country as well as to their homeland.                                                                                                                                        |

|                                     |      |                                                                                                     |                                                                                                                                                                              |                                                                                                                     |                                                                                                                                                                                                               |
|-------------------------------------|------|-----------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Drivas et al. (2020)                | 2020 | 30 OECD nations                                                                                     | Data from 30 OECD nations over the period 2000–2012 has been taken into consideration. It incorporates inventor migrants with innovation pursuit in the destination country. | The relationship between local production of technological knowledge and the migration of talented patent inventor. | The study shows that the proximity triggers local innovation. Highly skilled individuals are more efficient in improving local innovation. It promotes the inclusion of these inflows into the local economy. |
| Caviggioli, Jensen, Scellato (2020) | 2020 | European and US sub- regional region.                                                               | The data from 2006 to 2010 OECD REGPAT and the WIPO PCT metadata was incorporated which includes 200 PCT patents.                                                            | The influence of highly qualified migrants on the evolvement of technological innovation.                           | The result denotes an opposite relationship between movement and technological specializations. The strength of high-skilled migration and technological specializations is negative.                         |
| Ozgen (2021)                        | 2021 | European countries                                                                                  | The paper investigates micro-level associated company and employee-employed data sets in European countries.                                                                 | It studies the spillover effect of foreign student on regional innovation.                                          | The study shows a direct and positive relationship between knowledge spillover of international students and regional or individual levels of innovation.                                                     |
| Sinoi (2021)                        | 2021 | Czech Republic, Cyprus, Estonia, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, and Hungary. | Data of ten countries which enlisted the EU in 2004 were taken from 2011 to 2017 just after the financial crisis 2007–2010.                                                  | To examine the influence of highly educated immigrants on innovation.                                               | The estimations denote that highly educated immigrants, both employed or PhD scholars perform a significant part in patent advancement.                                                                       |
| Sequeira Nunn & Qian (2021)         | 2021 | United States                                                                                       | Migration of a panel of countries to US from 1860 to 1920 have been taken into consideration.                                                                                | The study investigate relationship between the immigrants and patenting.                                            | Increase in immigration to 50th percentile (0.049) leads to a rise in foreign patenting by 41%.                                                                                                               |

### 3. Data and methodology

The study analyses the data from the World Development Indicator (World Bank), which comprises data on international migration stock, and patenting by residents and non-residents. Research and development share are also employed along with GDP per capita. Besides, the migration data from the department of Economic and Social Affairs (UN data) is also used. A panel of various countries for 30 years, from 1990 to 2020. As the data of migration is available for quinquennially. So, we do the regression analysis for the panel having quinquennially period and country. To analyse the region variation, we categorize the data into six regions: Europe, America, Asia, Africa, Oceania and Caribbean. Table.1 describes brief notes on various variables and definitions. Here, we use international migrant stock, which has been taken as migration variables in the analysis as our analysis and theoretical perspective highlight it as a determinant of innovation (Lim & Morshed, 2015). GDP per capita is also considered a factor variable as the patenting is influenced. The research and development expenditure is a prerequisite for patenting or innovation. Sometimes, it is considered input innovation while patent application is considered output innovation (Zhang & Mohnen, 2022).

**Table-2. Variables and description**

| Sl. No. | Variables                          | Descriptions                                         | Definitions                                                                                                                                           | Sources          |
|---------|------------------------------------|------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| 1       | Patenting by Non-residents         | Patent application, Non-residents                    | Patent applications are filed by applicants who do not reside in the state or country.                                                                | WDI   DataBank   |
| 3       | Patenting by residents             | Patent application, Residents                        | Patent applications are filed by applicants who reside in the state or country.                                                                       | WDI   DataBank   |
| 4       | International Migrants             | International Migrant Stock                          | The number of persons born in a country other than the one in which they live, including refugees, is referred to as the international migrant stock. | WDI   DataBank   |
| 5       | GDP                                | GDP per capita, PPP (constant 2011 international \$) | GDP converted to international dollars using purchasing power parity rates.                                                                           | Jobs   DataBank. |
| 6       | Research & Development Expenditure | Research and development expenditure (% of GDP)      | R&D spending of the country, represented as a percentage of GDP.                                                                                      | WDI   DataBank   |

Source: World Development Indicator/World Bank

In order to analyse the data, we modeled the innovation in the left-side variable and migration on the right-side variable. The patent application has been considered as a proxy for innovation which is endogenous in the model. So, we employed system GMM regression which modeled as

$$\text{Basic model: } y_{it} = \alpha y_{it-1} + \beta x_{it} + u_i + \varepsilon_{it} \quad (i)$$

$$\text{Lag model: } y_{it-1} = \alpha y_{it-2} + \beta x_{it-1} + u_i + \varepsilon_{it-1} \quad (ii)$$

The differences can be

$$y_{it} - y_{it-1} = \alpha(y_{it-1} - y_{it-2}) + \beta(x_{it} - x_{it-1}) + (u_i - u_i) + (\varepsilon_{it} - \varepsilon_{it-1}) \quad (iii)$$

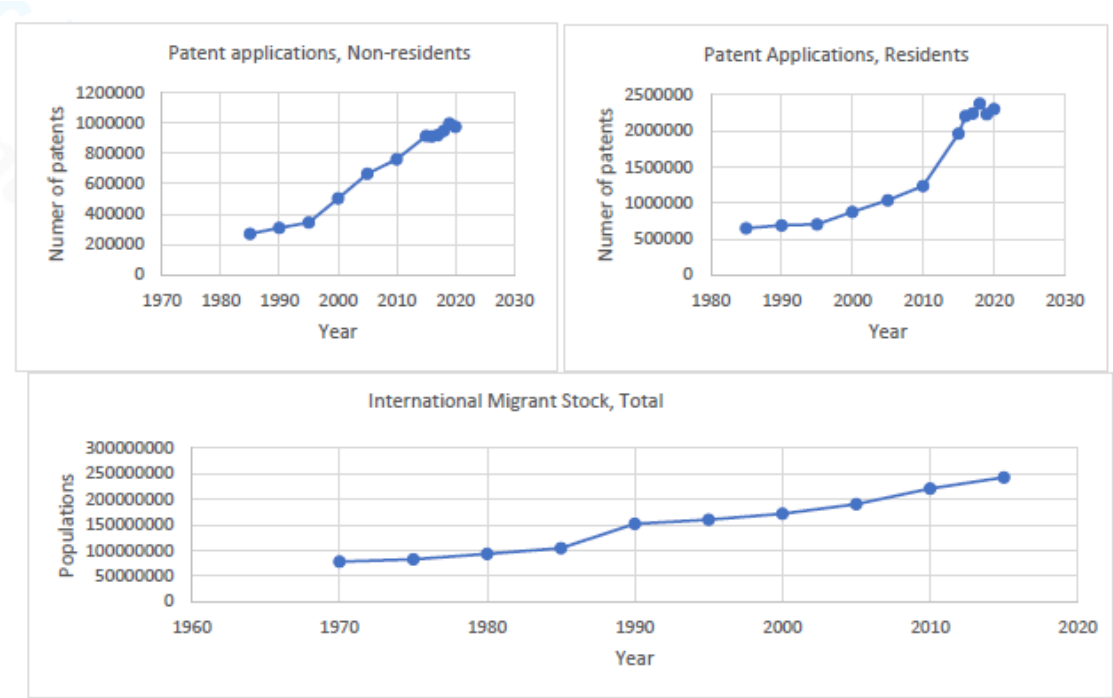
$$\Delta y_{it} = \alpha \Delta y_{it-1} + \beta \Delta x_{it} + \Delta \varepsilon_{it} \quad (iv)$$

The rationale behind applying system GMM is that it is a dynamic panel data model where the lag of the dependent variable is used as right-side variables. Secondly, we have only seven periods where the period is less than number of cross-section units. Thirdly, the instruments are internal rather than external.

#### 4. Analysis and findings

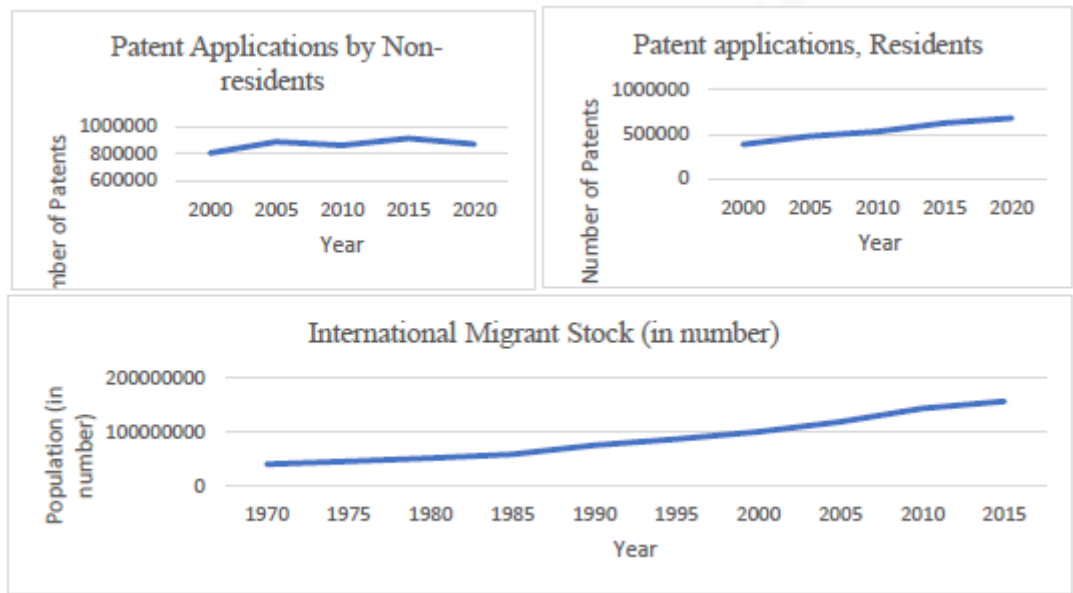
As per the study of migration data, 208.6 million migration population is reported in mid of 2020; it was about 153 million in 1990 (Migration Data Portal, 2023). On the other hand, the patenting scenario is also growing continuously, indicating the rise in innovative activities (Figure-1). Residents' patent application has risen continuously from 1985 to 2020 while non-residents patenting also grew from 2.7 lakh to around 10 lakhs from 1985 to 2020. So far, international migration is concerned. It has increased from 7.83 crore to 24.31 crore from 1970 to 2015. This shows an increasing trend of migration.

**Figure-2.** World-wide migration and innovation data



Sources: The data are taken from World Bank Indicators (WDI)

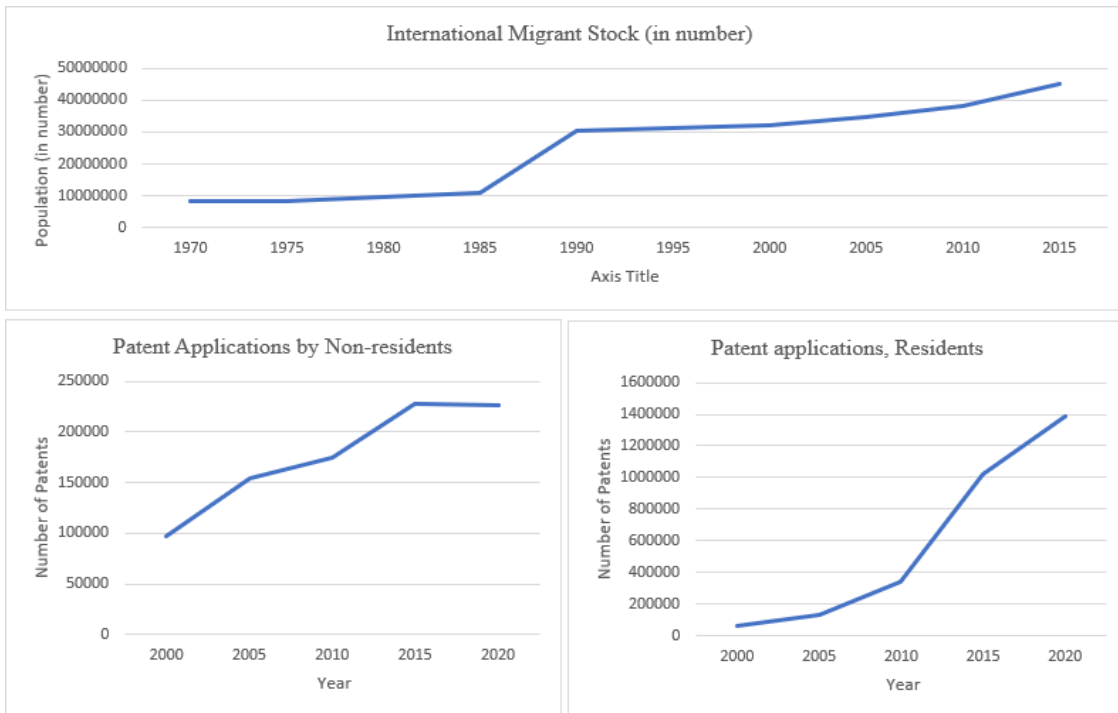
**Figure-3.** High-income countries.



Sources: The data are taken from World Bank Indicators (WDI)

Similarly, the migrants' stock in upper- and lower-middle-income countries even in lower- income countries, is rising. On the other hand, the patenting by non-residents of upper-middle- income countries is stagnant after 2015, while patenting by non-residents in lower- and lower- income countries is growing. The patenting by residents is increasing in upper-middle-income and lower-middle-income countries, while in lower-income countries, it is declining (shown in the appendix-2).

**Figure-4. Upper middle-income countries.**



The region-wise analysis is depicted in the Table-3. The correlation matrix of international migrants' stock and patent application in the six regions shows a diverse picture. Association with non-resident patenting is highly positive in Africa, America and Asia and the Caribbean while with resident patenting, it is highly positive in America and Asia. But non-resident patenting is negatively related in Europe.

**Table-3.** Region-wise correlation

|                                               | Region ↓         | Patent Applications,<br>Non-Resi-dents | Patent Applications,<br>Resi-dents |
|-----------------------------------------------|------------------|----------------------------------------|------------------------------------|
| <b>International<br/>Migration<br/>Stocks</b> | <i>Africa</i>    | 0.586116                               | -0.18519                           |
|                                               | <i>America</i>   | 0.987108                               | 0.993743                           |
|                                               | <i>Asia</i>      | 0.960354                               | 0.947383                           |
|                                               | <i>Caribbean</i> | 0.835482                               | -0.12814                           |
|                                               | <i>Europe</i>    | -0.83053                               | 0.736364                           |
|                                               | <i>Oceania</i>   | 0.847063                               | -0.02385                           |

To analyse the impact, the system GMM model applied taking three different equations. In that total patent application, patent applications by non-residents and patent applications by residents have been taken into consideration.

Innovation= f (Migration, Research & Development Expenditure Share, and GDP per Capita)

All the values of the variables are converted into logarithmic transformation before conducting the regression. The summary of those is shown in Table-4. The correlation table has shown in Table-5.

**Table-4.** Summary statistics

| Variables                          | Observation | Mean     | Std. Dev. | Min      | Max      |
|------------------------------------|-------------|----------|-----------|----------|----------|
| <i>Ln (Total patent)</i>           | 724         | 6.428621 | 2.649923  | 0        | 14.21908 |
| <i>Ln Patent by Non-residents</i>  | 710         | 5.635596 | 2.67472   | 0        | 12.69951 |
| <i>Ln Patent by Residents</i>      | 669         | 5.465879 | 2.723259  | 0        | 14.11177 |
| <i>Ln (International Migrants)</i> | 1,470       | 11.85483 | 2.106027  | 4.85203  | 17.70877 |
| <i>Ln (R&amp;D Share)</i>          | 453         | 0.957965 | 0.977207  | 0.01497  | 5.43562  |
| <i>Ln (GDP)</i>                    | 1,071       | 8.979679 | 1.24654   | 5.511154 | 11.7372  |



**Table-5.** Correlation matrix

|                                            | <b>Ln<br/>Total<br/>Patent</b> | <b>Ln<br/>Patent by<br/>Non-<br/>residents</b> | <b>Ln Patent<br/>by<br/>Residents</b> | <b>Ln<br/>(International<br/>Migrants)</b> | <b>Ln(R&amp;D)</b> | <b>Ln (GDP)</b> |
|--------------------------------------------|--------------------------------|------------------------------------------------|---------------------------------------|--------------------------------------------|--------------------|-----------------|
| <i>Ln<br/>Total<br/>Patent</i>             | 1                              |                                                |                                       |                                            |                    |                 |
| <i>Ln Patent by<br/>Non-residents</i>      | 0.9094                         | 1                                              |                                       |                                            |                    |                 |
| <i>Ln Patent by<br/>Residents</i>          | 0.8745                         | 0.6404                                         | 1                                     |                                            |                    |                 |
| <i>Ln<br/>(International<br/>Migrants)</i> | 0.6623                         | 0.5441                                         | 0.6641                                | 1                                          |                    |                 |
| <i>Ln(R&amp;D)</i>                         | 0.4957                         | 0.3379                                         | 0.6                                   | 0.3854                                     | 1                  |                 |
| <i>Ln (GDP)</i>                            | 0.3218                         | 0.2185                                         | 0.3378                                | 0.3331                                     | 0.6062             | 1               |

The system Generalised Method of Moment (GMM) denotes the international migration stock has significant and positive impact on total patenting (at 1% level of significance) and on patenting by non-resident (at 5% level of significance) (shown in Table-6). The results noted that 1% rise in migrant stock leads to 0.5392% increase in total patenting and 0.4896% rise in patenting by non-residents. Similarly, the research and development expenditure share of GDP also positively and significantly affect both total patenting and non-resident patenting activities. Evidently, 1% increment R&D expenditure share led to a 0.4848% increase in total patenting (at 10% significance level) and a 0.3042% rise in patenting by non-resident (at 10% significance level). Even the current year non-resident patenting is influenced by the previous year non-resident patenting (0.4896% increment at 1% significance level).

**Table-6. System GMM Analysis**

| Dependent Variables →                                           | <i>Ln Total Patent</i> | <i>Ln Patent by Non-residents</i> | <i>Ln Patent by Residents</i> |
|-----------------------------------------------------------------|------------------------|-----------------------------------|-------------------------------|
| Independent Variables ↓                                         | Coefficients (t-stat)  |                                   |                               |
| <i>Ln (Total patent) <math>it_{-1}</math></i>                   | 0.3000236<br>[1.5]     | 0.4896064***<br>[3.13]            | 0.8496915<br>[4.64]           |
| <i>Ln (International Migrants) <math>it</math></i>              | 0.5392071***<br>[2.85] | 0.3878414**<br>[2.54]             | 0.1179741<br>[0.76]           |
| <i>Ln(R&amp;D) <math>it</math></i>                              | 0.4848195**<br>[2.28]  | 0.3042941*<br>[1.83]              | 0.0792815<br>[0.41]           |
| <i>Ln (GDP) <math>it</math></i>                                 | -0.1089901<br>[-0.63]  | 0.0467499<br>[0.16]               | 0.1052179<br>[0.52]           |
| <i>America</i>                                                  | 1.018763<br>[0.89]     | 0.6909605<br>[0.72]               | -0.1188513<br>[-0.38]         |
| <i>Asia</i>                                                     | 0.574705<br>[0.5]      | 0.3587751<br>[0.36]               | -0.1458481<br>[-0.46]         |
| <i>Europe</i>                                                   | -0.3307073<br>[-0.3]   | -1.438165<br>[-1.45]              | -0.2820213<br>[-0.99]         |
| <i>Oceania</i>                                                  | 0.6936387<br>[0.59]    | 0.3408934<br>[0.35]               | -0.5042694<br>[-1.72]         |
| <i>Constant</i>                                                 | 4.64103<br>[0.73]      | -2.723639<br>[-0.37]              | 4.062455<br>[0.88]            |
| Number of Observations                                          | 215                    | 214                               | 212                           |
| Groups                                                          | 79                     | 78                                | 76                            |
| Instruments                                                     | 26                     | 26                                | 26                            |
| <i>Arellano-Bond test for AR (1)</i>                            | -0.86                  | -1.26                             | -1.56                         |
| <i>Arellano-Bond test for AR (2)</i>                            | 1.22                   | -0.34                             | -0.06                         |
| <i>Sargan test of Overid. Restrictions: <math>\chi^2</math></i> | 259.12***              | 228.32***                         | 276.39***                     |
| <i>Hansen Test of Overid. Restrictions: <math>\chi^2</math></i> | 28.52**                | 32.58***                          | 35.22***                      |

Note: Dependent variables are Total Patents, Patents by Non-residents, and Patents by Residents. Values in the parentheses are test statistics while \*\*\*, \*\* and \* indicate that the coefficients are significant at 1%, 5% and 10% significance level, respectively. The standard errors for system GMM are robust.

## 5. Discussion

The analysis and results demonstrate that international migration and patenting activities are continuously rising overall. Especially after globalization and liberalization policies, the movement has been easier and simpler across countries. Along with, the advancements of communications technology help

individuals stay in touch with their own nations. However, the dynamics of knowledge diffusion and innovation varies across regions and circumstances due to distinguished characteristics such as availability of capital, technological obtainability and accessibility of skilled labour.

However, the migration take place across the nations for various purpose like business, study, and so on (Ammassari, 2004). Generally, it is be caused by several factors, such as economic, social, and political ones, and can involve both permanent and temporary movement (Vertovec, 2009). International migration is primarily driven by political unrest, armed conflict, and natural disasters, which push migration by making individuals apply for asylum or refugee status in other nations. But the phenomenon of migration is changing with respect to regions and policies of the nations. And in the present globalized world, educated and skilled migrants are seen in a larger extent. And that is, they are becoming the carriers of knowledge that promotes new methods of production and innovation in the destination as well as in the host nations. The role of human capital is significant in regional development as skill migrants carry knowledge from the employees and spill it over to another receiving firm. The research analysis of Lewis (2011) on the effect of skilled and unskilled labor mobility on patent applications in US documented that the emigrants of Mexico in the US lead to slower growth and capital- output ratio. So far as innovation is concerned, the study pointed out that patenting is increasing just after the era of globalization, evidenced by Kim and Marschke (2005) and Castilo et al. (2016). As per their view, the patent application rises when scientists or high-skilled mobility occurs compared to low-skilled mobility. Braunerhlem et al (2014) made an empirical study in Sweden which reflects that the effect of innovation rises when worker collaboration exists in the region. In other words, the firm requires relevant knowledge for more patent applications.

## **6. Conclusion & suggestions**

Innovation and knowledge diffusion are the two sine-qua-non aspects closely associated with human resources development. At micro level, innovation and diffusion aid the enterprises to involve cost-effective production and higher mark up while at macro level, that leads to higher production and economic growth. Our study finds that both innovation and migration have a positive and cause-and-effect relationship. Innovation involves the process of developing new ideas, goods, services or procedures (Ramadani, & Gerguri, 2011) represented in terms of patenting output measure. And such innovative activities are associated with knowledge diffusion through migration. The study supports that exchanging and transferring information and skills from one person to another or organisation to another is crucial for novelty as well as economic growth (Storck, & Hill, 2009). The Spread of information is essential for innovation since it builds the groundwork for fresh concepts and technological developments. However, the present study posits a positive

association between immigration and innovation with empirical analysis. The theoretical findings also suggest the association between both immigration and emigration with innovative activities.

Besides, the study comes across certain limitations due to unavailability of data such as skilled migration, which need to be discussed in the forthcoming research for a conclusive relationship between the two. Besides, the study only analyses the data on immigration and does not incorporate emigration though incorporating emigration statistics is indispensable to understand the impact of innovative activities in outsourcing countries. The lacuna of the study is that international migration is driven by political unrest, armed conflict, and natural disasters which push the migration by making individuals apply for asylum or refugee status in other nations. And the international migrants stock data also includes such statistics, which affect the expected result. Conclusively, the study might not firmly provide the normative conclusion on migration and innovation, but it must provide guidance for further analysis on the same aspects.

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## Appendix-1

**Table-** Region wise migration and innovation

| Year      | Area wise international migration stocks | Area wise emigrants | Net Migration | Area wise Patent applications, non-residents | Area wise Patent applications, residents | Area wise Researchers in R&D (per million people) |
|-----------|------------------------------------------|---------------------|---------------|----------------------------------------------|------------------------------------------|---------------------------------------------------|
| Africa    |                                          |                     |               |                                              |                                          |                                                   |
| 1980      | 25189736                                 | 26101558            | -911822       | 7351                                         | 3272                                     |                                                   |
| 1985      | 25329470                                 | 25545442            | -215972       | 7952                                         | 4320                                     |                                                   |
| 1990      | 28293963                                 | 29444317            | -1150354      | 6821                                         | 1544                                     |                                                   |
| 1995      | 29290489                                 | 30016957            | -726468       | 6994                                         | 1538                                     |                                                   |
| 2000      | 26125800                                 | 27402532            | -1276732      | 3916                                         | 1633                                     | 47.75675                                          |
| 2005      | 26677948                                 | 27865330            | -1187382      | 8429                                         | 1743                                     | 786.3023                                          |
| 2010      | 29742815                                 | 31012744            | -1269929      | 9502                                         | 2127                                     | 3960.422                                          |
| 2015      | 36941004                                 | 37078332            | -137328       | 10075                                        | 2616                                     | 3885.759                                          |
| America   |                                          |                     |               |                                              |                                          |                                                   |
| 1980      | 25450018                                 | 24728566            | 721452        | 82893                                        | 68545                                    |                                                   |
| 1985      | 28818097                                 | 28828220            | -10123        | 87695                                        | 68979                                    |                                                   |
| 1990      | 33710119                                 | 32659882            | 1050237       | 118645                                       | 97766                                    |                                                   |
| 1995      | 38863009                                 | 37733855            | 1129154       | 145245                                       | 130663                                   |                                                   |
| 2000      | 45652066                                 | 44772317            | 879749        | 208784                                       | 174238                                   | 8764.579                                          |
| 2005      | 51235611                                 | 50823502            | 412109        | 259868                                       | 219443                                   | 10183.22                                          |
| 2010      | 58072002                                 | 57270948            | 801054        | 325476                                       | 252888                                   | 12537.48                                          |
| 2015      | 62303363                                 | 61122783            | 1180580       | 389266                                       | 300136                                   | 12525.72                                          |
| Asia      |                                          |                     |               |                                              |                                          |                                                   |
| 1980      | 56414273                                 | 57119044            | -704771       | 80776                                        | 344107                                   |                                                   |
| 1985      | 65268555                                 | 65412912            | -144357       | 103067                                       | 566053                                   |                                                   |
| 1990      | 77504094                                 | 81103334            | -3599240      | 135559                                       | 700289                                   |                                                   |
| 1995      | 79595337                                 | 83341670            | -3746333      | 186060                                       | 818832                                   |                                                   |
| 2000      | 87802221                                 | 90870046            | -3067825      | 319677                                       | 985230                                   | 17091.86                                          |
| 2005      | 1.01E+08                                 | 1.03E+08            | -2640306      | 487643                                       | 1202619                                  | 23796.34                                          |
| 2010      | 1.3E+08                                  | 1.33E+08            | -2196870      | 524335                                       | 1483743                                  | 29602.3                                           |
| 2015      | 1.49E+08                                 | 1.52E+08            | -2881974      | 654515                                       | 2821780                                  | 40724.17                                          |
| Caribbean |                                          |                     |               |                                              |                                          |                                                   |
| 1980      | 939024                                   | 1125589             | -186565       | 266                                          | 140                                      |                                                   |
| 1985      | 993418                                   | 1179434             | -186016       | 57                                           | 9                                        |                                                   |
| 1990      | 1062789                                  | 1254697             | -191908       | 130                                          | 6                                        |                                                   |
| 1995      | 1162510                                  | 1327265             | -164755       | 156                                          | 135                                      |                                                   |
| 2000      | 1267829                                  | 1434729             | -166900       | 309                                          | 16                                       |                                                   |
| 2005      | 1361194                                  | 1520076             | -158882       | 737                                          | 124                                      |                                                   |
| 2010      | 1403729                                  | 1568501             | -164772       | 558                                          | 29                                       |                                                   |
| 2015      | 1442576                                  | 1612579             | -170003       | 598                                          | 37                                       | 348.3643                                          |



| Year    | Area wise international migration stocks | Area wise emigrants | Net Migration | Area wise Patent applications, non-residents | Area wise Patent applications, residents | Area wise Researchers in R&D (per million people) |
|---------|------------------------------------------|---------------------|---------------|----------------------------------------------|------------------------------------------|---------------------------------------------------|
| Europe  |                                          |                     |               |                                              |                                          |                                                   |
| 1980    | 20335881                                 | 19994199            | 341682        | 125375                                       | 99302                                    |                                                   |
| 1985    | 20976949                                 | 21046004            | -69055        | 80813                                        | 97868                                    |                                                   |
| 1990    | 53033512                                 | 52386054            | 647458        | 50356                                        | 90406                                    |                                                   |
| 1995    | 56507169                                 | 55672616            | 834553        | 48034                                        | 118483                                   |                                                   |
| 2000    | 59551097                                 | 58241654            | 1309443       | 64736                                        | 152118                                   | 52005.06                                          |
| 2005    | 67422778                                 | 65957660            | 1465118       | 51649                                        | 132837                                   | 94045.26                                          |
| 2010    | 75748844                                 | 74692533            | 1056311       | 41548                                        | 146192                                   | 100581.1                                          |
| 2015    | 79539887                                 | 78316488            | 1223399       | 51815                                        | 134206                                   | 128058.4                                          |
| Oceania |                                          |                     |               |                                              |                                          |                                                   |
| 1980    | 3561667                                  | 3523460             | 38207         | 11657                                        | 7732                                     |                                                   |
| 1985    | 3853828                                  | 3813201             | 40627         | 2994                                         | 1008                                     |                                                   |
| 1990    | 4726138                                  | 4577576             | 148562        | 3869                                         | 802                                      |                                                   |
| 1995    | 5017151                                  | 4896233             | 120918        | 15714                                        | 3068                                     |                                                   |
| 2000    | 5354467                                  | 5230821             | 123646        | 25658                                        | 3391                                     | 3475.325                                          |
| 2005    | 6016999                                  | 5849399             | 167600        | 26414                                        | 4448                                     | 3544                                              |
| 2010    | 7117845                                  | 6926212             | 191633        | 27529                                        | 3994                                     | 4532.401                                          |
| 2015    | 8092841                                  | 7837271             | 255570        | 31680                                        | 3477                                     | 5417.667                                          |
| Others  |                                          |                     |               |                                              |                                          |                                                   |
| 1980    | 7.08E+08                                 | 7.22E+08            | -1.4E+07      | 222594                                       | 173688                                   |                                                   |
| 1985    | 7.79E+08                                 | 7.89E+08            | -1E+07        | 453898                                       | 824878                                   |                                                   |
| 1990    | 1.2E+09                                  | 1.21E+09            | -1.1E+07      | 494816                                       | 880244                                   |                                                   |
| 1995    | 1.23E+09                                 | 1.24E+09            | -1.2E+07      | 580438                                       | 981487                                   |                                                   |
| 2000    | 1.28E+09                                 | 1.29E+09            | -1.7E+07      | 1358943                                      | 2135523                                  | 26325.12                                          |
| 2005    | 1.38E+09                                 | 1.4E+09             | -2E+07        | 1748367                                      | 2511328                                  | 33906.26                                          |
| 2010    | 1.56E+09                                 | 1.58E+09            | -1.9E+07      | 2025343                                      | 2981699                                  | 38098.69                                          |
| 2015    | 1.72E+09                                 | 1.74E+09            | -2.2E+07      | 2419534                                      | 4472215                                  | 41330.2                                           |

## Appendix-2

**Figure -High income countries**

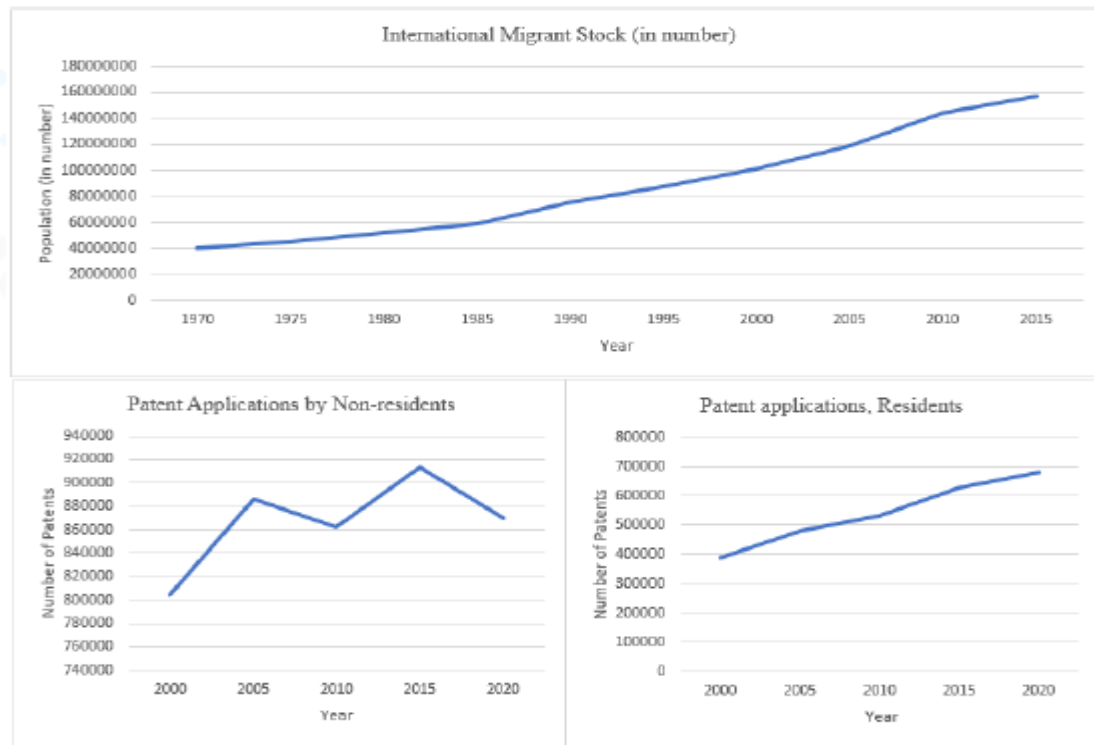


**Figure -Upper middle-income countries**

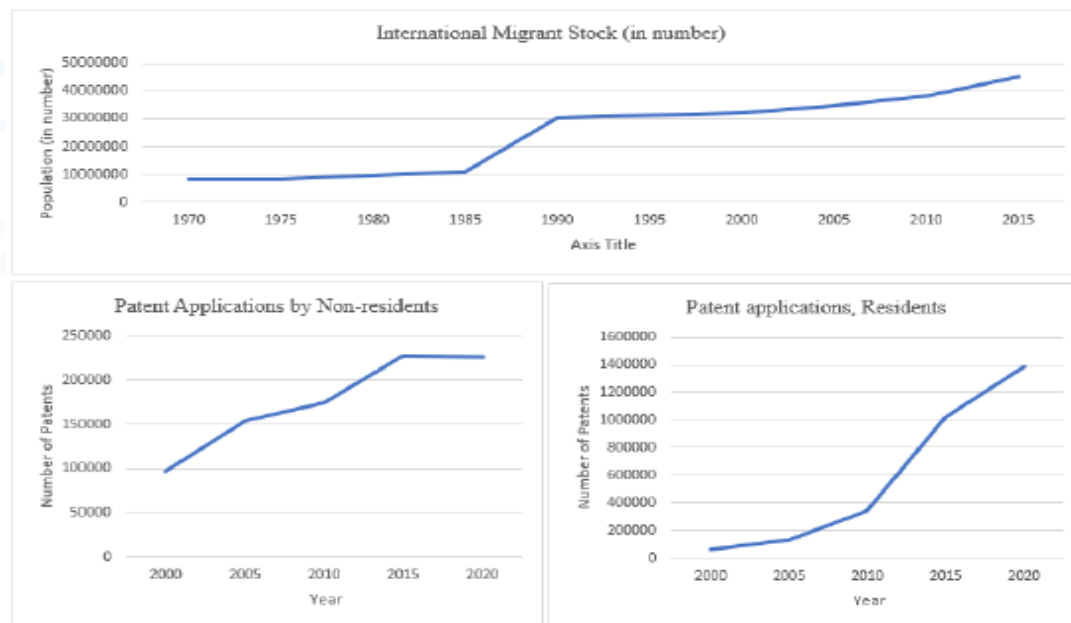


Figure -Lower middle-income countries

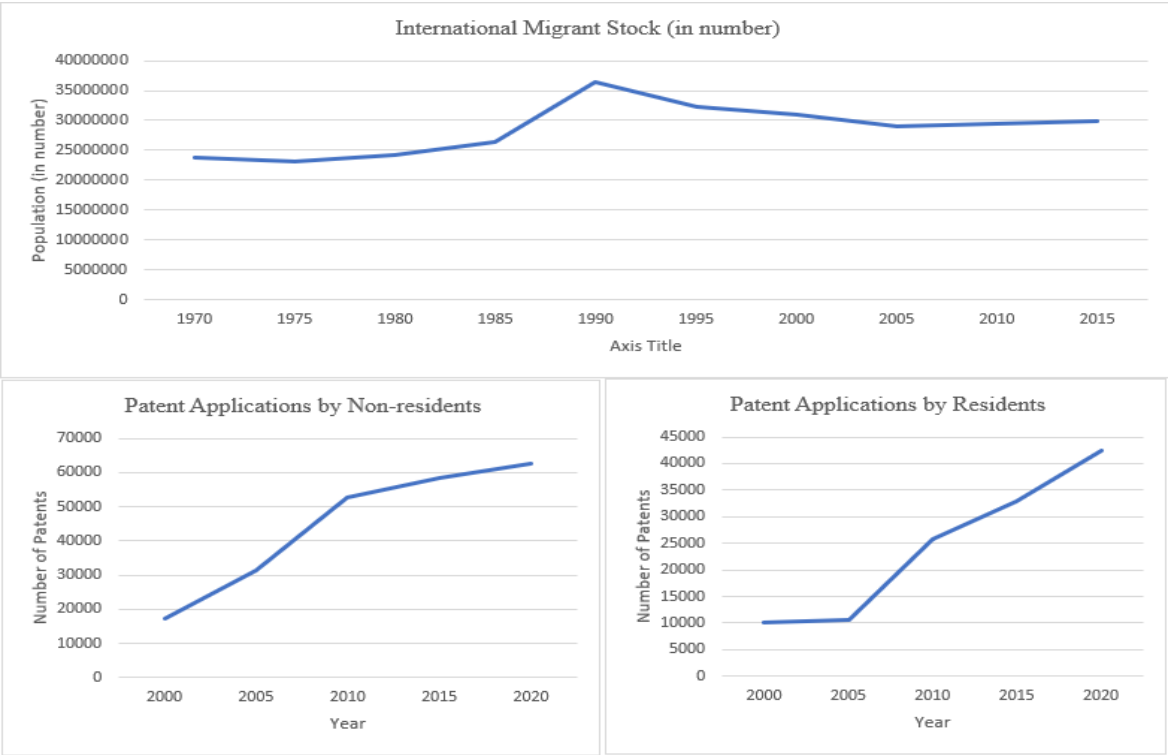
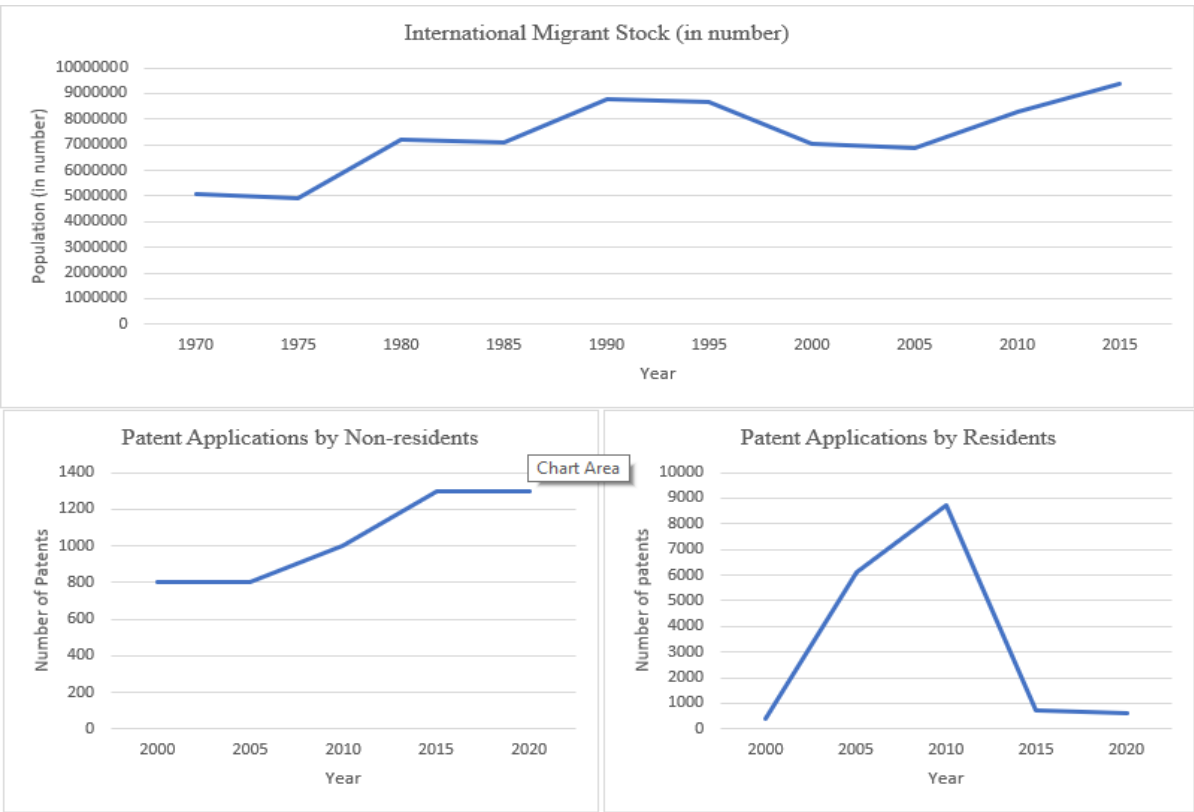


Figure -Low income countries



## Who creates jobs with broad skill-sets? The crucial role of firms

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### Abstract

Our study investigates the heterogeneity of skill demands within occupations, the firm activities that are associated with demand for broader skill sets, and the firm characteristics that are related to particular skills and different combinations of skills. We use a unique matched database of firm-level data and online job vacancy data for a developing economy, namely, India. Employing a multi-level machine learning technique and an innovative skill taxonomy, we identify and categorize skill requirements of firms. Our empirical analysis provides robust evidence of significant heterogeneity in skill requirements across firms within the same occupations. Additionally, we show that firms demanding diverse skills differ from their counterparts. Firms that are competitive in international markets, as well as those that are more innovative require digital skills and specific combinations of digital and other skills. Our findings highlight the crucial role played by firms in defining the changing nature of work.

## Introduction

The demand for new jobs and skills is currently a central topic in the policy and scholarly debates surrounding the changing nature of work. The rapid advances in technological innovation have the potential to transform the world of work, altering the characteristics of occupations and the skills required to perform them. Several studies investigating different dimensions of the labour market show that the skill requirements and task composition within occupations are changing over time, across countries, industries, firms and technological trajectories (Autor, 2015; Ciarli et al., 2021; Dwivedi et al., 2021; Hershbein and Kahn, 2018).

A significant portion of the literature on skills and tasks connects changes in relative demand across occupations to technological change (Autor et al., 2006, 2008; Autor and Dorn, 2013; Goos et al., 2009; Michaels et al., 2014). However, this literature, often centered around the degree of substitutability between human and automated labor, abstracts from the complex interplay between technology, firm decisions, and their capacity to innovate and reorganize production. By reducing (skill/routine biased) technological change to an exogenous unidirectional process, where firms are passive recipients of new technologies with no ability to shape or influence their development and implementation, it fails to fully recognize the active role of organizations, their decisions on technology adoption or development (Dosi et al., 2000; Ciarli et al., 2021), their internal power relationships and hierarchical layers (Dosi and Marengo, 2015; Cetrulo et al., 2020), and the social and institutional factors that also contribute to shaping the organization of work (Cetrulo et al., 2022; Fernández-Macías and Hurley, 2017; Mishel and Bivens, 2017).

We argue that a missing and crucial element in the discussion on the changing nature of skills is the role of the firm as the locus of the division and organization of labour, also in structuring tasks and skills. It is not only the rate of technological change that determines the scope of human intervention in the production process, but instead the organizational decisions and routines (Dosi and Nelson, 2010; Costa et al., 2021) that considerably regulate whether and which new technologies are to be introduced and the resulting reconfiguration of the amount and characteristics of the labour to be associated to these technologies. Firms may not only differ in the technologies they adopt, but also in how they use the same technology for various business functions, depending on their organizational routines. These differences could lead to variations between firms in the way they remodel their productive and innovation activities, which in turn could have differential effects on employment. Very few works recognize the crucial role of organizations in redesigning their activities and related organizational changes while analyzing the changing demand for skills.

Firms in developing countries often lag behind in technology adoption, which can vary significantly across different business functions (Cirera et al., 2021), and can have important consequences for the labor market. For instance, Martins-Neto et al. (2021) cite the lack of technology adoption as a reason for the scant evidence of job polarization in developing economies. In fact, significant differences in technology adoption among firms, particularly across business functions and sectors, could result in varying demand for skills among firms, even within the same occupation. However, this relationship is not clear-cut: thus far, the literature has not established a definitive association between technology use and changes in the composition of skills (Cirera et al., 2021). This raises the question of which firms demand diverse skills, and how diverse skill requirements are associated with different firm level activities.

