20TH ANNIVERSARY GLOBELICS INTERNATIONAL CONFERENCE 2023

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

Vol I - Science, technology, innovation: Theory and policy for a knowledge economy

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Volume I
Science, technology, innovation: Theory and policy for a knowledge economy

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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 acrossthe- 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

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Systems of innovation and economic theory: Discipline and discourse[1]

Mario Scerri[2]

1. Introduction

In the early 1980s Nelson and winter (1982) addressed the question posed more than eighty years earlier by Veblen (1898) as to why economics was not an evolutionary science. The volume of collected work edited by Dosi and others (Dosi et al, 1988) brought together contributions from a wide range of theoretical positions and schools of thought on the relation between technological advance and economic change. Concurrently the concept of national systems of innovation emerged in the writings of Freeman (1982, 1987, 1995), Lundvall (1985, 1992), and Nelson (1993). This remains, to date, one of the more comprehensive attempts at formulating the conceptual framework of an account of the general economy as an alternative to that provided by mainstream economics.[3] However, the promise held by the theoretical breakthroughs of the time has to a large extent not been fulfilled. Most of the research that followed focussed on a narrow interpretation of innovation as technology and its diffusion and deployment among private business enterprises. The narrow version of the system of innovation (Lundvall, 1992; Cassiolato and Lastres, 2000) is nowadays the most commonly used interpretation of systems of innovation, implicitly restricting the approach to an alternative, albeit significant, account of a sub-sector of the economy.

If the system of innovation approach to economic dynamics were to be studied as an emerging discourse[4] which alters the spaces of political economy, we will have to trace its genealogy and its various evolutionary paths. We will need to identify its common cause, its theme, and the counter-discourse against which it seeks its identity. We will have to chart its delineation lines, and its criteria for the inclusion of what are defined as its legitimate objects of analysis. If, to use Lundvall's term (Lundvall, 1992), the system of innovation approach can best be seen as a 'focussing device', we need to discern the direction of its lens and the outer limits of its focal range. The following section traces the origins of the system of innovation approach from List to Schumpeter in relation to the shifting core of mainstream economics. The section after that looks at the emergence of neoliberal economics as the mainstream and the relationship of the system of innovation concept to this mainstream. The final section concludes with a brief appraisal of the current positioning of the system of innovation approach within economics and the possibilities for the fulfilment of its promise to become an alternative general theory of economics.

2. The classical debate

The introduction of a systems approach to the study of political economy may be found in List's (1841) thesis on the 'national system of political economy', a harbinger of the national system of innovation. List had early on argued against the benefits of free trade advocated by Smith (1776) and Ricardo (1817). He maintained that the'cosmopolitical' economy premised by Smith, Quesnay (1758) and Say (1821) in their argument for the welfare benefits of free trade was a utopian world which bore little relevance to the reality of nations and nation states whose economic fortunes were the result of historical lines of path dependence and cumulative development (List, 1841: Ch. 11). He termed the study of these national economies as political economy in contrast to the cosmopolitical economy based on an assumption of a unified global economy devoid of contending national interests.

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While List is probably best known for the 'infant industry' argument for protectionism, echoed a century later in the Prebisch-Singer thesis (Prebisch, 1950; Singer, 1950), the lines of his argument which have significant implications for the study of political economy are less remarked on in the history of economic thought. His policy departure from the core school of economics at the time was the bringing to the fore the role of the state in altering the development trajectories of national economies, a normative injunction which was diametrically opposite to the advocacy of intra- and inter-national free trade stemming from Smith. The contribution of List to economic thought rests on three fundamental objections to what he terms the 'popular school'[5]:

> **firstly,** ... boundless cosmopolitanism, which neither recognises the principle of nationality, nor takes into consideration the satisfaction of its interests; **secondly,** ... a dead materialism, which everywhere regards chiefly the mere exchangeable value of things without taking

> into consideration the mental and political, the present and the future interests, and the productive powers of the nation; **thirdly,** ... a disorganising particularism and individualism, which, ignoring the nature and character of social labour and the operation of the union of powers in their higher consequences, considers private industry only as it would develop itself under a state of free interchange with society (i.e. with the whole human race) were that race not divided into separate national societies. ((List, 1841, Vol. II: 70, bold added)

Levi-Faur (1997: 360) maintains that List may be seen as the 'founding father of economic nationalism', a school of political economy which has, until relatively recently been neglected in light of the dominance of the two contending economic schools of liberalism and socialism. List questioned Smith's focus on a theory of value, exchange value, as the explanation of the wealth of nations, proposing instead a theory of 'productive forces' based on the capacity of humans to work and innovate. Levi-Faur is correct in pointing this contribution out as the theoretical foundation of human capital theory which Foucault (2004)[6] postulates as the cornerstone of American neoliberalism, pioneered in the works of Mincer (1958), Schultz (1961) and Becker (1962).[7] However, List's elaboration of his theory of productive forces goes considerably beyond the individual as the subject. In its emphasis of the critical role of social relations, of ideology[8], of national power, and of history it opens the way for broader approaches to the role of the complexity of human relations and social formations in the fortunes of national economies, such as Sen's (1999) theory of human capabilities and to Marxian critiques of human capital theory (*vide* Bowles and Gintis, 1975). To fully appreciate the extent of List's theory of productive forces it is worth quoting at length a passage from his work (List, op. cit.: 29-30):