The present paper aims at filling this gap and examines the extent of firm-level differences in the skills demanded within even narrowly-defined occupation categories, and how firm characteristics map into the demand for specific skills. We study this in the case of the labor market of India, using online vacancy data matched with comprehensive firm-level data and relying on an innovative skill taxonomy and methodology to implement it using vacancy data developed by the ILO Research Department for developing and emerging economies (Bennett et al., 2022) comprising information on digital, other cognitive,<sup>1</sup> manual and socio-emotional

## **1. Skills.**

Several recent studies analyse the changing demand for skills using online vacancy data, mainly focusing on the US labor market with Burning Glass Technologies data. These works show within-occupation variation in skill requirements, positive associations between cognitive and socio-emotional skills, wages and firm performance (Deming and Kahn, 2018), with rising educational requirements in high-wage cities and larger states (Blair and Deming, 2020; Modestino et al., 2020). This recent literature also suggests that AI skills are in high demand (Acemoglu and Restrepo, 2020), benefiting highly-qualified professionals, substituting for customer service activities (Alekseeva et al., 2021), and accelerating routine-biased technology adoption (Hershbein and Kahn, 2018). Copestake et al. (2021) focus on Indian service firms and find a rise in the demand and a wage premium for AI adoption in professional services, leading to net labor displacement and reduced wage offers in non-AI jobs. To our knowledge, this is the only study focusing on a developing economy to study the changing nature of skills. However, Copestake et al. (2021) only look at AI skills, while we examine how firms differ in their demand for a broader set of skills, and how different typologies of skills and their combinations relate to firm characteristics.

In our work, *firstly*, we analyze the heterogeneity of skills demanded across

firms within the same occupation. Secondly, we examine which firms demand heterogeneous skill sets, and study the characteristics of the firms that create skill-diversified jobs, by considering a rich set of firm-level characteristics such as size, age, wages, R&D investment, exporting and financial status. Our intuition is that firms that engage in complex activities, with an organizational environment that favours learning, demand for employees equipped with skills instrumental in performing more advanced functions, that will in turn involve more diversified tasks than the standard prescriptions for the job. *Thirdly*, with the aim of pinpointing which firm activities relate to which typology of skills, we investigate how the demand for digital, other cognitive, socio-emotional or manual skills, and their different interactions map into firm characteristics and performance. Our results indicate that firms with a high demand for diverse skills tend to be younger, pay higher wages, and engage in more complex activities. Our findings also show that specific types of skills are associated with different firm activities and outcomes. In particular, digital skills, as well as a combination of digital and manual skills, are related to higher wages. Digital skills are also linked to high engagement by firms in complex activities.

To our knowledge, this is one of the first studies providing evidence of high heterogeneity in the skills demanded by firms, even within the same occupation, and in particular in the context of a developing economy. Furthermore, this paper is also among the first studies distinguishing between digital and other cognitive, which in previous literature were often combined under the umbrella of “cognitive” skills (Deming and Kahn, 2018). As the changing nature of skill demand is often related to technological change, as mentioned above, we argue that digital and cognitive skills should be studied separately. In fact, by doing so, we are able to disentangle and highlight their distinct relationships with different kinds of firm activities. This distinction is even more relevant in the context of developing economies, for in the initial stages of digitalization adoption firms may require more digital than cognitive skills. Our results emphasize the role of complementary policies that should be implemented at the firm level along with educational policies to tackle changes in the world of work. We further discuss the policy implications of our analysis in the conclusion.

The article is structured as follows. Section 2 details the data sources, their degree of representativeness, and describes the construction of skill and occupational variables, through machine-learning techniques. Section 3 reports evidence on inter-firm heterogeneity in skill demands. In Section 4 we present the empirical results on firm characteristics related to the demand for skill-diversified jobs and for specific bundles of skills. Section 5 offers our conclusions.

## 2. Data

In this study, we use and merge two datasets, i) the online job vacancy data and ii) firm- level balance sheet data. In the present section we describe the two data-sets with initial statistics, the construction of the occupation and skill variables, the data operations that lead to the final matched data-set, and finally the degree of representativeness vis-à-vis the Indian labour market.

### 2.1 Online job vacancy data from the naukri portal

**General data features.** - Our first data source consists of online job vacancies posted on naukri.com, the leading recruitment platform in India.<sup>2</sup> Established in 1997, the platform caters to corporate recruiters, placement agencies, and job seekers. The data is collected through web scrapping and covers the years 2016, 2017, 2019 and 2020. This yields a sample size of around 20 million vacancies, excluding duplicates.<sup>3</sup> Each vacancy consists of a raw text that specifies different characteristics of the job, based on free descriptions. The observations are structured into separated fields, that include the job title, a detailed free-text job description containing the sub-fields “Role” and “Role Category” (which bear similarity with ISCO-08 2-digit and 4-digit occupational codes, respectively), and “Education” (which details the required educational attainments). Moreover, for each vacancy we observe the information on the respective industry, company name, date of the posting, workplace location, the required experience and skills, and the pay-rate – if disclosed by the company. A schematic overview of the vacancy data is provided in Appendix Table A1.

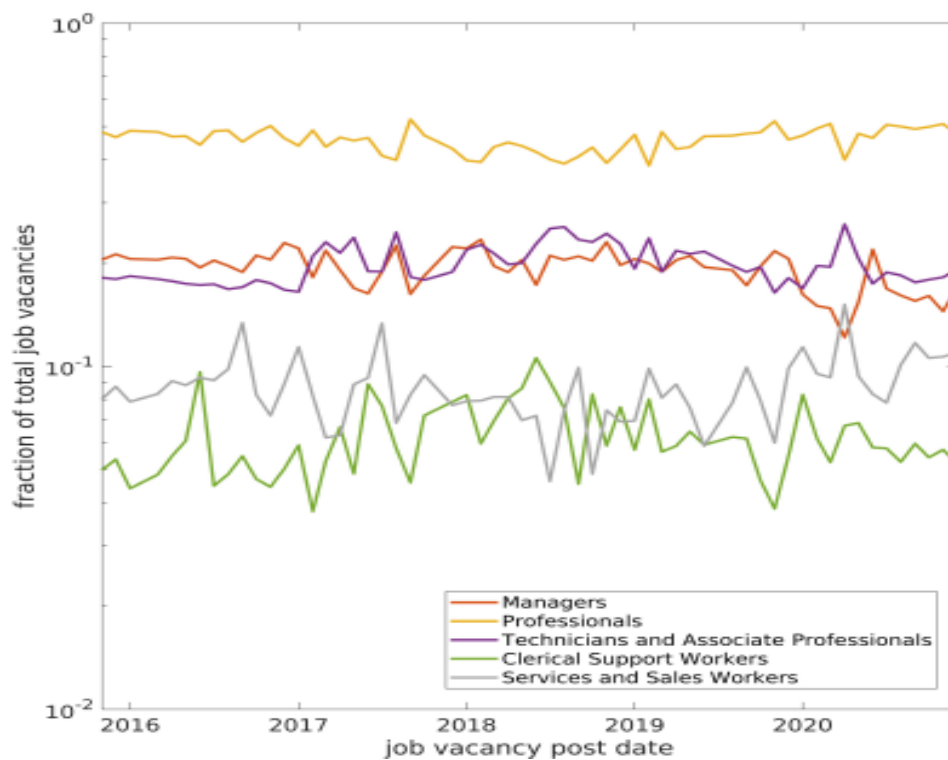
*Construction of the occupational variables.* - We use machine-learning techniques to map job titles to their corresponding ISCO-08 occupational codes at the 2-digit level. The 2-digit level allows us to differentiate the different roles with enough information, without being at risk of misclassifying when going into too much detail. We start with data from 2016 and 2017 and consider the highly disaggregated “Role” sub-field.<sup>4</sup> We organize all the roles into a single list with 678 unique words, taking into consideration only words that appear at least 10 times in the data. We then match the roles with 2 digit ISCO-08 codes by following a set of intuitive rules, that we summarize in Appendix Section B. In such a way we are able to classify 76 per cent of Naukri 2016-2017 job listings. However, the field “Role” is available only for few job posts in the 2019-2020 data. Moreover, while Naukri roles are a good first approximation for labeling firstly ISCO-08 4-digit and secondly 2-digit occupations, they are not always a direct or precise match, and therefore we refine the accuracy of our attributions by using a machine learning (ML) approach. To this end, we use a sub-sample of the 2016- 2017 labeled data as a training set for a Natural Language Processing (NLP) algorithm that, instead of focusing solely on the “Role” sub-field, takes into account the whole free-text “Job Title” field – see Appendix



Table A1 – and maps it directly to 2-digit ISCO-08 occupational categories. Next, we rely on the same NLP algorithm to classify the remaining 2016-2017 and 2019-2020 vacancies, thereby classifying 71 per cent of the whole sample – 11.1 out of 15.6 million online vacancies. The details of this procedure are provided in the Section B of the Appendix.

Figure 1 shows the time evolution of the shares of job posts in 1-digit ISCO-08 major groups. We observe a substantial time consistency across shares, that, albeit some within- year monthly variations, are almost stationary over time, indicating that the data is not subject to systematic fluctuations across time. In particular, the bulk of job posts in the Naukri data-set is concentrated in managerial, professional, technical, clerical and sales occupations, with very high percentages in Managers and Professionals and decreasing shares.

**Figure 1:** Occupational shares across time (1-digit level)



*The figure shows the time evolution of the shares of job posts in 1-digit ISCO-08 major groups present in the Naukri data-set.*

In lower skill-intensive macro occupations, as confirmed by the occupational shares for 2- digit ISCO-08 codes presented in Appendix Section C (see Appendix Figure C1). As can also be observed in the Appendix, as a further step, we benchmark our data-set against the 2017-18 Indian Period *Labour Force Survey* comparing occupational and industrial shares in the Naukri data against those in the survey – by mapping the industries reported by Naukri into the

2008 Indian National Industry Classification (NIC) at the 2-digit level. Thus, from Appendix Figure C2 it is possible to notice that the online vacancy data is biased towards higher-skilled occupations. However, while very low-skilled jobs are not present in the listings, middle-skilled clerical, service and technical occupations are fairly represented. This is clear also in terms of the sectoral distribution, confirming that, when focusing on online vacancies, the lion share of listings appears to be in the service sector, while low shares are present in construction and manufacturing, and no job ads are found in agriculture, mining or electricity, as can be observed in Appendix Figure C3. As an external validation, our observations on the occupational and sectoral representativeness of the vacancy data are in agreement to those presented in Copestake et al. (2021), who use similar data for India. Finally, we also geo-localised each vacancy by computationally cleaning the reported city names and presented the distribution of the vacancies by cities: over 85 per cent of the vacancies are concentrated in large urban areas, with the vast majority located in Bangalore, Delhi and other metropolitan cities (see Appendix Figure C4 for more details).

*Construction of the skill variables.* - We create the skill variables using the skill taxonomy developed by Bennett et al. (2022). Drawing from labour economics and psychology literature, this taxonomy distinguishes between the broad categories of cognitive skills, socio-emotional skills, and manual skills, divided into fourteen more detailed sub-categories.<sup>5</sup>

These are defined through a comprehensive compilation of keywords drawn from a selection of seminal studies that classify skills using online vacancy data (Deming and Kahn, 2018; Deming, 2017; Hershbein and Kahn, 2018; Kureková et al., 2016), and complemented by studies that similarly exploit different kinds of data sources (Atalay et al., 2020; Autor et al., 2003; Spitz-Oener, 2006). For the various analysis we present in the paper, we divide cognitive skills into two categories: digital skills and other cognitive skills. It is worth noting that while Bennett et al. (2022) include digital skills as a sub-skill within the broader category of cognitive skills, we disaggregated these two types of skills in this study.

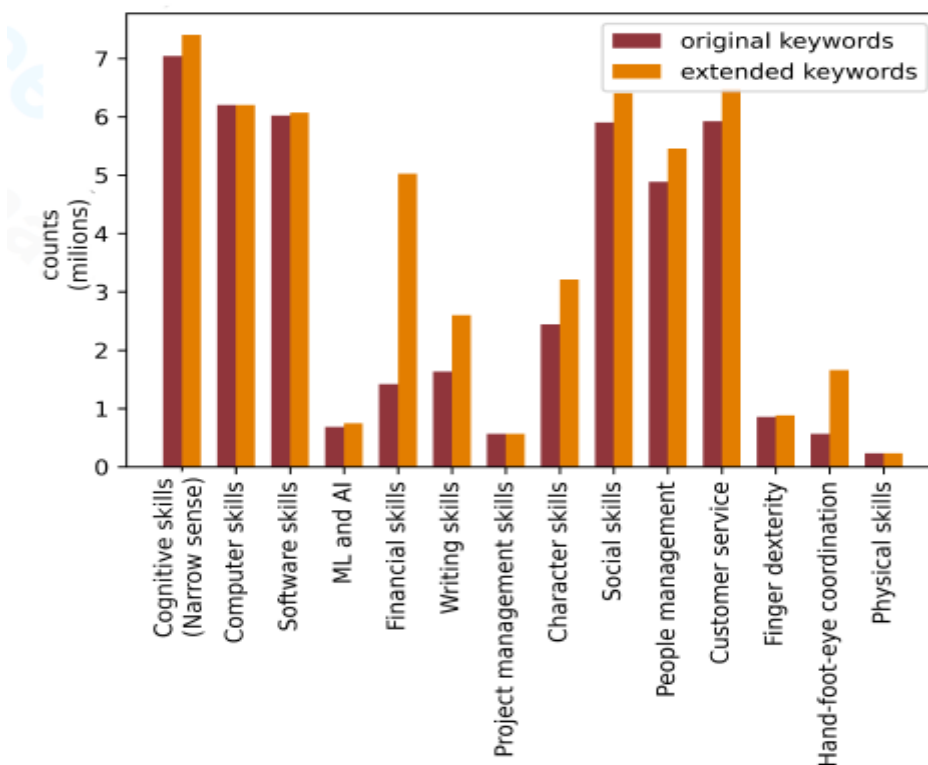
Next, we employ a Natural Language Processing algorithm to identify the presence of these keywords in Naukri listings and assign to each vacancy the respective skill sub-categories. To this aim, we clean and tokenize the description of the skills required in each vacancy. We then expand this approach by also considering synonyms of these keywords, identified through web-scraping of the website [www.thesaurus.com](http://www.thesaurus.com) homepage (methodological details are again provided in Bennett et al., 2022). By doing so, we are able to assign an average of 5.6 skill sub-categories to each vacancy. The resulting skills distribution is shown in Figure 2, which reveals that cognitive and, to a lesser extent, social, customer service, as well as different kinds of digital skills – especially computer and software competences – are highly represented in the

data, whereas, as expected, manual skills are less represented.

## 2.2 Firm-level information from the prowess data-base

As mentioned above, to study skill requirements of firms in the Indian labour market, we match our vacancy data with detailed firm-level information from the Prowess data-base, gathered by the Centre For Monitoring Indian Economy (CMIE), a private company providing information on Indian firms. The information is collected by CMIE from firms' annual balance sheets and income statements, and covers both publicly listed and non-publicly

**Figure 2:** Distribution of skills-subcategories identified in the vacancy data



*“Original keywords” refer to the keywords presented by Bennett et al. (2022) in their methodology, while “extended keywords” also include synonyms of the original keywords identified through web-scraping (see below and Bennett et al. (2022) for information on the methodology used). The y-axis reports the skill keyword counts in millions.*

traded firms from a wide cross-section of manufacturing, services, utilities, and financial industries. These companies account for around 70 per cent of India's industrial output, 75 per cent of corporate taxes, and more than 95 per cent of excise taxes collected by the Indian Government. Prowess is considered the largest firm-level database for India, has allowed researchers to track several dimensions of firm characteristics over time (Goldberg et al., 2010), and has been employed in different studies to investigate firm dynamics and production activities (Coad et al., 2020; Dosi et al., 2017; Goldberg et al., 2010). Hence,

Prowess allows us to observe rich information on the firms posting online vacancies, and to connect the nature of skills they demand to firm characteristics and performance, such as, their growth, profitability, size, age, R&D investments, wages and exporting status. The list of all the variables we exploit in the empirical analysis, along with their definitions and summary statistics, are presented in Table 1.

**Table 1:** Employed firm-level variables from Prowess and Naukri data-sets, definition and summary statistics

| Variable                         | Definition                                                                                 | Mean    | Median  | Std. Dev |
|----------------------------------|--------------------------------------------------------------------------------------------|---------|---------|----------|
| Firm Growth                      | Log difference in sales between $t$ and $t-1$                                              | 0.058   | 0.071   | 0.565    |
| Profitability                    | Profits over sales, relative to the sector average                                         | -1.988  | 0.063   | 18.00    |
| Sales                            | Total sales from industrial goods                                                          | 17113.2 | 1817.25 | 141595.3 |
| Firm Size<br>(proxied by sales)  | Log of total sales                                                                         | 5.59    | 6.00    | 2.93     |
| Firm Size<br>(proxied by assets) | Log of total assets                                                                        | 7.831   | 7.835   | 2.077    |
| Age                              | Number of years since the year of incorporation of firm                                    | 24.868  | 22      | 16.49    |
| Wage Intensity                   | Total wages paid by the firm over Total Sales                                              | 0.213   | 0.123   | 0.209    |
| Export intensity                 | Total value of sales of goods and services from outside India over Total Sales of the firm | 0.303   | 0       | 11.68    |
| Export dummy                     | Takes value 1 if firms has positive sales from selling goods and services outside India    | 0.226   | 0       | 0.418    |
| R&D Intensity                    | R&D expenditure over total sales of the firm                                               | 0.007   | 0       | 0.688    |
| R&D Dummy                        | Takes value 1 if firm spend on R&D                                                         | 0.146   | 0       | 0.353    |
| Skill Div. Index*                | Entropy of the skill distribution at the firm level                                        | 1.77    | 1.88    | 0.457    |

\*The construction of Skill Diversification Index is detailed in section 3.

\*The statistics is calculated for the matched sample of Naukri and PROWESS, comprising a total of 5237 firms.

*Data matching.* - We match the online vacancy data with the firm-level data for each year, exploiting information on firm names. In such a way, we are able to match 10 per cent of the vacancies. In fact, even though Prowess is the largest firm-level panel available for India, it presents similar caveats to other comparable private firm-level databases. It does not include informal enterprises and has a very low share of micro and small enterprises. This might

fundamentally contribute to the large share of unmatched data from online job vacancies and presents a limitation of our study. Even though we are not able to predict how our findings would change when including all firms in the Naukri sample, we believe in the validity of a large part of our results. In fact, higher skill diversification and the lion share of the demand for certain skills (digital and cognitive) and their combination is likely to be concentrated in medium and large enterprises, which are well represented in the Prowess database. As mentioned above, and in line with both occupational and sectoral distributions, online vacancy data are typically not representative of a country's labour force (e.g., see Deming, 2017; Deming and Kahn, 2018; Hershbein and Kahn, 2018) and our data is no exception in this regard.

The Naukri-Prowess matched data-set features 1556394 ads (as mentioned, around the 10 per cent of the original Naukri sample), 5237 firms, 209 cities (262 in the unmatched sample), with 25 per cent of the vacancies for managers, 39 per cent for professionals, 20 per cent for technicians, 9 per cent for clerical support workers, 8 per cent for service and sales workers, and very low percentages in craft workers, machine operators, and assemblers.<sup>6</sup> The average number of ads posted by each firm is 297 in a range going from 1 to 98100, and the "average firm" displays 297 ads, for jobs in 6 occupations located in 4 cities and requiring on average 5 skills.

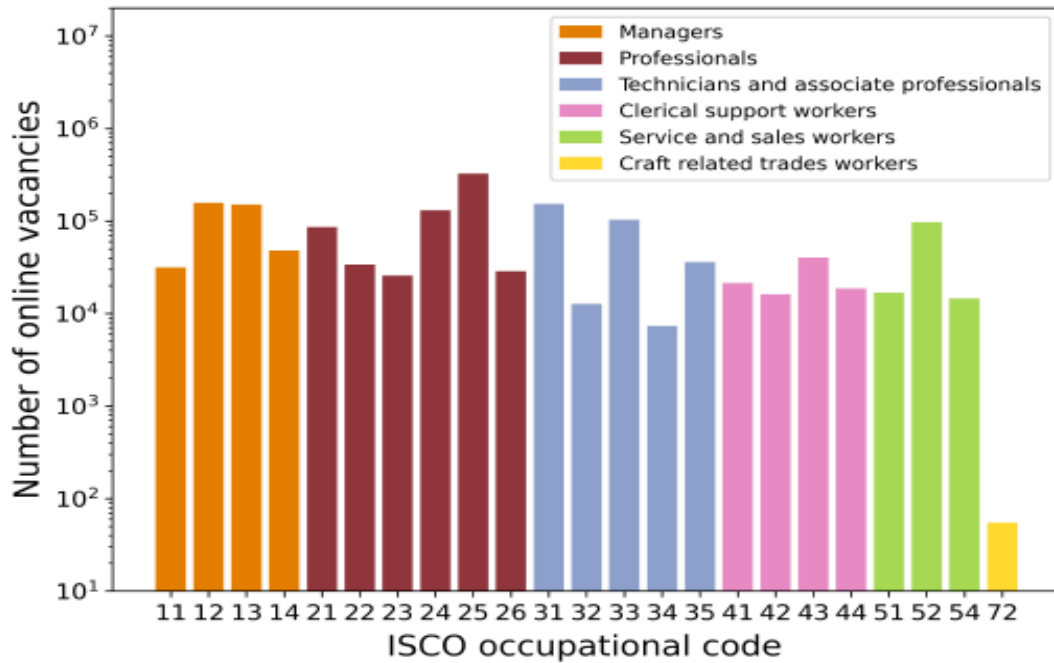
To better understand the occupational distribution of the matched data-set, in Figure 3 we report the number of vacancies for each 2-digit ISCO-08 occupation, a lower level of disaggregation, pooling all job posts over time. We observe that a large number of vacancies cover professional occupations – e.g., in finance, consultancy, manufacturing or ICTs –, and a lower percentage of managerial ones, which are likely filled through less publicly advertised channels. In orange we can observe how the combination of the ISCO-08 codes 12–*Administrative and commercial managers* and 13–*Production and specialized services managers* are the most represented among managerial occupations, while the most apical roles in code 11–*Chief executives, senior officials and legislators* displays a number of job posts lower by one order of magnitude. By contrast, the group of professionals (burgundy), the most represented among the online adverts, is more evenly distributed among 2-digit codes, with the prominent occupations being 25–*Information and communications technology professionals*, 24–*Business and administration professionals*, both with more than 100,000 ads, and 21–*Science and engineering professionals*. Among technical occupations (pale blue) 31–*Science and engineering associate professionals* and 33–*Business and administration associate professionals* are the most represented occupations, each with around 100,000 ads; while for services and sales workers (green) we find more than 100,000 ads for 52–*Sales workers* and more than 10,000 for 43–*Numerical and material recording clerks* (pink). The figure also shows that some occupational groups are not at all covered by the data, including craft and related trades workers, elementary occupations, and skilled agricultural and

fishery workers – as was also noted in terms of sectoral distribution of the Naukri vacancy data where jobs in manufacturing and agriculture are almost not present, while a good coverage in services and transport, storage, and communication industries is featured.

### 3. Inter-firm heterogeneity in skill requirements

We begin our analysis by studying the within-occupation heterogeneity in skill demand between firms. We thus aim at answering questions such as whether and to what extent the tasks performed by computer programmers differ from one firm to another.

**Figure 3:** Number of job posts, at the 2-digit ISCO08 occupational level (pooled)



The figure shows, for the matched data-set, the number of online job posts for each 2-digit ISCO-08 occupational categories, where the y-axis is displayed in logarithmic scale. Color indicates the corresponding 1-digit ISCO-08 groups.

Here, we look at the similarity (or lack of thereof) in the skill demand of each occupation across firms by building a skill vector  $S^{(i)}$  for each firm  $i$ , each occupation and year.  $S^{(i)}$  contains the fourteen categories identified in the ILO skill taxonomy, and is thus of dimension  $N_{\text{skills}} = 14$ . The entries of the skill vector are defined as  $S_l^{(i)} = N_{\text{jobs}}^{(i,l)}$  for  $(l = 1, \dots, N_{\text{skills}})$  where  $N_{\text{jobs}}^{(i,l)}$  denotes the number of jobs posted by firm  $i$  that require skill  $l$  in the chosen occupation (with  $N_{\text{jobs}}^{(i,l)} = 0$  if the skill is not sought after by the firm). Then, for each pair of firms  $i$  and  $j$  that listed at least one job post in the chosen occupation and year, we compute an index of similarity between the two corresponding skill vectors.

In practice, especially because we are interested in the frequency of the different skills demanded for each occupation rather than skill-intensity, we employ a measure of cosine similarity quantifying how similar the demand for skills is between each possible pair of firms that post job listings in a specific occupation in a given year, independently from the number of skills they require. The cosine similarity  $CS$  between the skill vector  $S^{(i)}$  of firm  $i$  and the skill vector  $S^{(j)}$  of firm  $j$  can be defined as the dot product between the two vectors divided by the product of their Euclidean norms. To express this formally:

$$\begin{aligned}
 CS(S^{(i)}, S^{(j)}) &= \frac{S^{(i)} \cdot S^{(j)}}{\|S^{(i)}\| \|S^{(j)}\|} \\
 &= \frac{\sum_{l=1}^{N_{skills}} S_l^{(i)} S_l^{(j)}}{\sqrt{\sum_{l=1}^{N_{skills}} S_l^{(i)2}} \sqrt{\sum_{l=1}^{N_{skills}} S_l^{(j)2}}} \quad (1)
 \end{aligned}$$

In our case, having only non-negative entries in the skill vectors,  $CS(S^{(i)}, S^{(j)})$  ranges between 0 and 1, with value 0 indicating orthogonality and thus complete de-correlation, and value 1 indicating that the two vectors are identical. Analysing the distribution of the cosine similarity between the required skills across all pairs of firms for each occupation allows us to observe the within-occupation heterogeneous demand for skills. More specifically, by means of a kernel density analysis, we observe its deviation from a normal distribution – i.e. to understand whether and to what extent the within-occupation skill non-similarity differs from the normal case.

As can be observed in Figure 4, at a first glance, the kernel densities of cosine similarity suggest asymmetry in the tails and significantly fat left-tailed distributions. In the following, we empirically test and quantify in a parametric way the observed empirical distributions and their deviations from a Gaussian. With this aim, we rely on the Subbotin family of distributions introduced into economic analysis by Bottazzi et al. (2002), a general and flexible distributional model that allows us to parameterize the two tails of the distribution. The Subbotin distribution takes the following functional form:

$$f(g; a, b, m) = \frac{1}{2 * a * b^{\frac{1}{b}} * \Gamma(1 + \frac{1}{b})} e^{(-\frac{1}{b} * |\frac{g-m}{a}|^b)} \quad (2)$$

with  $\Gamma(\cdot)$  standing for the Gamma function, and the three parameters defining the distribution being:

1.  $m$ , the location parameter which indicates the existence of a general trend in the data;
2.  $a$ , the scale parameter which determines the spread or dispersion of the distribution;
3.  $b$ , the shape parameter which indicates the shape/thickness of the tails.

When  $b=2$ ,  $f(g; a, b, m)$  becomes a Gaussian distribution, and when  $b=1$  a Laplace distribution, which are particular cases of the Subbotin family of probability densities. The smaller values of  $b$  correspond to fatter tails of the distribution. Bottazzi and Secchi (2011) extend the Subbotin distributions to a 5-parameter family of distributions, the Asymmetric Exponential Power (AEP) distribution, able to accommodate for asymmetries in the data, e.g., for asymmetric tails. The AEP parameterizes also the shape (and scale) of the two sides of the distribution. Therefore, in addition to the location parameter  $m$  representing the mode, it includes two positive scale parameters  $a_r$  and  $a_l$ , associated with the distribution width respectively above and below the modal value, and two positive shape parameters  $b_r$  and  $b_l$  describing the behavior of the right and the left tail, respectively. The AEP density presents the following functional form:

$$f_{AEP}(x; a_l, a_r, b_l, b_r, m) = \frac{1}{C} e^{\left( - \left[ \frac{1}{b_l} * \left| \frac{x-m}{a_l} \right|^{b_l} * \theta(m-x) + \frac{1}{b_r} * \left| \frac{x-m}{a_r} \right|^{b_r} * \theta(x-m) \right] \right)} \quad (3)$$

where the normalization constant  $C = a_l b_l^{1/b_l - 1} \Gamma(1/b_l) + a_r b_r^{1/b_r - 1} \Gamma(1/b_r)$ , and  $\theta(x)$  is the

Heaviside step function taking value 1 if  $x > 0$  and value 0 if  $x \leq 0$ .

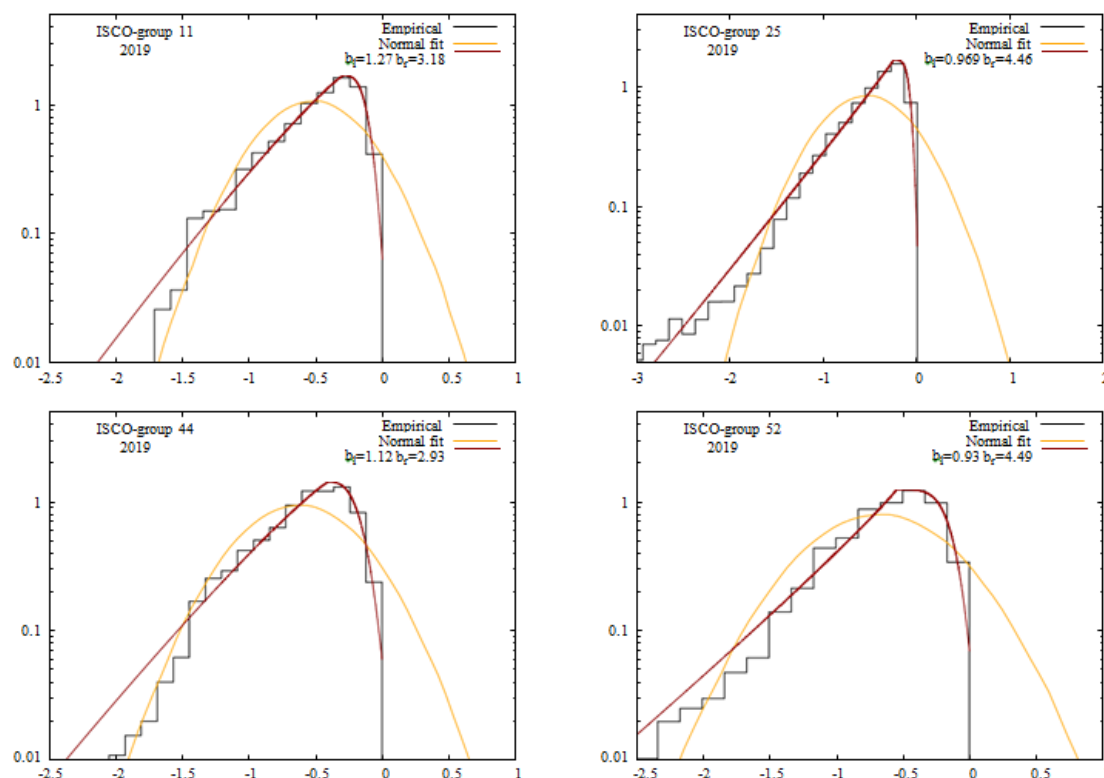
As mentioned above, a value for  $b_l$  ( $b_r$ ) lower than 2 would indicate that the left (right) tail is fat and there are more extreme events in the distribution than what one expects with respect to a normal. Please notice however that here we are not focusing on the right tail of the distribution since the maximum value is fixed and the cosine similarity cannot be greater than 1.

Figure 4 compares the empirical distribution of the cosine similarity with the AEP and normal fit for the selected two-digit occupational categories (11-Chief Executives, Senior Officials and Legislators, 25-ICT Professionals, 44-Clerical Support Workers and 52-Sales Workers), with the black curve representing the empirical histogram, the red curve the AEP fit, and the orange curve the normal fit, with the x-axis in log-scale. As noted above, from the figure it is visually detectable that the distributions are fat left-tailed. The maximum likelihood estimates<sup>7</sup> of the AEP parameters are presented in Table 2. The parameter values confirm the visual impression: the  $b_l$  parameters are always lower than 2, confirming the presence of a large number of firms demanding very dissimilar skills sets



within the same occupations, and this is widespread across all occupational categories and time.<sup>8</sup>

Figure 4: Empirical distribution across firms of cosine similarity (black) together with normal (orange) and Asymmetric Exponential Power (AEP) (burgundy) fits for the occupational categories: Chief Executives, Senior Officials and Legislators (ISCO 11), ICT Professionals (ISCO 25), Clerical Support Workers (ISCO 44), and Sales Workers (ISCO 52).



We therefore find very strong evidence of within-occupation heterogeneity in skills demanded across firms. To our knowledge, this is the first study empirically documenting such widespread differences between firms in skill requirements across occupational categories, emphasising the crucial role of firms and their activities in the changing nature of skills and with potential implications for future studies analysing job and skill dynamics.

**Table 2:** Estimates of the shape parameters ( $b_l$ ) and ( $b_r$ ) of cosine similarity distribution for different ISCO 2-digit categories

| <b>Occupations (2-digit)</b>                              | $b_l$ | $b_r$ | <b>N</b> |
|-----------------------------------------------------------|-------|-------|----------|
| Chief Executives, Senior Officials and Legislators        | 1.127 | 3.183 | 248678   |
| Administrative and Commercial Managers                    | 1.064 | 3.649 | 1927039  |
| Production and Specialized Services Managers              | 1.022 | 4.329 | 1463295  |
| Hospitality, Retail and Other Services Managers           | 1.108 | 3.737 | 380280   |
| Science and Engineering Professionals                     | 1.101 | 3.907 | 725177   |
| Health Professionals                                      | 0.991 | 3.784 | 125639   |
| Teaching Professionals                                    | 1.012 | 4.581 | 114341   |
| Business and Administration Professionals                 | 1.042 | 5.121 | 2078305  |
| Information & Communications Technology Professionals     | 0.969 | 4.459 | 895029   |
| Legal, Social and Cultural Professionals                  | 1.002 | 4.411 | 190512   |
| Science and Engineering Associate Professionals           | 0.982 | 5.974 | 817400   |
| Health Associate Professionals                            | 1.090 | 3.642 | 57537    |
| Business and Administration Associate Professionals       | 1.040 | 3.798 | 1169193  |
| Legal, Social, Cultural & Related Associate Professionals | 1.264 | 3.183 | 17547    |
| Information and Communications Technicians                | 1.066 | 3.492 | 129561   |
| General and Keyboard Clerks                               | 1.020 | 3.697 | 163053   |
| Customer Services Clerks                                  | 1.000 | 2.870 | 98521    |
| Numerical and Material Recording Clerks                   | 9.820 | 4.142 | 451221   |
| Other Clerical Support Workers                            | 1.125 | 2.933 | 155219   |
| Personal Services Workers                                 | 1.043 | 3.627 | 74882    |
| Sales Workers                                             | 0.930 | 4.495 | 356428   |
| Protective Services Workers                               | 1.061 | 3.946 | 36065    |
| Drivers and Mobile Plant Operators                        | 1.220 | 3.653 | 677      |

#### 4. Skill demand and firm characteristics

Having observed the firm-level variation in skill requirements in the previous section, here we focus on the firm characteristics that are associated to different skill demands. Specifically, in Subsection 4.1, we investigate which firms create more “skill-diversified” jobs, while in Subsection 4.2, we explore whether and how different types of skills (or combinations of them) relate to different firm outcomes.

##### 4.1 Which firms create “skill-diversified” jobs?

Our goal here is to understand which firms create jobs with diversified skills, that is, to trace the origin of the demand for diversified skills. Also on the basis of what we observed in the previous section, we hypothesize that studying the demand for skills at a mere occupational level may hide how the demand for different skill sets relate to the different activities performed at the firm-level.

For instance, while most software engineers require digital skills, a Google India's software engineer might also require socio-emotional skills to perform more complex and diversified tasks, such as strategizing with clients or overseeing co-workers, which might not be necessary in a firm performing less complex activities.

Our analysis will thus help answering the following questions: Which firms ask for a more heterogeneous skill set? Old or young? Big or small? Innovators or non-innovators? Exporters or domestic producers? Do higher-paying firms demand for employees with more diverse skill sets? In the following we address these research questions employing as dependent variable  $SDI_{i,t}$ , a measure of skill diversity for firm  $i$  at time  $t$ , which we quantify by means of Shannon entropy. More in detail, for each firm  $i$  we compute a normalized skill vector, whose component  $p_{i,s}$  represents the number of job ads posted by firm  $i$  requiring

skill  $s$ ,  $n_{i,s}$ , divided by the total number of skills required by the firm,  $N_i$ :

$$p_{i,s} = \frac{n_{i,s}}{N_i} = \frac{n_{i,s}}{\sum_s n_{i,s}}. \quad (4)$$

Therefore, the skill diversity of firm  $i$  at time  $t$  is defined as follows:

$$SDI_{i,t} = - \sum_s p_{i,s} \log p_{i,s} \quad (5)$$

$SDI_{i,t}$  is equal to zero for firms that demand only a single specific skill, while is maximal for firms demanding all skills with the same frequency.

We therefore estimate firm demand for a diverse skill set with the following model:

$$SDI_{it} = \beta_1 SIZE_{it-1} + \beta_2 AGE_{it-1} + \beta_3 WAGES_{it-1} + \beta_4 PFT_{it-1} + \beta_5 FGR_{it-1} + \beta_6 R\&D_{it-1} + \beta_7 EXP_{it-1} + b^f + l_{it} + o_{it} + d_t + e_{it}. \quad (6)$$

Where the independent variables, considered in the previous year  $t - 1$ , include several characteristics of firm  $i$ : size ( $SIZE_{it-1}$ ), age ( $AGE_{it-1}$ ), wages ( $WAGES_{it-1}$ ), firm-level spending on R&D ( $R\&D_{it-1}$ ), exporting ( $EXP_{it-1}$ ), and as performance variables profitability ( $PFT_{it-1}$ ) and sales growth ( $FGR_{it-1}$ ). A more detailed definition of the variables is provided in Table 1. We also include controls for the location, i.e. the city where the advertised job will take place ( $l_{it}$ ), occupation at 2-digit ISCO-08 level ( $o_{it}$ ), time ( $d_t$ ) dummies and firm fixed effects ( $b^f$ ). Using firm fixed effects allows us to control for any time-invariant unobserved variables, such as the sector in which the firm operates. This enables us to capture the effect of variables that do vary over time, as the different independent variables in our estimations.

**Table 3** shows the results using a fixed effect estimation, with different model specifications. The first two columns present the regressions without the variable firm growth, with the specification presented in the first column including time and occupation dummies. The specification in the second column also includes location dummies. The third and fourth columns present the same specification of the first two columns with the exception that we extend the model including also firm growth, defined as the sales log difference over two consecutive years.

The results we observe are robust to the various specifications. Concerning the baseline model, we observe that age shows a negative and significant relationship with skill diversification in all specifications, that is younger firms are more likely to demand more diverse skills. Wages show a strongly positive relation with the SDI index, suggesting that firms that demand more skill diverse jobs also pay higher wages. Among the performance variables, we do not find any positive relationship between either firm growth or profitability and demand for more skill diverse jobs. At times, the relationship is negative and significant. This could be due to the fact that, in a shorter time span, firms might be investing in new (and costly) activities related to the demand for more diverse skills, activities that might give returns only in a longer time span. Note that the analyses we present here are all of short-run nature, and the long-run effect of skill diversity on performances could be different. Concerning the extended firm-level controls, increased skill diversity is positively associated to R&D and exporting, i.e., higher levels of firm spending on R&D and export market performance are linked to higher diversity in skills. This is very interesting, since these are considered to be complex firm activities (Coad et al., 2021), associated with idiosyncratic patterns of learning by firms (Dosi et al., 2015). The results we observe suggest that what workers do at workplace significantly differ depending on the activities undertaken by the respective organization.

**Table 3:** Skill Diversification Index and firm characteristics

|                  | (1)                    | (2)                    | (3)                    | (4)                    |
|------------------|------------------------|------------------------|------------------------|------------------------|
| Log Sales        | 0.2231***<br>(0.0464)  | 0.1975***<br>(0.0625)  | 0.2316***<br>(0.0450)  | 0.1866***<br>(0.0578)  |
| Log Age          | -0.3984***<br>(0.1520) | -0.3994**<br>(0.1665)  | -0.4093**<br>(0.1615)  | -0.4611**<br>(0.2169)  |
| Wage Intensity   | 0.0155***<br>(0.0053)  | 0.0123*<br>(0.0065)    | 0.0146***<br>(0.0051)  | 0.0128**<br>(0.0061)   |
| Profitability    | -0.2277***<br>(0.0517) | -0.2797***<br>(0.0769) | -0.2149***<br>(0.0535) | -0.2921***<br>(0.0661) |
| R&D Intensity    | 0.0946***<br>(0.0311)  | 0.1058***<br>(0.0329)  | 0.1208***<br>(0.0379)  | 0.1486***<br>(0.0392)  |
| Export Intensity | 0.1151***              | 0.1082***              | 0.1236***              | 0.1086***              |

|                    | (1)      | (2)      | (3)                 | (4)                  |
|--------------------|----------|----------|---------------------|----------------------|
|                    | (0.0273) | (0.0329) | (0.0283)            | (0.0359)             |
| Firm Growth        |          |          | -0.2365<br>(0.1577) | -0.4328*<br>(0.2509) |
| Time dummies       | Yes      | Yes      | Yes                 | Yes                  |
| Occupation dummies | Yes      | Yes      | Yes                 | Yes                  |
| Location dummies   | No       | Yes      | No                  | Yes                  |
| Observations       | 2453     | 2453     | 2397                | 2397                 |
| R <sup>2</sup>     | 0.171    | 0.292    | 0.181               | 0.304                |
| Number of firms    | 1748     | 1748     | 1714                | 1714                 |

*Standard errors were clustered at the firm level and are shown in parenthesis*

*\*, \*\*, and \*\*\* denote significance at the 1, 5, and 10 per cent level*

*Dependent Variable: Skill Diversification Index; RHS variables are lagged by one year.*

## 4.2 Skill typologies and firm outcomes

In addition to estimating which firms require more diversified skill sets, we now investigate the relationship between the demand for specific typologies of skill sets and firm-level outcomes. Therefore, similarly to Deming and Kahn (2018),<sup>9</sup> to take into account diversified skill requirements, we construct our independent variable  $SKILL_{i,t}$  as the probability that a job advertised by firm  $i$  at time  $t$  requires a skill belonging to four main categories based on the skill taxonomy developed by the ILO, namely: Cognitive, Digital, Socio-emotional and Manual, and the various combinations of the above. In particular, we set  $SKILL_{i,t}$  to take values in the following 10 categories: [Cognitive, Digital, Socio-emotional, Manual, Cognitive & Digital, Cognitive & Socio-emotional, Cognitive & Manual, Digital & Socio-emotional, Digital & Manual, Socio-emotional & Manual ].

With the aim of understanding the relationship between firm-level outcomes and these different skill requirements, we estimate the following econometric specifications:

$$Y_{i,t} = \beta X_{i,t-1} + \delta SKILL_{i,t-1} + b^f + l_{it} + o_{it} + d_t + \eta_{it} \quad (7)$$

where  $Y_{i,t}$  represents the considered dimensions of firm  $i$ 's performance at time  $t$ , namely: wages, sales growth, relative profitability, exporting intensity and R&D spending;  $X_{i,t-1}$  represents firm size at time  $t - 1$ ;  $SKILL_{i,t-1}$  is the skill typology vector at time  $t - 1$  defined above;  $l_{it}$ ,  $o_{it}$ ,  $d_t$  and  $b^f$  are location, occupation, time and firm fixed effects. Note that to avoid spurious correlation between the intensity variable and the variable controlling for firm size, when the dependent variable is defined in terms of intensities, such as wage intensity (total wages over total sales), we control for firm size using the log of assets and not sales, since they enter the dependent variable. These details are clearly reported in the respective tables.

Tables 4 – 8 report the relationships respectively between wages, profitability, sales growth, exporting and R&D, and different skill requirements, according to Equation 7. The first column of each table presents the baseline specification with only the four main skill categories, namely cognitive, digital, Socio-emotional and manual. The specifications in columns 2-6 include also the different combinations of the four main skill categories, as detailed above.

In Table 4, with wage intensity as dependent variable, we can observe that the estimated coefficients of digital and socio-emotional skills are positive and significant in all model specifications, albeit socio-emotional skills are significant only at 10% level when considering also the interaction of digital and socio-emotional skills in column (3) and all the skill combinations in column (6). Digital skills show a statistically significant coefficient at the less than 1% significance level between 0.09 and 0.01 in all specifications, suggesting that the demand for digital skills by firms is associated with a 0.1% increase in wage intensity. In contrast, the coefficient of manual skills is consistently negative and significant showing that firms requiring manual skills offer lower wages. However, when manual skills are complemented with digital skills, it leads to higher wage intensity. Similarly, a combination of digital and socio-emotional skills is also associated to higher wage intensity. Furthermore, we do not observe any significant relationship between cognitive skills alone and wage intensity, while socio-emotional skills are significantly and positively associated with higher wage intensity. Concerning firm performance measures, Table 5 shows the results for firm profitability.

According to our analysis, both digital and socio-emotional skills are associated to lower firm profitability. This may suggest that firms that are looking for digital skills are investing heavily in technology, in other words, are in the process of technology adoption that may lead to lower profitability in the short run. Cognitive skills report a positive coefficient that is significant at 10% level in columns (2)-(4). While manual skills show positive and significant coefficients between 1.0 and 1.2 in all model specifications, considering also the complementary role of different skill typologies, the results suggest that firms requiring manual skills and a mixture of other competencies are more profitable, especially in the case of the interaction of manual or socio-emotional skills with digital skills.

**Table 4:** Wage intensity and skill requirements

|                           | (1)                   | (2)                    | (3)                    | (4)                    | (5)                    | (6)                    |
|---------------------------|-----------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Cognitive                 | 0.0002<br>(0.0028)    | -0.0002<br>(0.0028)    | 0.0008<br>(0.0028)     | 0.0001<br>(0.0028)     | 0.0004<br>(0.0029)     | 0.0006<br>(0.0029)     |
| Digital                   | 0.0102***<br>(0.0023) | 0.0098***<br>(0.0024)  | 0.0093***<br>(0.0024)  | 0.0088***<br>(0.0024)  | 0.0089***<br>(0.0025)  | 0.0092***<br>(0.0025)  |
| Social                    | 0.0043**<br>(0.0019)  | 0.0044**<br>(0.0020)   | 0.0036*<br>(0.0020)    | 0.0045**<br>(0.0020)   | 0.0041**<br>(0.0019)   | 0.0037*<br>(0.0020)    |
| Manual                    | -0.0056*<br>(0.0031)  | -0.0104***<br>(0.0034) | -0.0106***<br>(0.0033) | -0.0098***<br>(0.0034) | -0.0100***<br>(0.0034) | -0.0097***<br>(0.0034) |
| Cognitive & Digital       |                       | 0.0012<br>(0.0017)     | -0.0072**<br>(0.0034)  |                        |                        | -0.0099***<br>(0.0036) |
| Cognitive & Social        |                       | 0.0001<br>(0.0027)     |                        |                        | -0.0015<br>(0.0028)    | 0.0010<br>(0.0031)     |
| Cognitive & Manual        |                       | 0.0037***<br>(0.0011)  |                        | 0.0005<br>(0.0054)     |                        | 0.0049<br>(0.0059)     |
| Digital & Social          |                       |                        | 0.0074**<br>(0.0033)   |                        | 0.0035**<br>(0.0018)   | 0.0080**<br>(0.0037)   |
| Digital & Manual          |                       |                        | 0.0045***<br>(0.0011)  | 0.0073***<br>(0.0024)  |                        | 0.0089***<br>(0.0033)  |
| Social & Manual           |                       |                        |                        | -0.0036<br>(0.0054)    | 0.0035***<br>(0.0011)  | -0.0097*<br>(0.0058)   |
| Firm Size (Log of assets) | 0.0112***<br>(0.0005) | 0.0113***<br>(0.0005)  | 0.0113***<br>(0.0005)  | 0.0113***<br>(0.0005)  | 0.0113***<br>(0.0005)  | 0.0113***<br>(0.0005)  |
| Time dummies              | Yes                   | Yes                    | Yes                    | Yes                    | Yes                    | Yes                    |
| Occupation dummies        | Yes                   | Yes                    | Yes                    | Yes                    | Yes                    | Yes                    |
| Location dummies          | Yes                   | Yes                    | Yes                    | Yes                    | Yes                    | Yes                    |
| Observations              | 7,386                 | 7,386                  | 7,386                  | 7,386                  | 7,386                  | 7,386                  |
| R <sup>2</sup>            | 0.029                 | 0.029                  | 0.030                  | 0.030                  | 0.030                  | 0.030                  |
| Number of firms           | 3902                  | 3902                   | 3902                   | 3902                   | 3902                   | 3902                   |

*Standard errors were clustered at the firm level and are shown in parenthesis*

*\*, \*\*, and \*\*\* denote significance at the 1, 5, and 10 per cent level*

Instead, as can be observed in Table 6, digital, socio-emotional and manual skills are associated with higher firm growth, while cognitive skills show a negative and significant relationship to growth. By looking at the different skill combinations, we observe that both the combination of manual-digital skills, and cognitive-social skills are associated with higher firm growth. These

findings, together with the results on profitability, suggest that firms that invest in digital skills might suffer on profitability owing to their high investments, while these investments are boosting short-run sales growth.

Table 7 presents the estimation results with export intensity as dependent variable. In this case, the demand for digital skills appear to be important for performance in the export market, where effects are statistically significant at the 1% level in all specifications. The magnitude of the coefficient is also high: firms' demand for digital skills is related to a 1.4% increase in export intensity. Similar is the case for cognitive skills, with firms demanding cognitive skills being more likely to show higher export intensity. Contrarily, manual skills are consistently not significant, hinting at the fact that firms catering more to the domestic market are more prone to demand manual competences. However when manual skills are combined with cognitive or digital skills, they are related to higher exporting intensity.<sup>10</sup>

Table 8 presents the results with R&D intensity as dependent variable. Similarly to the case of exporting intensity, digital skills are positively associated with the innovative activities of firms. However, here, the magnitude of their effect is the highest: demand for digital skills is associated with around a 2.4% increase in the intensity of the R&D activity undertaken by firms. Likewise, cognitive skills are associated positively with R&D intensity, and the same is true for socio-emotional skills, albeit with slightly lower magnitude. The coefficient for manual skills are negative and significant, suggesting that more R&D intense firms have a lower demand for manual skills.<sup>11</sup>

**Table 5:** Firm profitability and Skill Requirements

|                     | (1)                        | (2)                        | (3)                    | (4)                        | (5)                        | (6)                        |
|---------------------|----------------------------|----------------------------|------------------------|----------------------------|----------------------------|----------------------------|
| Cognitive           | 0.1336<br>(0.1004)         | 0.1759*<br>(0.1007)        | 0.1718*<br>(0.1006)    | 0.1792*<br>(0.1002)        | 0.1550<br>(0.1012)         | 0.2058**<br>(0.1022)       |
| Digital             | -<br>0.5382***<br>(0.0820) | -<br>0.5048***<br>(0.0866) | -0.4861***<br>(0.0858) | -<br>0.4874***<br>(0.0838) | -<br>0.5509***<br>(0.0866) | -<br>0.5242***<br>(0.0870) |
| Social              | -<br>0.1967***<br>(0.0695) | -<br>0.2048***<br>(0.0695) | -0.2286***<br>(0.0702) | -<br>0.1936***<br>(0.0694) | -<br>0.1794***<br>(0.0694) | -<br>0.2189***<br>(0.0704) |
| Manual              | 0.1075<br>(0.1103)         | 1.1891***<br>(0.1227)      | 1.0373***<br>(0.1202)  | 1.1732***<br>(0.1226)      | 1.1835***<br>(0.1227)      | 1.1883***<br>(0.1231)      |
| Cognitive & Digital |                            | 0.0230<br>(0.0619)         | -0.0661<br>(0.1159)    |                            |                            | -0.2076*<br>(0.1256)       |
| Cognitive & Social  |                            | 0.0751<br>(0.0956)         |                        |                            | 0.0130<br>(0.0987)         | -0.0431<br>(0.1065)        |
| Cognitive & Manual  |                            | -<br>0.7636***<br>(0.0391) |                        | -<br>0.5507***<br>(0.1908) |                            | -0.3211<br>(0.2084)        |



|                    | (1)                   | (2)                   | (3)                       | (4)                   | (5)                        | (6)                       |
|--------------------|-----------------------|-----------------------|---------------------------|-----------------------|----------------------------|---------------------------|
| Digital & Social   |                       |                       | 0.4165**<br>*<br>(0.1131) |                       | 0.1079<br>*<br>(0.0623)    | 0.3542**<br>*<br>(0.1282) |
| Digital & Manual   |                       |                       | -0.7515***<br>(0.0399)    | -0.0450<br>(0.0858)   |                            | -0.1747<br>(0.1146)       |
| Social & Manual    |                       |                       |                           | -0.1637<br>(0.1866)   | -<br>0.7609***<br>(0.0391) | -0.2891<br>(0.2010)       |
| Firm Size          | 0.0656***<br>(0.0087) | 0.0553***<br>(0.0085) | 0.0560***<br>(0.0086)     | 0.0550***<br>(0.0085) | 0.0558***<br>(0.0086)      | 0.0554***<br>(0.0085)     |
| Time dummies       | Yes                   | Yes                   | Yes                       | Yes                   | Yes                        | Yes                       |
| Occupation dummies | Yes                   | Yes                   | Yes                       | Yes                   | Yes                        | Yes                       |
| Location dummies   | Yes                   | Yes                   | Yes                       | Yes                   | Yes                        | Yes                       |
| Observations       | 7,415                 | 7,415                 | 7,415                     | 7,415                 | 7,415                      | 7,415                     |

Standard errors were clustered at the firm level and are shown in parenthesis  
\*, \*\*, and \*\*\* denote significance at the 1, 5, and 10 per cent level Dependent Variable: Firm Profitability; RHS variables are lagged by one year

**Table 6: Firm Growth and Skill Requirements**

|                     | (1)                   | (2)                   | (3)                    | (4)                   | (5)                   | (6)                    |
|---------------------|-----------------------|-----------------------|------------------------|-----------------------|-----------------------|------------------------|
| Cognitive           | 0.1821***<br>(0.0229) | 0.2058***<br>(0.0231) | -0.1829***<br>(0.0230) | 0.1938***<br>(0.0229) | 0.2071***<br>(0.0230) | 0.1968***<br>(0.0232)  |
| Digital             | 0.0486***<br>(0.0168) | 0.0481***<br>(0.0173) | 0.0342**<br>(0.0172)   | 0.0259<br>(0.0172)    | 0.0431**<br>(0.0172)  | 0.0420**<br>(0.0173)   |
| Social              | 0.0887***<br>(0.0147) | 0.0863***<br>(0.0148) | 0.0823***<br>(0.0149)  | 0.0937***<br>(0.0148) | 0.0880***<br>(0.0147) | 0.0796***<br>(0.0149)  |
| Manual              | 0.1430***<br>(0.0253) | 0.0855***<br>(0.0265) | 0.0716***<br>(0.0263)  | 0.0727***<br>(0.0264) | 0.0865***<br>(0.0264) | 0.0842***<br>(0.0264)  |
| Cognitive & Digital |                       | -0.0436**<br>(0.0171) | -0.1767***<br>(0.0335) |                       |                       | -0.1889***<br>(0.0387) |
| Cognitive & Social  |                       | 0.1495***<br>(0.0280) |                        |                       | 0.1330***<br>(0.0296) | 0.1839***<br>(0.0323)  |
| Cognitive & Manual  |                       | 0.0787***<br>(0.0095) |                        | -0.0452<br>(0.0541)   |                       | 0.0013<br>(0.0628)     |
| Digital & Social    |                       |                       | 0.1297***<br>(0.0319)  |                       | -0.0150<br>(0.0172)   | 0.0649*<br>(0.0392)    |
| Digital & Manual    |                       |                       | 0.0930***<br>(0.0099)  | 0.0651***<br>(0.0245) |                       | 0.1872***<br>(0.0342)  |
| Social & Manual     |                       |                       |                        | 0.0671                | 0.0761***             | -0.0972*               |

|                    |                            |                            |                        |                            |                            |                            |
|--------------------|----------------------------|----------------------------|------------------------|----------------------------|----------------------------|----------------------------|
|                    |                            |                            |                        | (0.0502)                   | (0.0095)                   | (0.0576)                   |
| Firm Size          | -<br>0.1051***<br>(0.0031) | -<br>0.1076***<br>(0.0031) | -0.1078***<br>(0.0031) | -<br>0.1080***<br>(0.0031) | -<br>0.1077***<br>(0.0031) | -<br>0.1080***<br>(0.0031) |
| Time dummies       | Yes                        | Yes                        | Yes                    | Yes                        | Yes                        | Yes                        |
| Occupation dummies | Yes                        | Yes                        | Yes                    | Yes                        | Yes                        | Yes                        |
| Location dummies   | Yes                        | Yes                        | Yes                    | Yes                        | Yes                        | Yes                        |
| Observations       | 2,061                      | 2,061                      | 2,061                  | 2,061                      | 2,061                      | 2,061                      |
| R <sup>2</sup>     | 0.179                      | 0.185                      | 0.185                  | 0.185                      | 0.185                      | 0.187                      |
| Number of firms    | 1515                       | 1515                       | 1515                   | 1515                       | 1515                       | 1515                       |

Standard errors were clustered at the firm level and are shown in parenthesis

\*, \*\*, and \*\*\* denote significance at the 1, 5, and 10 per cent level Dependent Variable: Firm Growth; RHS variables are lagged by one year

**Table 7: Export Intensity and Skill Requirements**

|                           | (1)                        | (2)                    | (3)                    | (4)                        | (5)                        | (6)                    |
|---------------------------|----------------------------|------------------------|------------------------|----------------------------|----------------------------|------------------------|
| Cognitive                 | 0.0849***<br>(0.0157)      | 0.0850***<br>(0.0158)  | 0.0861***<br>(0.0157)  | 0.0915***<br>(0.0159)      | 0.0868***<br>(0.0159)      | 0.0912***<br>(0.0160)  |
| Digital                   | 0.1467***<br>(0.0134)      | 0.1426***<br>(0.0141)  | 0.1420***<br>(0.0140)  | 0.1394***<br>(0.0142)      | 0.1407***<br>(0.0139)      | 0.1362***<br>(0.0144)  |
| Social                    | -<br>0.0386***<br>(0.0105) | -0.0411***<br>(0.0106) | -0.0418***<br>(0.0107) | -<br>0.0433***<br>(0.0108) | -<br>0.0423***<br>(0.0106) | -0.0452***<br>(0.0109) |
| Manual                    | -0.0145<br>(0.0223)        | 0.0002<br>(0.0239)     | -0.0060<br>(0.0235)    | -0.0003<br>(0.0239)        | 0.0001<br>(0.0236)         | -0.0006<br>(0.0241)    |
| Cognitive & Digital       |                            | 0.0188<br>(0.0121)     | -0.0010<br>(0.0204)    |                            |                            | -0.0324<br>(0.0269)    |
| Cognitive & Social        |                            | 0.0239<br>(0.0172)     |                        |                            | 0.0188<br>(0.0196)         | 0.0399<br>(0.0244)     |
| Cognitive & Manual        |                            | -0.0146**<br>(0.0073)  |                        | -0.0650**<br>(0.0308)      |                            | 0.0095<br>(0.0479)     |
| Digital & Social          |                            |                        | 0.0311*<br>(0.0183)    |                            | 0.0245**<br>(0.0122)       | 0.0356<br>(0.0273)     |
| Digital & Manual          |                            |                        | -0.0113<br>(0.0077)    | 0.0410**<br>(0.0174)       |                            | 0.0386<br>(0.0256)     |
| Social & Manual           |                            |                        |                        | 0.0143<br>(0.0252)         | -0.0162**<br>(0.0073)      | -0.0606<br>(0.0418)    |
| Firm Size (Log of assets) | 0.0456***<br>(0.0032)      | 0.0457***<br>(0.0032)  | 0.0461***<br>(0.0032)  | 0.0457***<br>(0.0032)      | 0.0460***<br>(0.0032)      | 0.0463***<br>(0.0032)  |
| Time dummies              | Yes                        | Yes                    | Yes                    | Yes                        | Yes                        | Yes                    |
| Occupation dummies        | Yes                        | Yes                    | Yes                    | Yes                        | Yes                        | Yes                    |

|                  |      |      |      |      |      |      |
|------------------|------|------|------|------|------|------|
| Location dummies | Yes  | Yes  | Yes  | Yes  | Yes  | Yes  |
| Observations     | 7415 | 7415 | 7415 | 7415 | 7415 | 7415 |

Standard errors were clustered at the firm level and are shown in parenthesis

\*, \*\*, and \*\*\* denote significance at the 1, 5, and 10 per cent level Dependent Variable: Export Intensity; RHS variables are lagged by one year

**Table 8: R&D Intensity and Skill Requirements**

|                           | (1)                        | (2)                    | (3)                    | (4)                        | (5)                        | (6)                    |
|---------------------------|----------------------------|------------------------|------------------------|----------------------------|----------------------------|------------------------|
| Cognitive                 | 0.2685***<br>(0.0682)      | 0.2414***<br>(0.0686)  | 0.2625***<br>(0.0684)  | 0.2660***<br>(0.0683)      | 0.2596***<br>(0.0686)      | 0.2605***<br>(0.0690)  |
| Digital                   | 0.2475***<br>(0.0531)      | 0.1936***<br>(0.0545)  | 0.1928***<br>(0.0543)  | 0.2372***<br>(0.0541)      | 0.1882***<br>(0.0543)      | 0.1965***<br>(0.0546)  |
| Social                    | -<br>0.3463***<br>(0.0447) | -0.3330***<br>(0.0450) | -0.3485***<br>(0.0451) | -<br>0.3472***<br>(0.0449) | -<br>0.3428***<br>(0.0449) | -0.3454***<br>(0.0452) |
| Manual                    | -0.1758**<br>(0.0713)      | -0.2088***<br>(0.0746) | -0.1862**<br>(0.0741)  | -<br>0.2152***<br>(0.0744) | -<br>0.2117***<br>(0.0744) | -0.2126***<br>(0.0745) |
| Cognitive & Digital       |                            | 0.2210***<br>(0.0492)  | -0.0498<br>(0.1011)    |                            |                            | 0.0674<br>(0.1148)     |
| Cognitive & Social        |                            | 0.0598<br>(0.0874)     |                        |                            | -0.0349<br>(0.0915)        | -0.1587<br>(0.0994)    |
| Cognitive & Manual        |                            | 0.0333<br>(0.0279)     |                        | -0.3725**<br>(0.1787)      |                            | 0.0627<br>(0.2036)     |
| Digital & Social          |                            |                        | 0.3077***<br>(0.0965)  |                            | 0.2658***<br>(0.0493)      | 0.3660***<br>(0.1157)  |
| Digital & Manual          |                            |                        | 0.0061<br>(0.0288)     | 0.0998<br>(0.0679)         |                            | -0.3181***<br>(0.0984) |
| Social & Manual           |                            |                        |                        | 0.3351**<br>(0.1698)       | 0.0370<br>(0.0279)         | 0.2673<br>(0.1903)     |
| Firm Size (Log of assets) | 0.0435***<br>(0.0118)      | 0.0417***<br>(0.0118)  | 0.0414***<br>(0.0118)  | 0.0411***<br>(0.0118)      | 0.0407***<br>(0.0118)      | 0.0418***<br>(0.0118)  |
| Time dummies              | Yes                        | Yes                    | Yes                    | Yes                        | Yes                        | Yes                    |
| Occupation dummies        | Yes                        | Yes                    | Yes                    | Yes                        | Yes                        | Yes                    |
| Location dummies          | Yes                        | Yes                    | Yes                    | Yes                        | Yes                        | Yes                    |
| Observations              | 7415                       | 7415                   | 7415                   | 7415                       | 7415                       | 7415                   |
| R <sup>2</sup>            | 0.051                      | 0.052                  | 0.053                  | 0.051                      | 0.053                      | 0.054                  |
| Number of firms           | 3,916                      | 3,916                  | 3,916                  | 3,916                      | 3,916                      | 3,916                  |

Standard errors were clustered at the firm level and are shown in parenthesis

\*, \*\*, and \*\*\* denote significance at the 1, 5, and 10 per cent level Dependent Variable: R&D Intensity; RHS variables are lagged by one year

The results presented in this section complement our previous finding on the important role played by firm-level characteristics in the changing nature of jobs and skills. Our evidence suggests that the skills demanded by firms are indeed related to their different activities, learning processes and routines. A striking result is the positive association of digital skills with wages, firm growth, exporting and R&D intensity, suggesting that competitive firms close to the technological frontier have higher demand for digital skills. Furthermore, manual jobs are associated with lower wages but higher growth, and the combination of manual and digital skills brings higher wages and can also be positively associated to exporting. A significant element of novelty of our analysis is to explicitly look at manual skills and analyze separately cognitive and digital skills and thus to disentangle their different relationships with firm characteristics and performance

## 5. Concluding remarks

In this paper we investigated the heterogeneous demand for skills within occupations across firms, and the firm activities that relate to it, using online job vacancies posted in India between 2016 and 2020. By relying on the free-text data from Indian Naukri job portal, using a multi-level machine learning empirical strategy, and a novel skill taxonomy and a methodology to implement it in the vacancy data, developed by the ILO (Bennett et al., 2022), we extract information on occupational skills and match them with information about the hiring firm drawn from the Prowess firm-level data-set.

*Firstly*, we find strong evidence of within-occupation heterogeneity in skill demand across firms, which holds true for all the analyzed occupations. We empirically quantify this heterogeneity by employing a method based on cosine similarity that allows for an in-depth distributional analysis across different skills. *Secondly*, we document that firms demanding more diversified skills are younger, pay higher wages, and are dynamic organizations with high engagement in complex activities, such as exporting and R&D investment. *Thirdly*, we observe that specific types of skills are associated with different firm activities and outcomes. Digital skills appear to be associated with higher wage intensity, while there is no significant relationship between other cognitive skills and wage intensity. Manual skills are positively linked to firm growth, and to lower wages, however, we detect a wage premium when manual skills are complemented by digital skills. Further, disentangling between digital and cognitive skills enables us to also shed light on the different roles they play in firm dynamics. Our results confirm that highly innovative and internationally competitive firms demand both digital and other cognitive skills, which, together with the combination of digital and socio-emotional skills, show positive and significant associations to higher growth, engagement in exporting and innovation. The positive association between high export intensity and higher demand for other digital and cognitive skills is

expected. To remain competitive in international markets and to maintain their global value chain positioning, firms might be pushed to upgrading, adopting new digital technologies and acquiring complementary cognitive competences. However, other cognitive skills alone are non-significant for wages and profitability in the short-run, likely indicating that they might take longer to translate into positive outcomes.

Our evidence suggests that different firms require different skills, even for the same occupation. This suggests that it is not simply the pace of technological change that shapes the job skill-content, but also organizational characteristics are important drivers of the within-occupational demand for skills. Therefore, when analysing the changing world of work and, especially in the debate on skilled/unskilled or routine/non-routine labour, the role of organizations, their structures and routines should be appropriately accounted for. Technological trajectories, innovation and skills co-evolve and are affected by the ways in which firms organise activities and production processes, and by the economic and institutional set-up they develop in. The skill requirements of similar occupations may not be as universal as in the common interpretation of O\*NET based studies (Acemoglu and Autor, 2011; Autor, 2013), they could be time-varying, context- and organization-specific. If occupational skill requirements are indeed firm-specific, this presents a compelling case for firms to play a crucial role in training their workforce, rather than relying merely on finding pre-trained and specialized candidates. In fact, while labor market policies, especially education and training policies, might certainly be beneficial for workers in overcoming skill obsolescence, these are far from sufficient. As pointed out also by Dosi and Virgillito (2019), firms should be incentivized to invest in enhancing employees' learning via on-the-job training schemes, which can be tailored to the organization's complex needs. In this scenario, the role of workers' organizations will be extremely important in pushing for organizational investments in labour force training and up- or re-skilling. This may help workers to cope with technological advancements in their firms and hence help to re-distribute benefits from technological advances and productivity gains.

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## Appendices

### A. Data structure

In table A1 we present a schematic structure of the online job posts. As reported in the first column, the different fields are Job Title, Job Description, Post Date, Company, Skills, Education, Industry, Job Location, Experience and Pay-rate. The Field description, as reported in the second column describes the various fields. The sub-fields within the “Job Description” includes Role category, Role, Key skills and Company Profile.

### B. Mapping of 2-digit occupations

To create variables for occupations at the 2-digit ISCO-08 level, we start with data from 2016 and 2017 and consider the highly disaggregated “Role” sub-field. We organize all the roles into a single list with 678 unique words, taking into consideration only words that appear at least 10 times in the data. We then match the roles with 2 digit ISCO-08 codes following some intuitive rules: (i) From the official ISCO-08 repository<sup>12</sup>, we consider the description of the around 6000 occupations at the 4-digit level. If the naukri role corresponds exactly to an ISCO-08 occupation title (4-digit level), a direct match is established. (ii) When we are not able to classify a 4-digit occupation but the match with a 2-digit index is clear-cut, we directly classify it at 2-digit level. (iii) Otherwise, we cross-check with the more detailed description of occupational titles provided by the SOC-2020 classification<sup>13</sup>, which can easily be reclassified into ISCO-08. (iv) If we are still not able to find any correspondence, we proceed with a manual Google search and/or a more thorough manual inspection of the naukri data. Finally, we obtain our correspondence table between naukri role categories and

**Table A1:** Schematic structure of naurki.com online job posts

| Field           | Field description                                                                                                                                                                                                           |                  |                                                                                                                                                                                                                                                                                                                               |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Job Title       | Occupational title with varying degree of detail (e.g. "Large Molecule Analyst", "Testing Analyst", "Applications Developer") or alternatives (e.g. "Sales Engineer (electrical)/Sr. Sales Engineers/ asst. Sales Manager") |                  |                                                                                                                                                                                                                                                                                                                               |
| Job Description | Detailed free text job description of variable length that contains the sub-fields in the following column                                                                                                                  | <b>Sub-field</b> | <b>Sub-field description</b>                                                                                                                                                                                                                                                                                                  |
|                 |                                                                                                                                                                                                                             | Role category    | Synthetic description of the role similar to ISCO-08 sub-major groups (2-digits)                                                                                                                                                                                                                                              |
|                 |                                                                                                                                                                                                                             | Role             | More detailed description of the role, similar to ISCO-08 unit groups (4-digits)                                                                                                                                                                                                                                              |
|                 |                                                                                                                                                                                                                             | Key skills       | Required skills description, also detailing required educational attainment (under- and post-graduate degree or Ph.D., e.g. "UG:BSc - Any specialisation, PG:M.Sc - Any Specialization, Bio-Chemistry, Chemistry") or lack of (e.g. "PG:Graduation Not Required", "Doctorate: Doctorate Not Required") and working experience |
|                 |                                                                                                                                                                                                                             | Company Profile  | Name of the hiring company or of the recruitment agency and the company for which it is looking for candidates; company                                                                                                                                                                                                       |

|                  |                                                                                                                                                                                                 |  |                               |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|-------------------------------|
|                  |                                                                                                                                                                                                 |  | description of varying length |
| <b>Post Date</b> | <b>Year/Month/Day and posting time</b>                                                                                                                                                          |  |                               |
| Company          | Name of the hiring company or of the recruitment agency and the company for which it is looking for candidates                                                                                  |  |                               |
| Skills           | Short skill category (e.g. "Medical", "Sales", "IT Software - Application Programming" . . . )                                                                                                  |  |                               |
| Education        | Required educational attainment (or lack of, e.g. "Graduation Not Required") and field of study                                                                                                 |  |                               |
| Industry         | Hiring company industry, can provide different alternatives with varying degree of detail (e.g. "Pharma/Biotech/Clinical Research", "Electricals/Switchgears", "IT-Software/Software Services") |  |                               |
| Job Location     | Indian city or area (e.g. "Bengaluru/Bengalore", "Mumbai suburbs")                                                                                                                              |  |                               |
| Experience       | Required years of working experience                                                                                                                                                            |  |                               |
| Pay-rate         | Wage range per annum in INR (may also depend on the working experience and credentials of the candidate)                                                                                        |  |                               |

## **ISCO-08 2-digit occupations.**

To then refine our classification of the 2-digit occupations and extend it to years 2019 and 2020, we perform the following steps:

### **1. Pre-processing of Job titles**

To implement the machine learning approach, we process the sample. Firstly, we discard job vacancies that do not contain the “Job Title” field. Secondly, we clean all 2016-2017 free-text job titles by eliminating capital letters, numbers, punctuation, symbols, prepositions, stop words and commonly used sentences that we deem as noise (for instance, the initial sentence of a large number of ads begins with “we are writing for. . .”). This is also done for the subset of adverts that were classified through the computational mapping, a balanced sub-sample where all naukri role categories are univocally matched with 2-digit ISCO-08 codes, and to which we will refer to as the 2016-2017 labeled data (16-17LD). The classes of our classification are 2-digit ISCO- 08 sub-major groups and each of these is populated by a number of job titles. To avoid any bias in the classification, by assigning class weights inversely proportional to their times of appearance, to train the NLP algorithm we create the balanced 16-17LD dataset, where we have about 5,000 examples of job adverts for each 2-digit ISCO-08 class. Thirdly, by jointly considering all the words that appear in the ISCO-08 and SOC-2020 Index of occupational titles, we create a list of about 8,000 *relevant words – the relevant word vector*. We then further clean all the naukri job titles in the 16-17LD and remove from the balanced set all the words that do not appear in the relevant word vector.

### **2. Conversion to vector with word embedding**

By relying on the fastText library<sup>14</sup>, we then transform the clean job titles in vectors by using word embedding – i.e., a representation of words as real-valued vectors that encode their meaning such that words that are closer in the vector space are expected to have similar meaning.

### **3. Train-test split**

Thanks to the large size of our sample, by using an ad hoc Python library, we split the 16-17LD into two sub-sets: the training set (around the 70 per cent of the 16-17LD), that will be used to train the support vector machine, and the test set (around 30 per cent of the 16-17LD), that will be used to assess the performance of the machine.

#### 4. Training of Support Vector Machine classifier

After processing and splitting the 16-17LD data, we feed the train set to the SVM classifier. The latter removes noise from the data-set and provides a more accurate classification, that helps us discriminate cases where the ISCO-08 2-digit occupational code identified through the naukri role correspondence table actually diverges from the content of the job title.

#### 5. Evaluation and classification of unlabeled job posts

For each job advert, the SVM classifier outputs an ordered list containing the probabilities that the job advert belongs to each possible class (i.e., 2-digit ISCO-08 sub-major groups), from the most to the least probable. Bearing in mind that classes with probabilities higher than 60 per cent are not to be found, a match between an online vacancy and ISCO-08 code is established only when its probability is higher than 40 per cent.

A final manual double-check is then performed, also comparing the SVM and the naukri role data classification. In fact, also when using the SVM it is possible to obtain misclassifications, especially in a number of problematic classes. For instance, often the algorithm misclassifies “Protective services workers” (ISCO-08 code 54) as armed forces (ISCO-08 sub-major group 03), for which virtually no vacancies are reported in the naukri portal. A similar misclassification issue appears for the term *engineer*, that is very common and may appear also in job titles where the role actually being sought is electronic operator or electrician. This is especially the case for “Electrical and electronic trades workers” (ISCO-08 sub-major group 74). Therefore, with the aim of avoiding any of such inconsistencies when running the SVM on the whole sample in the next step of the pipeline, the sub-major groups 03, 74, 83 and 93 are excluded from the 16-17LD balanced sample, and the SVM is retrained on 24 ISCO-08 sub-major groups rather than 28.

6. *Execution of the SVM algorithm for the whole naukri.com data-set* Carrying out this set of operations on the 16-17LD has allowed us to obtain a new correspondence table of job titles to ISCO-08 2-digit codes. Using this set of clean job titles univocally classified, to label the remaining vacancies: we carry out the same procedure on the whole 2016-2017 and 2019-2020 data-sets. By following these steps, we are able to classify the 71 per cent of the whole sample – 11.1 out of 15.6 million online vacancies.

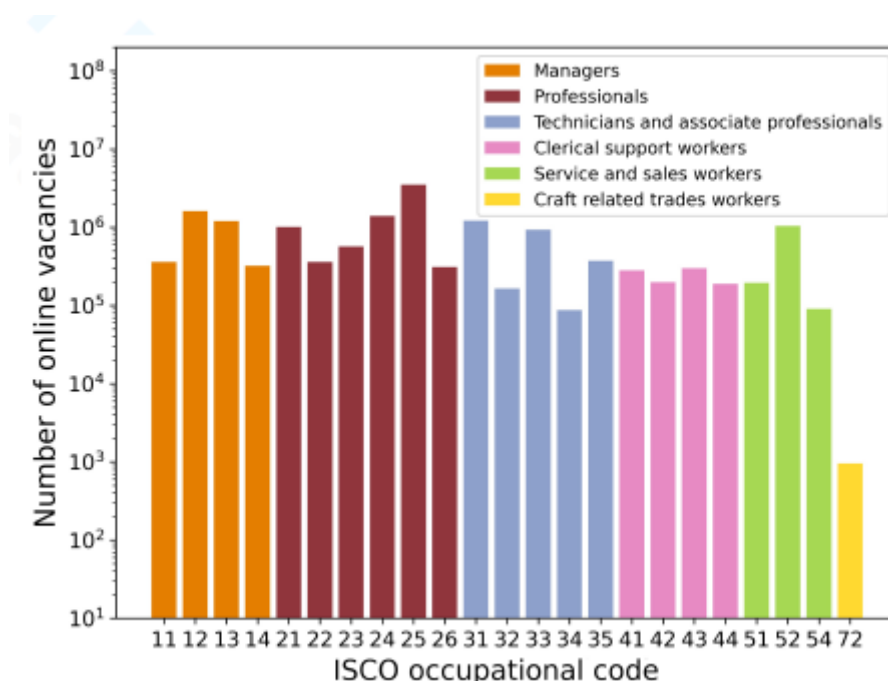
#### C Representativeness of the vacancy data

Figure 3 reports the number of vacancies for each 2-digit ISCO-08 occupation. For each ISCO-08 broad category the occupational shares of the online listings are the following: 57 per cent for professionals; 29 per cent for managers; 10 per cent for technicians & associate professionals; 2 per cent for service and sales

workers; 1 per cent for clerical support workers;

0.8 per cent for craft and related trades workers; 0.2 per cent for elementary occupations; while no listings are found for skilled agricultural, forestry, fishery workers, plant & machine operators, assemblers and armed forces occupations. We thus observe that a large number of the vacancies cover professional occupations – e.g., in finance, consultancy, manufacturing or ICTs –, and in lower percentage managerial ones, whose hiring process probably also employs less publicly advertised channels.

**Figure C1:** Occupational shares at the 2-digit level (pooled)



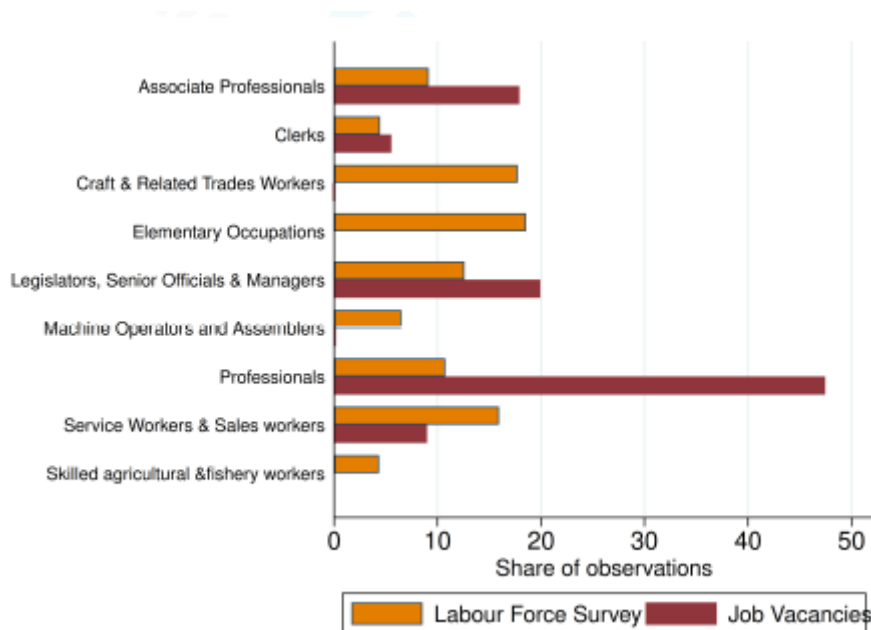
*The figure shows the number of online job posts, considering the entire Naukri sample, for each 2-digit ISCO-08 sub-major group, where the y-axis is displayed in logarithmic scale. Color indicates the corresponding 1-digit ISCO-08 major groups.*

To benchmark our data, we rely on The Periodic Labour Force Survey (PLFS), which is a nationally representative labour survey conducted by the Indian National Statistical Office (NSO). Given the time frame of our vacancy data, we use the 2017-18 wave. In their annual report, the Government of India (2019) provides the percentage distributions of workers by broad occupational divisions, namely 1-digit level, which are equivalent to the ISCO 1-digit level occupational classes. They show that the share of the workers in division 1 (legislators, senior officials and managers), division 2 (professionals) and division 3 (technicians and associate professionals), increased from 7.9 per cent to 9.1 per cent for rural males, from 5 per cent to 8.75 per cent for rural females,

decreased from 31.15 per cent to 30.45 per cent for urban males and increased from 31.95 per cent to 34.65 per cent for urban females (Government of India, 2019).

In Figure C2 we show the occupational shares at the 1-digit level for both PLFS data and job vacancy data. As expected, the skilled categories of workers have a higher representation in online vacancy listings contrary to the elementary occupations.

**Figure C2:** Occupational shares in the labour force survey compared with the vacancy data at the 1-digit level (percent)

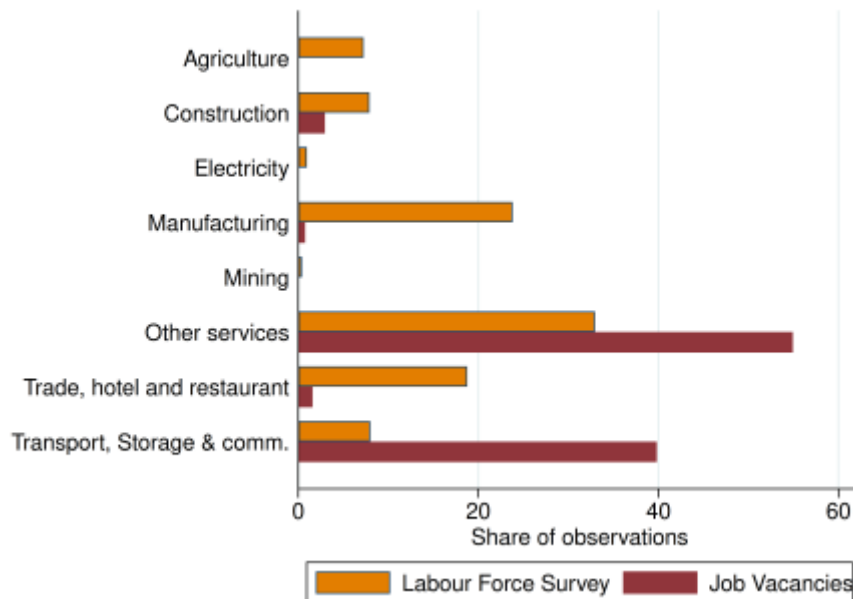


*Occupational shares in the 2017-18 Periodic Labour Force Survey (PLFS) (orange) and Naukri vacancy data (burgundy). The PLFS data are obtained from Government of India (2019), which provides statistics by gender and rural and urban categories. Here, we compute the average of the shares of urban males and urban female categories.*

We also look at the sectoral shares of jobs. The PLFS uses the National Industrial Classification (NIC) 2008 and provides data for broad industrial categories. In Figure C3, we show the sectoral shares in the job vacancy data (burgundy) as opposed to the employment figures reported in the Periodic Labour Force Survey (orange) by broad industry division, taking into consideration only urban female and male workers. Figure C3 confirms the absence of agriculture and a very low share of manufacturing jobs in the naukri data. PLFS data shows higher shares also in trade, hotel and restaurant, while for other services (including finance and insurances), transport, storage and communications the number of job ads is more than 20 percentage points higher than the employment share reported in the national survey. It is worth

noting that the national survey includes public sector workers, with the vast majority of government jobs still following traditional advertisement channels, such as Government gazettes or newspapers, whereas naukri vacancies include mostly private firms.

**Figure C3:** Sectoral shares in the labour force survey compared with the vacancy data at the 1-digit level (percent)

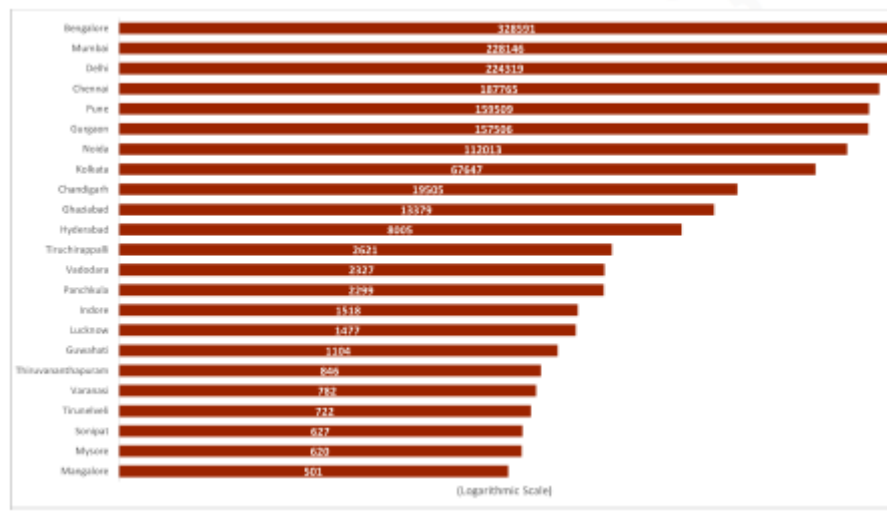


*Sectoral shares in the 2017-18 Periodic Labour Force Survey (PLFS) (orange) and Naukri vacancy data (burgundy). The PLFS data are obtained from Government of India (2019), which provides statistics by gender and rural and urban categories. Here, we compute the average of the shares of urban males and urban female categories.*

The regional distribution of the naukri job listings reveals that over 85 per cent of vacancies are concentrated in large urban areas. Figure C4 reports all cities with above 150,000 inhabitants in which respectively at least 500 vacancies were advertised in 2020. We observe a higher representation of metropolitan cities, with the vast majority of vacancies being located in Bangalore, Delhi and its satellite cities Gurgaon and Noida, Mumbai, Chennai and Pune, all showing over 100,000 advertised vacancies, followed by Kolkata, Chandigarh, Ghaziabad and Hyderabad, with figures of one or two orders of magnitude lower. Overall, these figures indicate that there is substantial regional variation across major cities in India.



**Figure C4: Number of vacancies at the city level**



*The figure shows the number of job vacancies by Indian city for cities with above 150,000 inhabitants and at least 500 advertised vacancies, 2020 (x-axis in logarithmic scale).*

## Notes

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- <sup>1</sup> We refer to these skills as “other cognitive skills” since the skill classification by Bennett et al. (2022) includes “digital skills” as a subset of “cognitive skills”. In this work, we analyze digital and cognitive skills separately, as you will see in the following sections.
  - <sup>2</sup> See, e.g., <https://www.tribuneindia.com/news/brand-connect/top-10-job-search-portals-in-india-372146> and <https://economictimes.indiatimes.com/news/how-to/looking-for-a-job-hera-are-top-5-job-portals-to-help-you-find-the-right-job/articleshow/89075753.cms>
  - <sup>3</sup> We use the id associated to each job post to remove the few duplicates present in the naukri.com data-set.
  - <sup>4</sup> A higher disaggregation allows us to obtain a more accurate matching because a 4-digit misclassification will less likely affect the 2-digit assigned code.
  - <sup>5</sup> Among cognitive skills, the sub-categories are cognitive skills (narrow sense), general computer skills, specific software and technical support skills, machine learning and artificial intelligence skills, financial skills, writing skills, and project management skills. Socio-emotional skills comprise character skills, social skills, people management skills, and customer service skills. Finally, manual skills are divided into finger dexterity skills, hand-foot-eye coordination skills, and physical skills.
  - <sup>6</sup> Note that the number of firms included in each regression analysis reported later is limited by the firms that report specific variables used for analysis.
  - <sup>7</sup> The parameters are estimated by maximum likelihood method (MLE) following Bottazzi and Secchi (2011).
  - <sup>8</sup> Even though we do not report them here for the sake of brevity, the tests were performed for all occupations and years, yielding similar results and documenting fat-tailed distribution in all our data-sample. The analysis is restricted to only occupational categories with sufficient number of observations to run the estimation and hence we have excluded the ISCO-group 72.
  - <sup>9</sup> Unlike Deming and Kahn (2018), we also take into consideration the category of manual skills, and separate cognitive skills into digital and other cognitive skills.
  - <sup>10</sup> We obtain similar results also with export dummy as dependent variable, that takes value 1 in case of exporting and 0 otherwise.
  - <sup>11</sup> We obtain similar results also with a R&D dummy as dependent variable, that takes value 1 if the firm spends on R&D and 0 otherwise.
  - <sup>12</sup> <https://www.ilo.org/public/english/bureau/stat/isco/isco08/>.
  - <sup>13</sup> <https://www.ons.gov.uk/methodology/classificationsandstandards/standardoccupationalclassificationsoc/soc2020>.
  - <sup>14</sup> Fast Text is an open-source library created by Facebook AI Research (FAIR) lab for word embedding and text classification in over 150 languages. It can be built as a Python module and is available at: <https://fasttext.cc/>.

## Capacity building and chameleon-like education: re- strategizing for the effective implementation of inclusive education policy in nigeria, west africa.

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### Abstract

Education is a fundamental human right that should be accessible to all individuals regardless of their circumstances. However, in Nigeria and many parts of Africa, access to education remains a challenge due to several factors such as disability, financial constraints, and geographical location. This study explores the concept of inclusive education and the need for capacity building to implement it effectively in Nigeria and the continent at large. The United Nations recognizes inclusive education as a critical component of achieving the Sustainable Development Goals, particularly SDG4, which focuses on providing quality education for all. This paper examines the National Policy on Education regarding inclusive education and highlights the challenges facing its implementation in Nigeria. The study proposes practical solutions to these challenges, including providing adequate facilities and resources, increasing public awareness of the importance of inclusive education, and providing specialized training for teachers in the education sector. By implementing these solutions, Nigeria can ensure that every citizen has access to quality education, which will contribute to national development and the achievement of the country's goals. In summary, this study underscores the importance of capacity

building for the chameleon-like educational system in Nigeria and Africa at large. It emphasizes the need for a strategic approach to implementing inclusive education policies, which will ultimately lead to a more equitable and sustainable education system for all.

**Keywords:** Inclusive education, SDG4, Policy, People with disabilities,

## **Introduction**

Africa is known to be the second largest continent in the world both in size and population with about 54 countries in it. Africa is greatly rich in cultural heritage and diversity with a wealth of natural resources. Regardless of the categorization of countries of the world along the labels “developed, developing and underdeveloped”, education is what no country of the different classification can outgrow instead it is considered an/a unavoidable, indispensable and worthwhile investment that begets national development and advancement.

Education is described as the way through which innovation, development and growth is being acquired by every citizen in every nation. In several policy agendas, education is seen as having a transformational role in achieving sustainable development and the SDGs on the continent. According to UNESCO, Education for Sustainable Development equips individual/students to make knowledgeable decisions and responsible actions in the interests of environmental integrity, economic viability, and a just society for current and future generations, while valuing cultural variety.

In view of this, education in practice, from a global perspective is not the exclusive reserve of a particular bloc, continent, country or persons. As against the hitherto belief that education should be offered only to persons who are potential contributors to economic and national development, the agenda 17 of the Sustainable Development Goal 4 as adopted by the conglomeration of nations under the headship of the United Nation in 2015 reads “to commit to providing inclusive and equitable quality education at all levels for all people, including persons with disabilities”. In corroboration, “inclusion” is the core value of the global movement “Education for All (EFA) agenda of 2000”. This is an innovative idea to remove every barrier on education.