> The present state of nations is the accumulation of all discoveries, inventions, improvements, perfections, and exertions of all generations which have lived before us; they form the mental capital of the present human race, and every separate nation is productive only in proportion in which it has known how to appropriate these attainments of former generations and to increase them by its own acquirements, in which the natural capabilities of its territory, its extent and geographical position, its population and political power, have been able to develop as completely and symmetrically as possible all sources of wealth within its boundaries, and to extend moral, intellectual, commercial, and political influence over less advanced nations and especially over the affairs of the world.

This passage from List highlights the complex combination of various factors which enter in the determination of the developmental capabilities of the national economy. More than that and especially significant not only for the system of innovation approach but for evolutionary economics in general, this passage brings in the critical importance of historical streams of accumulation in the determination of the fortunes of national economies. In his comparisons of the historical paths of the development of different European economies, List introduces the concepts of specificity, path-dependency and cumulative development which were to become the cornerstones of the system of innovation approach to economic dynamics. The focus on technology and knowledge and its integration at the core of the national economy,[9] which is essentially exogenous to the economic system conceived by the neoclassical school, is echoed less than two decades later in Marx's *Grundrisse*.[10]

List particularly objected to Smith's notion of the 'invisible hand' which argues that the unfettered single-minded pursuit of individual gain assures the maximisation of societal welfare, an outcome which is guaranteed by the forces of competition. This argument was then extended to the global economy in the advocacy for free trade policy, based on the presumed equivalence of the private family economy to the national economy.[11] List's counter arguments formed the basis, not only for the case for protectionist policy in the case of unequal trading partners (the infant industry argument), but also for the critique against the school of economic individualism (Hayek, 1948; von Mises, 1949) which laid the foundation for the Chicago School version of neoliberalism.[12] Lundvall (1992), Freeman (1995) and Soete et al (2010) unequivocally identify List as the progenitor of the national system of innovation concept with his emphasis on knowledge, broadly defined, accumulated over time as the outcome of linked interactive processes set within a framework of social and power relations, as the prime determining factor in the evolution of the fortunes of national economies. They see him as the pioneer in the development of a systemic approach to the understanding of political economy, spanning economic and non-economic sectors from an institutional perspective.

If Smith's classical economic liberalism was so very explicitly List's *bete noire*, it is not immediately obvious to discern the positioning of Schumpeter's critical thought. The recurrent engagement throughout most of his work, culminating in his *Capitalism, Socialism and Democracy* (1943), with Marxian economics was an ongoing critique of various facets of Marx's work. However, read properly most of Schumpeter's critique of Marx was against a vulgar utopian and totalising version of Marxism.[13] Substantively, there are numerous significant commonalities between Schumpeter and Marx in their analysis of capitalism. Both see capitalism as historically and spatially specific and both view the bourgeoisie as the font of innovation and human progress.[14] Both authors also predict the eventual collapse of capitalism through processes which, while different, are inevitable and propose strikingly similar views on the dynamic (r)evolutionary nature of capitalism.[15] However, Hodgson (2002) argues that, in spite of Marx's insistence on historical and locational specificity, Marxian economics cannot avoid the ahistorical, transcendental universality of its key concepts. Ironically, this places Marxian economics alongside neoclassical economics as universal meta-accounts of the general economy[16] and this perhaps is where Schumpeterian and Marxian economics part ways.

More fundamentally, it was the Lausanne school, spearheaded in the late nineteenth century by Walras (1899) and Pareto (1897), which constituted the emerging dominant school against which Schumpeterian economics is set. The high level of abstraction of neoclassical economics, divesting economic agents of historical, spatial, and cultural contexts, combined with the extremely restrictive assumptions of full and perfect information places the neoclassical paradigm as diametrically opposite as one can get to Schumpeter's understanding of economic dynamics. Schumpeter was probably the first consistently critical anti-equilibrium economist who implicitly discarded comparative static analysis and Paretian welfare prescriptions.[17] It is therefore ironic that Schumpeter's work was still strongly anchored in the neoclassical paradigm which, especially since Alfred Marshall's *Principles of Economics* (1890), had already become the dominant language of economics. The first section of *The Theory of Economic Development* is basically a general equilibrium depiction of a static economy. His critique of Marx's labour theory of value (Schumpeter, 1943: 21) states that it would only work under conditions of perfect competition, i.e. where the value of the marginal product of labour is equal to its marginal revenue product and to its marginal cost which under the neoclassical construct of perfect competition is a constant. Schumpeter also states that labour would have to be the only factor of production and it would have to be uniform for the labour theory of value to hold.