Inclusion is the new face of the discourse “Education right, equality and equity; for a certain few or all?” The philosophy does not only points out the fact that education should be offered to all irrespective of their physical disposition, abilities, economic power, socio-cultural background, it also changes the whole narrative of how to cater for the special child, hitherto mainstreaming and integration. Although inclusive education connotes offering equal access and quality education to all learners without any form of discrimination (Sambo and Gambo, 2015) however, it remains a misunderstood concept that differs as a result of contextual usage and circumstantial factors (Sambo et al 2015; Anastasiou and Kauffman, 2012)

Some are of the opinion that it is offered to the special child under certain categories, this is exemplified in the National Policy on Education in Nigeria which states that “Special education is designed to meet the unique needs of persons with special needs that the general education programme cannot cater for” (Federal Government of Nigeria, 2014: p.52). Adetoro (2014) stressed that, this is in congruity with international best practice. According to UNESCO (2005), inclusion is seen as “Recognition of the right to education and its provision in non-discriminatory ways”. The implication of this is that, inclusive education welcomes diversity of students by removing barriers to education specifically with certain learners excluded hitherto from education for reasons which might include sex, ethnic, language, religion, nationality, economic condition or disabilities. Although, children with disabilities have dominated the research focus under the discourse “inclusive education”

The way in which regular schools respond to students with disability can be a measure of quality education for all students (UNESCO, 2015). Fareo (2015) stressed that, inclusion is an innovative idea strategically developed and designed to correct the shortcomings observed in the mainstreaming and segregation education programme for students with special needs. She further stressed that as against the principle of mainstreaming or segregation, inclusion is an educational arrangement that accommodates both students with special educational needs and regular students together under one learning environment. The chameleon-like education is adaptive in structure, curriculum, resources, school practices, policies and pedagogy. it is aimed at satisfying the multiplicity of student’s diverse needs. In relation to inclusion, it is the adaption of the regular class or education practice, that is modification of physical facilities, structure, curriculum, pedagogy, equipment and assessments in order to suit the diversity of learners (Obi, Mensah and Avoke, 2007; Ashi, 2010; Mitchell, 2015).

Inclusive education must soar on the principle of adaptive education for effective implementation. Children with disabilities like every child have their needs and specialty that the regular school in its’ structural arrangement cannot satisfy. There is a need to transform the school system to suit the

inclusive philosophy, this should cover infrastructural facilities; attitudinal belief among stakeholders; teachers competences, beliefs, attitude and disposition; curriculum; assessment and assistive technological supports. These factors are imperative for the successful implementation of the inclusive practice, while their absence would work against the process altogether.

With the philosophy still left crawling among Africa countries, many have only enshrined the philosophy into their policy framework with little to show for it in terms of action. Not much was done or has been done in preparing for the implementation of the inclusive practice. In support of this, Howgego, Miles, and Meyers (2014) reported that “the evidence underpinning inclusive education in African countries are weak”. There is low budget prioritization given education with the government nations considering the modification of the educational structure to suit the inclusive practice as expensive and costly (Cornelius-Ukpepi, and Opuwari, 2019). Relatedly, Chumo and Kosgei (2019) in their study, found out that facilities such as ramps, runway, paths, sanitary, toilet and latrines were not designed to be used by learners with disabilities. Adeyanju (2019) reported that no primary or secondary school in Lagos State, Nigeria has a walk-way for learners with wheelchairs. This also extends to the level of integration of assistive technology to the inclusive classroom. With little investment in technology among African Nations, the regular schools are incapacitated in offering assistive technology that supports learning among learners with disabilities.

Unpreparedness in the area of personnel cannot be underemphasized. Adeyanju (2019) argued that certain questions must be addressed over the issue of personnel if all schools are to accommodate children of different specialty. Shamrma and Michael diary as cited in Ireri et’ al (2020) also stressed that teachers have negative attitude towards inclusive practice and also lack the knowledge and skill to be an adaptive teacher under the inclusive education system. Relatedly, claiming that inclusive education is the sole responsibility of the school is a misconception and a myth. All educational stakeholders are expected to be involved in the process, specifically in the area of attitude, belief and acceptance of the programme.

All these begs the question, How readily adaptable, welcoming, receptive and accommodating are the schools in terms of infrastructural facilities, teaching, curriculum, equipment, attitude and acceptance, integration of assistive technology and other structural supports? With the level of skewness on the progress of the programme among developed and developing nations, building capacity is of great necessity among African Nations for the effective implementation of inclusive education. Capacity building must be undertaken across certain critical areas, such as; Attitudinal disposition among stakeholders (parents, school administrators, teachers, policy makers and the community at large), Personnel capacity building which must cover pre-

service training and in- service training; Physical facilities covering improvement of existing structure and putting up new adaptable structures that enhances the inclusive practice; Increasing assistive technology; and quality assurance.

### **The concept of inclusive education**

In achieving individual nation goals and objectives, special attention must be given to equality in order for citizen of the country to work towards achieving the same goal. Education has be described as a way through which knowledge and valuable information are been passed for effective growth and development. One of 17 SDGs emphasized on the need for quality education. For quality education to be achieve, it must be noted that every citizen of a nation must be educated in order to achieve the main goal of the quality education.

A community is made up of different types of humans, there are people without disabilities and also, there are people with disabilities (PWD). People with disabilities are often not given special attention in the community due to the fact that they have little or nothing to contribute to the development and growth of the community. However, this is at the detriment of the national goals.

The idea of inclusive education first emerged in the 20th century when several nations battled to accept and enhance the education of individuals with disabilities in their community. Committee on the rights of PWD 2016, identified the goal of inclusion which is to provide all students of the relevant age range with an equitable and participatory learning experience and environment that most closely matches their needs and preferences. They further described Inclusion as a process of systemic transformation that involves adjustments and adaptations in educational material, instructional tactics, approaches, and institutions in order to remove obstacles.

In the View of UNESCO, they perceived inclusive education as a process of addressing, rejoining and answering to the diversity of needs of all learners through increasing participation in learning, cultures and communities, and reducing exclusion from education and from within education. UNESCO described inclusive education as a way of ensuring equality in learners, this does not necessary pertain to the PWD only but diversity of learners and their ability to assimilate adequate and timely. UNESCO identified the objective of inclusive education which goal is that the whole education system will facilitate learning environments where teachers and learners embrace and welcome the challenge and benefits of diversity. The learning environment including the buildings, teachers, instructional materials etc.

## Inclusive education policy in Nigeria

According to Global Education Monitoring Team, in a report submitted by Helen Pinnock 2020 explained that inclusive education in Nigeria is regarded as the process of addressing all barriers and providing access to quality education to meet the diverse needs of all learners in the same learning environment.

In every nation, a policy seeks to address the guidelines and rules which is expected to be implemented and also serve as a direction to that nation. Recognizing the SDG 4, the Nigeria national policy on Education is designed specially at building a free and democratic society, united, strong and self-reliant nation. It is also designed to help also helps to build a great and dynamic economy for the country. According to NPE 2004, The philosophy of Nigeria's education is based on: the development of the individual into a sound and effective citizen; the full integration of the individual into the community; and the provision of **equal** access to educational opportunities for all **citizens** of the country at the primary, secondary and tertiary levels both inside and outside the formal school system. Examining the philosophy of Nigeria's education as stated in the National Policy on Education, emphasizes are on equal educational opportunities to every citizen which includes PWD, the nomadic and the normal child as they are part of the citizens of the country.

The first edition of the NPE in 1977 identified the right of children with disabilities to education but it fails to clearly defined the type of education they should receive and the quality of personnel support needed for implementation. However, the fourth education which as reviewed in 2004 in collaboration with the Universal Basic Education Act specially calls for inclusive, free education for people with special needs, it also emphasized the needs of giving the right and needed training of the special education teachers and regular census as well as monitoring of people with special needs for educational provision.

Section 3.0 of the national policy on special education specifically stated that special education should be given to the 3 categories of people:

1. Persons with disabilities: These includes people with physical and sensory impairments which are albinism, who because of their condition cannot cope with regular school/class methods and processes without formal Special Needs Educational training. The section further explained this this category, and they include persons with:
  - Visual Impairment (total, partial sightedness and low vision).
  - Hearing Impairment (mild, moderate, severe/profound hearing Impairment).



- Physical and Health Impairment (paraplegia, quadriplegia, seizures, orthotoid, cerebral palsy, etc).
  - Mental Retardation/Intellectual Disability) Intellectual Developmental Disability (educable, trainable, bed ridden).
  - Behavioural Disorders (hyperactivity, hypo activity/the socially maladjusted/emotional disorder).
  - Speech Impairment (stammering/stuttering, voice disorders, etc).
  - vii. Learning Disabilities (dyscalculia, dyslexia, auditory processing disorder, visual processing disorder, attention deficit disorders etc).
  - Multiple Impairment (intellectual with visual impairment).
  - Autism Spectrum Disorders. x. Albinism (an inherited genetic condition that affects the production of melanin – the pigment responsible for colouration of skin, eyes and hair).
  - And any other disabilities or persons' inadequacy that may limit their abilities which are not listed here
2. At risk children and youth: These people include the nomadic, migrant fishermen, farmers, hunters, and almajiri, among others, who, because of their way of life and means of subsistence, are unable to access the conventional educational provision and services and, as a result, need special needs education and services to address their unique needs and circumstances.
  3. Gifted and talented children: These are people who have very high IQs, are naturally gifted in particular areas (such as the arts, creativity, music, leadership, intellectual prodigiousness, and psychomotor prowess), and as a result, they don't feel sufficiently challenged by the regular school/college/university programs in terms of pace and curricula.

According to Lucy, Ezekiel & Orodho (2015) research on inclusive education, it was acknowledged that the Nigerian constitution makes a provision for proper education for all children in the country but since the number of special child needs stands at 0.42%, Inclusion has not been effective. They further explained that Inclusion of all pupils in the conventional schools is part of an international agenda which calls for the full inclusion of all pupils with learning disabilities into all aspects of life. In Motitswe's diary as cited by John et al (2021) noted that inclusive policy is an important means to achieve the implementation of the inclusive education in every nation. Motitswe (2012) explicates the another important of inclusive policy in Africa as it will averts learners with disabilities and other special needs children from abuse of their human rights and unfair discrimination including being denied access quality education.

### **The place of the community in inclusive education**

Many studies have showed that inclusive education is one of the major parts

of education that is important and its policy must be implemented by some nations who has noted adopted it. However, some communities are not helping the children with disabilities. In the study of Arvind (2015), it was noted that “negative societal attitudes founded on ignorance often cause children with disabilities to be perceived as different, dependent, and incapable, which leads to exclusion via marginalization, institutionalization, abandonment, or neglect”. The look and manners at which children with disabilities are being handled and seen in the community is one of the factors that hinder their confidence in going or moving outside their environment for actualization of their dreams and purposes. It also hinders them from doing what they think they can do. Arvind further noted that children with disabilities are not only faced with social issues but also some contextual factors such as family class, the way of life of their community, their immediate location, type of disability.

The barriers and limitations placed on people with disabilities by the communication also includes political/leadership enablement, they are not seen as someone who can lead or contribute to the development of their communication. According to Arvid’s study, he elucidates that parent of children with disabilities hide their children’s disabilities in order to avoid exclusion or intimidation.

Supporting and helping children with disabilities and the marginalized children in the communication, Inclusive education is one of the important aspects that must be considered because of its advantages which includes promoting co-operation, love and unity among children and learners in Nigerian community and the world at large. It must be noted that inclusive education policy, if implemented in Nigerian communities and the globe at large, it will reveal to the younger and coming generation that different type of people makes up a community and everyone depends on each other for survival and the community development.

### **Inclusive education: A global perspective**

In the study of Florence & Ashi (2016), it was discovered that the practice of inclusive education has been effective over the years in some African countries which includes Uganda, Ghana, Kenya and Liberia while other African countries are still presently at the level of implementation and reviews in inclusive societies. In most developing countries the national policies on education are extracted and formulated by adopting international agencies policies, declaration and strategies. Those international agencies include: United Nations International Children and Emergency Fund (UNICEF), the United Nation Educational Scientific, and Cultural Organization (UNESCO).

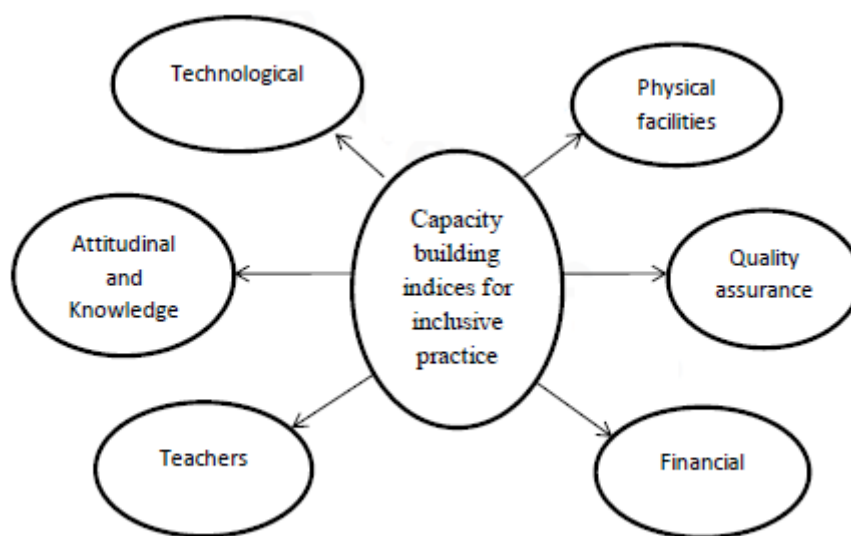
In the study of Abubakar (2019), it was noted that United Nations International Children and Emergency Fund (UNICEF) began to invest much

effort to the issue of education for children as a central goal in the late 90s. Abubakar further noted that the UNICEF organization then produced a compulsory international instrument known as the Convention on the Rights of the Child (CRC) in 1989. Out of the achievement and landmarks of the convention is the setting out of 54 articles and two Optional Protocols. Which states that, "State Parties shall respect and ensure the rights set forth in the present Convention to each child within their jurisdiction without discrimination of any kind, irrespective of the child's or his or her parent's or legal guardian's race, colour, sex, language, religion, political or other opinion, national, ethnic or social origin, property, disability, birth or other status". In accordance to this article, many countries enacted their own child's Rights Act which includes the inclusive education policy.

### **Capacity building for inclusive education**

Inclusive education is beyond the misconception of been regarded as just an educational programme, rather it is understood to be an education philosophy that is unanimously advocated for by several international policies and agendas. However, the implementation process appears skewed. In this light, Kaushik (2016) reported that, "while inclusive education has been implemented successfully in many countries, other countries are still in the process of achieving this goal". In the same vein, Sambo et al (2015) claims that inclusive education in Nigeria is more of an idealism than a laudable practice. A policy remains an abstraction without putting in place certain structures and needed capacity that enhances the effective implementation of the policy.

"Capacity building is defined as the process of developing and strengthening the skills, instincts, abilities, processes and resources that organisations and communities need to survive, adapt, and thrive in a fast changing world" (United Nation, n.d.). Ojokuku (2014) defined capacity building as the process of improving and reinforcing an organisation in the areas of administration, finance, human resources, and facilities. Capacity building is aimed at improving upon the performance of the organisation. It goes beyond the provision of training and development for staff, but offering every needed structural support for the actualization of development and improvement in performance. Jackline (2018) highlighted the following as capacity building areas required for development, these include; human resource capacity building, knowledge management capacity building, leadership capacity building, and financial resource capacity building.



*Source: Researchers model of capacity building areas or indices for inclusive practice*

### **Stakeholders' attitudinal and knowledge capacity building**

There is a negative belief held by the society about people with disabilities or special need, the school is just part of the larger society as such the success of the programme could be undermined if the immediate environment are not well intimated and sensitized about the inclusive philosophy. Knowledge capacity building entails providing information for the purpose of increasing awareness about a particular discourse among people. The environment must be conducive to support the implementation of the inclusive practice. Stakeholders such as parents, teachers, administrators, employers of labour and the community at large should be integrated into an advocacy programme of creating awareness and sensitization about the inclusive practice. The goal of such capacity building is that everyone should be aware about the programme and how in their various little ways could offer support for the actualization of the practice.

### **Teachers capacity building**

Teachers are indispensable in the implementation of any educational programme. They translate the details of the education policy framework and curriculum into practice. Inclusive education requires that all children irrespective of their peculiarities are to be taught under the same classroom environment. However, one could argue that, most African country's appears unprepared in the area of human resource, since most teachers in the regular school lack the pedagogical and technical skill and knowledge needed to teach and provide a conducive and inclusive classroom setting for students

with disabilities. This is exemplified in the argument of Adeyanju (2019), he posed certain questions referring to them as unaddressed issue, according to him “if all schools must accommodate children of different physical and mental status, how do teachers without training in special education fit in? Is the policy suggesting a compulsory training in special education for all prospective teachers? What happens to the crop of teachers who had their training before the introduction of inclusive education policy? In summary, do we have adequate teachers who can teach both special needs and the regular learners?

Aside the aspect of lacking the specialized skill needed to teach the students with disabilities, scholars have also pointed out the aspect of the negative attitude and lack of commitment of the teachers towards students with disabilities (Eunice, Nyangia and Orodho, 2015; Sambo et al, 2015; Omede et al’ 2016; Cornelius-Ukpepi et al, 2019). In the opinion of Sambo et al (2015) such teachers as a result of their frustration to the capability of student with special need in the area of learning style and pace they label such student “slow learners”. In explaining the reason behind this frustration, Shade and Stewart dairy as cited in Omede and Momoh (2016) argued that most teachers believe that they do not have the professional skill required to handle student with special need. Omede et al (2016) corroborated that most teachers were not developed professionally before integrated into the inclusive classroom.

“The effective implementation of inclusive education depends on the high quality of professional preparation of teachers at pre and in-service levels to equip them for and update their knowledge and skill in meeting the needs and aspirations of a diverse school population (Omede et al, 2016)”. Teachers capacity building or otherwise referred to as teachers preparation for inclusive education is not limited to providing training and development programme for existing teachers, but should also cover the aspect of changing the attitudes of both prospective and in-service teachers’ and redesigning the teachers education programme to accommodate inclusive education. This implies that, the whole teaching workforce, past, present and future must be under consideration. In support of this, Kaushik (2016) also added that the capacity building for prospective inclusive teachers and in-service teachers should prepare them for the following;

- To understand the concept and philosophy behind inclusive education.
- To make them understand and committed towards the global and national commitments towards education of children with diverse needs.
- To enable them in creating conducive and healthy teaching learning environment in inclusive schools.

- To enable them to identify and utilize existing resources for promoting inclusive practices.

In addressing this issue, teachers' capacity building must cover three main components which includes; firstly, is addressing the aspect of teachers disposition and attitude towards the programme, secondly is providing training and development programme for existing teachers and thirdly, restructuring the teachers education programme to accommodate a compulsory special education course for all prospective teachers.

The disposition of teachers and other stakeholders towards inclusive education is essential to the effective implementation of the programme. There must be a coordinated effort towards sensitizing the mind of both prospective and in-service teachers. Inclusive education should be advocated for as a philosophy in our curriculum across all levels of education. Most educational programme can only succeed if its' implementers believes in the goal of this programme, otherwise they become lackadaisical and frustrate the whole process.

In-service training is a type of training offered to teachers who are currently and have been teaching the regular classroom, such training is aimed at updating the knowledge and skill of teachers amidst new changes to the teaching profession, curriculum, technological advancement or educational policy. Most teachers who are currently in service do not have the necessary skill to teach student with special need as such, training and development programme must be offered to them on regular basis in preparing them for the realities of the diverse class. This should also involve collaborative and participative teaching that is, peer them with special education teacher.

The aspect of redesigning the teachers' education programme must be initiated, this must involve making the inclusive education a compulsory course in every semester or session, with emphasis on practice rather than the hitherto theoretical approach to teaching inclusive education in our various tertiary institutions. According Adeyanju (2019), prospective teachers must have some knowledge of sign language and how to use several others specialized equipment needed to teach students with special needs. Prospective teachers should be given the opportunity to have field experience on how handle an inclusive classroom through practicum, simulation or role playing.

In addition, human resource capacity building should not stop with the teachers, capacity building should be provided for other non-teaching staff in the education system, specifically the area of engaging and handling students with special need.

### **Physical facilities capacity building**

Accessibility of the school to learners with special needs is essential to the effective implementation of inclusive education. Children with special needs could be excluded from the regular school due to the barriers posed by the inaccessibility of the school environment. "Physical facilities entail provision of all the relevant physical facilities ensuring their proper utilization, and maintenance, authorizing and approving the procurement of all teaching-learning equipment in consultation with the heads of departments" (Chumo et al, 2019).

Physical facilities capacity building is the modification of existing facilities and the provision of new adaptive buildings and other equipment modeled to suit the purpose of the inclusive practice in the school. This should cover the provision, modification, availability, adequacy, accessibility, utilization and maintenance of physical resources. The school environment should be adaptive enough to cater for students with special needs. According to UNESCO (2004) Building ramps to classrooms and school buildings, construction of adapted latrines, enlargement of classroom windows, painting walls to improve the lighting, leveling of the play grounds to ease mobility makes the school environment adaptive and accessible to students with special needs.

### **Financial resource capacity building**

One the major indices to measuring government prioritization of education is from the amount voted to education as stated in the budget. Financial resource capacity building means providing fund needed for every expected monetized operation and activities. Government must show financial commitment to the inclusive education by providing special funds. This should also cover the aspect of ensuring accountability and judicious and transparent utilization of the funds.

### **Technological capacity building**

The domineering influence of information and communication technology on almost all sectors cannot be overemphasized. This became more emphasized during the covid-19 novel Virus that led to the lockdown of all sectors of the economy, arguably, only organisations that were ICT inclined were able to continue operation. Building capacity in the area of technology has become a major area in which every organisation and nations of the world has continued to invest into, as it a factor for competitive advantage and edge differential to national development respectively. Integration of technology into the education system as made education become borderless and less restrictive. Mulkah and Femi-Adeoye (2020) reported that the Dakar framework for action (April 2000) identified the use of ICT as one of main

strategies for achieving the world declaration of Education for all adopted at Jomtein in 1990 and called on all nations to harness new information and communication technologies to achieve these goals. They also added that, that during the Hwachong Education conference march 2010, it was recognized that developments in ICT have opened up exciting new possibilities for teaching practices in order to better engage and excite learners.

Technological capacity building is in response to technological advancement, this is the provision, upgrading and integration of information and communication technology precisely assistive technology for the implementation of inclusive education. In addition, it also entails training teachers on how to use the following technological devices specifically to suit the purpose of inclusive education. Technological capacity building must fulfill the various criteria; availability, adequacy, accessibility, continuous upgrading, must address diverse learners, maintenance, provision of technological expert and training of human resource on usage. There are several assistive technology that supports and enhance learning among learners with special need. Assistive technology can be defined as technological devices modified to suit the peculiarity of learners with special need in the following areas; learning, functionality, interaction and communication with others, carrying out daily tasks independently and their mobility. Assistive technology is any equipment or tool or device that helps learners by compensating for their learning disability (Nwahunaya, Ede, Abiamuwe, Attah and Asogwa, 2020). Assistive technological device differ depending on the peculiarity of the learner.

**Table:** Use and application of assistive technology in education

| Category/Area of Function | Assistive Technology application                                                                                                                      | Need and Relevance in Classroom learning                                                                                  |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|
| Reading                   | Electronic books, Book adapted for page turning, Single word scanners, Predictable texts, Tabs, Talking electronic devices/ software, Speech Software | For students having difficulty in reading and understanding written text and in paying attention to the reading assigned. |
| Writing                   | Pen/Pencil grips, Templates, Word processors, Word card/ book/ wall, software, Spelling/ Grammar checker, Adapted papers                              | For students having problem in writing or composition                                                                     |
| Mathematics               | Calculators, Talking Clocks, Enlarged Worksheets, Voice Output Measuring Devices, Scientific Calculators                                              | For students having computational problems and confusions, and finding it difficult to perform well in Math Lessons       |



| Category/Area of Function                                               | Assistive Technology application                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Need and Relevance in Classroom learning                                                                                                                                                                       |
|-------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Vision                                                                  | Eye glasses, magnifier, Screen magnification, Screen Reader, Braille Large Print Books, CCTV, Audio Lesson Tapes                                                                                                                                                                                                                                                                                                                                                                                                                                                               | For student who have difficulty in seeing or lack complete vision                                                                                                                                              |
| Hearing                                                                 | Hearing Aids, Pen and paper, Signaling Devices, Closed Captioning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | For students who have difficulty in hearing or are absolute hearing impaired                                                                                                                                   |
| Computer access                                                         | Word prediction, Alternative Keyboards, Pointing Option, Switches, Voice recognition Software                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | For students finding it difficult to access the computer in its' standard form and have difficulty in performing academic tasks.                                                                               |
| Augmentative/ alternative Communication                                 | Communication Board, Device with speech synthesis for typing, Eye gaze board/ frame, Voice output device                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | For students having problems in comprehension of language, and lacking the ability to express it, or are unclear in speech and demonstrate delayed expressive language                                         |
| Learning Disability and Attention Deficit Hyperactivity Disorder (ADHD) | Use of applications/ devices depending upon the degree of disability/ difficulty, in the area of reading and writing (Dyslexia), hand-eye coordination, written expression and composition (Dysgraphia), difficulty In fine motor skills, Coordination (Dyspraxia), Math (Dyscalculia) and Attention (ADHD) like - Talking electronic devices, Calculators, Electric Organizers, Highlighters, Pencil Grips, Post-its, Computers, Spelling/ Grammar Checker, Electronic Organizers, Recorded materials, Hand held Scanners, Print or picture schedule, Electronic Diaries etc. | For students having problem in language development, reading and writing (Dyslexia), hand-eye coordination (Dysgraphia), difficulty in fine motor skills coordination (Dyspraxia), Math (Dyscalculia) and ADHD |

Source: Adopted from (Ahmad, 2015)

### Partnership capacity building

Partnership capacity building involves expanding and entering into affiliations with organisations; local and international, Non-Governmental Organisation, health institutions, experts, the community and other stakeholders that could offer support of different kind towards the actualization of the inclusive practice. Sambo et' al (2016) argued that, the

inclusive practice thrive when all sectors are involved. They further reiterated the need for community engagement as well as implementing partners and other NGO's domiciled in special need education. According to them, the community could help in the following areas;

- Take part in consultations and project meetings before the project starts, including identifying children with disabilities in their area
- Join, participate in and manage local project committees
- Run regular awareness and sensitization meetings for others in their community
- Take part in school management committees such as school based management committee
- Participate in assessing school accessibility and the need for adjustments to make schools more accessible
- Help identify children with disabilities in the area

Thus, the school, education ministries and government must open up relationship with different organisation that could offer support. Inclusive education is not limited only to classroom learning, but also offering equal chances to them in the work of works. This should also cover understudying countries that are exceling in the implementation of the programme hereby seeking expert assistance or exchange programme. Teachers' also require support staff such as psychologist and health practitioners in providing specialized support to learners with special needs.

### **Challenges of inclusive education in Africa**

Prioritization of education is best measured not just in the professionalism of a policy framework but also in the budgetary allocation voted for education, which marks the basis for a positive attitude towards education. The aspect of finance is crucial to the implementation of any educational programme, sadly this is the major area most Africa nations are underperforming. There is low budget prioritization given education, with the government of nations considering the modification of the educational structure to suit the inclusive practice as expensive and costly (Cornelius-Ukpepi, and Opuwari, 2019). Nwoagba's diary as cited in Igwe et' al (2014) also pointed out inadequate funding as the retrogressing factor to the growth of special needs education in Nigeria. According to him, this has heavily affected every other area of the programme that covers provision of needed resources and the professional development of human resources.

Ireri, King'endo, Wangila and Thuranira (2020) in his study revealed that the insufficient fund available for inclusive practice in Kenya is inextricably linked to the problem of inadequate physical facilities. They also added that most schools in Kenya have not been able to successfully remove the barriers

that facilitate learners with physical disabilities to access and participate fully in their learning process. Relatedly, Chumo and Kosgei (2019) in their study, found out that facilities such as ramps, runway, paths, sanitary, toilet and latrines were not designed to be used by learners with disabilities. Adeyanju (2019) reported that no primary or secondary school in Lagos State, Nigeria has a walk-way for learners with wheelchairs. The architectural design of most regular schools does not support the inclusionary practice. Inadequacy of facilities extends to the lack of teaching and learning equipment needed to teach the learners with special needs.

Relatedly, this also extends to the level of integration of assistive technology to the inclusive classroom. Technology is perceived as a massive innovation that has answers to a lot of questions related to human task and activities. There are lots of technological devices that have been created to support the functionality of learners with special needs in every of their various aspect of life. On the contrary, with little investment in technology among African Nations, the regular schools are incapacitated in offering assistive technology that supports learning among learners with disabilities.

Unpreparedness in the area of personnel cannot be underemphasized. Adeyanju (2019) argued that certain questions must be addressed over the issue of personnel if all schools are to accommodate children of different specialty. Shamrma and Michael diary as cited in Ireri et' al (2020) also stressed that teachers have negative attitude towards inclusive practice and also lack the knowledge and skill to be an adaptive teacher under the inclusive education system.

Relatedly, claiming that inclusive education is the sole responsibility of the school is a misconception and a myth. All educational stakeholders are expected to be involved in the process, specifically in the area of attitude, belief and acceptance of the programme. The problem of attitudinal barrier extends to the community at large. The community has a big role to play in the implementation of the inclusive education; they could help in the identification and assessment of learners with disabilities which has been a major setback in the implementation of the philosophy, as the government lacks accurate census of all the children with special needs; the community must also be sensitized and reoriented on the inclusionary practice, many of them continue to regard such children as an offshoot of a curse and do not perceive them to have a place in the society than to lay in the street as beggars; the community could also provide support in the place of security, mobility, resource mobilization and moral support. Education is a concern for and of all, as such the community cannot be ostracized from the educational system.

The legal support needed for the implementation of the inclusionary practice is more on paper than in reality. For example in Nigeria the bill on

discrimination against persons with disabilities prohibition act was not passed into law until January 23rd, 2019. Igwe, Rasak, Jerry, and Adebisi (2014) argued that this bill was dragged longer than expected, which according to them was a reflection of the insensitivity of government. This has heavily affected the implementation of the programme. Irrespective of the laws, not much have been done in the place of enforcement. We still have a whole lot of persons with disabilities that roam around the streets begging around. In support of this Mitchell diary as cited in Ileri et al (2019) postulated that inclusionary practices in schools are not in tandem with the legislations and policies enacted and formulated respectively by several countries.

### **The chameleon-like education and the inclusionary practice in the classroom**

The chameleon-like education is multifaceted although it could also be referred to as adaptive educational system. This is a type of education of which the structure, programme content, curriculum, resources, philosophy, policies and total make-up is adaptive, flexible, functional, relevant and inclusive in nature and practice to satisfy the multiplicity of the diverse peculiarities of students; learning styles or requiring special need. In this context, it covers ensuring that the physical facilities, teachers and pedagogy, curriculum or course programme and assessment are adaptive to support the inclusionary practice. This aspect of adaptive education takes serious cognizance of learners peculiarities in designing the classroom, the model of curriculum, type of school plant, the choice of teaching strategy and assessment. The more adaptable the educational system is in satisfying the diversity among student with special needs the greater the chance for the inclusionary practice to thrive. Transforming the existing regular schools to an inclusive setting remains out of our depth.

### **Conclusion**

Capacity building for inclusive education involves the process of improving the various school structures, facilities, attitudes and resources in order to enhance the accessibility of the regular school to student with special needs. Capacity is critical to achieving the goal of inclusive education. Most African country's appears to be unprepared capacity-wise for the full implementation of inclusive education. These areas include finance, human resources, physical facilities, technological support, quality assurance and stakeholders'/environmental disposition and attitude towards the programme. One cannot continue to overlook these critical areas if a laudable practice is expected in the implementation of inclusive education, in other words to re- strategize is to build capacity in the identified areas. Building capacity for the effective implementation of inclusive education is improving upon certain critical areas which should not be limited to finance, staff

training, physical facilities or management structure, but also changing the attitude persons and stakeholders towards a policy through awareness and advocacy; strengthening partnership; and exploring the positive externalities that technological advancement offers.

### **Recommendation**

- Re-strategizing for the effective implementation of inclusive education policy in Nigeria, all hands must be on deck; school heads must ensure that teachers are sufficient in the school.
- Extra training on special education must be given to all teachers all level of education so as for them to cope well in teaching both students with disabilities and without disabilities.
- Public awareness on the danger of excluding people with disabilities from social services should be done for every community to have a different look and show love to people with disabilities as they are also member of the community.
- Children with disabilities needs to be orientate on how to build a good self-esteem and self-confidence.
- Monitoring team should be set up at different community to monitor the growth and behaviours of others towards people with disabilities.
- Government should provide adequate funds for support in schools in order to successfully implement the inclusive education policy in the country.
- Adequate facilities should be provided in schools and student should be encouraged to use the facilities adequately.

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## The use of blockchain technology for tracking and verifying carbon credits in carbon offsetting schemes

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### **Abstract**

The use of blockchain technology for tracking and verifying carbon credits in carbon offsetting schemes has the potential to address some of the weaknesses of current systems, such as lack of transparency and standardization. This study reviewed existing literature on the use of blockchain technology in carbon offsetting and examined several case studies of blockchain-based platforms, including The Carbon Credit Blockchain, The Environmental Asset Platform, The Blockchain Carbon Accounting System, The Carbon Ledger, and The Carbon Trade Exchange. The results suggest that blockchain technology can enhance the efficiency, transparency, and integrity of carbon credit tracking and verification. However, further research is needed to address limitations such as scalability and regulatory challenges. In retrospect, this study highlights the potential of blockchain technology to improve the effectiveness of carbon offsetting efforts to create better green economies.

## **Introduction**

Carbon offsetting is a widely used approach to reduce greenhouse gas emissions and mitigate the impacts of climate change, especially in Europe. One of the key components of carbon offsetting is the tracking and verification of carbon credits, which are used to measure and record emissions reduction. The carbon credits are generated through projects that reduce, avoid or remove greenhouse gas emissions and can be traded in the carbon market. However, current carbon credit tracking and verification systems have been criticized for their weaknesses, including lack of transparency, inefficiency, and lack of standardization. In terms of transparency, current carbon credit tracking and verification systems have been criticized for their lack of transparency and accessibility, which makes it difficult for stakeholders to understand the details of the carbon credits being generated and traded (Jiang, Song & Yu, 2022). According to Liu et al. (2015), this lack of transparency can make it difficult for stakeholders to ensure that the carbon credits are generated and traded ethically and sustainably. Besides, current carbon credit tracking and verification systems have been criticized for inefficiency and high transaction costs. This can make it difficult for small-scale projects to participate in the carbon market and make it difficult for stakeholders to make informed decisions about buying and selling carbon credits.

Accordingly, this inefficiency can also make it difficult for stakeholders to ensure that the carbon credits are being generated and traded efficiently and cost-effectively. The current carbon credit systems lack standardization, making it difficult for stakeholders to compare and trade carbon credits across different projects and countries (Fawcett & Parag, 2010). The lack of standardization can also make it difficult for stakeholders to ensure that the carbon credits are being generated and traded consistently and reliably. Ostensibly, this research paper explores these weaknesses in more detail and identifies potential solutions to improve the tracking and verification of carbon credits to create better green economies. Besides, this research will focus on how blockchain technology can provide a more transparent, efficient, and standardized way of tracking and verifying carbon credits, which could solve the current issues in carbon credit tracking and verification systems.

## **Research questions**

1. How can blockchain technology be used to improve the tracking and verification of carbon credits in carbon offsetting schemes?
2. What are the key advantages and limitations of using blockchain technology for tracking and verifying carbon credits in carbon offsetting schemes?

3. What factors influence the adoption of blockchain technology for tracking and verifying carbon credits in carbon offsetting schemes?
4. What are the existing blockchain-based carbon offsetting projects, and what are their key features?
5. How can blockchain technology increase trust and transparency in carbon offsetting schemes?

## **Literature review**

Carbon offsetting is a common practice for curtailing greenhouse gas emissions to fight the effects of climate change and provide safeguards for building green economies. One of the key components of carbon offsetting is the tracking and verification of carbon credits, which are used to measure and record emissions reduction (Liu et al., 2015). However, current carbon credit tracking and verification systems have been criticized for their weaknesses, including lack of transparency, inefficiency, and standardization.

A study by Smith et al. (2018) found that current carbon credit tracking and verification systems often lack transparency, making it difficult for stakeholders to understand and trust the data that is being reported. This can lead to a lack of confidence in the carbon offset market and make it difficult for organizations to demonstrate their emissions reductions to stakeholders.

Similarly, Jones et al. (2019) found that current carbon credit tracking and verification systems are often opaque and lack traceability, making it hard to ensure the authenticity and integrity of the carbon credits.

Another study by Jones et al. (2019) found that current carbon credit tracking and verification systems are often inefficient, with many manual processes and a lack of automation. This can lead to increased costs and a lack of scalability, making it difficult for organizations to participate in the carbon offset market. Additionally, Liu et al. (2020) found that current carbon credit tracking and verification systems often lack proper technical support. Therefore, the systems are vulnerable to errors and fraud.

Williams et al. (2020) also found that current carbon credit tracking and verification systems lack standardization. As such, it is difficult for organizations to compare and trade carbon credits across different systems and regions. That challenge leads to fragmentation in the carbon offset market and can make it difficult for organizations to participate in the global carbon offset market. Zhang et al. (2021) established that current carbon credit tracking and verification

systems utilize different methodologies and protocols, which makes it hard to ensure consistency and comparability across various systems.

These findings demonstrate that current carbon credit tracking and verification systems have inadequacies that make it challenging to support green economies. These weaknesses can make it difficult for organizations to participate in the carbon offset market and lead to a lack of confidence overall. Traditional carbon offsetting schemes rely on central authorities to track and verify carbon credits, which can lead to high costs and slow processes (Jiang, Song & Yu, 2022). In retrospect, blockchain can provide a decentralized system for tracking and verifying carbon credits, reducing the need for intermediaries and increasing the process's speed and efficiency.

The use of blockchain technology for tracking and verifying carbon credits in carbon offsetting schemes has gained traction and acceptance as a potential panacea for solving the weaknesses of the current systems. Blockchain, a decentralized and distributed digital ledger, can provide transparency, immutability, and tamper-proof record-keeping, which can help improve the efficiency and credibility of carbon credit tracking and verification.

Other studies have examined the potential of blockchain technology in the context of carbon offsetting. A study by Li et al. (2019) established that blockchain technology could provide a secure and transparent platform for issuing, trading, and retiring carbon credits. The authors also highlighted the potential for blockchain to reduce transaction costs and increase the liquidity of carbon markets. In this regard, Böhringer and Larsen (2019) argued that blockchain technology is the panacea to improving the transparency and traceability of carbon offset projects, making it easier to verify the authenticity of carbon credits.

However, there are also challenges and limitations to using blockchain technology in carbon offsetting. A study by Banse and Brink (2018) argued that blockchain-based carbon offsetting systems are still in the early stages of development, and challenges such as scalability, standardization, and governance must be addressed. Additionally, a survey by Rauchs et al. (2018) highlighted the need for proper regulation and oversight to ensure the integrity and accuracy of carbon credit tracking and verification on a blockchain platform.

Further, another study by Yang et al. (2018) examined the applicability of blockchain technologies for carbon credit trading and offsetting in China. The authors of this study proposed a blockchain-based carbon offsetting platform that allows for the tracking and verification of carbon credits, as well as the trading of carbon offsetting products and services. The study found that the blockchain-based

platform had the potential to improve the transparency, efficiency, and security of carbon-offsetting transactions in China.

In addition to these studies, several examples of pilot projects and initiatives are currently exploring the use of blockchain technology for carbon offsetting. For example, the Carbon Credit Solution (CCS) is a blockchain-based platform that enables companies to offset their carbon emissions by purchasing carbon credits generated by renewable energy projects. The platform uses smart contracts and tokens to track and verify the ownership and retirement of carbon credits. Another example is the Carbon XPRIZE project, a global competition that encourages the development of blockchain-based carbon offsetting solutions. The competition includes several teams and organizations working on various blockchain-based projects, including carbon credit tracking and verification systems. Further, the Carbon Trade Exchange (CTX) is a blockchain-based platform that facilitates the trading of carbon credits between companies and governments.

## **Theoretical framework**

### **Theory of the firm**

The theory of the firm is a central concept in economics, which explains the behavior and decision-making of firms in a marketplace. In the context of blockchain technology for tracking and verifying carbon credits in carbon offsetting schemes, the theory of the firm can provide insight into the motivations and incentives of companies to adopt and implement blockchain systems (Oliveira & Martins, 2011).

One key aspect of the theory of the firm is the concept of transaction costs, which are the costs associated with making an economic exchange. In the case of carbon offsetting, transaction costs include the costs of measuring, reporting, and verifying emission reductions. Blockchain technology can reduce transaction costs by offering an immutable and tamper-proof system that enhances transparency for acceptance by all stakeholders. The other aspect of the theory of the firm is the concept of information asymmetry, in which case, some parties in an economic system have better access to information than others (Oliveira & Martins, 2011). In the case of carbon offsetting, information asymmetry can occur when companies are not transparent about their emission reductions, making it difficult for buyers of carbon credits to verify the authenticity of the credits. Blockchain technology can help to reduce information asymmetry by providing a transparent and tamper-proof record of emissions reductions that can be easily accessed and verified by all stakeholders (MacMinn & Holtmann, 1983).

In addition to transaction costs and information asymmetry, the theory emphasizes the centrality of trust and reputation in economic exchanges. In the case of carbon offsetting, companies may be reluctant to adopt blockchain technology if they are not convinced of its security and reliability. However, as blockchain technology becomes more widely adopted and proven in other industries, companies may be more likely to trust and adopt it for carbon offsetting.

Several studies have investigated the potential of blockchain technology for carbon offsetting. For example, Li et al. (2020), in examining carbon credit tracking using blockchain in China, made some interesting findings. The study established that blockchain technology could play a key role in ensuring credit tracking was transparent and efficient to reduce the risk of fraud and misrepresentation of carbon credits. Another study by Li et al. (2019) made similar findings in the context of the Paris Agreement. The survey concluded that blockchain technology improved the transparency and accountability of carbon-offsetting projects and helped reduce the costs and complexity of the schemes.

Further, Wang et al. (2020) explored the United Nations Framework Convention on Climate Change's Clean Development Mechanism to determine how blockchain could be synchronized in the framework. The survey indicated that blockchain technology can help to reduce the costs and complexity of carbon offsetting.

### **The theory of planned behavior (TPB)**

The theory of planned behavior (TPB) is a psychological theory that explains human behavior due to the interaction between attitudes, subjective norms, and perceived behavioral control. In the context of the use of blockchain technology for tracking and verifying carbon credits in carbon offsetting schemes, TPB can be applied to understand how individuals and organizations may form attitudes and perceptions towards blockchain technology and how these attitudes and perceptions may influence their behavior in terms of adopting and implementing blockchain-based carbon offsetting systems (Aboelmaged & Gebba, 2013).

The TPB posits that intention influences individual behavior. Other factors include attitude, subjective norms, and perceived behavioral control. In the context of blockchain-based carbon offsetting, an individual's attitude towards blockchain technology may be influenced by their perceptions of the technology's effectiveness in tracking and verifying carbon credits and their perceptions of the technology's security, privacy, and scalability (Ndubisi, 2006). Subjective norms refer to an individual's perceptions of socially acceptable values or behaviors. In

the context of blockchain-based carbon offsetting, an individual's subjective norms may be influenced by their perceptions of what is considered an appropriate response to climate change and their perceptions of what is considered socially responsible behavior in terms of carbon offsetting (Ndubisi, 2006).

Perceived behavioral control refers to the extent to which an individual considers a certain behavior easy or challenging to perform. In the context of blockchain-based carbon offsetting, an individual's perceived behavioral control may be influenced by their perceptions of the availability and accessibility of blockchain-based carbon offsetting systems and the technical expertise and resources required to implement such systems (Aboelmaged & Gebba, 2013).

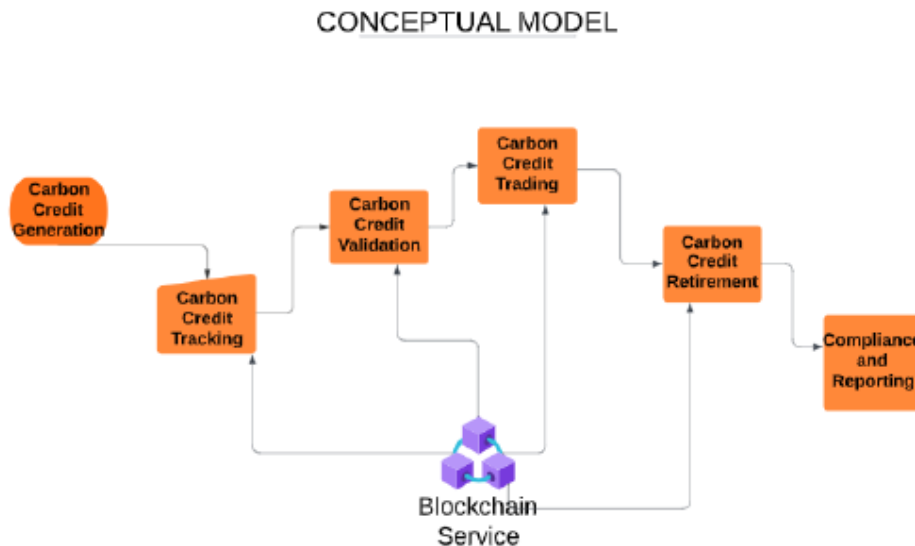
Scholars can use TPB to comprehend how individuals and organizations may form attitudes and perceptions toward blockchain technology and how these attitudes and perceptions may influence their behavior in terms of adopting and implementing blockchain-based carbon offsetting systems. For example, in a survey, Liu et al. (2020) used the TPB to understand the adoption of blockchain technology in the context of carbon trading. The scholars found that perceived behavioral control, subjective norms, and attitudes toward blockchain were key factors in determining the intention to adopt blockchain-based carbon trading systems.

In summary, the theory of planned behavior (TPB) can be useful in understanding the adoption of blockchain technology for tracking and verifying carbon credits in carbon offsetting schemes. It can help identify the key factors that influence individuals' and organizations' attitudes and perceptions towards the technology, and how these attitudes and perceptions may influence their behavior in adopting and implementing blockchain-based carbon offsetting systems.

### **Conceptual model**

The diagrammatic representation of the conceptual model for the proposed carbon offsetting scheme using blockchain technology is shown in Fig. 1 below. The component of the model are discussed below.

**Fig. 1** Showing the proposed conceptual model



**Carbon credit generation:** This component would involve creating and issuing carbon credits through activities such as carbon sequestration, renewable energy generation, and energy efficiency improvements.

**Carbon credit tracking:** This component would involve the use of blockchain technology to track and record the issuance, ownership, and transfer of carbon credits. The blockchain would provide a secure and transparent record of all transactions, ensuring the integrity and verifiability of the carbon credit data.

**Carbon credit validation:** This component would involve the verification of the validity and authenticity of carbon credits by an independent third party. This could include assessments of the emissions reductions or sequestration activities associated with the credits, as well as checks on the compliance of the activities with relevant standards and regulations.

**Carbon credit trading:** This component would involve the buying and selling carbon credits on a decentralized marketplace. Blockchain technology would facilitate the peer-to-peer trading of carbon credits, enabling organizations to offset their emissions by purchasing credits from other organizations.

**Carbon credit retirement:** Further, this component will involve the permanent removal of carbon credits from circulation, ensuring that the total supply of credits remains in line with emissions reduction targets. The blockchain would facilitate the tracking and verifying credit retirement, ensuring that retired credits are not re-issued or traded.



**Compliance and reporting:** This component would involve reporting carbon credit data to regulatory bodies and other stakeholders. Blockchain technology would enable organizations to provide transparent and verifiable data quickly and easily on their carbon credit holdings and transactions, facilitating compliance with emissions reduction targets and regulations.

### **Research methodology: Case studies**

The methodology of this study was a literature review and case studies. Case study research is a well-established methodology particularly useful when studying complex phenomena in real-life contexts. It allows for collecting rich, in-depth data and examining multiple perspectives and factors that may influence the phenomenon under study. One of the benefits of using case studies in this research was that it allowed for the examination of the use of blockchain technology for tracking and verifying carbon credits in carbon offsetting schemes in real-world situations (Rowley, 2002). The technique provided valuable insights into the practical challenges and opportunities of implementing such systems and the potential impact on stakeholders.

Another benefit of case studies is that it allows for the examination of multiple cases, which can increase the generalizability of the findings (Zainal, 2007). For example, if multiple case studies are conducted in different countries or types of carbon offsetting schemes, the findings can be used to draw broader conclusions about the potential of blockchain technology in this context.

However, one of the weaknesses of case studies is that they may be affected by researcher bias. Case study research depends on how a researcher interprets information. However, researcher bias and contextual perspectives can influence findings (Zainal, 2007). This was mitigated by using multiple researchers and triangulating data from different sources. Another potential weakness of case studies is that they may not be generalizable to other contexts. The findings may only be applicable to the specific cases studied and may not be applicable to other situations (Zainal, 2007). This is a common criticism of case study research; however, it was mitigated by using multiple cases and examining the findings in light of existing theories and literature.

### **Case studies of real use-cases of blockchain technology in carbon trading schemes the carbon credit blockchain (CCBL)**

The Carbon Credit Blockchain (CCBL) is a decentralized platform that utilizes blockchain technology to track and verify carbon credits generated by small-scale clean energy projects. The platform utilizes smart contracts. The smart contracts

can self-execute based on the buyer and seller agreement (Swinkels, 2023). These smart contracts automate the carbon credit issuance, trading, and retirement process, making the system more efficient, secure, and transparent. The CCBL platform allows project developers to register their clean energy projects on the blockchain and issue carbon credits based on the verified reduction of greenhouse gas emissions. These carbon credits can then be traded on the platform's decentralized marketplace, where they can be purchased by entities looking to offset their own carbon emissions (Khodai, 2022). The platform also allows for the retirement of carbon credits, ensuring that they are not double-counted, and that emissions reduction is accurately accounted for.

The unique benefit of the CCBL platform is its transparency. This increased transparency helps build stakeholders' trust and ensures that carbon credits are only issued for verified emissions reductions. Additionally, CCBL platform are efficient. By automating the carbon credit issuance, trading, and retirement process, the platform reduces the administrative burden associated with traditional carbon credit tracking and verification systems (Climate News, 2022). That can lead to cost savings and a more streamlined process for all parties involved.

The CCBL platform also allows for the inclusion of small-scale clean energy projects, which may have been excluded from traditional carbon offsetting schemes due to high transaction costs. By reducing these costs, the platform can help promote the development of small-scale clean energy projects and increase their contributions to reducing greenhouse gas emissions. However, there are also some limitations to the CCBL platform (Khodai, 2022). One limitation is that the platform currently only supports small-scale clean energy projects, and it may not be able to handle the large volumes of carbon credits generated by large-scale projects.

Another limitation is that the platform is rudimentary and in beta version, and it may take sometime before it becomes widely used by the industry.

### **The environmental asset platform (EAP)**

The Environmental Asset Platform (EAP) is a blockchain-based platform that aims to create a decentralized marketplace for carbon credits and other environmental assets. The platform was developed to address the weaknesses of current carbon credit tracking and verification systems, such as lack of transparency, inefficiency, and standardization. The key features of the EAP is its ability to verify and track carbon credits generated by a wide range of activities. This includes reforestation, energy efficiency, and renewable energy projects. The platform uses smart

contracts to automate the process of carbon credit issuance, trading, and retirement (Carbon Credits, 2022). The program allows for a more efficient and transparent process, as all transactions are recorded on the blockchain and can be easily audited.

EAP also allows for the creation of a decentralized marketplace for carbon credits. It means that credits can be traded directly between buyers and sellers without intermediaries. That can help increase carbon credit liquidity and make it easier for small-scale projects to access the carbon market. In addition to carbon credits, the EAP also allows for the verification and tracking of other environmental assets, such as water rights and biodiversity offsetting credits.

The process allows for a more holistic approach to environmental management, as different types of assets can be traded and tracked on the same platform (Granicus, 2022). One of the benefits of the EAP is its ability to increase transparency and accountability in the carbon market. By recording all transactions on the blockchain, the platform makes it easy to track the origin and ownership of carbon credits. This can help to reduce the risk of fraud and increase confidence in the carbon market. Another benefit of the EAP is its ability to increase the efficiency of the carbon market (Carbon Credits, 2022). By automating the carbon credit issuance, trading, and retirement process, the platform can reduce the administrative costs associated with carbon offsetting. This can make it more attractive for small-scale projects to participate in the carbon market.

However, there are also some limitations to the EAP. One limitation is the need for a sufficient number of users to participate in the platform for it to be effective. Without sufficient participation, the platform may not be able to achieve the desired level of transparency, efficiency, and liquidity. Another limitation is the need for accurate and reliable data to be entered into the platform. Inaccurate or fraudulent data can compromise the platform's integrity and reduce confidence in the carbon market. Nonetheless, the Environmental Asset Platform (EAP) is a promising blockchain-based solution for tracking and verifying carbon credits in carbon offsetting schemes (Carbon Credits, 2022). It can increase transparency, accountability, and efficiency in the carbon market and make it more accessible for small-scale projects.

However, it also has some limitations that need to be considered.

### **The blockchain carbon accounting system (BCAS):**

The Blockchain Carbon Accounting System (BCAS) is a blockchain-based platform that aims to address the challenges of current carbon credit tracking and

verification systems by providing a transparent, efficient, and standardized system for carbon credit management. The platform is specifically designed for carbon sequestration activities such as afforestation and reforestation, which are considered one of the most cost-effective ways to remove carbon dioxide from the atmosphere (Jones, 2020).

BCAS uses smart contracts to automate the process of carbon credit issuance, trading, and retirement. Smart contracts are self-executing digital contracts that can automatically verify and enforce the terms of the agreement between parties, eliminating the need for intermediaries and reducing the costs and risks associated with traditional carbon credit trading. This ensures that carbon credits are issued, traded, and retired in compliance with the relevant standards and regulations and that the carbon credits are accurately tracked and verified. One of the key features of BCAS is its use of satellite imagery and other remote sensing technologies to monitor and verify the carbon sequestration activities that generate carbon credits (Tang & Lie, 2020).

This allows for real-time monitoring of the carbon sequestration activities, ensuring that the carbon credits are accurate and reliable and generated by activities consistent with the relevant standards and regulations.

BCAS also uses a decentralized and distributed ledger system to provide a transparent and tamper-proof record of all transactions and activities related to carbon credits. This allows for a complete, accurate, and verifiable record of all carbon credits, which can be used for auditing, reporting, and compliance purposes. The BCAS platform is also designed to be easily integrated with other systems, such as carbon offset registries, carbon trading platforms, and carbon accounting systems (Jones, 2020). This allows for seamless and efficient trading of carbon credits across different platforms and jurisdictions, which can help to increase the demand for carbon credits and to support the development of a global carbon market.

One of the case studies, The Forest Carbon Partnership Facility (FCPF), has been using BCAS to track and verify carbon credits generated by reforestation and afforestation projects in developing countries. The FCPF is a global partnership that aims to reduce deforestation and forest degradation emissions and enhance forest carbon stocks. By using BCAS, the FCPF can ensure that the carbon credits generated by its projects are accurately tracked and verified and consistent with the relevant standards and regulations (Tang & Lie, 2020). The platform also allows for more efficient trading of carbon credits, which helps to increase the demand for carbon credits and to support the development of sustainable forest management practices.

In essence, BCAS is a blockchain-based platform that aims to provide a transparent, efficient, and standardized carbon credit management system specifically designed for carbon sequestration activities such as afforestation and reforestation. Its use of smart contracts, satellite imagery, and other remote sensing technologies, and a decentralized ledger system, provides a transparent and tamper-proof record of all transactions and activities related to carbon credits, which can be used for auditing, reporting, and compliance purposes. Also, it helps to increase the demand for carbon credits and to support the development of a global carbon market.

### **The carbon ledger**

The Carbon Ledger is a blockchain-based platform that aims to create a decentralized marketplace for carbon credits. The platform allows for verifying and tracking carbon credits generated by various activities such as energy efficiency, renewable energy, and carbon capture and storage. The Carbon Ledger is designed to address the weaknesses of current carbon credit tracking and verification systems by providing a transparent, efficient, and standardized system for tracking and trading carbon credits (PWC, n.d). The platform utilizes blockchain technology to create a secure and immutable record of carbon credit transactions, which stakeholders can easily audit and track.

One of the key features of The Carbon Ledger is its ability to track and verify carbon credits at a granular level. The platform uses smart contracts to automate the carbon credit issuance, trading, and retirement process, which allows for tracking individual carbon credits and their associated emissions reductions. This granular tracking capability is particularly useful for small-scale clean energy projects, which often struggle to access existing carbon credit markets due to high transaction costs and lack of standardization.

The Carbon Ledger has been tested and implemented in several pilot projects, including a project to track and trade carbon credits generated by a small-scale hydroelectric power project in India. The results of this pilot project showed that the platform could track and verify carbon credits successfully. It could significantly reduce transaction costs and increase access to carbon credit markets for small-scale clean energy projects. The other notable feature of the Carbon Ledger is its ability to create a decentralized marketplace for carbon credits. The platform allows for trading carbon credits between different entities, including individuals, companies, and governments (Carbon Interface., n.d). This decentralized marketplace allows for greater flexibility and efficiency in trading carbon credits and can also help increase the liquidity of carbon credit markets.

Despite its potential benefits, The Carbon Ledger also has some limitations. One of the platform's main challenges is the need for a robust and reliable method for measuring and verifying carbon emissions reductions. The platform relies on accurate and verifiable data to track and verify carbon credits, and currently, there is a lack of standardization and transparency in carbon accounting methods (PWC, n.d). Additionally, the platform is still in the early stages of development and implementation, and it will be important to continue testing and refining the platform in order to ensure its scalability and long-term viability.

Therefore, The Carbon Ledger represents a promising solution for addressing the weaknesses of current carbon credit tracking and verification systems. Its use of blockchain technology allows for the creation of a transparent, efficient, and standardized system for tracking and trading carbon credits, which has the potential to increase access to carbon credit markets for small-scale clean energy projects and create a more efficient and liquid carbon credit market (PWC, n.d). However, its success will depend on overcoming the challenges of measuring and verifying carbon emissions reductions and ensuring the scalability and long-term viability of the platform.

### **The carbon trade exchange (CTX)**

The Carbon Trade Exchange (CTX) is a blockchain-based platform that aims to create a decentralized marketplace for carbon credits. The platform allows for verifying and tracking carbon credits generated by various activities, such as energy efficiency, renewable energy, and carbon capture and storage. The CTX platform utilizes blockchain technology to create a transparent and secure system for tracking and verifying carbon credits (Carbon Trade Exchange, n.d.). The platform uses smart contracts to automate the process of carbon credit issuance, trading, and retirement. This ensures that the carbon credits traded on the platform are legitimate and accurately represent the emissions reductions they claim to represent.

One of the key advantages of the CTX platform is its ability to create a decentralized marketplace for carbon credits. This allows for a more efficient and cost-effective system for trading carbon credits, as it eliminates the need for intermediaries such as brokers and registries (Climate Action, n.d). Additionally, the decentralized nature of the platform ensures that carbon credit transactions are transparent and verifiable by all parties involved. Another advantage of the CTX platform is its ability to handle a wide range of different types of carbon credits. The platform can handle carbon credits generated by various activities, such as energy efficiency, renewable energy, and carbon capture and storage. This allows for a more flexible and inclusive carbon offsetting market.

However, the CTX platform is still in development and has not yet been fully implemented. Therefore, it is still unclear how well the platform will perform in practice and whether it will be able to overcome the challenges facing current carbon offsetting systems (Climate Action, n.d). Despite this, the CTX platform has the potential to significantly improve the tracking and verification of carbon credits and create a more efficient and effective carbon offsetting market. Further research is needed to evaluate the performance of the CTX platform and its impact on carbon offsetting.

## **Results and discussion**

The results of this study indicate that blockchain technology has the potential to significantly improve the tracking and verification of carbon credits in carbon offsetting schemes (Jiang, Song & Yu, 2022). The case studies of the Carbon Credit Blockchain (CCBL), Environmental Asset Platform (EAP), Blockchain Carbon Accounting System (BCAS), Carbon Ledger, and Carbon Trade Exchange (CTX) all demonstrate the ability of blockchain to provide transparency, efficiency, and standardization in the carbon credit market.

One key finding is that blockchain technology allows for the real-time tracking and verification of carbon credits, which can increase the accuracy and credibility of carbon offsetting schemes. Smart contracts in these platforms also enable the automation of carbon credit issuance, trading, and retirement, reducing the need for manual intervention and increasing efficiency. Additionally, since blockchains enjoy decentralization, all parties involved, including stakeholders, can access similar information and verify carbon credit records seamlessly. Another important finding is that blockchain-based carbon offsetting systems can facilitate the participation of small-scale clean energy projects, increasing the diversity of carbon credit sources and promoting the development of low-carbon economies (Woo et al., 2021). The Environmental Asset Platform (EAP) and Carbon Ledger, for example, allow for the verification and tracking of carbon credits generated by a variety of activities, such as reforestation, energy efficiency, and renewable energy.

While blockchain technology is pivotal in leveraging tracking and verifiability of carbon credits, it has certain limitations that require solutions. One limitation is the lack of standardization in the field, as there are currently multiple blockchain-based platforms for carbon offsetting, each with different protocols and standards (Jiang, Song & Yu, 2022). Additionally, a lack of regulatory frameworks for blockchain-based carbon offsetting systems could pose challenges to integrating these systems into existing carbon markets.

## Conclusion

This study aimed to explore the use of blockchain technology for tracking and verifying carbon credits in carbon offsetting schemes. The literature review revealed that current carbon credit tracking and verification systems had been criticized for their weaknesses, including lack of transparency, inefficiency, and standardization. Blockchain technology has been proposed as a potential solution to these issues, as it allows for the creation of decentralized and transparent systems for tracking and verifying carbon credits. The case studies of the Carbon Credit Blockchain (CCBL), Environmental Asset Platform (EAP), Blockchain Carbon Accounting System (BCAS), Carbon Ledger, and Carbon Trade Exchange (CTX) provided further insight into the potential benefits and limitations of blockchain-based carbon offsetting systems.

The results suggest that blockchain technology can potentially improve the transparency, efficiency, and standardization of carbon credit tracking and verification. However, further research is needed to fully understand the feasibility and scalability of these systems, as well as to identify and address any potential challenges and limitations. Additionally, there is a need to develop international standards and regulations for blockchain-based carbon offsetting systems to ensure consistency and comparability across different projects and countries.



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## MNC subunit competence creation – Technological distinctiveness and knowledge sourcing

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### **Abstract**

This paper proposes a model by which to measure the extent to which a multinational corporation (MNC) subunit's knowledge sourcing influences that subunit's likelihood to engage in competence creation {CC}. We examine on a technological field level the extent to which a subunit's activity is distinct from that of its parent company (defined as technological distinctiveness), then analyze how this technological distinctiveness is related to the knowledge sourcing patterns of the subunit, as measured by the MNC's knowledge structure, as well as the geographical and technological dispersion of knowledge sources of the subunit. This study focuses upon each subdivision of the broadly defined chemical industry, distinguishing petroleum, pharmaceutical and biotech, from general chemicals. As predicted, a positive relationship is found between a subunit's technological dispersion of knowledge sourcing and its technological distinctiveness. Less expected, there is also found a negative relationship between the geographical dispersion of a subunit's knowledge sources and its technological distinctiveness.

## 1. Introduction

The concepts of “exploitation” and “exploration” were first introduced into organizational learning theory in 1991. (March, 1991). At page 85 of his seminal paper, Professor March defined exploitation as “the refinement and extension of existing competencies, technologies, and paradigms” and exploration as “experimentation with new alternatives that have returns that are uncertain, distant, and often negative.” Based on this distinction, studies in a wide range of management fields have shown that the pursuits of exploitation and exploration require substantially different structures, processes, strategies, capabilities, and cultures, and may have different impacts on firm adaptation and performance (He & Wong, 2004). In general, exploration is associated with organic structures, loosely coupled systems, path breaking, improvisation, autonomy and chaos, and emerging markets and technologies; whereas exploitation is associated with mechanistic structures, tightly coupled systems, path dependence, routinization, control and bureaucracy, and stable markets and technologies (Ancona et al., 2001).

The theory of organizational capability, an extension and synthesis of the knowledge-based view of organizations, is premised upon the notion that organizational capability is essentially the amalgamation of individual’s specialized knowledge (Grant, 1996). According to organization theories, a firm’s competence arises from the knowledge, skills, and related routines that constitute its ability to create and deliver superior customer value (Day 1994). The development of a firm’s competence can take two routes – exploitation or exploration. When a firm takes the route of competence exploitation, it invests resources to refine and extend existing skills and processes, with an eye to improve efficiency and the reliability of existing innovation. In contrast, firms pursuing competence exploration invest resources to acquire new knowledge, skills, and processes, with the aim of attaining flexibility and novelty in product innovation through increased variation and experimentation (March, 1991; Atuahene-Gima, 2005).

In the context of MNCs, different operating units in various locations may conduct a variety of innovative activities, some involving competence creation (CC) and others involving competence exploitation (CE). Following up previous research into CC and CE in MNC subsidiaries (Cantwell & Mudambi, 2005), innovation is examined here focusing upon either CC or CE types of activities. When engaged in CE activities, a subunit is following the technological trajectory of the MNC group and further developing the firm’s strong technology. While CE activities are innovative, they do not emphasize novelty in innovation. On the other hand, CC types of activities focus on creating competence in technological areas that are new to the corporate group, or are a relatively weak area for the group. Subunits focusing on CC types of activities have a better chance of creating future competence for the MNC

group, hence they might receive special recognition within the group. However, there is also the risk that heavily investing in CC activities too distant from the corporate group's core technological trajectory may result in a subunit or business unit falling out of the loop.

A large MNC tends to have multiple operating units overseas, sometimes more than one in a single country. From a business standpoint this is necessary for various reasons, especially when a host country provides several opportunities for foreign investment, and these opportunities are exploitable by different divisions of the MNC. Setting up multiple subsidiary entities may also become necessary for legal or political reasons when a MNC needs to divide its foreign operation into different units, and sometimes these registered companies may even only exist for the record-keeping purposes. In such settings, it becomes difficult to conduct research on the subsidiary level of a MNC to match company activities in a geographical area to a particular subsidiary. Therefore, we have developed a different unit of study for this research: an MNC subunit is defined as an operating unit of a MNC in a location outside its home country. Instead of looking at the organizational structural of a MNC's foreign entity this study examines innovative activities of the MNC that are taking place outside the home country of the parent. Parent, in this study, refers to that part of the MNC conducting innovative activities in the company's home country.

In examining a subunit's capability to create competence, this study focuses on the ability not just to be innovative, but also to be innovative in a way that is different from the parent company. This distinction may be externally driven, such as a mandate from the parent company, or by a local specialization providing an available pool of knowledge that is related to, but distinct from, the MNC group's core area of expertise. It can also be internally driven – for instance, by an autonomous subunit seizing a local opportunity. This could mean two things for a subunit's knowledge sourcing: one, the subunit taking knowledge sourcing in an entirely new direction from the parent company, as a foundation for distinctive innovation; and two, the subunit merely widening its sourcing of knowledge, but still reinforcing its capability to create distinct innovation. This study defines the term technological distinctiveness as the extent to which a subunit's level of technological specialization in a given field is distinct from its parent company. Hence we have our research question:

*Research Question: how does a subunit's knowledge sourcing pattern influence its local competence creation, and hence its technological distinctiveness from the parent company?*

The next sections of this paper examine the literature on CC, and discuss subunit technological distinctiveness and the connection between subunit CC and knowledge sourcing. The data and research method used in this study are discussed in section four; results and indications are discussed at the

conclusion of the paper.

## **2. Competence creation by MNC subunits**

### **2.1 From competence creation to technological distinctiveness**

When a MNC establishes a foreign subsidiary that is either resource-seeking or market-seeking, the conventional wisdom for foreign direct investment (FDI) is to exploit the existing competence of the parent group. Technological knowledge required in foreign production of this kind is mostly created at the parent's home facilities, and then transferred via an internal corporate network to foreign production locations (Cantwell & Piscitello, 2000; Cantwell & Mudambi, 2005). With the increasing complexity of technology and the internationalization of production, more attention is being given to competence-seeking and knowledge-seeking activities through foreign investment. The competence-based theory of the firm treats the firm as an institution with capabilities built through continuous internal learning; the major issue of a firm is then no longer the exploitation of established competence, but rather how to create new competence in a geographically dispersed and technologically diversified system leveraging not only the MNC internal resources but also the technology base in the host country (Cantwell, 1991; Cantwell & Piscitello, 2000).

The MNC parent group initially defines a subunit's strategic role, locating subunits into specific markets to exploit the local market, local resources (natural or labor) or local competencies. To achieve either of the first two strategic objectives, a subunit will usually be tasked to replicate the parent group's established competence in the new location. To achieve the third objective, a subunit may be given the freedom to create new competencies, which end up benefitting the MNC group as a whole. Thus, whether a subunit is engaged in CC or in CE, its strategic assignments will be moderated by a combination of parent-group fiat, subunit autonomy and locational factors such as industry expertise, the availability of a high-quality workforce, and government policies encouraging FDI. When subunits are given autonomy to create competencies in new innovative and profitable technologies, in turn elevating the subunits' stature within their MNC networks, they can expect to be rewarded with more favorable resource allocations. The management of an innovative subunit may then command even greater autonomy to pursue CC that builds upon local knowledge sources (Cantwell & Mudambi, 2005).

Before a subunit can fulfill a CC mandate, it needs to be capable of innovating *per se*. Then its innovative activities must be focused on exploring new inventions that are novel to the parent MNC group. These activities require the assimilation and recombination of knowledge from different sources – from the parent group to build a strong innovation base, and from external sources to expand into new areas of innovative capability. Because MNC subunits can

handle a variety of operations, it is often difficult to define them as being either of the CC or the CE variety. For instance, a subunit with a CE mandate can sometimes establish competence in an area that is new to the parent group, and is even outside the core competence of that subunit. Or a subunit carrying out a CC role might nonetheless manage some operations using only its parent group's established competence, with little creative invention in areas new to the home base. It is more appropriate then to examine the individual innovative activities of a subunit, instead of treating every subunit as a monolith that pursues only CC or CE.

Focusing upon individual fields of technology, the degree to which a subunit's specialization in that field is different from the specialization of its parent can be referred to as its *technological distinctiveness*. By quantifying how much the subunit's degree of specialization is different from its parent, this analytical framework improves upon merely identifying a subunit's innovative activities as CC or CE. Technological distinctiveness is an index that quantitatively compares the composition of CC or CE activities of the subunit and its parent. It is different from other innovativeness measures for a MNC subunit; its focus is upon the "distinctiveness" between a subunit and its parent company, hence the extent to which the subunit is "creating" new technology instead of "exploiting" existing competencies of the MNC group.

The factors that can influence the degree of technological distinctiveness, and therefore influence the CC of a subunit, are various. Externally, both the mandate from the parent company and the technological influence of the host country environment can impact the subunit's technological distinctiveness in certain fields. Internally, the degree of management autonomy, the strategic role assigned to the subunit, and the intellectual capabilities of subunit personnel can impact a subunit's technological distinctiveness. Needless to say, the level of the parent's technological expertise is an important element in the analysis of how "distinct" the subunit's capabilities are. If the level of specialization of subunit and parent are both high, for example, the technological distinctiveness of the subunit in a particular field might actually be relatively low.

## **2.2 Inherited influence: MNC knowledge structure**

From the MNC's point of view, the structure of its innovation network and the positioning of a subunit within this network are likely to be two of the most important determinants of the mandate that is assigned to the subunit. Traditionally, the structural concentration of a MNC's innovation network favors the home base, with research and innovation mostly initiated at the parent company, and then transferred to other parts of the international group. Within this type of structure, foreign subunits are usually conducting incremental innovative activities around the areas of expertise of the parent



company; exploration into new areas of technology is not consistent with the innovation network structure. Therefore we propose:

*Hypothesis 1a: There is a negative relationship between the level of a MNC's structural concentration of innovative activity and the degree of a subunit's technological distinctiveness from its parent company.*

Where the MNC keeps innovative activities concentrated at home, we project that there will be fewer opportunities for any subunit to develop technological distinctiveness from the parent. However, this effect will likely change as the parent permits the share of innovative activity to become diversified among all international locations of the MNC group. That is to say, if innovative activities are not limited to the MNC home location, and other foreign locations are allowed to play important roles in the innovation network, then we should see a greater probability that subunits will become technologically distinctive from their parents even in fields that are not within the existing expertise of the parent company. Therefore, we propose the following hypothesis:

*Hypothesis 1b: There is a positive relationship between a subunit's share of innovative activity within its international corporate group and its degree of technological distinctiveness from its parent company.*

### **3. Knowledge sourcing and competence creation**

#### **3.1 Knowledge sourcing of a MNC subunit**

Due to the "stickiness" of knowledge, the process of transferring knowledge can be difficult and time-consuming (Szulanski, 1994). Because knowledge is both explicit and tacit, and is considered to be embedded within the organization, it is difficult to transfer knowledge between firms (Kogut, 1988). A great deal of early research was undertaken to better understand how organizations create, transfer, absorb and recombine knowledge (Polanyi, 1966; Winter, 1987; von Hippel, 1988; Kogut and Zander, 1992; Nonaka, 1994; Szulanski, 2000; Gupta and Govindarajan, 2000).

In the traditional model of MNC knowledge transfer, technology is conveyed internally, primarily within intra-firm networks by transfer from the parent to the subsidiary (top down). Gupta and Govindarajan (1991, 2000) constructed typologies of the roles played by MNC subsidiaries as knowledge is being transferred throughout this intra-firm network.

As later studies have shown, however, it is possible, and perhaps necessary, for knowledge to be transferred externally. For instance, Mowery et al (1996) have argued that the formation of strategic alliances and the building of absorptive capacity have facilitated inter-firm knowledge transfers.

The traditional view of MNC knowledge transfer does not fully account for the

newer roles many subunits are playing in the innovation process. Over the past few decades, foreign subunits have proven that they can do more than simply reproduce their parents' core technologies. New knowledge has found its way externally to subunits, resulting in remarkable innovations that the subunits have shared within their MNC groups. This trend has only gained momentum since it was first spotted by researchers in the early 1990s.

In this newer view of MNC knowledge transfer, subsidiaries rely, more heavily than before, on inter-firm networks that lie outside of the MNCs' boundaries. Subsidiaries draw on these external knowledge sources to extend their knowledge horizons, expand into new technology sectors, and recombine knowledge to create unique capabilities. When a MNC has only limited resources to allocate on strategic development, it may be difficult for a subsidiary to focus upon both the intra- and inter-firm knowledge networks.

Geography plays an important role in knowledge sourcing. Although modern developments in communication and information technology have vastly expanded the pathways available for knowledge sourcing from dispersed geographical locations, it is still widely believed that the transfer of technology happens more effectively when the source and recipient of knowledge are in close physical proximity. This study examines how geography influences a subunit's technological distinctiveness from its parent.

As science has advanced into more complex areas, the development of new technology often requires an understanding of disciplines from many, seemingly unrelated fields. In such cases, knowledge sources will be more dispersed throughout different technological fields. This study also examines how the technological diversity of a subunit influences the subunit's technological distinctiveness from the parent.

To avoid confusion, it is helpful to clarify the definitions of two terms we use throughout this paper: "network" and "knowledge sourcing." In the domain of social science, networks are social structures made up of individuals (or organizations) called "nodes," that are connected by one or more specific types of interdependency, such as friendship, kinship, common interest, financial exchange, or relationships of beliefs, knowledge or prestige. In the domain of organization studies, the term is somewhat more restricted; the formation of a network requires actual connections (most of the time in the forms of personal communication or interaction) between the nodes. These definitions can be found in studies on business networks, knowledge flows, technology diffusion, etc. (Owen-Smith & Powell, 2004; Hansen & Lovas, 2004; Bell & Zaheer, 2007). Thus, the term "knowledge network" is used in studies of social networking activities, interchangeably with the terms "knowledge flow" and "knowledge transfer" (Van Geenhuizen, 2008), to describe interpersonal exchanges of information.

In this study, however, the “networks” we are examining consist of organizations, not individuals, that accumulate information and knowhow about different fields of technology, not about common familial or other social connections. They do not necessarily operate by using interpersonal transfers of knowledge. The ties MNC subunits develop to other entities enable them to share a similar knowledge base, apply common technologies, and build upon one another’s knowledge creation activities. To distinguish our terminology from that used in social science studies, we refer to this type of connection as “knowledge sourcing” – an exchange of the knowledge of two or more organizations (at least one at the subunit level) that are tied to one another through the process of production and innovation. The sourcing activity itself can be either a direct or indirect knowledge transfer. That is to say, there may not be actual direct knowledge “flows” between a subunit and its knowledge sources, but there is a consequential relationship between a subunit’s innovative activities and the preceding sources of knowledge that accumulated technological knowhow that enabled these activities.

Within MNC intra-firm networks, knowledge sourcing includes connections between subunits and their MNC headquarters, and among subunits in the same MNC group. This type of knowledge sourcing is by definition international; it reflects the way a multinational corporation has chosen to delegate innovative activities among various subunits within that MNC. Outside of an MNC network, a subunit’s knowledge sourcing will come from its connections with local actors and other external international sources.

### **3.2 The relationship between knowledge sourcing patterns and CC activity**

The relationship between a subunit’s knowledge sourcing patterns, on the one hand, and the degree of its technological distinctiveness from its parent, on the other, is the principal focus of this study. For subsidiaries that obtain technology from diverse technological fields, or in diverse geographical markets, do these patterns portend that they will create technologies that are distinctive from that of their parent groups?

The causality between knowledge sourcing and competence creation can flow in both directions, of course. A subunit may receive a directive from its parent company to assume a competence-creating role, and then focus its knowledge sourcing into dispersed technological fields and geographical locations in order to carry out that mandate. Or it might be that the subunit has somehow discovered dispersed sources of knowledge due to some location-specific or human-resource factor, and chosen to exploit these readily available knowledge sources to develop a technological specialization different from its parent. In either scenario, it is useful to understand the relationship between the sourcing pattern and the degree of technological specialization that may result.

We examine this process through two dimensions – technological dispersion and geographical dispersion of knowledge sources. The former looks at the diversity of the technology fields from which knowledge is being sourced; the latter examines the geographical locations of these knowledge sources according to how concentrated, or scattered, they are.

Technological dispersion is determined by looking at the nature of the technologies a subunit is employing. Usually the more complex the technology is, the more diverse is the knowledge it needs to source from. The development of new technology requires the recombination of existing knowledge across various sectors, as well as the creation of new knowledge. The historical study of technological change has shown an inexorable progression of increasingly diversified technological development along with a more complex and complementary accumulation of knowledge (Pavitt, 1982; Vertova, 1999; Cantwell and Piscitello, 2000; Cantwell and Vertova, 2004). If a subunit is sourcing from dispersed technological fields, it is likely achieving innovative breakthroughs (Pu & Cantwell, 2013). And these innovations are likely to push the subunit into new areas of expertise beyond those of its parent company. Therefore we hypothesize:

*Hypothesis 2a: There is a positive relationship between the technological dispersion of a subunit's knowledge sources and the subunit's technological distinctiveness from its parent company.*

As we have already noted, proximity (geographically speaking) facilitates the transfer of knowledge. So it should be expected that knowledge transfer will take place more effectively when the sources of knowledge are geographically concentrated to one another, rather than dispersed. This explains the traditional view of MNC knowledge transfer: namely, that MNCs set up their operations so that each foreign subunit will receive most of its technology from its parent by means of internal sourcing (top down) from the parent's home country. Of course, when a subunit acquires its technological knowhow in this manner, it is unlikely to be striving for technological diversification from its parent.

On the other hand, we surmise that when a subunit seeks to acquire knowledge from geographically dispersed sources, it must be doing so to break out of the normal pattern, and find new novel technologies that are not available from the parent. The geographic dispersal of knowledge sources, therefore, might signal that a subunit is promoting its own technological diversification from the parent group. Thus, we hypothesize:

*Hypothesis 2b: There is a positive relationship between the geographical dispersion of a subunit's knowledge sources and the subunit's technological distinctiveness from its parent company.*

The next set of hypotheses draws upon the notion that a subunit's knowledge

sourcing pattern will be influenced by either its integration with its home country or its embeddedness with its host country. That MNC subsidiaries become embedded in their local environments has been observed and studied for a number of years (Uzzi, 1996, 1997; Birkinshaw et al., 2002). Uzzi (1997) suggested that embeddedness is a logic of exchange that promotes economies of time, integrative agreements, Pareto improvements in allocation efficiency, and complex adaptation.

System embeddedness is the dependence of a system, especially a social system, upon its environment (Birkinshaw et al, 2002). Economic behavior, for example, is considered to be a system embedded within the social structure (Granovetter, 1985). The system embeddedness of knowledge – our focus in this study – is dependent upon organization structure. And some knowledge is much more sensitive to its social and physical context than other knowledge. Andersson and Forsgren have researched the subsidiary- embeddedness issue (Andersson & Forsgren, 1996; Andersson, Forsgren, & Holm, 2001; Andersson, Bjorkman, & Forsgren, 2005), and concluded that external technical embeddedness positively affects the subsidiary's expected market performance, and thus increases the subsidiary's role in MNC competence development, using absorptive capacity theory (Andersson et al., 2001).

It is arguable then that high embeddedness in a host country may frequently result in a subunit diversifying its technology into areas of the host country's expertise that are not those of the parent company. Thus, if a subunit's knowledge sourcing is heavily concentrated on its host country location, this could dilute the parent-subunit knowledge-sourcing pattern and promote the technological distinctiveness of the subunit. Therefore we exclude the knowledge sources from subunits' host countries, and propose the following hypotheses with the expectation of stronger positive relationships than those in hypotheses 2a and 2b:

*Hypothesis 3a: Excluding host country sourcing, there is a positive relationship between the technological dispersion of a subunit's knowledge sources and the subunit's technological distinctiveness from its parent company.*

*Hypothesis 3b: Excluding host country sourcing, there is a positive relationship between the geographical dispersion of a subunit's knowledge sources and the subunit's technological distinctiveness from its parent company.*

It is generally believed that knowledge sourced from the parent company (or home country) will have an impact on a subunit's innovative activities that is as significant, if not more so, than knowledge sourced from the host country. If a subunit is concentrating its knowledge sourcing from its home country, especially in groups where MNC integration is high, it is more likely that the subunit is relying upon its parent company's technological expertise. Hence it will be less likely to innovate in areas that are distinct from its parent company.

That is, subunit reliance upon home-country sources should have a negative impact on the subunit’s technological distinctiveness (tested in our model as a control variable).

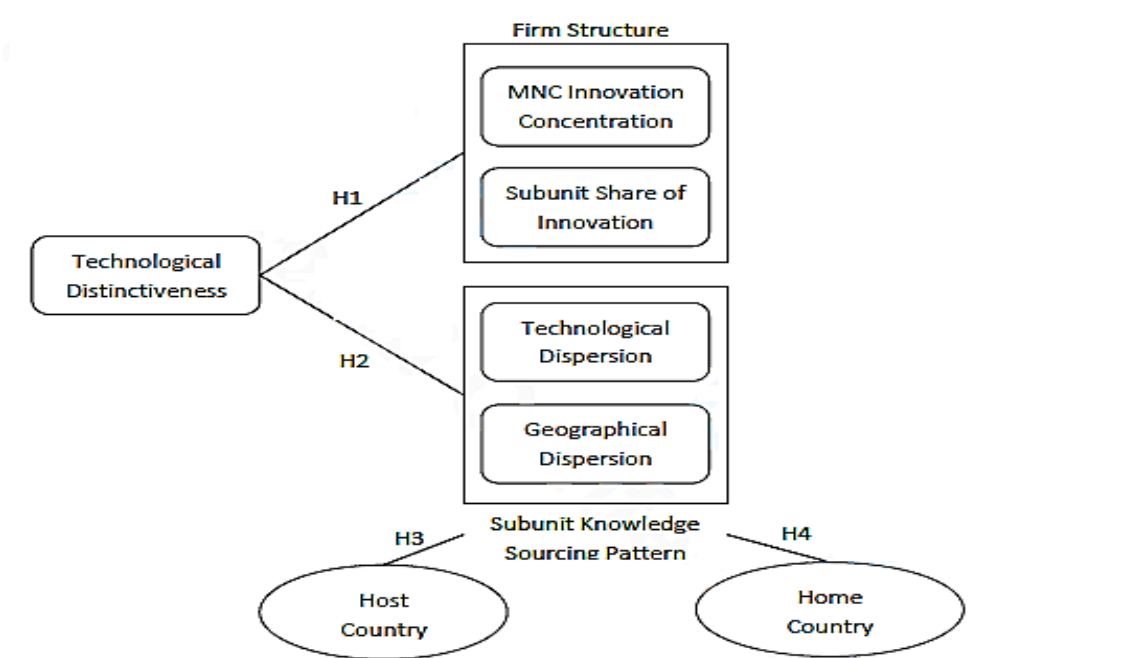
When sources from the home country are excluded from a sample, or when we focus only on knowledge sources outside a subunit’s home country, we should expect to see an even stronger positive relationship between its technological dispersion of knowledge sources and its technological distinctiveness from the parent company, and a stronger positive relationship between its geographical dispersion of knowledge sources and its technological distinctiveness from the parent company. The corresponding hypotheses are:

*Hypothesis 4a: Excluding home country sourcing, there is a positive relationship between the technological dispersion of a subunit’s knowledge sources and the subunit’s technological distinctiveness from its parent company.*

*Hypothesis 4b: Excluding home country sourcing, there is a positive relationship between a subunit’s geographical dispersion of its knowledge sources and degree of technological distinctiveness from its parent company.*

The following framework in Figure 1 summarizes the conceptual model of this study.

**Figure 1** Conceptual Framework



## 4. Data and measures

### 4.1 Data description

The study uses step-wise GLS regression models with a technological-field-level unit of analysis. Data is constructed at the MNC subunit level, comprised of U.S. patents of 157 large chemical industry firms granted between 1976 and 2006. In order to minimize any potential for distortion from the use of small numbers, a five-year window is constructed to aggregate patent numbers into a higher level, creating data panels through the 31-year period. The patent data records in this study come mainly from three sources: the NBER U.S. patent database, a patent database developed by Dr. John Cantwell, and some individual patent records pulled directly from the USPTO patent database. The data consist of U.S. patents granted to 157 large corporations in the general chemical industry between 1976 and 2006. The general chemical industry is selected as the object of research because its development has fully matured over a century, yet the industry is widely dispersed into numerous technology sub-sectors, some of which have newly emerged within the past few decades. Its historically consistent concentration upon technological development has taken place not only in traditional fields of research, but also in newly emerging sectors, such as biotechnology. And because the chemical industry, more so than many other industries, strives to protect its intellectual property through patents; the analysis of patenting behavior in the chemical industry can reveal meaningful trends in the advancement of technology.

One of the challenges of using company patent data from a general patent database is the task of attributing individual patents to firms. Although each patent has one or multiple assignees that will generally indicate its affiliation with an organization, these assignee codes are not a reliable identifier of the actual subunit where a patented innovation was achieved. Some firms may have multiple assignees of their patents for policy reasons; some may attribute all patents to their parent company even when the technological breakthrough was actually made in a foreign location. Table 1 shows the distribution of the countries of origin of the subject MNCs.

**Table 1** Distribution of multinational firm home countries

| Country     | Number of Firms | Number of Patents |
|-------------|-----------------|-------------------|
| Australia   | 2               | 100               |
| Belgium     | 1               | 973               |
| Canada      | 2               | 101               |
| Denmark     | 2               | 1,144             |
| Finland     | 1               | 102               |
| France      | 7               | 18,747            |
| Germany     | 8               | 31,285            |
| Israel      | 1               | 240               |
| Japan       | 30              | 47,405            |
| Korea       | 2               | 154               |
| Netherlands | 2               | 2,084             |
| Norway      | 2               | 375               |
| Switzerland | 6               | 16,496            |
| Taiwan      | 2               | 13                |
| UK          | 10              | 19,327            |
| US          | 77              | 148,122           |
| Total       | 155             | 286,667           |

Affiliates of the selected MNCs have first been identified through the Who Owns Whom database. Then these company names were carefully matched to the standard company name data on the NBER database. In this way, all possible assignee codes associated with our target firms were extracted. However, as we discussed above, these assignee codes are not being used to identify foreign subunits. Instead, they are being used in a third step to extract all patents assigned to the target firms. We were able to extract a total of 286,667 patents that are assigned to the target firms in the general chemical industry from the NBER patent database. Then, in a fourth step, we identified for each of these patents the first inventor's country location. The geographic location of first inventors in those patents attributable to international corporate groups can then be used to examine the geographical distribution of the technological activity of these firms (Cantwell, 1995). Each patent invented in a certain country is an indicator of innovative activity by a firm in that host country. Column 3 of Table 1 shows the distribution of patents from each home country. Table 2 shows a distribution of patents invented in host countries.



**Table 2** Distribution of patents among host countries

| Country         | Number of Patents |
|-----------------|-------------------|
| US              | 153,916           |
| Germany         | 40,341            |
| UK              | 13,613            |
| Italy           | 1,445             |
| France          | 9,646             |
| Japan           | 47,776            |
| Netherlands     | 1,083             |
| Belgium         | 2,727             |
| Switzerland     | 8,445             |
| Sweden          | 856               |
| Denmark         | 1,167             |
| Canada          | 2,427             |
| Australia       | 526               |
| South Korea     | 674               |
| Other Countries | 2025              |
| <b>Total</b>    | <b>286,667</b>    |

The primary field of technological activity of each patent is derived from the U.S. patent class system, and these fields are grouped into 56 technological sectors (Cantwell and Andersen, 1996). The grouping is established on the basis of the class system, providing economic meaning for each of these fields. Due to a limitation of this industry sample, some fields among these 56 are not as highly represented as others; as a result an analysis performed across these 56 fields of technological sectors would produce a skewed result. To remedy this problem, we further grouped these 56 fields into 31 respective fields; each of these 31 fields have meaningful representative numbers, so as to assure a comparable structure of data distribution.

**Table 3** Distribution of patents among technological fields

| tech31    | Field                                                                           | Freq.         |
|-----------|---------------------------------------------------------------------------------|---------------|
| 1         | Food and tobacco products                                                       | 1,735         |
| 2         | Distillation processes                                                          | 738           |
| 3         | Inorganic chemicals                                                             | 4,139         |
| 4         | Agricultural chemicals                                                          | 5,035         |
| <b>5</b>  | <b>Chemical processes</b>                                                       | <b>13,636</b> |
| 6         | Photographic chemistry                                                          | 9,461         |
| 7         | Cleaning agents and other compositions                                          | 15,082        |
| <b>8</b>  | <b>Synthetic resins and fibres</b>                                              | <b>37,678</b> |
| 9         | Bleaching and dyeing                                                            | 3,130         |
| <b>10</b> | <b>Other organic compounds</b>                                                  | <b>48,999</b> |
| 11        | Pharmaceuticals and biotechnology                                               | 57,747        |
| 12        | Other chemicals and Related - disinfecting, preserving, textiles and explosives | 815           |

| <b>tech31</b> | <b>Field</b>                                        | <b>Freq.</b>   |
|---------------|-----------------------------------------------------|----------------|
| 13            | Metallurgical processes                             | 2,488          |
| 14            | Miscellaneous metal products                        | 4,080          |
| <b>15</b>     | <b>Chemical and allied equipment</b>                | <b>10,947</b>  |
| 16            | Paper making apparatus                              | 1,808          |
| 17            | Assembly and material handling equipment            | 1,694          |
| 18            | Other specialised machinery                         | 3,553          |
| <b>19</b>     | <b>Other general industrial equipment</b>           | <b>2,813</b>   |
| 20            | Mechanical engineering nes                          | 3,870          |
| <b>21</b>     | <b>Electrical devices and systems</b>               | <b>2,146</b>   |
| <b>22</b>     | <b>Other general electrical equipment</b>           | <b>4,427</b>   |
| <b>23</b>     | <b>Office equipment and data processing systems</b> | <b>2,431</b>   |
| 24            | Electrical equipment nes                            | 4,290          |
| 25            | Transport equipment                                 | 896            |
| 26            | Rubber and plastic products                         | 4,056          |
| 27            | Non-metallic mineral products                       | 14,143         |
| 28            | Coal and petroleum products                         | 6,579          |
| 29            | Photographic equipment                              | 2,417          |
| <b>30</b>     | <b>Other instruments and controls</b>               | <b>14,019</b>  |
| 31            | Other manufacturing and non-industrial              | 1,815          |
| <b>Total</b>  |                                                     | <b>286,667</b> |

## 4.2 Technological distinctiveness

Conceptually, technological distinctiveness is a variable that enables us to examine the extent to which a subunit's specialization in certain technological fields is different from its parent company. This variable can serve as an indicator of that subunit's competence creation (CC).

To understand the rationale behind the construction of such a variable, we review the concept known as Revealed Technological Advantage (RTA). RTA is an index that demonstrates the level of technological specialization for one unit of observation (a subunit, a firm, or even a geographic location – country or region) in a given technological field. It was first pioneered in the work of Soete (1980) and then further developed by Patel and Pavitt (1991) and Cantwell (1995). The RTA index of a firm in a particular technological field is derived from the firm's share of patenting in that field divided by its share of patenting in all sectors, and is defined as follows:

$$RTA_{ij} = (P_{ij} / \sum P_{ij}) / (\sum P_{ij} / \sum \sum P_{ij})$$

In which  $P_{ij}$  is the total number of patents of firm  $i$  in field  $j$ . The index varies around unity, such that values greater than one suggest a firm's comparative advantage in the field of activity in question relative to other firms in the same industry, while values less than one are indicative of a position of comparative disadvantage (Cantwell and Piscitello, 2000). When this is calculated at the

level of a subunit, the unit of analysis is changed from firm to subunit – a firm's activities within a foreign host country. In the meanwhile, if we enlarge the unit of analysis to the country level, then this index can be used to ascertain comparative advantage or disadvantage of a country's activities in certain technological fields.

While the RTA index illustrates a subunit's technological advantage/disadvantage in certain fields, a mechanism still needs to be introduced to compare the positioning of both the subunit and its parent company, which then operationalizes technological distinctiveness – the extent to which the subunit's degree of specialization in a certain technological field is distinct from its parent company. Simply put, we need a method to effectively compare the RTA between a subunit and its parent company in each field. Such a method was employed by Cantwell and Santangelo (2002) to assess the co-presence or absence of a matching degree of specialization between the two groups of firms in each patent class. That method draws on the measure of intra- industry trade across sectors in the international trade literature (Grubel and Lloyd, 1971, 1975). The Grubel-Lloyd index generates a variable GLi by comparing the export and import of good i:

$$GL_i = \frac{(X_i + M_i) - |X_i - M_i|}{X_i + M_i} = 1 - \frac{|X_i - M_i|}{X_i + M_i} \quad ; \quad 0 \leq GL_i \leq 1$$

Where Xi measures the export, and Mi measures the import of a good i. If GLi = 1, there is only intra-industry trade, whereas if GLi = 0, there is only inter-industry trade. Cantwell and Santangelo (2002) further developed this model as a measure of co-presence of a matching degree of specialization between the two groups of firms (k) (where k = 1 or 2) in a particular ICT patent class (c) in each region (r):

$$C_{rc} = 2 \min (RTA_{1rc}, RTA_{2rc}) / (RTA_{1rc} + RTA_{2rc}); \quad 0 \leq C_{rc} \leq 1$$

In our study, because we seek to examine technological distinctiveness, we use the reverse of co- specialization, which is:

$$TD_{ij} = 1 - \frac{RTA_{ij} + RTA_{pj} - |RTA_{ij} - RTA_{pj}|}{RTA_{ij} + RTA_{pj}} = \frac{|RTA_{ij} - RTA_{pj}|}{RTA_{ij} + RTA_{pj}}$$

Where  $TD_{ij}$  denotes the technological distinctiveness of subunit i in field j,  $RTA_{ij}$  is the revealed technological advantage of subunit i in field j, whereas  $RTA_{pj}$  represents the revealed technological advantage of subunit i's parent company in field j.

This measure of distinctiveness does not specify the direction of distinction – a large number (closer to one) of  $TD_{ij}$  could indicate either the subunit is distinctively more specialized in the field than its parent company, or the parent company is distinctively more specialized than its subunit. In order to capture the effect of a subunit's competence creation, one more step is needed: to identify subunits that are more specialized than their parent companies in the focal fields. Accordingly, in our data processing, we must screen out situations when  $RTA_{ij} < RTA_{pj}$ , and subsequently set the value of  $TD_{ij}$  to zero, indicating that this subunit has no distinct specialization in this field compared to its parent company.

### Independent variables:

Firm Innovation Concentration (FirmCon) – a term that denotes the level of concentration of a MNC group's innovative activities. This variable is measured in the same way as the HHI index of concentration, by aggregating the square of share of innovative activities of all subunits in a MNC group. If  $P_i$  indicates the number of patents in subunit  $i$ , then the formula for *FirmCon* is:

$$FirmCon = \sum_i \left( \frac{P_i}{\sum_i P_i} \right)^2$$

*Subunit Share (SubShare)* – a subunit's share of patent within its MNC group.

*Technological Dispersion* – The extent to which knowledge sources are drawn from diverse technological fields. The measurement of technological dispersion, as well as geographical dispersion of knowledge sources, is based upon the reverse of the Herfindahl-Hirschman index (HHI) of concentration.

<sup>1</sup> The formula is:

$$TechDisp_i = 1 - \sum_{j=1}^{31} \left( \frac{P_{ij}}{\sum_j P_{ij}} \right)^2$$

In which  $TechDisp_i$  indicates the technological dispersion of subunit  $i$ 's knowledge sources, and  $P_{ij}$  is the number of patents of subunit  $i$  cited in technological field  $j$ .

*Geographical Dispersion* – The extent to which knowledge sources are drawn from dispersed geographical locations. The calculation of geographical dispersion of knowledge sources follows the same method as for technological dispersion, concentrating upon the distribution of geographical locations associated with cited patent first inventors, rather than upon technological

fields of patents.

*Non-host Tech Disp* – Technological dispersion of knowledge sources excluding those from the host country.

*Non-host Geo Disp* – Geographical dispersion of knowledge sources excluding those from the host country.

*Non-home Tech Disp* – Technological dispersion of knowledge sources excluding those from the home country.

*Non-home Geo Disp* – Geographical dispersion of knowledge sources excluding those from the home country.

**Control Variables:**

*GPT Share* – Share of technological innovation that falls into the category of GPT fields.

*Inter Region Share* – Share of knowledge sources that are from a different geographical region than the host country of the subunit.

*Home Share* – Share of knowledge sources from the home country of the MNC group.

*Host Share* – Share of knowledge sources from the host country of the subunit.

*US-Home* – Dummy variable indicating whether the MNC firm is U.S. originated.

*US-Host* – Dummy variable indicating whether the subunit is located in the U.S.

*RTA Host* – The revealed technological advantage of a subunit's host country in a given field. This variable controls for the host country's technological specialization effect on subunit technological distinctiveness.

*Host Type* – Dummy variable indicating type of host country: developed country or developing country.

*Firm size* – Total number of patents of a given MNC. The variable of firm size uses the log result of patent number.

*Industry* – Dummy variables designed to subdivide the general chemical industry into subcategories based on a MNC group's main activity: chemical, pharmaceutical and biology (phar), petroleum and energy (petr).

## 5. Results and discussion

The results of our data analysis are shown in the following Table 10. Most of the models are shown to be fit; however a few models indicate relationships between the independent and dependent variables that are the opposite of what we proposed in our hypotheses. In order to minimize the effect of the small number problem, as well as to test the robustness of the methodology, we then selected the sample with several cut-off points of subunit patent numbers. Table 11 reports the results of analysis with a cut-off point of 50, which means all subunits in that sample have more than 50 patents in the corresponding five-year window.

**Table 4** Results for study 2 - All data

|               | 1      |     | 2      |     | 3            |     | 4            |     | 5           |     | 6            |     | 7            |     | 8            |     | 9            |     |
|---------------|--------|-----|--------|-----|--------------|-----|--------------|-----|-------------|-----|--------------|-----|--------------|-----|--------------|-----|--------------|-----|
| US_home       | 0.031  |     | 0.031  |     | -0.04        | *   | -0.057       | **  | -           |     | -0.049       | **  | -0.04        | *   | -0.049       | **  | -0.05        | *   |
| US_host       | 0.011  |     | 0.01   |     | -0.03        |     | -0.06        | **  | -           |     | -0.044       |     | -0.03        |     | -0.047       | *   | -0.04        |     |
| hs_share      | -0.069 | *   | -0.08  | *   | -0.04        |     | 0.012        |     | -           | **  | -0.024       |     | -0.05        |     | -0.031       |     | -0.04        |     |
| hm_share      | -0.14  | *** | -0.125 | *** | -0.14        | *** | -0.116       | *** | -           | *** | -0.136       | *** | -0.15        | *** | -0.121       | *** | -0.14        | *** |
| RTA_host      | 0.013  | *** | 0.013  | *** | 0.013        | *** | 0.014        | *** | 0.01        | *** | 0.013        | *** | 0.013        | *** | 0.013        | *** | 0.013        | *** |
| host_type     | -0.065 |     | -0.061 |     | -0.07        |     | -0.073       |     | -           |     | -0.074       |     | -0.07        |     | -0.08        |     | -0.07        |     |
| log size      | -0.109 | *** | -0.108 | *** | -0.1         | *** | -0.105       | *** | -0.1        | *** | -0.107       | *** | -0.1         | *** | -0.106       | *** | -0.1         | *** |
| phar          | -0.036 | **  | -0.029 |     | -0.01        |     | -0.005       |     | -           |     | -0.008       |     | -0.01        |     | -0.008       |     | -0.01        |     |
| petr          | 0.038  |     | 0.037  |     | 0.008        |     | 0.012        |     | 0           |     | 0.008        |     | 0.008        |     | 0.008        |     | 0.008        |     |
| gpt_share     |        |     | 0.083  | *** | 0.052        | **  | 0.054        | **  | 0.05        | **  | 0.054        | **  | 0.052        | **  | 0.05         | **  | 0.052        | **  |
| intreg_share  |        |     | -0.02  |     | 0.01         |     | 0.034        |     | -           |     | 0.003        |     | 0.01         |     | 0.001        |     | 0.01         |     |
| _cons         | 0.878  | *** | 0.844  | *** | 0.665        | *** | 0.574        | *** | 0.78        | *** | 0.634        | *** | 0.671        | *** | 0.637        | *** | 0.658        | *** |
| struct        |        |     |        |     | <b>0.299</b> | *** | <b>0.319</b> | *** | <b>0.3</b>  | *** | <b>0.327</b> | *** | <b>0.298</b> | *** | <b>0.327</b> | *** | <b>0.302</b> | *** |
| sub_share     |        |     |        |     | <b>0.003</b> | *** | <b>0.002</b> | *** | <b>0</b>    | *** | <b>0.002</b> | *** | <b>0.003</b> | *** | <b>0.003</b> | *** | <b>0.003</b> | *** |
| ced_td        |        |     |        |     |              |     | <b>0.138</b> | *** |             |     |              |     |              |     |              |     |              |     |
| ced_gd        |        |     |        |     |              |     |              |     | -           | **  |              |     |              |     |              |     |              |     |
| nhsced_td     |        |     |        |     |              |     |              |     | <b>0.12</b> |     | <b>0.086</b> | *** |              |     |              |     |              |     |
| nhsced_gd     |        |     |        |     |              |     |              |     |             |     |              |     | <b>-0.01</b> |     |              |     |              |     |
| nhmced_td     |        |     |        |     |              |     |              |     |             |     |              |     |              |     | <b>0.093</b> | *** |              |     |
| nhmced_gd     |        |     |        |     |              |     |              |     |             |     |              |     |              |     |              |     | <b>0.01</b>  |     |
| R sq          | 0.047  |     | 0.052  |     | 0.092        |     | 0.1          |     | 0.09        |     | 0.094        |     | 0.092        |     | 0.095        |     | 0.091        |     |
| Chi2          | 131.61 | *** | 146.59 | *** | 239.9        | *** | 271.71       | *** | 245         | *** | 255.51       | *** | 240.1        | *** | 258.05       | *** | 240          | *** |
| * $p < .10$   |        |     |        |     |              |     |              |     |             |     |              |     |              |     |              |     |              |     |
| ** $p < .05$  |        |     |        |     |              |     |              |     |             |     |              |     |              |     |              |     |              |     |
| *** $p < .01$ |        |     |        |     |              |     |              |     |             |     |              |     |              |     |              |     |              |     |

**Table 5** Results for study 2 - Large subunit sample

|                                        | 1      |     | 2      |     | 3      |     | 4      |     | 5      |     | 6      |     | 7      |     | 8      |     | 9      |     |
|----------------------------------------|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|
| US_home                                | -0.083 | *   | -0.055 |     | -0.138 | *** | -0.15  | *** | -0.087 |     | -0.139 | *** | -0.114 | **  | -0.139 | *** | -0.126 | **  |
| US_host                                | -0.073 |     | -0.064 |     | -0.087 | *   | -0.102 | **  | -0.044 |     | -0.087 | *   | -0.053 |     | -0.091 | *   | -0.075 |     |
| hs_share                               | 0.085  |     | 0.138  | *   | 0.161  | **  | 0.2    | *** | -0.079 |     | 0.161  | **  | 0.109  |     | 0.154  | **  | 0.104  | *   |
| hm_share                               | -0.067 |     | -0.117 |     | -0.116 |     | -0.088 | **  | -0.299 | *** | -0.109 |     | -0.224 | **  | -0.09  |     | -0.155 | *   |
| RTA_host                               | 0.024  | **  | 0.025  | *** | 0.025  | *** | 0.027  | *** | 0.027  | *** | 0.026  | *** | 0.026  | *** | 0.026  | *** | 0.026  | *** |
| log size                               | -0.129 | *** | -0.119 | *** | -0.098 | *** | -0.105 | *** | -0.098 | *** | -0.106 | *** | -0.092 | *** | -0.109 | *** | -0.094 | *** |
| phar                                   | 0.074  | **  | 0.088  | *** | 0.094  | *** | 0.097  | *** | 0.092  | *** | 0.097  | *** | 0.093  | *** | 0.1    | *** | 0.092  | *** |
| petr                                   | 0.096  | **  | 0.099  | **  | 0.045  |     | 0.052  |     | 0.024  |     | 0.042  |     | 0.058  |     | 0.042  |     | 0.052  |     |
| gpt_share                              |        |     | 0.171  | *** | 0.06   |     | 0.046  |     | 0.076  |     | 0.057  |     | 0.051  |     | 0.052  |     | 0.052  | *   |
| intreg_share                           |        |     | 0.116  | *   | 0.137  | **  | 0.16   | **  | 0.094  |     | 0.127  | *   | 0.137  | **  | 0.12   | *   | 0.152  | **  |
| _cons                                  | 0.788  | *** | 0.598  | *** | 0.458  | *** | 0.371  | *** | 0.77   | *** | 0.437  | *** | 0.563  | *** | 0.407  | *** | 0.512  | *** |
| struct                                 |        |     |        |     | 0.248  | *** | 0.27   | *** | 0.237  | *** | 0.271  | *** | 0.217  | *** | 0.287  | *** | 0.231  | *** |
| sub_share                              |        |     |        |     | 0.003  | *** | 0.003  | *** | 0.003  | *** | 0.003  | *** | 0.003  | *** | 0.003  | *** | 0.003  | *** |
| ced_td                                 |        |     |        |     |        |     | 0.134  | *** |        |     |        |     |        |     |        |     |        |     |
| ced_gd                                 |        |     |        |     |        |     |        |     | -0.32  | *** |        |     |        |     |        |     |        |     |
| nhsced_td                              |        |     |        |     |        |     |        |     |        |     | 0.067  |     |        |     |        |     |        |     |
| nhsced_gd                              |        |     |        |     |        |     |        |     |        |     |        |     | -0.145 | **  |        |     |        |     |
| nhmced_td                              |        |     |        |     |        |     |        |     |        |     |        |     |        |     | 0.407  | *** | -0.078 |     |
| nhmced_gd                              |        |     |        |     |        |     |        |     |        |     |        |     |        |     |        |     |        |     |
| R sq                                   | 0.052  |     | 0.074  |     | 0.134  |     | 0.139  |     | 0.143  |     | 0.134  |     | 0.149  |     | 0.138  |     | 0.139  |     |
| Chi2                                   | 63.48  | *** | 77.48  | *** | 137.19 | *** | 144.21 | *** | 151.1  | *** | 139.76 | *** | 146.84 | *** | 146.23 | *** | 140.37 | *** |
| * p < .10<br>** p < .05<br>*** p < .01 |        |     |        |     |        |     |        |     |        |     |        |     |        |     |        |     |        |     |

Comparing Tables 10 and 11, we see that most of the effects we hypothesized have been confirmed by the data, except in the instances we discuss below. Hypothesis 1a is not supported by our data analysis in both samples (Model 3 in both samples). In fact, there is a consistent strong positive relationship between a MNC's structural concentration of innovative activities and a subunit's technological distinctiveness, instead of the negative relationship we proposed. It seems that something about a concentration of innovative activities at the parent level encourages, or at least allows, foreign subunits to pursue new technology in distinctive, non-core areas.

There are two possible explanations for this result: (1) the firm's structural concentration could in fact be partially focused on the focal subunit. In that case, the subunit might be expected to account for a higher share of distinctive innovation within the MNC group. (2) In some cases, if a firm has a highly concentrated innovation structure, it might be focusing its technological development in core areas of specialization and in concentrated locations (usually the home country base), leaving foreign locations to pursue innovation in non-core areas of specialization. As a result, those subunits that conduct some level of R&D outside of the home country focus their efforts in new areas of technological innovation that are distinct from the MNC parent.

The first explanation could be further tested by examining how the MNC group's structural concentration of innovation correlates with the subunit's

share of innovation within the group. The second explanation could be tested by examining the parent company's innovation activities to confirm that the structural concentration is indeed within the home country base only.

Hypotheses 2a, 3a, and 4a examine the relationship between technological dispersion of knowledge sources and a subunit's technological distinctiveness. Each of these hypotheses is supported in the sample with all data (Models 4, 6, and 8); however, this is not true with respect to the large subunit sample. In that sample, Hypotheses 2a and 4a are supported in Models 4 and 8, while Model 6 shows an insignificant result. (1) This indicates that concerning knowledge sources outside of the host country, there is no significant positive relationship between the technological dispersion of knowledge sources and the subunit's technological distinctiveness. In other words, for large subunits, knowledge sources that contribute to distinctive competence creation tend to be located within the subunit's host country. Another implication of these results is that large subunits tend to be more diversified in their technological fields than smaller subunits; therefore, their capability to develop novel areas of specialization is not strongly dependent on the technological dispersion of their knowledge sources. To put it another way, when the level of technological diversification is constantly high, from the result of study, we can expect a similarly high technological dispersion level, and as these levels get higher their numbers shown in the data gets closer to 1, resulting in very small variation among observations. Therefore it is difficult to capture the relationship between technological dispersion and technological distinctiveness among large subunits. (2) The insignificant result in Model 6 may indicate that for large subunits, knowledge sources from the host country play a significant role in building up a subunit's capacity to develop innovations that are novel to the MNC group.

When these sources are taken out of the sample, no relationship can be confirmed between the technological dispersion of international knowledge sources and the subunit's technological distinctiveness. This means that innovative activities that rely on knowledge sourcing around the globe take place in areas of expertise that are inherited from the parent company.

Hypotheses 2b, 3b, and 4b, examine the relationship between the geographical dispersion of a subunit's knowledge sourcing and its technological distinctiveness. It is shown in both samples that Model 5 is significant with a negative coefficient. This result is inconsistent with the hypotheses, which proposed a positive relationship between the two. Interestingly, this is consistent with the results shown in the previously discussed models for technological dispersion. Generally speaking, the greater the geographic dispersion of a subunit's knowledge sources, the less likely it is to develop a high level of technological distinctiveness. This outcome is not so surprising in light of our previous discussion about local embeddedness and competence



creation. A highly locally embedded subunit, especially in regions with high specialization of technological fields, might be expected to show a more geographically concentrated pattern of knowledge sourcing, and is more likely to develop technological specialization in fields that are not within its parent's expertise. With this understanding, it is then easier to understand the unsupported results in Models 7 and 9 for Hypotheses 3b and 4b.

Note that the control variable of firm size shows a consistent negative effect on the technological distinctiveness of the subunit. As firms get larger, they are more likely to technologically diversify in a wide range of fields, in extreme cases producing a calculation very close to 1.

Therefore, in such cases it is very difficult for subunits to specialize in innovative activities that are distinct from the expertise of the MNC group. Imagine the most extreme case: a MNC group so large that it already has a high level of RTA in all fields that its subunits could possibly develop; in such a case, it would be impossible for its subunits to develop something distinct!

We also note that as to the control variable of host country RTA, in both samples there is a consistently significant positive effect on subunit technological distinctiveness. This is predictable; if a host country specializes in a certain technological field, it is more likely that a subunit there would learn from sources in the host country and develop an expertise in this field. This confirms once again our understanding of the importance of local embeddedness.

Two additional effects emerged upon a comparison of the all-data-sample with the large subunit sample. First, in the large subunit sample, subunits in the pharmaceutical industry tend to be more likely to develop technological distinctiveness compared to other industries; however, this effect is not found in the all-data-sample. Note that our sample selection is based on patenting numbers during the given time period. One could therefore explain that for large subunits, pharmaceutical companies tend to place more emphasis on competence creation, compared to companies in other sectors. However, this effect is only distinct for large subunits. If smaller sized subunits are all included in the sample, pharmaceutical industry no longer stands out in the likelihood of developing technological distinctiveness.

Second, in the all-data sample, the share of patents in GPT fields has a positive impact on technological distinctiveness, but this effect is not found in the large subunit sample. That the former is true supports the general argument about GPT fields, that they increase the possibility of firms developing novel innovation. Therefore, a positive relationship is shown. However, as we discussed at the end of Section Three, because large subunits are likely to be intrinsically diversified due to their size, having a high share of patents in GPT fields would not produce a similar impact on distinctiveness.

These results demonstrate that the capability of subunits to carve out fields of technological distinctiveness is to some extent grounded upon local knowledge sources. An important factor is the contrast between a subunit's home and host country's technological environment – whether the subunit's host country can provide specialized technology in fields that the home country cannot provide. Hence a subunit's technological distinctiveness in some ways reflects the local technological distinctiveness of the host versus the home country.

## **6. Conclusion**

The innovative activities of overseas subunits of multinational corporations (MNCs) can be placed within two categories: either competence exploiting (CE) – exploiting the core competence base of the parent group – or competence creating (CC) – creating new competencies that were not already among the strengths of the parent company. This research examines the extent to which the fields of technological expertise of MNC subunits are distinct from those of their parent companies, and how this technological distinctiveness is related to their knowledge sourcing patterns. We found out that the technological dispersion of a subunit's knowledge sourcing for activities in a certain field has a positive relationship with the subunit's technological distinctiveness in that field, while the geographical dispersion of sourcing in a given field has a negative relationship with technological distinctiveness. These findings confirm the relationship between knowledge sourcing patterns and subunit technological distinctiveness, while supporting the current literature on subunit technological diversification, internationalization, and local embeddedness.

This study contributes to the current body of scholarship in two ways.. First, on a theoretical level, it contributes to existing knowledge in the areas of MNC knowledge accumulation and competence creation, by establishing a new connection between these two areas, and further by identifying an evolutionary trajectory for MNC subunit strategic role development. Second, on an empirical level, the study offers a new way to study MNC subunit innovation, as well as the relationship between subunit knowledge sourcing and innovative activity. This methodology can promote further study of these two interdependent aspects of subunit strategy.

However, due to the type of data (patent database), it is very difficult to identify real subunits for analysis. By using the firm-country combination to indicate an MNC's innovative activity in a foreign country, regional variations of innovative activity of an MNC within a large country are not accounted for. A potential solution is to divide the country into different regions, so that these regions can be analyzed comparably to other countries.

Another limitation of the data is the identification of patent affiliations of citations. The current dataset does not provide this information. If further

research can be based on a complete dataset of patent and corporate-affiliation information, it will become possible to examine the relationship between inter-firm and intra-firm knowledge sourcing patterns, and their impact on subunit innovation.

Patent continuations create some muddled data, and result in the multiple counting of a single invention, and the over-counting of patents within one firm. If invention level data could be acquired, this problem would be avoided. One suggestion for a future improvement to this study is to rule out non-independent patents by the same inventors within each firm. This process requires using the original USPTO dataset to identify all inventor information, as well as patent continuation information.

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## Note

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<sup>1</sup> HHI was first used in 1951 to analyze the concentration within the steel industry, calculated by adding the squares of a firm's market shares in per cent (Weinstock, 1982).

$$HHI = \sum_{i=1}^n S_i^2$$

Where  $S_i$  is the market share of firm  $i$  measured in percentage points. This definition implies that shares of larger firms are given greater weight than those of smaller companies. The calculation of HHI should vary between 0 and 1; a higher value of HHI indicates a higher level of concentration in the market

## Do university incubator's strategies influence academic entrepreneurship?

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### **Abstract**

Technology and innovation has been central to achieving growth and development worldwide. In this context, the role of technology business incubators are considered ideal for encouraging early-stage technology development. In addition, technology incubators often act as buffers for high-tech firms by providing necessary technologies, which has the advantage of creating jobs and wealth. The university start-up model does act as an important player in fostering the growth and development of start-ups as well as the nation's innovation platform. However, the study suggests that not all start-ups supported by the university incubation model become successful. So, the the main aim of this paper is to explore the factors: why do some academic incubators function well, while others fail? And what role does the incubator play in spearheading the incubation pathway? More precisely, the paper will try to find out the possible ways the incubators follow to facilitate the incubation process and make the start-up journey successful. In addition, the paper explores the role of incubators in facilitating the technology incubation process and how these start-ups are adding benefits to both incubators and the nation.

**Keywords:** Technology Business Incubation; India; Start-ups; Academic Incubator; Incubation; Entrepreneurship.

## 1. Background

In the last two-decade technology business incubation has become an important component in stimulating growth and development worldwide (Eisenhardt, 2017; Chandra & Fealey, 2009). Although the start-up originating from these incubation centres only constitutes a small part of the total population of small and medium business, besides this the incubator does act as an important driver in promoting employment and economic growth simultaneously (Lala & Sinha 2019; Chandra et al, 2012; Madaleno et al 2018; Smith & Hannigan 2015; Hallen et al 2016). However, it is found that the start-ups do suffer a high-risk of failures as it is found that there are well defined numbers of start-ups which are even not able to survive the second year of incubation (Ahmad & Ingle 2013; Oakley 2012).

In this regard, the role of technology business incubator is quite significant in strengthening the entrepreneurial ecosystem. The incubator supports the start-up by providing services such as office space, and other resources. In addition to it, the support of the incubator is not confined only in providing technology-oriented support somewhat the incubator also shares professional and research consultancy services with the incubatees. In addition to it, the incubators also provided business and marketing training to scale up their business (Rice 2002; Bruneel et al 2012). Besides these supports provided by the incubator, there have been numerous examples in the incubation literature which suggest that still there is quite a significant gap in understanding the process of incubation.

While the majority of the research on technology incubation has focused on subjects related to incubation configuration and resources sharing (Aernoudt 2004; Soetanto & Van Geenhuizen 2010), and some looks to measure the influence and impact of technology incubation on economic growth (Clarysse et al. 2005; Aernoudt 2004; Soetanto & Van Geenhuizen 2010). To sum up, these studies were more focused in presenting an overview of the incubation process rather than providing a comprehensive overview of the process. In other words, the highlighting point of these studies was more focused on explaining the attributes of incubation rather than the practices of incubation model (Hackett & Dilts 2004; Phan et al 2005).

In addition most of the studies on technology incubation is filled with the example of best practice incubators, which in a way not able to represent the problems associated with the rest of the incubators. That's why there is still a lack of explanations on why the incubators failed to impact the performance of the start-ups (Bruneel et al., 2012; Van Weele et al., 2018; Mian et al., 2016).

To address these limitations this study has taken the root to understand the process of incubation and what role does technology incubator perform in the innovation ecosystem. To explore the central theme the study has represented



the data in two-mode qualitative and quantitative modes. This chapter is aimed at developing a cross-section qualitative approach to address the central theme of the thesis. As proposed in our research questions, the chapter shed lights on the various challenges faced by the start-ups by addressing two main questions, first, *"What are the challenges faced by the start-ups in India?"* and secondly, *"What practices do the incubator perform to address these challenges?"*

The main objective of this chapter is to unfold both the challenges and the practices performed by some incubators, which in a way formulate an effective and efficient incubation ecosystem. Although it has been found that almost all the incubators have similar configuration and policies for the start-ups but still some incubators are having an extra edge over others. In other words, the qualitative approach developed in this chapter is intended to triangulate the quantitative measures used in the previous chapter, and also to provide a comprehensive description of the factors that influence the process of incubation.

## **2. Research design**

To explore the challenges of technology incubation of Indian start-ups, a total of 13 semi-structured interviews with the start-up founders, top officials of incubation centre, mentors, faculty-in charge, and other stakeholders from the selected 7 (seven) technology business incubators for the study. These incubators are located at a different location in the country having R&D in a wide variety of area.

Moreover, the interview is being one of the most important methods of data collection as it allows the researcher to identify unexplored areas, helps in identifying different patterns, and most importantly it helps in understanding the participants' perception towards a chosen topic. So to understand the challenges associated with the incubation process our study has chosen interview as an appropriate method for collecting data.

In doing so the interviewees were approached while going through a pilot study, and field study for the existing study. However, the final selection of 13 samples is constrained by the willingness and interest shown by the representatives to participate in the study. The chosen sample is homogenous in the sense that only the early start-ups related to academic institutions exploring new technological, product and services were selected for the study. Further, the sample is also diversified as it is not classified only based on one kind of support such as infrastructure, but more on other range of services provided by the incubator.

Moreover, this kind of variation in a homogenous sample as in case of technology incubators is much needed for comparing the performance of the incubator. The selected sample for the study reflects the same kind of variation

as it includes start-ups from a different technological background, locations, and other range of support provided by the incubators. In addition to it, the study has chosen a diversified background of the interviewee for the study, the reason for such selection is to provide an in-depth analysis of the challenges faced by the incubates and also to provide a reliability of the study by triangulating it with the existing study, thereby minimising individual biases and misperception.

However, the sample taken for the qualitative analysis is not fixed to the number mentioned, as during the survey the interview was conducted with more than 30 people but as they were not complete or the officials after few questions refuse to answer. So for that reason, the data from those interviews is not been counted. However, those interviews do provide us with some overview of our study and also added our understanding of the topic.

## **2.1 Overview of incubator**

The overview of selected incubators has been categorised under its affiliation, salient feature, along with their broad dimension in the incubation process. Table 1 provides a comparative overview of the incubator in terms of their establishment, salient feature, and the broad area of R&D by the incubators apart from the accreditation these centres have received.

**Table 1** Overview of the incubators

| Name of the Incubation Centre                                       | Establishment                                      | Name of the Host Institute & Establishment Year | Legal Status of Incubation Centre                                                            | Salient Feature                                                                                     | Broad Area                                                                                | Accreditation                                             |
|---------------------------------------------------------------------|----------------------------------------------------|-------------------------------------------------|----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| SIDBI Innovation and Incubation Centre                              | 2003                                               | IIT Kanpur (1959)                               | Part of Host Institute                                                                       | In-house Prototype Manufacturing                                                                    | IT, Electronics, Biotechnology and other Engineering Discipline                           | Best Incubator for the Year 2011 by NSTEDB                |
| IIT Madras Incubation Cell                                          | 2001                                               | IIT Madras (1959)                               | Section 25 Company Act                                                                       | Diversified Incubation centre like Rural, Bio-incubator apart from Technology                       | IT, Electronics, Biotechnology and other Engineering Discipline                           | Best Incubator for the Year 2003 by NSTEDB                |
| IIT Guwahati Technology Incubation Centre                           | 2010                                               | IIT Guwahati (1994)                             | Society Act                                                                                  | Diversified research domain Incubation Centre located in North-East engaged in Regional Development | IT, Electronics, Biotechnology, Design, Automation and other Engineering Discipline       | One of the pioneer incubation centre in North-east region |
| Centre for Innovation, Incubation and Entrepreneurship (CIIE- IIMA) | Initiated in 2002 but full-fledged working in 2008 | IIM Ahmedabad (1961)                            | Initially part of the institute but after 2008 it is registered under Section 25 Company Act | Diversified research domain from agriculture, water to electronics and many more                    | IT, Electronics, Agriculture, Water, and other engineering disciplines                    | National award for the best incubator for the Year 2019   |
| KIIT Technology Business Incubator (KIIT-TBI)                       | 2009                                               | KIIT 1992                                       | Registered under section (8) non-profit company                                              | Diversified research domain from Biotechnology, IT to tyre for automobile and many more             | Biotechnology, IT, Electronics, Artificial intelligence, and other Engineering Discipline | National award for the best incubator for the Year 2017   |

| Name of the Incubation Centre                                  | Establishment | Name of the Host Institute & Establishment Year | Legal Status of Incubation Centre                   | Salient Feature                                                             | Broad Area                                                                              | Accreditati on                                            |
|----------------------------------------------------------------|---------------|-------------------------------------------------|-----------------------------------------------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-----------------------------------------------------------|
| VIT - TBI Vellore                                              | 2003          | VIT1984                                         | Registered under Society Act                        | Diversified research domain includes Pharmaceuticals , food and agriculture | IT, Software, Electronics, Food, Agriculture Automation, Embedded Systems and Many More | Best Incubator award from NSTEDB in 2008                  |
| Innovation and Entrepreneurship Center (IIEC)- IIT Gandhinagar | 2011          | IIT Gandhinagar (2008)                          | Registered under section (8) not for profit company | Diversified research domain                                                 | Diversified technology domain                                                           | Newly Established incubator with promising J3 R&D profile |

Firstly, the chosen incubators for the study are academic incubators or in other words the incubators which are either established or supported by the academic institutions. Although the incubators resemble homogeneity in its nature and function, but with heterogeneity in its application, and functions the sample provides diversity. The incubation centre at IIT Madras established in the year 2001 has two more incubation centres under the same roof. The incubator established namely: RTBI (Rural Technology Business Incubator-2006) and IITM Bio-Incubator (2014). The foremost idea to establish this incubator apart from the parent technology incubation centre is to promote both sectoral and inclusive technology. On the other hand, SIIC incubation centre at IIT Kanpur has been established in collaboration with the SIDBI (Small Industrial Development Bank of India) in the year 2008. The centre apart from its diversity in addressing broad areas of research and product development in all high-tech areas like IT/Electronics, Bio- technology and Nano-technology, has not divided its operation based on technology or sectors.

In addition to it the incubation centre at IIM Ahmedabad is not a technology incubation centre just as the other incubation centre in the list but with diversified start-ups operating in almost all the technology domain including solar, AI (Artificial Intelligence), IoT (Internet of Things) and many more, the incubator has become remarkably important in the incubation ecosystem. In addition to it, the incubator also acts as a mentor for other newly established incubation centres thus outsourcing its technological and knowledge base through consultancy, which is rather unique among all the incubators in the country.

Further, the incubation centre at IIT Guwahati and KIIT TBI is the best performing incubation centre in the eastern region. Well for IIT Guwahati it is the only incubation centre in the North- East which is functional and performing well, besides this, it is also attached to the only biotechnology park in that region which provides support to other academic and research institutions in that region. For KIIT- TBI it is one of the best performing private institutions affiliated incubation centre which is also awarded the best incubation centre in the private institutions' category after VIT-Vellore by the government of India. Besides its cutting edge R&D in the area of biotechnology, the incubation centre also supports research in the area of AI, IoT and also agriculture and service sector. Along with this the incubator also provides prototypesupport for the incubatees in both biotechnology and other technological domain.

Moreover, with the diversified domain of research by the incubatees and with a high percentage of successful graduation of start-ups the incubation centre at VIT-Vellore has been chosen as the sample for the study, in addition to all these incubators with high performance in the academic and R&D profile among the

newly established IIT's in the country, the incubation centre at IIT Gandhinagar has been chosen as the other incubation centre for the study.

On the other hand, besides the homogeneity and heterogeneity in the affiliation and operations of the incubators, the incubators are well established and accredited in the national and international avenues. The specialisation of in-house prototype manufacturing support to the incubatees through ranges of laboratory and consultancy across the entire department affiliated to the parent institutions, and the diversity in incubation process based on sectoral along with the geographical location has imparted diversified attributes in analysing the innovation at these TBI's. However, besides these attributes, the broader question that arises at this point is how this diversity will feature as an important component in understanding the incubation process in India.

## **2.2 Data collection**

The data collected for this research is qualitatively resulting from the interview conducted for understanding the challenges in the incubation process. The interviewees were approached personally through email or during the pilot survey by asking their interest and permission for conducting the interview. All the interviews were conducted in November 2017 to March 2018 and again in May 2018 to November 2018 phase-wise. Table 2 provides an overview of the interviewees, their affiliation and the incubator to which they are associated. Meanwhile, the personal detail of the interviewee is not being disclosed.

Almost all the interviewee was conducted at the respective incubation centre for validation of the data and to code the informal conversation. The interviewee took an average 50 minutes, during which the interviewee was well-versed about the aim of the study and the guided research questions. Accordingly, the interviewee was conducted with a common set of questions regarding the objective and history of the start-up or incubator (the detail of which is mentioned in appendix III and IV) their objective, and the challenges they faced during the incubation process. Initially, the interviewee was asked open-ended questions, but later on, the questions were more specific to explore the challenges faced by them. In addition to the interview also includes the discussion on possible solutions to the challenges faced and how the incubators undertake these constraints.

All the interviews were recorded and were coded in a particular theme, the coding of data was done using *Nvivo 12* software. During the initial stage, the interview script was coded in two categories i.e. startup and startup officials. Later on, it is further classified according to the affiliation, host institute, and other categories so that to minimise the risk of amalgamation. In the second phase, the code was further categorised according to the theme and are triangulated with the existing literature. In doing the study eventually create a schematic overview of the challenges faced by both the incubator and incubates

during the incubation process. Further, the analysis also provides a platform to compare and trace the possible solutions that the incubator follows to minimise these constraints

**Table 2 Overview of interviewees**

| Interviewed    | Incubator        | Gender                                                    | Academic Qualification | Affiliation                                               |
|----------------|------------------|-----------------------------------------------------------|------------------------|-----------------------------------------------------------|
| Interviewee 1  | IIT-Madras       | Male                                                      | Engineering Graduate   | Start-up                                                  |
| Interviewee 2  | IIT-Madras       | Female                                                    | Post Graduate          | Top-level incubator official                              |
| Interviewee 3  | IIT-Madras       | Male                                                      | Engineering Graduate   | Start-up                                                  |
| Interviewee 4  | IIT- Guwahati    | Male                                                      | Engineering Graduate   | Start-up                                                  |
| Interviewee 5  | IIT- Guwahati    | Male                                                      | Graduate               | Mentor                                                    |
| Interviewee 6  | IIT-Kanpur       | Founder Member (Including both Male and Female officials) | Engineering Graduate   | Founder Member (Including both Male and Female officials) |
| Interviewee 7  | IIT-Kanpur       | Male                                                      | Doctorate              | Mentor/ In-charge                                         |
| Interviewee 8  | IIM- Ahmedabad   | Male                                                      | Post Graduate          | Start-up                                                  |
| Interviewee 9  | IIM- Ahmedabad   | Includes both Male and Female                             | Post Graduate          | Top-level incubator official                              |
| Interviewee 10 | IIT Gandhinagar  | Male                                                      | Post Graduate          | Start-up                                                  |
| Interviewee 11 | IIT Gandhinagar  | Male                                                      | Post Graduate          | Incubator Official                                        |
| Interviewee 12 | KIIT-Bhubaneswar | Male                                                      | Post Graduate          | Start-up                                                  |
| Interviewee 13 | VIT Vellore      | Female                                                    | Post Graduate          | Top-level incubator official                              |

*Source: Author's compilation*

### **3. Challenges to incubation process**

Technology incubation has been one of the important components in promoting innovation by bringing radical ideas into workable one through various support and services to the incubates. Yet the success of start-ups is quite uncertain, which in a way bound its trajectory and the services provided by government, universities, and funding agencies (Shane, 2000; Gosens et al., 2014). Therefore to understand the process of incubation it is always important to address the challenges related to it. In doing so the chapter classifies the challenges consistently identified in our sample through various themes and how these challenges are addressed by various incubators.

#### **3.1 Lack of early stage funding**

Funding has always been a key component in the incubation process.

Meanwhile, the process of financing and also the amount of financial assistance is quite diverse for the start-ups at various stages ranging from pre-incubation, incubation and graduation phase. Besides these variations, early-stage funding has always been a key aspect in the incubation process mainly for the academic incubates (Wissema, 2009; Marda 2015; Lalkaka, 2006).

To understand how financing has contributed to the development of technology incubation, it is enormously important to comprehend the perspectives of different actors.

"[...] funding has always been one of the key drivers in the incubation process." (Interviewee 1)

"[...] financing has always been the soul of academic entrepreneurship." (Interviewee 4)

In some cases, the projects which seem to be promising never comes out from the rough ideas.

"[...] there are many projects that are sound potential but they seem to remain in the rough sketches due to uncertainty in funding." (Interviewee 5)

"[...] at the initial stages the students were highly enthusiastic [...] in experimenting their ideas but with times due to high administrative hurdle and uncertainty [...] they chose not to opt for incubating it." (Interviewee 6)

However, it is not that financing is the only constrain in the incubation process but there seem to be other factors also which influences early-stage funding for the incubatees.

"[...] funding has never been a problem for us or maybe for the other incubatees, but the most important thing which influences funding is the product [...] whether it is promising or not and how the consumers are going to react to it." (Interviewee 3)

"[...] we have provided funding for almost all the in-house incubatees and even if some of them are left out and the product seems to be promising [...] we provide them funding from our fund." (Interviewee 2)

"[...] to facilitate a smooth entrepreneurial ecosystem, we have our funding criteria [...] we support incubatees with our funding so that the process of incubation is not stopped [...] that's why we have funding for all the in-house incubatees." (Interviewee 7)

"[...] according to me the most important thing that facilitates funding for the start-up is the potential of the product and what response it has received from the target group [...] then only the investors will be



interested in it." (Interviewee 13)

In addition to the above-mentioned responses by a different actor, it is also to be mentioned that the profile of the institution and its R&D base also provides an added advantage in receiving funding for the start-ups. Along with that the administrative hurdle of getting the second instalment and lack of funding at different stages also adds up the challenges in the incubation process.

"[...] it is to be mentioned that getting funding also depends on the credential of the institutions also, although we have received the same but [...] it is found that the start-ups originating from IIT's or IIM's receive funding for their start-ups quite easy as compare to start-ups operating in any other institutions." (Interviewee 12)

"[...] collaboration or mentorship with established entrepreneur also provides added advantages in getting funding for the start-ups." (Interviewee 10 and 11)

Government funding plays a major role

"[...] In India government plays a major role in promoting innovation through incubation, [...] as most of the early-stage funding for the start-ups are provided by various government agencies and department [...] In addition to it these ministries also provides sector-specific funding for the incubatees." (Interviewee 9 and 7)

"[...] it is been observed that it is relatively quiet difficult in getting the second instalment of funding for the start-ups." (Interviewee 1)

Dis-investment of Equity

"[...] Ownership or total control of the company is also an added disadvantage among the young entrepreneur, as most of the foreign investors are wants to have equity of the company in return to the investment in the said start-ups." (Interviewee 2)

### **3.2 Lack of support from academic institutions**

With the shift in the structure of the universities from teaching and research to entrepreneurial mode, universities have become a significant player in spearheading the mechanism of innovation and development (Wissema, 2009; Mowery & Sampat 2005). Accordingly, the role of universities is not limited in only providing laboratory or other support but in a way, it involves active support from the institutions in every aspect. Concerning this the responded in this study has pointed out the possible factor to its support for technology incubation.

"[...] university plays an extremely important role in not only promoting

incubation but also research in the area of academic entrepreneurship." (Interviewee 7 and 9)

"[...] The institutes/ universities apart from providing teaching and research support have also spread its hand in promoting incubation [...] concerning it provides various labs and consultancy services to the start-ups." (Interviewee 9, 5 and 2 )

"[...] however, the support provided, varies from institutions to institutions [...] some of them lacks technological infrastructure mainly in prototype making, while others lack people with business expertise. (Interviewee 1, 12, and 4)

In addition to these, there are few universities which have dedicated course on entrepreneurship or they tend to provide lectures on entrepreneurship.

"[...] To promote incubation our institutions (i.e. IIT Madras) has come up with a dedicated course on entrepreneurship [...] apart from this the institute has also provided lectures by various experts on start-ups and how to grow your business." (Interviewee 1,3 and 6)

"[...] though our institute is specialised in providing management skills, it does provide lectures and organize events focusing on entrepreneurship." (Interviewee 8 and 9)

"[...] although the institute provides us the necessary technological support for the development of our product, there is lack of guidance on how to develop start-ups[...] although the institute organises annual tech events this is not sufficient for us." (Interviewee 10, 12 and 4)

Apart from this, there has not been much of an initiative taken by the universities in promoting incubation.

"[...] internship has been one of the key academic activities which allow students to learn various technological and other aspects [...] the institutions tend to promote internship and various national and international institutions or multi-national companies rather than promoting the same in a start-up." (Interviewee 1, 4, 12, and 8)

### **3.3 Lack of academic entrepreneurship culture**

Social and cultural norms have a great value in society, the norms apart from providing a pathway towards our life also influence our activities in society. In this regards, there must be a constructive and positive attitude towards entrepreneurship, so that it can influence the process of technology incubation (Gnyawali & Fogel, 1994). However, it has been found in the work of various scholars which includes the work of (Ojha, 2009) and (Lala & Sinha, 2019) that middle-income group in India tends to focus towards professions

which are of low risk and has steady income source other than an uncertain and irregular profession like entrepreneurship. In doing so the individuals who opt for start-ups as a profession often faces words of discouragement from families and friends even if their idea is relatively unique. In this regard, the respondent identifies the possible factors that impede them in selecting the profession of entrepreneurship.

"[...] In the initial phase it was quite difficult in starting our start-ups, the problem was not due to the technological or other incubation related factors, but due to unacceptable and discouraging words from the family". (Interviewee 1).

"[...] starting a start-up was quite a tough job for me [...] I have to hide things from my parents as they were not happy with my decision to jump into an uncertainty profession after graduating from IIT's". (Interviewee 6 and 3).

"[...] it is quite unfortunate that besides a successful idea and being achieved a successful response from the market [...] still graduates opt for a secure job rather than choosing the profession of an entrepreneur". (Interviewee 9).

"[...] in my view incubation is not all about technology, ideas and funding, rather it is also about how you convince your people rather than convincing the customers or investors [...] if you can do it, then your startup is half established." (Interviewee 2, 7 and 9).

However, in addition to the support from family and friends, universities also play a significant role in accelerating the entrepreneurial culture. But with a primary focus on academics and R&D, the entrepreneurial part is often being ignored by the academic institutes.

"[...] incubation cannot flourish by only providing space, internet and other office assistance but it is more about providing an entrepreneurial culture in the institute." (Interviewee 10 and 12),

"[...] with fewer events and lectures to showcase and discuss our ideas, the functionality of the incubators seems superficial." (Interviewee 4 and 12).

"[...] incubation is not all about infrastructure but it more of an integration of many functions, which we lack in our institutions [...] organisational culture do affects the working of incubatees, but whenever I used to visit other incubation centres, the organisational culture encourages me a lot ." (Interviewee 10).

### **3.4 Lack of business or market support**

The market is being one of the most important components of the innovation ecosystem. The market apart from testing the validity of the product also provides an opportunity for the new one to be tested in the market. In this

regard, the role of the incubator is quite significant in promoting start-ups. Concerning this, the start-ups across the chosen incubation centre have mixed experience and the detail of which is mentioned below.

"[...] The market has always been a key aspect in the incubation process, though our product was excellent it is only the customers who are the final judge [...] the incubator besides mentoring us through various business skill provided us with the right platform for the successful commercialisation of our product." (Interviewee 1).

"[...] the main success of our incubation program lies in the success of the incubatees, apart from providing best services [...] our primary motto is to provide market or at least an effective platform for the start-ups, such that their product is accepted in the market". (Interviewee 2)

"[...] the performance of our incubation centre is quite exceptional with almost all the start-ups incubated have graduated or in the route of being graduated [...] besides this it is also observed that the start-ups are not getting enough marketing space as they should be [...] to solve this we have situated an outreach incubation centre for the start-ups in a metro city so that the start-ups can adequately advertise themselves." (Interviewee 7).

"[...] Marketing of our product is one of the important components in the success of start-ups. However, with less attention paid by the incubators [...], it is up to the start-ups to advertise themselves, in doing so, the start-ups used to rent offices in the metro city to maximise its reach to the customers and also investors." (Interviewee 4 and 12).

"[...] it has been observed that most of the start-ups graduated from our incubation centre are successful in becoming a successful enterprise, but still the liabilities of newness remains with the start-ups [...] to protect the start-ups from liabilities of newness in the market, often the start-ups are integrated or promoted through collaboration with a big firm in the market." (Interviewee 2)

"[...] Besides technology, reaching the product to the market is also a key factor in the success of start-ups, it has been observed that successful incubators do provide an effective platform for the start-ups to advertise themselves properly, which in somehow I lack in my incubator." (Interviewee 10).

"[...] Business skills are equally important in comparison to technology for the start-ups " [...] in doing so, the incubators are more inclined towards the technological development rather than understanding and developing business skills [...] due to this reason it is quite hard to understand the market, besides product demand". (Interviewee 4 and 12).

"[...] we are finding quite hard in understanding the business strategy [...] so now we are taking extra lessons from different farms in understand the marketing /business strategy, [...] in doing so we are losing our dedication in start-ups". (Interviewee 10 and 4).

"[...] the incubator has provided us an effective platform through a quarterly event where we can meet with the potential customers or investors." (Interviewee 8).

"[...] mentoring is one of the important components in the incubation process [...] the mentors provide effective and efficient solutions to the start-ups. [...] however, it is also mentioned that mentors are not there to reject your ideas/ views but rather they tend to provide you knowledge about the current scenario, and how you can undertake it ." ( Interviewee 6).

"[...] though the start-ups incubating in our incubation centre are mostly the alumni of our institutions. [...] these students are well trained in business administration [...] besides this these incubators are provided with mentors so that the chances of failure can be minimised to zero". (Interviewee 9).

"[...] mentoring do provides a significant support for the incubatees [...] but this push becomes limited when the incubator provides support to certain technology". (Interviewee 12)

"[...] Apart from the funding for the incubatees, the incubator also provides some funding for the start-up to undergo survey for their product[...] the main objective of this funding is to understand whether the innovation is feasible and accepted in the market or it requires more modification [...] these efforts do minimise the risk of failure for our incubates". (Interviewee 2).

#### **4. Incubators response to challenges**

The above-mentioned discussion about the incubation process provides an overview of the challenges associated with various actors connected with the incubation process. Overall, it seems that the main problems of incubators and incubatees in India are not disinclination or incapability towards technology incubation, rather it is more about the problems in early-stage funding, lack of marketing or business support, lack of academic entrepreneurship culture and lack of support from academic institutions.

However, it is to be noted that the challenges faced by different actors are not the only challenges that the interviewees identified. For example, a few interviewees also mentioned the administrative hurdle in operating and starting a start-up. Meanwhile, it is to be noted that the challenges mentioned in the study are the one which is consistently identified by almost all the actors participating in the discussion. Further, it is also to be mentioned that the

challenges identified in the study have its Institutional cause, which makes it difficult for the start-ups to overcome them.

Meanwhile, the next part of the chapter discusses how incubators can help start-ups in overcoming the challenges identified in the study. In doing so, the study has elaborately studied incubator practices and how it tries to overcome these challenges.

#### **4.1 Lack of early stage funding**

Funding has always been a critical aspect of the incubation process. The process which is divided into various stages starting from the pre-incubation period, to growth and further graduation stage, in all these steps the role of funding is quite significant. In other words, the whole process of incubation which includes the performance of both the incubatees and incubators are mainly depended on the funding. However, it has been found that some incubators use various practices to help start-ups overcome the challenge of early-stage funding. The steps used by the incubators are mentioned below.

##### **4.1.1 Supporting the incubatees with own funding**

An incubator plays quite a significant role in developing start-ups in a successful enterprise. Although it is a predetermined responsibility of the incubator to provide various services and support to the incubatees, sometimes these supports seem to be not quite sufficient for the start-ups to grow. Accordingly, there have been numerous start-ups which hold great potential are forced to exit from the incubation ecosystem, one of these factors is early-stage funding.

Although the funding landscape of India is relatively diverse with funding at every stage of the incubation process and also funding is being provided for sector-specific projects, but still, it is found that not all start-ups received the benefit of seed funding. In this regard, the role of an incubator is quite significant, it has been found that the incubator at IIT Madras, IIT Kanpur and IIM Ahmedabad (Mainly) provided their self-fund for the projects that seem promising. One of the officials from these incubation centres says that *"incubation is quite a tough process, and funding is its heart, so our effort is to take care of your main part so that you concentrate in other aspects."* Another official stated that *"our main goal is to achieve a 100 per cent success rate in incubating start-ups, in doing so we provide our funding so that not only the start-ups grow into a successful enterprise, but also the technological capability of the nation"*.

Meanwhile, it is also to be mentioned that these incubators are not limited in providing funding at the early stage but they do tend to provide funding to the incubatees at every stage of incubation.

#### **4.1.2 Enabling collaboration of start-ups**

The incubators apart from providing funds for the start-ups enable them to collaborate with established enterprise or start-ups. This collaboration provides enormous support for the newly established start-ups. As one of the officials illustrated that the main objective of enabling such collaboration for newly established incubatees is that *"this collaboration provides a soft landing of the start-ups in the market under a branded enterprise, in addition to it the collaboration with established start-ups also provides an added advantages for the start-ups in getting funding for their project."* Consequently, with the establishment of these linkages the success rate of both the incubator and incubatees increase to a higher order.

#### **4.2 Lack of support from academic institutions**

With the shift in the structure of the universities from teaching and research to entrepreneurial mode, universities have become a significant player in spearheading the mechanism of innovation and development (Wissema, 2009; Mowery & Sampat 2004). In other words, academic institutions do play a vital role in promoting innovation through the process of incubation. Accordingly, incubators use several practices to improve the interaction between universities and start-ups, so that the process of incubation develops quite efficiently. In doing so the incubators follow certain practices which are mentioned below:

##### **4.2.1 Provides access to lab and other infrastructures**

By providing access to research labs and Intellectual property right offices, the incubator enables start-ups to access state of art knowledge about the latest trend in both scientific knowledge and business strategy which in a way provides them with the competitive advantages over other start-ups. However, according to an incubator official *"the advantage of accessing these labs to the incubators, provide them additional confident in experimenting their product, without the fear of loss due to testing of the final product."*

##### **4.2.2 Entrepreneurial curriculum and lectures**

Apart from providing access to lab and other infrastructures, the role of academic institutions is not finished. On the other hand for an effective and efficient incubation process, the incubator does have to provide essential learning to the start-ups. As most of the academic entrepreneurs are not aware of the latest business regulations and practices, the role of the academic institutions become very critical. In this scenario, the incubator does provide lectures to the start-ups on topics related to *"how to start a start-up business"* and many more. In addition to it at IIT Madras, there is a dedicated Masters course on start-ups and entrepreneurship. The main objective of such a course is to

provide knowledge to the students regarding start-ups and its various process and procedure. According to an incubator official of IIT Madras "According to an incubator official of IIT Madras *"the course on start-ups and entrepreneurship provides an effective platform for the students to experiment their ideas and become a start-up."*

### **4.3 Lack of academic entrepreneurship culture**

Over the past decades, entrepreneurship has become a buzz word in the academic literature, the word which is mainly integrated with either new product or process in the market is also adding value in formulating economic growth and development worldwide. In this regard the role of start-ups as is equally important while analysing the entrepreneurial ecosystem. Incidentally, the role of the incubator is equally important in not only promoting innovation but also to promote academic entrepreneurship by providing an exceptional entrepreneurial culture. The main objective in emphasising for an effective entrepreneurial culture is deeply rooted towards out approach towards entrepreneurship, as in India it has been found that the family and friends do not support academic entrepreneurship as a top career decision. So, in this regard, the role of incubators is equally important in creating an entrepreneurial culture among the academic entity. In doing so, the incubator follows these steps to boost the entrepreneurial culture.

#### **4.3.1 Organising start-ups Events**

The incubator to create an entrepreneurial culture organises start-up annual events, which includes annual tech events, hackathon and many more, the main objective of doing so it to expose the start-ups as well as the students to the entrepreneurial ecosystem. In doing so some of the promising and early-stage start-ups stated that *"the event like this inspired us a lot in getting the mindset in starting a start-up, and explore the world of opportunity."* In addition to it, start-up events also provide early exposure for various investors, as they have an opportunity to witness budding ideas in raw format. According to some investors, *"these events provide us with an ideal opportunity to witness cutting edge technology in raw format; otherwise, it is quite hard to be updated with the latest technology and its application."*

#### **4.3.2 Creating an entrepreneurial club or society**

Creating an entrepreneurial club or society forms a group of likelihood individuals dedicated towards a similar goal. However, these societies do create a sense of belongings and provide motivation and comfort for the start-ups or early-stage entrepreneur. According to a start-up *"the main benefit of these entrepreneurial clubs is that when we discuss with each other, we found that entrepreneurship is not an easy task and all of us faces a similar problem, that provides us inspiration that we are in a right path and we will surely be a successful enterprise."*



#### **4.4 Lack of business or market support**

Unlike funding business and marketing, support does hold one of the key aspects of the incubation process. The process which tends to initiate from the lab is finally tested and become successful once it is accepted by the customer. In this regards the role of business and marketing strategy is exceptionally important. Accordingly, incubators use various practices to enable start-ups to promote their product or services to the customers. In doing so, the incubators follow various methods, the detail of which is mentioned below.

##### **4.4.1 Establishing an outreach centre**

Geographical location does act as one of the important components when we think of reaching the product to the customer. Also, apart from reaching out to the customer, location does act as an important factor when it comes to reach-out of effective investors for the start-ups. Overall locations do act as a catalyst in the incubation process and the incubator who are located in metros or industrial town are certainly having this advantage. But it is also true that not all incubators can locate themselves in metros, in this regard the incubator do setup outreach centres in metros or industrial town location so that the start-up residing in these centres do backup themselves with the advantage of the location in their growth. In doing so the incubator of IIT Kanpur has opened an outreach centre at Noida so that the incubatees located in Kanpur can also take advantage of this location for reaching out both the customer and investors.

##### **4.4.2 Creating a soft landing ecosystem**

The main objective of incubation is to provide an effective platform for the start-ups to develop their idea into an efficient product, in doing so the incubator provides various supports and services. But besides these efforts, the condition of "newness and smallness" has always been a threat to the growth of the incubatees. To reduce this risk the incubator does share their networks with the start-ups so that the collaboration with other big enterprise does help them in creating a soft landing. In addition to it, the incubator at IIT Madras does provide the sharing of resources and collaboration of graduating incubatees with the larger forms or enterprises located at the IIT Madras Research Park. The park apart from providing R&D support to the start-ups do share their network so that the constrain of "Newness and Smallness" is no more a problem for the start-ups.

The above-mentioned practices performed by the incubators are focused on facilitating the incubation process with an effective and efficient interaction between the start-ups and the incubator. By doing so, the incubator fosters a culture of entrepreneurship at the university/ institute, which in a way helps in

building a prospective and proficient incubation innovation system. Further, it has been found through the interviewees with various actors that although the incubator tries to present an effective entrepreneurial environment, with limited resources and monolithic practices the incubators are unable able to develop. Table 3 provides a detailed overview of the various challenges experienced by the incubators and the effective practices performed by these incubators to lessen them.

**Table 3 Overview of Challenges and Practices Performed by Incubators**

| Challenges/ Practices                                              | Incubation Centre                      |                            |                                     |                                       |                 |                                     |                                     |
|--------------------------------------------------------------------|----------------------------------------|----------------------------|-------------------------------------|---------------------------------------|-----------------|-------------------------------------|-------------------------------------|
|                                                                    | IIT Madras                             | IIT Kanpur                 | IIT Guwahati                        | IIM Ahmedabad                         | IIT Gandhinagar | KIIT Bhubaneswar                    | VIT Vellore                         |
| <b>Lack of Early Stage Funding</b>                                 |                                        |                            |                                     |                                       |                 |                                     |                                     |
| Supporting the Incubatees with Own Funding                         | Yes                                    | Yes                        | Not Started                         | Yes                                   | No (In special  | No                                  | No                                  |
| Enabling collaboration of Start-ups                                | Yes                                    | Yes                        | Just Started                        | Yes                                   | Term) No        | May Initiate                        | No                                  |
| <b>Lack of support from Academic Institutions</b>                  |                                        |                            |                                     |                                       |                 |                                     |                                     |
| Entrepreneurial Curriculum and Lectures                            | Both (Throughout the Year)             | Only Lecture               | Features only annual lecture series | Both (Throughout the Year)            | Occasionally    | Features only annual lecture series | Features only annual lecture series |
| Lab and other infrastructures                                      | Yes                                    | Yes                        | Partial                             | Only IT related, no technological lab | Not Present     | Yes                                 | Yes                                 |
| Lack of Academic Entrepreneurship Culture                          |                                        |                            |                                     |                                       |                 |                                     |                                     |
| Organising Startups Events                                         | Yes                                    | Yes (Also at School level) | Features Features only annual Event | Yes (Throughout the Year)             | Not started     | Features only annual Event          | Features only annual Event          |
| Creating an Entrepreneurial Club or Society                        | Yes                                    | Yes                        | Present but not so active           | Yes                                   | No              | Present but not so active           | Present but not so active           |
| Lack of Business or Market Support Establishing an Outreach Centre | Not Required as it is located in Metro | Yes                        | Not Yet                             | Not Required                          | No              | Not Yet                             | Not Yet                             |
| Creating a Soft Landing Ecosystem                                  | Yes                                    | Yes                        | Initiating                          | Yes                                   | Not Yet         | Initiated                           | Initiated                           |

*Source: Author's own compilation from field data*

## 5. Discussion and conclusion

The main aim of this study is to understand the challenges faced by start-ups in India? and what practices does the incubator exercise to address these challenges. In doing so, the study takes the route of qualitative research method. The interview was conducted with the actors associated with the seven incubation centre chosen for the study. Further, the study finds four (4) major challenges faced by the incubatees in India; these challenges do restrain the growth of incubatees as well as the incubators in India.

However, while undergoing the study it is found that the challenges faced by the start-ups are mainly associated with the way the incubator practices the process of incubation or in other words it has "*institutional root*". Most of the practices identified during the study are associated with the linkages between the start-ups and actors connected with the incubation process. For this reason, the intention to study the role of network or network incubators is quite applicable while understanding the process and practices of technology incubation (Bruneel et al 2012; Hackett & Dilts 2004; Smith and Hannigan 2015; Hallen et al 2016).

The previous studies on technology incubation are mainly focused on the way the resources and services were provided to the start-ups. Moreover, these studies were more concentrated in linking the performance of the incubator and start-ups with these resources. However, our study suggests that although incubators play a significant role in the entrepreneurial ecosystem the role of incubators is not limited in only providing the linkages rather it is more of addressing the challenges faced by the start-ups and how the incubator's bridges those gaps for strengthening the entrepreneurial ecosystem. Consequently, the study provides a detailed overview of the limitation of the incubator's and how the incubator can address it so that to provide a safeguard for the start-ups to grow.

The finding in the study suggests important implication for both the incubators as well for the policymakers. The policymakers should be aware that early-stage funding is one of the important drivers of the incubation process, and many incubators, as well as the start-ups, fails due to unavailability of funds at the early-stage level. But it has been found in the study that incubators like IIT Madras, IIT Kanpur and IIM Ahmedabad are creating their fund for supporting the potential start-ups, in addition to it the incubators also enable the start-ups to collaborate with large enterprises for better exposure to the market, and funding.

In other words, the incubators do have to shift their position from the monolithic practices they used to perform towards the new and innovative steps for strengthening the incubation ecosystem. However, besides the

advantages of technology incubation, questions have been raised on the effectiveness of academic incubators in India. As such there are some incubators which are functioning well, these incubators integrate the function of its network and new and innovative practices to strengthen the incubation process. As a result, the start-ups are provided with an effective platform, which helps them in undergoing collaboration with large enterprise and enables a business-friendly environment to grow.

Further, it is also to be noted that incubators are not the only solution to the institutional problems integrated with the incubation process, besides this the social and cultural attitude do have a larger say in strengthening the academic entrepreneurship. The lack of entrepreneurial culture among the students and faculties is one of the major reasons in the progress of academic entrepreneurship. However, there are some incubators which have tried to overcome these challenges by introducing lectures and courses on entrepreneurship. These practices do encourages the early-stage start-ups in settling towards the entrepreneur as a career.

Moreover, strengthening the entrepreneurial ecosystem requires a good amount of time, the incubators which are established much earlier do have an added advantage as in case of IIT Madras, IIT Kanpur, and IIM Ahmedabad to capitalise their institutional and research resources and experience to counter the challenges in the incubation process. On the other hand, the incubators who are newly established or are relatively new in practising the incubation model may use the practices performed by these established incubators as mentioned in the study to address the challenges faced by the start-ups. Accordingly, the study recommends the incubators to be more focused on supporting the start-ups more than the conventional support and services. The study does recommend providing various funding options for high growth and potentially feasible project. In addition to it, the study also suggests sharing of various networks with the start-ups for enabling collaboration with a larger enterprise. On the broader note, the study does an emphasis on greater connectivity between various actors and agencies for an effective and efficient incubation system.

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## Effect of entrepreneurs' level of education on uptake of new technology and innovativeness: The case of SMEs operating in Nairobi

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### Abstract

This paper explores how entrepreneurs' level of education influences uptake of new technology and innovativeness of SMEs operating in Nairobi, Kenya. Based on a mixed methods approach, the study employed both quantitative survey and in-depth qualitative interviews to determine how entrepreneurs' level of education impacts not only their ability to recognize the value of new technology, but to assimilate and utilize it in the development of new innovations within their firms. The results indicate a positive correlation between owner's level of education and uptake of new technologies and innovativeness, with those with secondary school and above, reporting higher levels of uptake of new technologies and new product development, compared to those with lower level of basic education. The findings contribute to the growing literature on technology transfer and innovation in developing countries and could guide policy intervention towards technology upgrading in these countries.

**Main Words;** *entrepreneur's education, new knowledge, new technology uptake, SMEs*



## Introduction

Scholars believe that what primarily drives economic development in today's knowledge-based economy is the innovative capacity; spurred by appropriable knowledge, coupled with technological capacity, human capital development and externalities, as entrenched in the systems approach of innovation literature (Edquist, 1999, Lall & Pietrobelli, 2002; Lundvall et al, 2002, 2009). Economic progress in this era is found to be less reliant on traditional resources such as financial capital and labour and instead, is driven by knowledge, innovation and capability of economic players to leverage on technological changes happening across the world (Anderson et al, 2016).

Technology innovations are seen to drive the biggest economies in the world today, allowing more efficient production of better goods, services and processes towards sustainable development (OECD 2018). The economics of technology innovation is modelled on the background of economic theory and places technology, innovation, entrepreneurship, and knowledge at the centre of the model of economic growth (Luenendonk 2016). Africa countries including Kenya, however have weak technology development and transfer systems, hindering their social economic growth and industrial development (Chege and Wang, 2020; Ngungi, Mcorege and Muiru, 2013). A major challenge in Kenya specifically is the low capability of local enterprises, most of which are small and medium enterprises (SMEs) that make up to 98% of the economy (CBK -2020), to identify and absorb potential transformative knowledge capital; which often remain underutilized in knowledge-based institutions such as universities and research institutes.

Just like their counterparts the rest of Africa, most SMEs in Kenya generally suffer structural weakness such as poor ability to manage technology as a strategic weapon, due to lack of professionals with technical skills and poor managerial competencies due to low levels of education (Were 2016). Furthermore, most of these entrepreneurs are necessity driven, with low financial bases and thus have low propensity to risk that comes with attracting and utilising new technologies. The SMEs are generally characterized by restricted levels of technology, inappropriate technology and inadequate firm level capacities to support adaptation and absorption of modern technologies (Muturi, Gesimba and Kithinji, 2014). Consequently, the SME sector continues to experience perennially low productivity, poor quality and limited range of products, resulting in low competitiveness (Moyi and Njiraini, 2005). Other scholars highlight that because these SMEs operate with very low technologies; applying to a great extent outdated or obsolete technologies in their production processes; they face tough competition with imported products, mostly from China.

The SMEs play a significant role in facilitating the development of the global

economy by constantly participating through the creative process, encouraging the advancement of technology, organizational innovation, job creation, income generation, economic competitiveness, and other aspects of social development in general, along with industrial expansion, in particular. New technology and innovativeness mostly come from higher education institutions due to their vast research as well as research institutions. The uptake of this new knowledge to SMEs owners determines their innovativeness which not only aid organizational success but also helps businesses to cope with the ever-changing environmental situations as well as tap business opportunities that they bring along. This paper aims to interrogate the impact of the owners' level of education in technology and innovativeness uptake from higher education institutions.

### **New technology and innovativeness**

Innovativeness has been defined as the level of innovation incorporated (Göktan & Miles, 2011) or the ability to bring radical innovations to the market (Eggers et al., 2014) through technologies, processes, or products (Nelson and Winter, 1982). The radical nature of innovations reveals the creation of disruptive knowledge, which is considered the essence of innovation in the literature (Schumpeter, 1934). In consequence, the degree of innovation of the firm's developments is a key issue when studying innovativeness (Bouncken et al., 2015). Firms must purpose to understand, adopt and implement innovativeness for their businesses to be more adaptive to environmental changes as well as for them to have better performance.

The higher education institutes and research institutions are on the forefront match towards creating novel ideas that suit environmental changes and at the same time conduct research on innovative ways of alleviating the major issues faced by SMEs. There is always a dearth of literature on research conducted with corresponding findings on innovation. The various types of innovation, product and process as well as their interaction for better business performance. The complex and multidimensional character of innovation is reflected in the inter- relationships that exist between technological innovations (product innovation and process innovation), and those innovations coming from the administrative system (organizational innovation and marketing innovation) (Varis and Littunen, 2010). In order for firms to be successful in innovativeness, they must find a balance in practising the different types of innovation in accordance with their needs (Weerawardena, 2003). Thus, innovative performance is really a construct made up of the different forms of innovation carried out by the firm (Hagedoorn and Cloudt, 2003). However, dynamic capabilities as organizational processes shaping resources and competences are not directly producing goods or services but create value by triggering and fuelling firm innovation (Tresna & Raharja, 2019).

In order to achieve an ample conceptualisation of innovation, it is necessary to consider the technological and non-technological novelties and improvements that firms develop. In adoption of innovation, the specific firm must adopt those that are applicable to their situations. Currently, organisational and marketing innovations are integrated into standardised assessment systems of innovative results at the institutional and firm level (Caird et al., 2013). However, the knowledge accumulated concerning these two types of innovation remains limited (Armbruster et al., 2008; Camisón and Villar-López, 2011). The Oslo Manual (OECD, 2005) differentiates between worldwide, market, and firm-only innovation. The latter category is associated with innovation or technology adoption or absorption, while the other two types represent more pure forms of innovation activity. From telegraphs, telephones and computers to the Internet and contemporary ICT software, technological dualism has shifted from a focus on access to physical IT infrastructure to accessing ICT knowledge which has been described as human and intangible IT resources (Graham, 2011). This includes “the application of technological tools that support the process of starting and running a new venture” (Keyhani and Jonsson, 2017). The SMEs owners must get this information and guidance on adoption for it to benefit their businesses. According to Morrison et al., (2003), firm innovation can be prompted by the entrepreneur’s ambition to grow and to take risks. In SMEs, firm growth seems to be closely linked to the owner’s capacities, ambitions and skills.

The research institutions and the higher education institutions in Kenya have a mandate and have taken long strides to come up with opportunities that are aided by the development of science and technology which have a positive impact in the growth and development of small and medium enterprises. They have developed several novel strategies of enhancing business performance, methods of coping with possible challenges that may hamper business growth and various policies that would make the business arena more friendly for growth of SMEs.

Empirical research has identified two dimensions of innovative capacity associated with, respectively, the capabilities for internal knowledge creation and the capabilities for the external adoption of technologies for innovation (Mahroum and Al-Saleh, 2013). Indeed, innovation depends on both the adoption of new technology (Gil et al., 2012) and the intensity of internal R&D in companies (Gómez and Vargas, 2009). According to Martínez-Román & Romero (2017), these dimensions have been insufficiently studied in the literature, despite the importance that they may have for the policy and management of innovation in SMEs. The studies that have been carried out, the methodological approaches and research objectives lead to the identification of latent dimensions in a firm’s innovativeness and uptake of new technology by SMEs. This study seeks to unravel the dimension that mostly hinders the uptake of new technology from institutions of research and higher learning. What really creates the innovative capability of a firm?

## Education level of entrepreneurs

According to Martínez-Román & Romero (2017), the personal conditions of the owner as the main decision maker are determinants in the innovative behaviour and capability of SMEs, especially in the initial phases of the business. The entrepreneurs' level of studies is one of the personal characteristics which tend to appear in the literature linked to innovative success (Koellinger, 2008; Marvel and Lumpkin, 2007) and economic performances in small firms (Kangasharju and Pekkala, 2002). The success of a business may not so much be a function of the owner's level of education, but adoption of new knowledge largely depends of the decisions made by the owner of the SMEs. It mostly turns out not to be so evident though (Keizer et al., 2002). The indirect influence of education through other personal features of the entrepreneur has been observed, for instance, by way of motivation and management style (Romero and Martínez-Román, 2012). A higher level of studies tends to be linked with a greater degree of cognitive complexity, one that promotes creativity (Thompson et al., 2010), as well as the discovery of business opportunities (Clarysse et al., 2011), and the entrepreneur's capacity for technological absorption (Hoffman et al., 1998). This is why it seems reasonable to consider the entrepreneur's educational level as being among the most influential characteristics in the innovative behaviour of small-sized firms. In the same breath, it is wise to also consider the educational level of the senior management as a particularly influential factor in the adoption of new technology (Autry et al., 2010; Correa et al., 2010), even in less technology-intensive industries (Romero and Martínez-Román, 2015). The two considerations will go a long way in determining the innovation capability of a particular firm. Identifying capabilities enable a firm to recognise favourable opportunities and possible threats with the aim of devising new strategies for dealing with external factors (Sivusuo, 2019).

A firm's 'innovation capability' can be understood as the potential to innovate (Saunila & Ukko, 2012), or more specifically the "ability to continuously transform knowledge and ideas into new products, processes and systems for the benefit of the firm and its stakeholders" (Lerro, Linzalone & Schiuma, 2009). It has been suggested that innovation capabilities are so-called higher-order capabilities or "the ability to mould and manage multiple capabilities" (Lawson & Samson, 2001). Firms that possess these capabilities have "the ability to integrate key capabilities and resources of their firm to successfully stimulate innovation" (Lawson & Samson, 2001). In that case, it is imperative to study the education of the owner or business manager in terms of their level, in terms of how they access knowledge and technology and its relevance to their business as well as study the barriers they encounter towards their business growth and expansion.

## **SMEs**

Ability of organizations to adapt to the ever-changing environmental situations is easier and faster for those organizations with innovative capabilities as opposed to those without (Faiña *et al.*, 2016). The organizations' capacity to either generate or improve ideas, products, processes, services or behaviour enable them to realize a competitive edge and hence improve on the overall performance (Jantunen, 2005). Firms utilize their resources and capabilities for the development of innovations, such as new products, services or processes (Hill, Brandeau, Truelove & Lineback, 2015).

Most of the available literature is largely on world- wide and market innovations, but firm-only innovations should not be underestimated, particularly in the case of SMEs. This type of innovation can bring SMEs closer to the efficient technical frontier and favour their survival and economic success. In addition, the adoption of technology generated outside the firm can be accompanied by substantial modifications and adaptations that actually involve market innovations. Organizations must be able to manage change in an increasingly volatile and complex service eco-systems (Yoo & Kim, 2015) to succeed in the contemporary globalized and hyper-velocity business environment (Crossan & Apaydin, 2010; Francis & Bessant, 2005). Dynamic capabilities, therefore, are central to innovation (Tidd, 2012), as they are linked to sustained competitiveness under these conditions (Eisenhardt, 2004).

The need for business owners to adopt ICT is compelling. Digital technologies are key enablers of small firm performance (Benitez-Amado *et al.*, 2010). This study sought to interrogate SMEs based in Nairobi to test their uptake of new technology from higher education and research institutions and their innovativeness.

## **Research problem**

Kenya, like most of the countries in Africa, has weak technology transfer systems that hinder her social economic growth and industrial development (Ngudi, Mcorege & Muiru, 2016). Furthermore, the technology transfer and uptake of new technology, culminating in low innovativeness in small and medium enterprises is hampered by lack of knowledge by the business owners. In most cases, they tend to look for solutions by themselves or cite the encountered issues as mere business challenges instead of searching for Knowledge from the relevant forces. A study by Ibrahim and YuSheng (2020) in Ghana examined impact of innovation adoption on banks' performance. The study revealed that banks that had innovated more had higher performances. The study used a sample of 450 bank employees and customers. It is in the interest of this study to establish the impact of owner's education on the uptake of new technology and innovativeness in SMEs in Nairobi, Kenya.

## **Study objective**

This study aims to establish the impact of owner's education on the uptake of new technology and innovativeness in SMEs in Nairobi, Kenya.

## **Specific objectives**

- i. To establish the impact of owner's level of education on new technology uptake and innovativeness in SMEs in Nairobi.
- ii. To evaluate the effect of knowledge and technology sharing by research institutions on new technology uptake and innovativeness in SMEs in Nairobi.
- iii. To determine the perceived barriers to uptake of new technology and innovativeness of SMEs in Nairobi

## **Review of literature**

The theory of Organizational Learning as proposed by Garvin (1993) postulates that organizations can sustainably attain above average performance through organizational learning. Organizations should ensure that their employees are well equipped with novel knowledge for purposes of obtaining desirable organization performance (Armstrong, 2006). The theory recommends that organizational activities must be aligned to be adaptive to dynamic environmental changes (Murray & Donegan, 2003). While acknowledging that learning in an organization is most commonly done through training, Winter (2000) recommends that organizations must learn faster and better than their competitors from failures and success in order to attain high performance. Training entails an investment in attainment of skills for entrepreneurs in pursuit of enhancement of work productivity. Randhawa (2009) defines training as the act of augmenting talents to enhance productivity.

Edith Penrose is credited to have proposed this theory in 1959. It postulates that sustainable competitive advantage and performance results from the resources that are inimitable, unsubstitutable, tactic in nature and synergetic. The theory contends that this competitive advantage would cease to exist if the competitors could replicate the resource that gives the organization a competitive edge but this can only be possible if the organization lacks a certain superiority. According to Clulow, Gerstman and Barry (2003) having superior and adequate resources is a vital element needed to make organizations with competitive advantage over their competitors. The resources may be human or material resources (Passemard, 2002).

In agreement with this, Nyambegera (2002) believes that realization of organizational objectives depends more on optimal utilization of human as

opposed to physical capital. Lawler(2008) observes that organizational goals can only be achieved by focusing on human capital.

The resource-based view of the firm (RBV) is a popular strategic management perspective suggesting that very specific resources, competencies and capabilities are necessary to sustain a firm's competitive position (Barney, 1991; Penrose, 1959; Petraf, 1993; Spender, 1996; Wernerfelt, 1984). According to the RBV, it is the creation, ownership, management and deployment of intangibles, specifically knowledge and relationships, which explain variations in performance. In particular, intangibles that are valuable, rare, inimitable and non- substitutable, and therefore heterogeneously distributed, explain variation between firms. A firm must exploit and successfully deploy resources that competitors are not able to copy in order for resources to be of value. This perspective suggests that a key determinant of competitive advantage includes the internal organization of firms, and acts in conjunction with the external industry structure and positioning view of strategy as a key determinant of competitive advantage (Porter, 1980; 1985). In order to extend the theory to incorporate external market variations Teece et al. (1997) coined the term dynamic capabilities. Teece et al. (1997, p. 517) state that "winners have been firms that can demonstrate timely responsiveness and rapid and flexible product innovation, coupled with the management capability to effectively coordinate and redeploy internal and external competences". Hence, the dynamic capabilities perspective is not only inward-looking in relation to the organization and its strategies but also incorporates the notion of innovation. The core idea of the dynamic capabilities' perspective is that sustained performance is achieved by aligning the organization with shifting external environmental demands by achieving evolutionary fitness, defined as "how well a dynamic capability enables an organization to make a living by creating, extending, or modifying its resource base" (Helfat et al., 2007, p. 120). By definition, therefore, dynamic capabilities involve adaptation and change because they build, integrate and reconfigure other resources and ordinary capabilities.

Virginia (2019) studied innovation capability and Kenya insurance companies' performance. The research used descriptive statistics and all the insurance players in the country formed the study population. Data gathering was done using a semi structured questionnaire. The performance of Kenya insurance firms after implementation of innovation was established through linear regression approaches. The study revealed that insurance companies have a strong commitment to employee training and development thus improving the organizational capacity for innovation. Regression analysis established that innovation was significant in influencing organizational performance. The findings suggest that in order to enhance the insurance companies' performance, employees should be encouraged to come up with ways of achieving organizational goals and objectives by being creative

and innovative.

### **Data and methodology**

This study applied explanatory and descriptive research designs as it sought to systematically manipulate theoretically relevant variables and examine the outcome variables. It was cross-sectional in nature as it involved observation of a group of people at one specific point in time. The study applied a quantitative case study as it sought to adopt a quantitative paradigm.

The design was applied as it was deemed to be suitable as the researcher endeavoured to clarify phenomenon functions by determining the existing factors that produce change in it without manipulation of the independent variable. It was adopted to help interpret the relationship between entrepreneur's / manager's education and uptake of new technology and innovativeness

### **Research model**

The study will apply descriptive research design with the aim of accurately and systematically describing the SMEs in Nairobi County and their situation in uptake of new technology and innovativeness. This method will allow the researcher to thoroughly investigate the background of the research problem before further research can be carried out.

### **Target population**

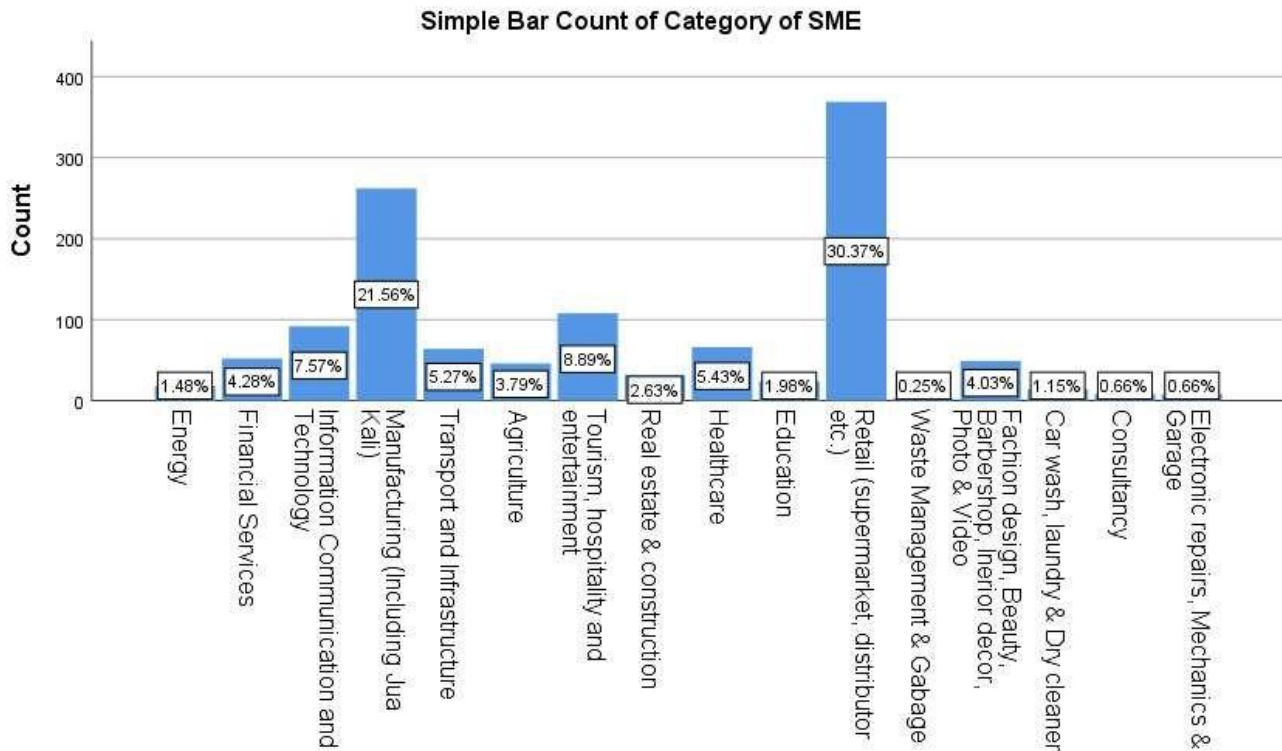
The population of the study comprised of the business owners (entrepreneurs) or senior managers SMEs in Nairobi City County. The owners were involved in the study as they were deemed appropriate due to the mandate of making decisions about the businesses they run as well as their knowledge about the business challenges and opportunities they encountered. Assistant researchers were employed to collect data from the SMEs in Nairobi County which were evenly distributed geographically. They were also mandated to collect data from businesses across the industries. A total of 1,200 business owners were interrogated for the study between January and February 2023.



## Distribution of the target population

The distribution of SMEs in Nairobi County was as shown in Figure 1 below.

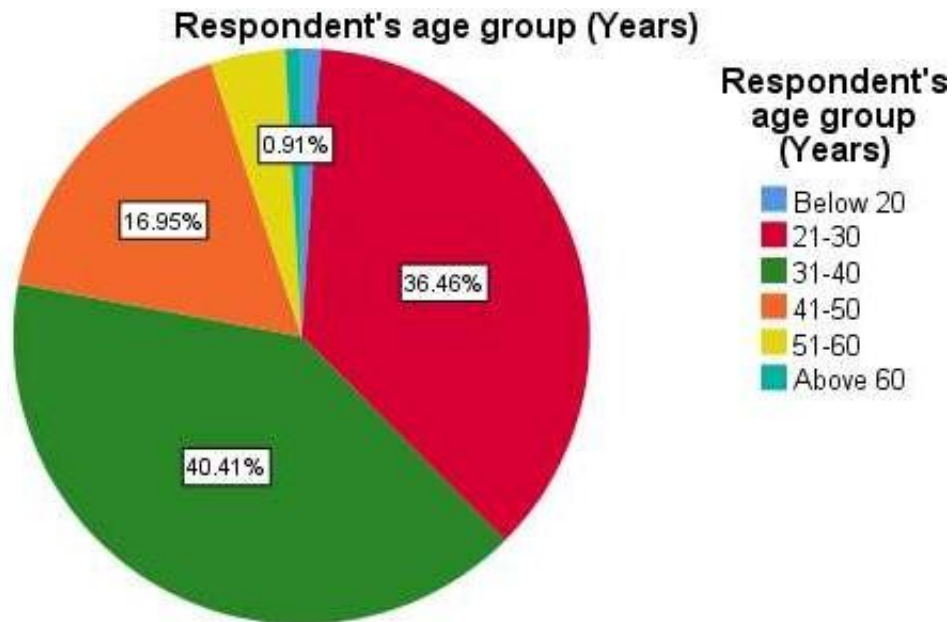
**Fig. 1;** Distribution of SMEs by industries in Nairobi County, Kenya.



From the figure above, it is evident that most of the SMEs are manufacturers (21.56%) and retailers (30.37%). These are industries that are faced by several challenges that hamper their growth and development and whose solutions lie within the research and innovation revelations that have been done in higher education and research institutions. There was no particular SME that was observed not to be in need of any invention or innovation. There is always room for innovation and technology transfer.

## Distribution of the Target Population by Age

Fig. 2; Respondents age group (Years)

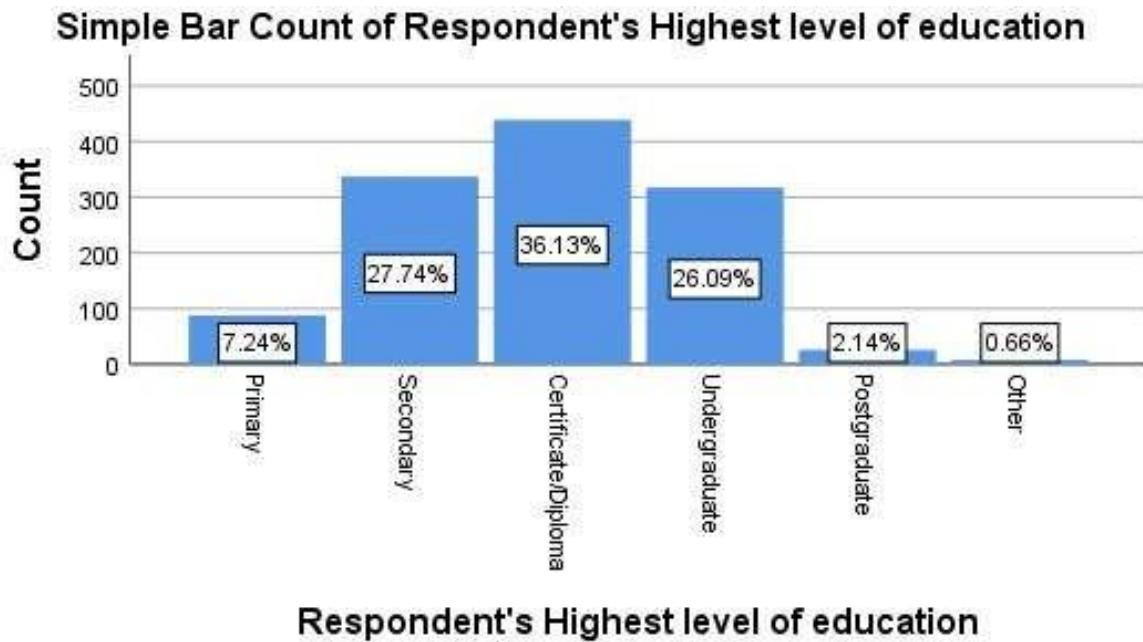


From the findings, the greatest percentage of business owners were aged between 31 to 40 years of age (40.41%) followed by entrepreneurs aged between 21 and 30 years of age (36.46%). The researcher observes that in Nairobi County, establishment of SMEs is not taken as a retirement plan but as a starting venture. This is a step in the right direction as growth and development of SMEs is expected. Also, the owners have the necessary energy and time to embrace innovation in their day to day running of businesses.

### Respondents highest level of education

The researcher sought to establish the respondents' highest level of education so as to gauge the respondents' ability to take up new knowledge and technology from the higher education institutions as well as their innovativeness. The chart below shows the distribution.

**Figure 3;** Respondent's highest level of education

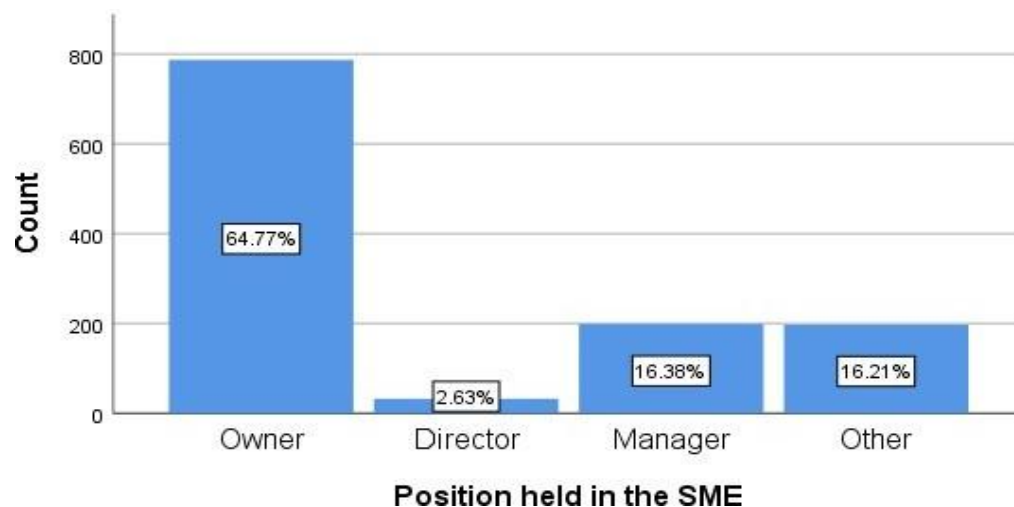


From the figure, the respondents who have only but primary education form a low percentage of 7.24%. These people may be disadvantaged on uptake of new technology and innovativeness if the complexity is beyond what they can handle intellectually.

#### **Respondents' Position in SMEs**

Figure 4 shows the distribution of respondents according to their positions in the business.

**Figure 4;** Distribution of Respondents by Positions in the SMEs



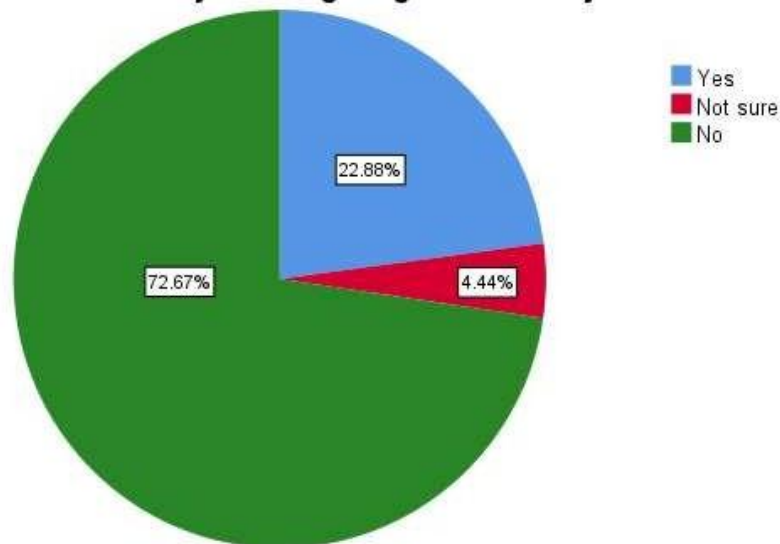
This was interrogated to evaluate the decision-making role that they enjoyed. From the results, the majority of the respondents (64.77%) were business owners. This indicates that on uptake of new technology and innovativeness, they are able to make the decisions if only they are guided.

### **Invention and innovation**

The respondents were also interrogated on whether they have been able to come up with new products (invention) or come up with new ways of running their businesses. The response obtained is as shown in figure 5 below.

**Figure 5; Innovation and Invention of SMEs**

**Pie Chart Count of Have you come up with a new product or implemented new ways of doing things in the last 2 years**

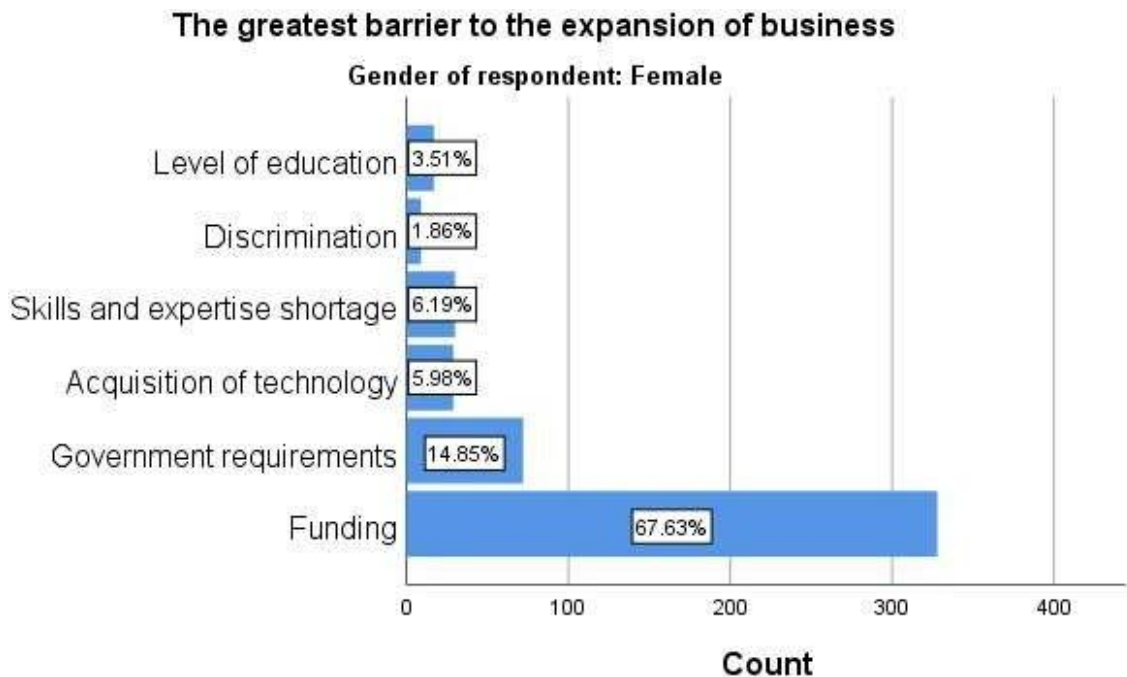


The results indicated that only 22.88% of the respondents have been able to be innovative or have taken part in invention. This trend is unacceptable in a growing country at the heart of the capital city of Kenya at the wake of the fast-paced advancement in information and technology.

### **Barriers to inventions and innovations**

It also necessitated the researcher to find out what are the main barriers to technology uptake and innovativeness in SMEs?

**Figure 6; Greatest Barriers to Expansion**



Respondents argue that while HEIs are building capacity how to be employees but not employers, spearhead new areas and new ways of doing things. The main factors that limit SMEs from coming up with new products and implementing new ways of doing things were identified as:

- Inadequate capabilities (technical, financial, and market) to compete with mega businesses
- Limited/no access to training, mentorship, and inadequate role models
- Legal and regulatory requirements to patent new products
- Failure to understand market trends, and Unwillingness to adapt to changing trends
- Capital-intensive nature of the innovation process

### **Sampling design and procedure**

The study adopted Clustering sampling design for purposes of inclusion. Eight regions in Nairobi City County were interrogated for the study. Purposive sampling method was then applied where only SMES in Nairobi city county were selected for the study out of 47 counties in the republic of Kenya. Purposive sampling is a non-probability sampling procedure where an in-depth exploration of research questions is enhanced through selection of the most

suitable respondents (Selvam, 2017). This method was preferred because there was no sampling frame and at the same time for purposes of inclusivity on gender and differently abled individuals.

### **Data collection instrument**

Collection of primary data was done through a structured questionnaire as a data collection instrument which was ideal because it is common to most people. Besides the ease associated with analyzing data collected through a structured questionnaire, it also has the benefit of minimizing possible researcher biases by eliminating the impact of the researcher's opinion on the respondents. The structured questionnaire enabled a standardized way of gathering responses as well as enhanced the easy analysis of data that was collected. It was also selected since the target population was literate. The questionnaire was deemed appropriate to bring out the owners' experience about uptake of new technology and innovativeness in their businesses in Nairobi City County as well as their position about knowledge. Matrix questions were applied where a scale calibrated into two or three points was chosen to facilitate gathering of varied but standardized responses.

As a requirement when conducting research, the researcher obtained a data collection authorization permit from the National Commission of Science, Technology and Innovation (NACOSTI) for authorized data collection. In observation of ethical procedures, the research assistants explained to the respondents on the purpose of the study and the usage of the information given before collecting data. The questionnaires were administered by the research assistants across the county. Questionnaires were filled up by the research assistants as they interviewed the respondents. The response was good as a considerable number of responses had been filled within two months. The research respondents were also invited for dissemination workshop after data was analysed and valid conclusions were drawn.

### **Data analysis and presentation**

Processing of data applied a step-by-step approach through a number of stages. Collected data was edited through a scrutiny of collected raw data to detect any errors or omissions. In rare cases, corrections were made to ensure that the collected data was consistent, accurate and organized. The questionnaires had information classified into specific concepts which reduced the collected data into homogeneous groups and arranged into logical order and displayed in compact form. Data coding was carried out by assigning symbols and figures in order to limit the number of categories of the responses. For ease of presentation and facilitation of reliable description, percentages were used to present data into a range of 0-100. Descriptive statistics were used to analyze quantitative data in terms of percentages, standard deviation and mean. Presentation of the results was then done by the use of charts and tables. SPSS computer package

was employed in the analysis of the collected data and various forms of tables were applied to interpret and present the results for better understanding.

## **Findings**

From the study outputs, findings were drawn to the fact that the new knowledge and technology availed by research and higher education institutions is applicable in the type of SMEs in Nairobi City County. The higher education institutions and the research institutions have the necessary information required by SMEs to enhance their growth and innovativeness. The level of owners' education determines not only their decision-making abilities but also their uptake of knowledge and technology from the higher education and research institutions.

The respondents do not have access to information on how information is disseminated from the higher education and research institutions. It is also evident from the study that the greatest barrier to innovativeness is not the fundings as claimed by the SMEs but access to information about inventions and innovation. This is because the higher education institutions and research institutions have collaborations with business incubation centres and sources of funds for business.

## **Discussion of findings and recommendations**

The type of new knowledge and technology emanating from higher education and research institutions should be packaged in a manner that is understandable to people at different levels of knowledge. The institutions should create dissemination hubs where invention and innovation ideas should be made available for access by SMEs. There should also be business incubation facilities offered by the institutions to aid knowledge and technology transfer. The SMEs should be taken through programs that focus on capacity building and equipping SMEs with the knowledge they need to embrace innovativeness for purposes of growth and development. Some policy makers should be involved in determining better policies that aid in improving the business arena of Nairobi City County. Based on these findings, further research should be carried out to determine to what extent the level of education of an entrepreneur impact on new knowledge and technology uptake by SMEs in Nairobi City County.

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# Valuation of Intellectual Property on Non-Fungible Token (NFT) Transaction for NFT Platform in Indonesia

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## Abstract

Recently, NFT enables its owner to sell and buy intellectual properties. The research result shows that an NFT transaction process - such as in the sale and purchase of intellectual property - required a determined price valuation. The authors consider that it is necessary to determine a clear valuation system to predict the exact price of the intellectual property digitally transacted on NFT. The price database on NFT can be used to determine the price by first collecting the NFT and can also calculate the value of the NFT in the future.

**Keywords:** NFT; intellectual property; valuation; digital transaction; digital economy; copyrights; NFT price

## 1. Introduction

NFT rose to prominence in April 2021, when work from a renowned neo-expressionist artist, Jean-Michel Basquiat gained public interest. It was said that there was a potential dispute over his work. "Free Comb with Pagoda," since Daystorm – the small firm that sold the drawing was suspected to have neither

license nor copyright for their actions in putting the drawing onto public bid and give a right to the winner to destroy the original physical copy. Basquiat had died in 1988 in his prime, after his death, his estate was administered by his father, until 2013, and then it was continued by his sisters afterward. The licensing agent handling Basquiat's work affirmed that Basquiat's estate never conveys license or copyright to parties other than itself. Hence, the trading of his unique and artistic works – which by its fact involve large sums of money, is inciting public debate.<sup>1</sup>

As such, NFT became a hype, notably in the field of art, it gives the possibility for people to own digital files of artwork while simultaneously destroying the original, if they so desired. But obviously, art enthusiasts – including the art licensing body that manages Basquiat's artwork are at rage and strongly against this notion.<sup>2</sup>

From Basquiat, many other examples come to follow, not long ago, an art collector bought a copy of Banksy's work, burned the original, and turned the digital copy into an NFT. Another example, is the viral video showing a baby biting his brother's finger, known as 'Char-lie Bit Me', it was sold as NFT for USD 500,000, with the video taken off from the internet after the sale has ended.<sup>3</sup> What exactly is NFT? How exactly its valuation can determine the price of a work? This article will answer both questions from a legal perspective, with the help of abundant technical explanations. The number of emerging NFT platforms in Indonesia makes the author want to provide input and at the same time take advantage of the emergence of government regulation number 24 of 2022, with the valuation in NFT it is expected that digital copyrights can be used as collateral.

## **2. NFT transaction**

### **2.1 Non-fungible token**

Despite that NFT's use case was pioneered by the digital transformation of artworks, however, to consider that NFT is solely defined as digital art is a misinterpretation. In fact, discussion on NFT will always involve matters concerning cryptocurrencies, smart contracts, and blockchain (commonly known as Distributed Ledgers<sup>4</sup>. (DLTs) Blockchain is a distributed and decentralized cryptography ledger, that is made available to the public by adding immutable information and records. DLT uses a non-proprietary underlying technology, any person can either create and run their network or join pre-existing one.<sup>5</sup> In other words, blockchains, including ethereum, shall also be included in the discussion.

Different from bitcoin with its promise of online currency secured from government's intervention – NFT is a particular digital asset or token, that can be proven unique and cannot be exchanged with other digital asset or token. From this understanding, its uniqueness speaks for itself why it can be easily

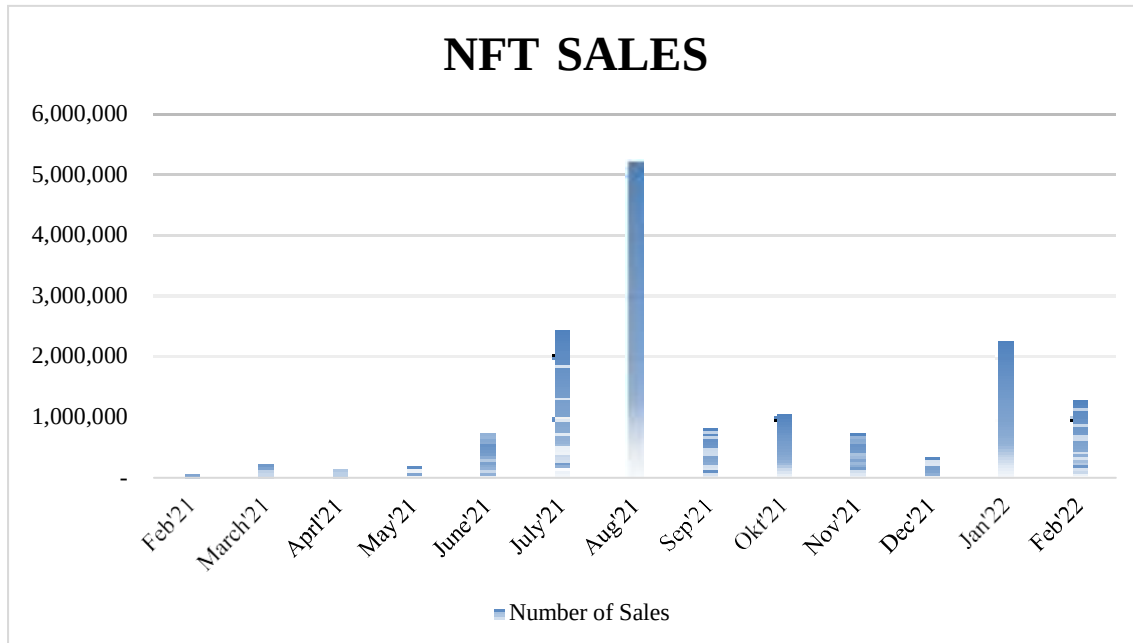
seen by anyone. Aside from functioned as information embedded to an asset, NFT may as well work as a digital asset,<sup>6</sup> as it is created under specific framework or standard using an on-chain. NFT has many features, among them, ethereum is one of the most widely used. There are many services possibly produced from ethereum, one of which is Ethereum Request for Comment ('ERC'). ERC is a form of smart contract that enable its users to access information on creating, issuing and distributing a blockchain. This way, NFTs can be managed, traded and owned following the framework property or protocol as specified according to the issuing property and following the smart contract entered into by the registrant.<sup>7</sup>

Ethereum shares common characteristics with other NFTs, such as (1) uniqueness, (2) transparency – profitability of ownership; (3) immutability of archiving and the (4) asset program capability. In terms of first, uniqueness and specificity, the characteristic of NFT lies on the limitation of its individual token. People can also find that NFT is either artificially, numerically or historically scarce. Artificial scarcity refers to its rarity of code or publishing specification. Since numerical aberration is related to artificial, thus, it is relative to range. Meanwhile, historical scarcity refers to significant historic element in an NFT's work<sup>8</sup>. The example of historical element in an NFT is the part of Cryptopunks' allure, which is considered as one of the first generative NFTs ever issued, and thus – unique in that sense<sup>9</sup>.

The following characteristic is the transparency and profitability of the ownership. For NFT that has a tangible asset in the real world, proof of ownership becomes the basis underlying the possession of assets, aside from the potential of fractional ownership.<sup>10</sup> Immutability is the next characteristic, where quality assurance inherent in all blockchain-based tokens may generate advantage to the NFT. Information embedded in the token is impervious to tampering without the compromise of the blockchain protocol's owner, in time, it will be resulting into substantial trust and transparency. Lastly – program capability of the assets, many considered this as an important differentiating factor that separates NFTs from the real-world assets. In addition to supporting artistic or business expressions, NFTs are as programmable as the software. Additionally, practical applications demonstrate how NFTs can be used as collateral in many DeFi applications, similar to mortgages.<sup>11</sup>

Ethereum is considered as the most popular token on NFT, its standard setting token is ERC- 20 that has rules on equivalence and value. Many non-exchangeable tokens often consist of digital records and conversion in such forms.<sup>12</sup> The NFT transactions were less than 1 million in the beginning of the year, but in August 2021, NFT users reached its peak with 5 million transactions of sales. This dynamic remains until the beginning of 2022, where the number of NFT sales reached 1.3 million transactions in February.

**Figure 1 : NFT Sales in 2021-2022**Source : nonfungible.com



Source : nonfungible.com

In carrying out transactions through NFT, one shall required to be aware on the technical knowledge regarding how NFT works and the relevant processes involved within:

## 2.2 Smart contract

In NFT, smart contracts are taking role to store unique information, such as ownership and transaction details<sup>13</sup>. Creators can add identities, secure links to files, and many more into the smart contracts within the NFT. Besides, they can also define specific rules on the NFT trading – for example, the royalty percentages received for each subsequent sale. Aside from making each NFT unique and valuable,<sup>14</sup> smart contracts enable creators or developers to specify the terms & conditions of NFT they want – for example, special rights granted to a specific group of people within certain NFT projects. This feature includes capability of exclusive access to drop for early supporters, gain prizes for participating in contests, lower minting fees for subsequent reductions, breeding collection, and many more<sup>15</sup>.

Smart contract explains all information on NFT in detail, by reading it, people is supposed to have better understanding to the NFT, either concerning the popularity of a project, ownership rights, details of transactions, or many others; it can even print NFTs directly.<sup>16</sup>

Within smart contracts, parties who do not recognize each other and participants in a decentralized system who entered into agreements without third parties; they usually propose a unified method engineered to build applications in various industries. The applications operated on top of smart contracts usually based on state transition mechanisms. The participants may share status containing instructions and parameters to ensure transparent implementation.<sup>17</sup> The smart contracts itself usually used in most NFT activities to ensure that the transactions executed as agreed.<sup>18</sup>

### **2.3 Intellectual property on NFT**

NFT helps intellectual property commodities such as art, games, collections and many more to find path in digital sales, at times, with unreasonable and unpredictable price. In its own way, NFT has become a new channel to motivate intellectual property owners to be more productive<sup>19</sup>. Due to NFT's unique aspects, intellectual property owners need to recalculate their strategy in protecting and licensing the respective rights attached to their works<sup>20</sup>. The IP protection strategy should include specific safeguards relating to NFTs.<sup>21</sup>

Many people assume that a sale of an artwork in the form of NFT will subsequently sell the same in its real form. However, in reality, this is not the case, sale and purchase in NFT signifies exchange of value to the digital records of the work only. NFT buyers spend a vast sums of money to buy metadata files and short strings of numbers and letters. It is indeed dubious in artistic value, however, that is the very hallmark of NFT.<sup>22</sup> Despite of that fact, NFT transactions are supposedly still involve matters on the transfer of rights, especially digital copyrights managed by digital managements. In Indonesia for example, the Copyright Law obligating any transfer of copyright to be "in writing ..., signed by, or on behalf of the person granting the rights." There is a grey area in this regard, since in case of transfer of rights, most of NFT transactions are having a hard time to comply with the statutory regulations. It isn't easy to judge whether digital form of work as NFT can met with and corresponds to the legal requirements and formalities required in transferring copyrights.<sup>23</sup>

Recognition of intellectual property rights goes into a whole different level after registration, it is not a new fact however, that its process in Indonesia is lengthy due to the existing bureaucracy system. Application of patents and trademarks may take years while securing copyright may take months. NFT may speeding up this process with a considerable confidence and assurance, that it may as well works as a mean of recording and protecting intellectual property's ownership.<sup>24</sup> This realization comes from the fact that blockchain is a place where people record ownership of works, it cannot be changed easily and hence may act as a verification method against the authenticity of a copyrighted work. Transfer of ownership in blockchain is also controlled and traceable, making NFT becomes

a possible exciting concept in the field of intellectual property.<sup>25</sup> The help from unique features in NFT technology possibly offer alternate protection to intellectual property applicants while they are waiting for the formal protection from the governmental institution. NFT ease the sale and purchase cycle, where creators have better chance, access and opportunities of earning money from their works. Blockchain also record transaction , it is capable of tracking intellectual property's ownership and may also facilitate patent's acquisition by democratizing intellectual property's licensing process.<sup>26</sup> NFT system in embedding automated royalty collection in each work is supporting intellectual property market in a way, and provide inventors with financial benefits whenever their innovations are licensed.<sup>27</sup>

When purchasing an NFT, one's ownership of a unique digital version of the underlying work or asset will be recorded in a token. When the NFT is transferred to someone else, the digital version of the underlying work or asset will also transferred along with it.<sup>28</sup> In most NFT issuances to date, it seems that there is a clear intention from the seller to not to procure ownership interest to the underlying asset. In other words, buying NFT is considered as equivalent to buying physical artwork, which rarely involves the subsequent transfer of the copyright.<sup>29</sup>

With respect to the underlying work in NFT, the original creator has the exclusive right to both retain the copyright and take specific actions concerning the underlying works limited by it, for instance – making additional copies, distribute, display or sell the works to other parties.<sup>30</sup>

When purchasing an NFT, one shall receive a token typically attached with the right to use a unique digital version of the embedded work for personal use, and to resell the copies of the work.<sup>31</sup>

The use of right granted to the buyers will be determined by the terms and conditions of the applicable license granted upon the NFT acquisition, which will be varied one another in each token. According to this fact, NFT companies or managers may enforce a more permissive terms and conditions in their licenses, that may allow him to access a broader range of rights to exploit the unique digital versions of the acquired work in the respective NFT.<sup>32</sup>

Some jurisdictions have recognized certain crypto assets as qualifying "property" (rights "in-rem"), however, the question will be, whether the courts will identify NFT as the proof of legal ownership of digital versions of linked assets or not<sup>33</sup>. Technically, NFT holders only have a unique set of numbers that amount to tokens in their electronic wallet, it allows them to decide where or to whom the NFT should be transferred. Arguably, it creates a factual control to the related assets that is similar to property rights. The logic behind this is the capability of the token to proof the originality of digital copy of the underlying images, sounds or texts embedded in the NFT.<sup>34</sup>



Despite its possibility to become an alternate intellectual property protection, NFT does not necessarily transfer copyright. Therefore, NFT buyers in this regard, have an unclear scope of rights' enforcement. This fact is raising question, whether NFT buyers can ask the original author to take action against someone who has created an unauthorized version of the underlying content? If for instance, someone forge the NFT, who will or can take action against him?

Besides, given that the copyright remains attached to the original creator, what if he then publishes more versions of the NFT, which increase the availability of the asset? In this case, the NFT may have its market value reduced, and may as well seen as non-beneficial factors for the buyers.<sup>35</sup>

### **3. Intellectual property valuation on NFT**

#### **3.1 Intellectual property valuation**

NFT may at times sold in unreasonable price, people will surely wonder, where does this price comes from and how to measure the value of the assets – if there is any valuation method exist from the first place. Before going to NFT valuation, one must firstly understand the gist behind intellectual property valuation. It is just as important, since most underlying assets in NFT involve man-made works that automatically entangled with intellectual property.

Basically, valuation<sup>36</sup> is the act of estimating or assigning monetary or other value to a matter – whether physical or non-physical, tangible or intangible. As an intangible matter, intellectual property relatively has an hassle-free valuation method, since it is already formally protected under either trademarks, patents, or copyrights. It is possible to trade them in unregulated market. Valuation involves the process of identifying and measuring the financial benefits of an asset,<sup>37</sup> it contains of two concepts. First, the narrow sense, the process of calculating the financial value of an asset which shall be resulted into "price." Second, the broader sense, the process of understanding the importance of intellectual property in a business and the process of managing intellectual property for the purpose of acquisition and exploitation.<sup>38</sup> Intellectual property owners, especially for patents, usually need a valuation to calculate or determine the value of their intangible assets.<sup>39</sup> There are three available methods commonly used to this date (i) market- based, (ii) cost-based or based on past and future economic benefits, and (iii) revenue approaches, as might be explained below.

#### **3.2 Market-based approach**

Intellectual property and intellectual capital are generally not developed for sale, even in case of trade, the value in the marketplace often represent only a tiny bit of a more significant transaction, where the details usually kept confidential. Thus, the market-based approach valuation in terms of intellectual

property and intellectual capital is more of an assessment to the fair market value of an object within the same market, of course, the comparison is made with the same goods or the substitute.<sup>40</sup>

Often times, appraiser is underlying their assessment by comparing intangible asset in question with the actual price people paid for similar assets with intellectual property or in similar circumstances. This method is popular in estimating an asset's fair value since it refers to transaction price or the multiplication of valuation implied in the transaction price of identical or similar assets in the market. The problem within this method however, is that it is usually challenging – almost impossible for the appraiser to find comparable deals. Since most intellectual property is made unique to a particular business entity, while intellectual capital does not represent presence of an tangible asset.<sup>41</sup>

### **3.3 Cost-based approach**

The cost-based approach is determining the value of an asset according to the internal expansion or external purchase made against the development of works, it is based on the principle of substitution. Within the cost-based approach, there is a component called a replacement cost, which shows today's cost of purchasing the replacement for intangible asset that has a comparable utility provided by the same assets available in the market<sup>42</sup>.

Due to its potential failure in capturing the revenue projection from assets embedded with either intellectual property or intellectual capital, it is usually inappropriate to use this approach to determine real valuation of an asset. Replacement cost adjusted to the obsolescence of an intangible asset is capable of creating a hypothetical to the new intangible asset comparable to its predecessor. Instead of determining real valuation, this method is more appropriate to be used as a cross-checking tool or as a rational decision-making model, that can assist purchasing decisions of assets with intellectual property that have relatively short history.<sup>43</sup>

### **3.4 Income-based approach**

This approach values intellectual property assets based on the economic income they will most-likely generate or in short, intangible assets adjusted for current values. As there are many aspects related to the calculation of income, different type of measurement to the economic income may be applicable in this regard, for instance, the gross or net income, gross profit, net operating income, income before tax, net income after tax, operating cash flow, net cash flow, etc.<sup>44</sup> The most essential element in applying the income method is to ensure that the discount or the capitalization rate applied will be lowered consistently according to the economic income measurement.<sup>45</sup>

The biggest challenge in applying this method is to estimate the revenue, setting a realistic discount rate and determining the reasonable life cycle of intangible assets and intellectual property assets. While the longevity of the intellectual property itself will be largely depending on many factors such as technology obsolescence, revenue reduction, product life cycle, intellectual property's adaptability against dynamic in the market, etc. Since the factors are often far from subjective, it is necessary to assess inputs from those factors through the experience of a specialist.<sup>46</sup>

In terms of estimating royalty rates, one must consider the comparability of the licensing transactions, notably the profitability and growth factors between the intellectual property subjects and the its comparison. Some transactions also have some kind of upfront and milestone payments that can tag along with the royalty payments; these valuation nuances should be considered before arriving at a comparable royalty rate applicable to a certain intellectual property subject.<sup>47</sup>

In the income approach, the DCF method formula commonly used in the income approach is<sup>48</sup> as follows:

$$PV = \sum_{t=1}^n \frac{CF(t)}{(1+r)^t}$$

PV = Present Value

CF = Cash Flowr = Risk

t. = Time

Despite being common, the traditional methods as mentioned above have their own list of possible defects, which may limit their own effectiveness. These include, particular buyers, different negotiation skills, and the distorting effect of the peaks and troughs of economic cycles. Nonetheless, it is still helpful to have several valuation methodologies on hand, it may help to provide a rational basis to set fair price both to the intellectual property and the intellectual capital. However, intellectual capital is rarely valued or assessed through traditional valuation methods. Hence, the author believes that it is time for alternative assessment approaches to go to the surface.

### **3.5. Artificial intelligence valuation intellectual property for price on NFT**

The unpredictability of price and dependency on bargaining process at auction, are making NFT becoming both most sought after and much avoided commodity at the same time. While the former is mostly occurred to intellectual property

owners seeking for huge profits overnight, the latter probably happened to many collectors. This unpredictability of price in NFT may either benefit or harm the buyers, they might buy at a high price, just to see it plunged when the popularity declines.

*Since its technology is difficult or impossible to duplicate, NFT is unique and as a consequence, it is valued by people. It is renowned that NFT is also a rare collector's item, which makes its price increase day by day. Some people in groups or communities are active in creating NFT that stands out from the rest, for instance among celebrities and big brands. When they try to sell NFT, it will most likely to be a hit due to their credibility and recognition. It is then worth to note that building a community around credible and recognized membership in NFT are also important. Meanwhile, people who invest early in artistic projects usually expect rewards and additional benefits in return for their investment. Fundamentally, human emotions and culture are driving the relevance and sensation arising around the NFT projects. As a result, there is a bargaining process in determining NFT's price. At times, the cost of a work can be very expensive due to a high demand and increasing trend, making NFT's price relatively dynamic, and cost of a work does not always have a fixed price.*

Based on the nature of its price, NFT can be categorized as Veblen goods in digital form, whereby community plays a vital role in determining its value. According to Thorstein Veblen, (1899) "Veblen effect" appears when consumers from the rich show a willingness to pay in a very high price for equivalent functions of goods and services that are conspicuous to advertise their wealth, thereby achieving more excellent social status. Veblen's writings have spawned a large amount of research on "prestige" or "status items,"<sup>49</sup> one of which is describing the "Veblen effect" as mentioned earlier. The goods categorized as influenced by this effect are those commodities whose price increased in line with demand, it provides value as a form of social recognition to their owners. A simple example of Veblen goods is Rolex, as a watch, it theoretically has less functionality than smartwatch, but people still buy it. It is a given since people do not buy Rolex to know the time but to gain public recognition.

Analogously, having an NFT at an expensive and illogical price gives the owner a first class recognition around his community. NFT's value may increase even more as investors and passionate fans discuss it in their community channels, for instance such as on Discord or Telegram, subsequent trade amongst themselves often follow. Style of language, interactions and jokes inside such community, are determining the possible price of an NFT. Those communities are keeping the wheels turning in driving the force behind the success of many NFT projects. They hold an important role in the growth sector, it increased sales volume up to \$10.7 billion in the third quarter of 2021.<sup>50</sup>

Nevertheless, this uncertainty in NFT's price and valuation is influencing the

essential value of the relevant work. Due to the absence of fixed or minimum price of a work, NFT's pricing becomes obscured. In time, this might harm NFT's owner when they invest to a work that might suddenly slumped in price. In this case, the author consider that a valuation method is still needed to give people some kind of manual in presuming the price calculation of a work. The conventional valuation methods as described above may be usable in this regard to evaluate works sold in NFT, among the 3 approaches, the market-based approach and the income-based approach are possibly the most appropriate to measure the value of the NFT.

### **3.6 Database for market based approach on NFT system**

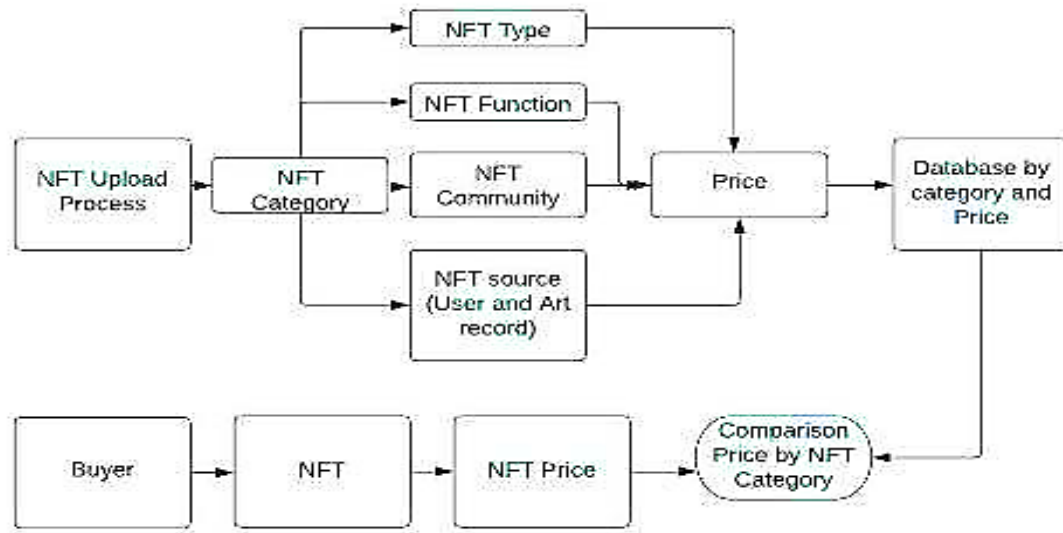
Since the NFT system was born until the time the work to be evaluated was uploaded, there will be a lot of data that can be categorized based on its type or function in the NFT, this data can be used as a database to compare the prices of existing works and the works to be priced. Database of similar works and their prices are also important for consumers who will buy works so that consumers do not buy works that are too expensive and lead to losses.

In contrast to patents on NFT, which are dominated by copyright, the calculation does not focus on new technologies and life cycles because copyright only focuses on "original" works or not works uploaded in the NFT. Therefore, when recording works in NFT, detailed data must also be entered in the system, such as when the work was created, where the work was made, who made it, whether there is proof of copyright registration from the territory, whether or not the work is reproduced and so on. This data will be recorded in the NFT and become a database when there is data that is almost the same or similar, what is also important is the transaction price that has been carried out for a copyrighted work in the NFT is also important to be used as a database and informed to NFT users. Because the essence of the market base is to determine prices based on market prices, so the more data for similar works, the more valid the prices that will be used as references.

As discussed, one might measure NFT's value by comparing at least 2 similar works in using the market-based approach. Despite that it might be hard or nearly impossible to find similar works when intellectual property or intellectual capital are involved, however, this method might actually help to give the gist in estimating a work's valuation. Buyers as the party who submit demand, also have different interest from one another, they might have different judgment in mind for the same work. Likewise, intellectual property is often times uniquely attached to a particular business entity, while intellectual capital does not represent a concrete asset. In this regard, the goal is most likely unrelated to finding the similar work, yet to value a work based on how scarce a similar work is in the market. Rarity and uniqueness of a work might become a determining factor in judging estimate fair value of a work in NFT.

In this article the author offers a database recording to form a price comparison in NFT sales which will be illustrated in the following diagram:

**Figure 2 :** NFT price database recording for price comparison in NFT sales



For this reason, an appraiser will most likely need other valuation element to support the process of using the market-based approach. In evaluating works in NFT, the element of market price alone shall not be sufficient to determine a fair purchase value of a work. Other factors that might be important is utility, reputation and liquidity. Utility refers to the answer to the question on how NFT can be used and what the owner can do with it, while reputation refers to the value attached to the NFT as meant by the original creator, and liquidity refers to the answer to the question on how easy it is to acquire and sell the NFT<sup>51</sup>. A social media company called Enevti realized this issue and thus created a swappable NFT social media platform to help fans to connect with their favourite creators.

In terms of liquidity, the price of a work in NFT is evaluated by assessing on how easy will a company convert its assets into cash. Liquidity is a term used in the securities market. It allows investors to estimate the duration of time they will likely need to liquidate their shares and assets into cash. If the company is illiquid, investors will become wary, the company will face challenges in raising funds and thus may stop growing. In a nutshell, liquidity refers to the degree of which an asset or security can be bought or sold in the market without affecting the asset's price. NFT's liquidity is the degree of easiness where it can be purchased or sold within the network for cash inreturn<sup>52</sup>.

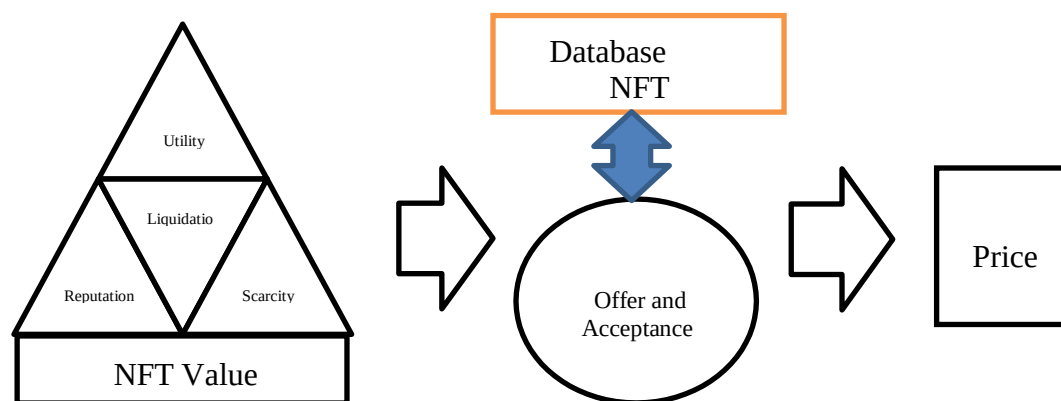
In most cases, NFT<sup>53</sup> trading is not made for cash, but for swaps, buyers usually exchanging tokens or token shards one another, that represent different NFTs in

identical blockchain. This token exchanging transaction however, may cause problems in terms of liquidity, since there are no cash involved within. After all, liquidity of a network depends on its size, the number of transactions took place within, and the liquidity attached to that system. It means that liquidity is a significant factor in determining the price of an NFT, since the price stability of an NFT (or any assets attached therein) shall be increased as its liquidity advanced. Now, if NFT's uniqueness were only limited to embedded to just one blockchain, then there would be a limited number of transactions, which in theory would go against the increase of price and price stability.

Liquidity is a problematic aspect to adopt in producing mass NFTs in the real world as an asset for trading. For all of the reasons above, it is challenging to determine the definition of liquidity for an NFT<sup>54</sup>, since different assets will have different liquidity depending on each user's needs. Some people may want to swap their NFTs one another, yet some may wish to take it in a liquidity pool (DeFi), while the rest may intend to exchange it for cash instead. All-in-all, easy liquidity is essential for NFT in increasing the number of broad users and to enable it to be accepted by widercommunity<sup>55</sup>.

Other than liquidity, supply and demand may as well take role in maintaining price stability. Unlike stocks or bonds that requires a centralized system to enable people acquiring them, NFT is managed in a more decentralized system where two users can transfer unique crypto assets between them directly. Nonetheless, the author consider that it is not enough to generate NFT value.<sup>56</sup> Instead of just standing in one aspect of either scarcity, utility, reputation, or liquidation, it appears that NFT value may shine brightest when the aspects are combined to extend its relevance:

**Figure 3 :** NFT Price using database price



As mentioned earlier in this paper, each and every elements of NFT valuation has its own down sides, and it appears that appraiser will pretty much face hurdles in using just one element within an approach over another<sup>57</sup>. It will be

a whole different story if an appraiser try to fill-in the gap resulted from a certain element used in a method by using another element in the same approach in return, for instance, by combining the utility, reputation, liquidation, and scarcity elements of the NFT to produce a certain value.

The utility element may answer the very purpose of the presence of a work, be it just used as an avatar or used as a valuable collection. It may as well be used as a rare asset,<sup>58</sup> where the more usability it can give, then the higher its value will be. Meanwhile, a *reputation* of an NFT refers to *the journey gone through by a work right from the start until it is purchased by a buyer. The more famous the work, the higher the price will be, and the fame in this regard shall be determined by the combination of assessment from the owner of the work, the value of previous transactions, and reviews from the previous buyers and influencer.* For instance, a work will gain higher reputation when a community consider that this work is attractive, communication containing information about this work will travel among the community members through social media such as Twitter, Youtube and Instagram. Some might take photographs,<sup>59</sup> and automatically many parties will bid for this work's reputation.<sup>60</sup> The liquidity of a work is related to its location, whether an NFT is created by a trusted source or not. It is also concerning the easiness of an NFT to turn into cash and whether it is complicated to liquidate it or not. This element will notably be more important if the transaction is made for business purposes, and not for owner's personal satisfaction only.<sup>61</sup> To add the 3 elements, scarcity might close the final gap, as it defines the uniqueness of the work, it might signify NFT value by how difficult it is to find similar work in the market. Even though each NFT is unique, each NFT has different degree of scarcity. The harder it is to find similar work, then the more valuable an NFT would be.<sup>62</sup>

Although there has been no uniform approach to calculate NFT valuation, however with this scheme, it is not impossible to estimate NFT's price. Indeed, some elements such as reputation and scarcity are relatively difficult to calculate, yet the presence of other elements in this regard may as well cover the shortfall. Since NFT is unique, to estimate the value of a work in an NFT, one must conduct a specific valuation to a designated work or NFT on a case by case basis. In the end, valuation shall be useful at the gate of decision making when a purchase and sale activities occur, either to calculate the value of an asset, an artist or a work's owner. It can also help NFT owners or other parties that might be harmed or injured due to the uncertain price in NFT.<sup>63</sup> After all, accurate decision making is a must in the NFT space. One wrong move or decision making will possibly tarnish one's reputation, it is arguably the most important currency for anyone involved in the industry. Even with all the money in the world, the best ideas, or the most profitable network connections, one wrong move may end up denylist a person from his community. Once the crash happened, it will be difficult to restore any grades he intends to show.

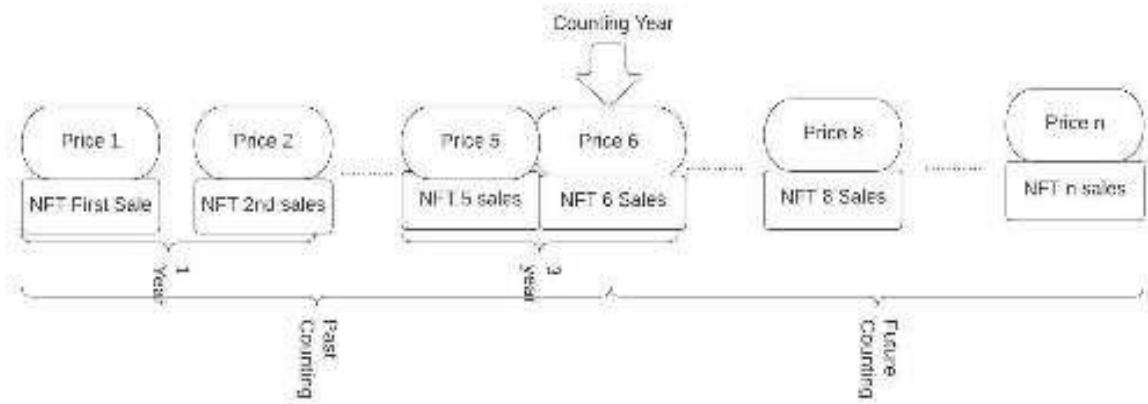


### 3.7 Database for income based approach on NFT system

The price database in works in the NFT can also be used for calculating the income bases approach. Although in NFT it is not necessary to calculate the value of future works because what is needed is the price of the current NFT, there is nothing wrong if we study to think ahead that NFT in the future also needs asset valuation so that it can be used as collateral<sup>64</sup>. Based on this, we can first map out what the function of the database is in calculating asset valuation based on this income-based approach. The price database for an NFT item whose asset value will be calculated from this database will record the price since the first NFT was sold until the year this NFT is calculated, then what is the function of this database for future calculations, from this database it can be seen up and down from sales works that will affect the value of the dicount rate in calculating the Income base approach.

This value can also apply vice versa, if the database shows a stable value, then a stable risk DCR value is used in the range of 0.5-0.75. Then the database can help determine the value of future NFT works. This assessment scheme can be described in the following scheme:

**Figure 4 :** Database Record For Valuation Income Base Approach



if the database collected from the NFT was first sold in figure 4 at price 1, then if the calculation starts from the sixth price at the 6th sale, the cashflow starts from the first sale until the year of calculation to predict the value of income in the coming year, the price in the scheme in figure 4 is applied in the DCF formula.

$$PV = \sum_{t=1}^n \frac{CF(t)}{(1+r)^t}$$

PV = Present Value CF = Cash Flow

r = Risk

t. = Time

In calculating the formula if you see a fluctuating NFT price, it means that the risk (r) becomes high, the database will affect the valuation of the NFT work and this value must be present when the NFT buyer will make a purchase transaction for an NFT on one of the NFT websites, the buyer will not feel disadvantaged buying NFT. This is because the system has assessed the future value of the purchased NFT. With this scheme, it is hoped that it will minimize the losses that will be suffered by NFT buyers<sup>65</sup>.

#### **4. Conclusion**

Every work submitted to the NFT supposedly part of intellectual property, thus, it has several methods of intellectual property protection, notably towards the digital record of the works until the very ownership can be transferred to the buyers. In NFT, intellectual property owners can monetize and get remuneration over the NFT they own through conducting transactions, this will surely come with a price. Unfortunately, prices in NFT are sometimes being erratic, unreasonable and difficult to predict, which in turn confusing both the sellers and buyers. They might as well have no idea on what is more fateful to execute, and whether they might be at loss or not. Nonetheless, being difficult does not mean impossible, the author consider that there must be a definite method to determine the price of an NFT, and this paper will hopefully able to give such recommendation.

To determine a pricing, one must start from valuating NFT works, from the existing conventional method of intellectual property valuation, the market-based approach is probably the most appropriate to use in this regard. In the market-based approach, the valuation of a work traditionally viewed from comparing value of at least 2 similar goods in the market, which in this case, 2 similar works that have been traded in NFT. Albeit it is theoretically seen as possible, it is practically not, the unique characteristic of an NFT making it quite tricky to find similar works in NFT. To fill-in the gap, an appraiser may look at other elements that affect the value of an NFT work, namely the utility, reputation, liquidation and scarcity. Indeed, the reputation and scarcity elements are still challenging to quantify in determining one's work value. However, the combination or addition of these elements in executing the market-based approach may help to ease the task of an appraiser to value a work in the NFT on case by case basis. The value resulted may be used as a reference to determine the price of an NFT, particularly in the transaction process

occurred between the seller and buyer at the time they submit requests and offers. After all, the end price shall be the number they agreed upon in the bargain process. Ultimately, NFT is a mean for creators to shake up the art industry and expand features and functionality, and it will be helpful for many existing and future industries. Thus, it is important for the relevant community to continuously develop better system for the NFT market, including the estimation to valuation and pricing mechanism. the price database can be used to determine the price by first collecting the NFT of a type and showing the comparison price the buyer will buy the work in the NFT and the price database can also calculate the value of the NFT in the future based on the income basis approach which can be used as information for the value of the buyer of the asset which will be purchased in NFT for the next few years.

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## Notes

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