It is almost as if Schumpeter is not fully aware of the enormity of the promise of a rupture with established thought on economics held out by his theory of economic dynamics. As a consequence, Schumpeter's contribution can still be read, using neoclassical language, as endogenizing factors which were previously thought of as exogenous causes for an outward shift in the production possibilities frontier, rather than an outright dismissal of the conceptual framework behind it. It is worth noting that when Schumpeter lists the sources (types) of innovation he almost always refers to them as 'new combinations'[18] adhering to the language of choice under conditions of scarcity rather than opening up to the possibility of questioning scarcity as a meaningful consideration in the understanding of the limits to development.

Schumpeter's classification of 'new combinations' (innovation) is worth reproducing in its entirety (ibid: 66):

> (1) The introduction of a new good — that is one with which consumers are not yet familiar — or a new quality of a good. (2) The introduction of a new method of production, that is one not yet tested by experience in the branch of manufacture concerned, which need by no means be founded upon a discovery scientifically new, and can also exist in a new way of handling a commodity commercially. (3) The opening up of a new

> market, that is a market into which the particular branch of manufacture of the country in question has not previously entered, whether or not this market has existed before. (4) The conquest of a new source of supply of raw materials or half manufactured goods, again irrespective of whether this source already exists or whether it has first to be created. (5) The carrying out of the new organisation of an industry, like the creation of a monopoly position (for example through trustification) or the breaking up of a monopoly position.

There are three critical aspects of Schumpeter's thought on innovation which arise from this excerpt. In the first place, the introduction of disruptive innovations as the source of creative destruction and development marks a radical theoretical break with the static and comparative static analysis of neoclassical economics. Secondly, the site of innovation as the source of economic development is confined to private enterprises, affirming capital as the engine of progress and development (vide Nelson, 1990). In this regard it is worth noting Sweezy's commentary on Capitalism, Socialism and Democracy, where he concludes that Schumpter's '... selection of the entrepreneur, a special sociological type, as the primum mobile of change can be called into question. We may instead regard the typical innovator as the tool of the social relations in which he is enmeshed and which force him to innovate on pain of elimination' (Sweezy, 1943: 96). Thirdly, within the context of private enterprise Schumpeter's understanding of innovation is remarkably comprehensive. Schumpeter's first two types of innovation refer directly to technological innovations (product and process), although the second one also opens up the consideration of marketing strategy as innovation. The other three categories refer specifically to non-technological innovations, dealing with various aspects of business strategy. It is interesting that the flow of theoretical work on the economics of innovation which emerged from Schumpeter's contribution focussed almost entirely on technological innovations. Only with the introduction of the system of innovation approach in the 1980s and the broad version of the concept (Lundvall, 1992) was a comprehensive version of the national system of innovation introduced in a theoretically systematic manner.

3. Discipline and discourse

Given that the foundation of the new approach to the understanding of innovation and economic change was set as a counter to the mainstream neoclassical paradigm, it is important at this stage to examine certain core aspects of the dominant voice which defined the discipline of economics. If the ideal of scientific probity in the social sciences was linked to the natural sciences, the epitome of scientific endeavour for economics towards the end of the nineteenth century was to be found in Newtonian physics which had at that time, before the scientific revolution stemming from the work of Max Planck and Albert Einstein, so comprehensively explained the known universe that physicists were concerned that there was nothing of significance left to discover about the physical world. The ambition to achieve a scientific equivalence in economics was fulfilled in the formulation of the general equilibrium model of the economy developed by Walras and the Lausanne school, with the underlying general optimality conditions provided by Vilfredo Pareto. This enterprise required the shedding of all but the simplest behavioural assumption guiding economic agents classified as consumers, firms and labourers.

Action, for every category of agent, is determined by the same marginal cost-benefit principles to the extent that all agents, be they producers or consumers, are in the business of production, whether of goods and services or of utility, guided by the same equimarginal principle of optimisation. This general model, consisting of sets of simultaneous equations for consumption, production, and consumption and production combined, is used to derive a unique solution which represents the economy-wide optimal allocation of resources to reach the maximum level of welfare, given resources and technical knowledge, all of which are exogenous to the system.

Hayek (1942) was disdainful of neoclassical economics, viewing it as yet another example of the lamentable creep of scienticism[19] over the social sciences and, in the specific case of the neoclassical general equilibrium model, a type of tautology. This he succinctly explains in a brief paragraph:

> If we possess all the relevant information, if we can start out from a given system of preferences, and if we command complete knowledge of available means, the problem which remains is purely one of logic. That is, the answer to the question of what is the best use of the available means is implicit in our assumptions. The conditions which the solution of this optimum problem must satisfy have been fully worked out and can be stated best in mathematical form: put at their briefest, they are that the marginal rates of substitution between any two commodities or factors must be the same in all their different uses. (Hayek, 1945: 519)

This dismissive attitude has not critically entered the mainstream of debates on the neoclassical model and the consequence of this is a confusion which has grown over generations of economists trained under the auspices of the neoclassical paradigm about the theoretical core of equilibrium theory in general. Mittermaier (2020: 86) clearly outlines the lines of this confusion when he says that

> Some economists treat equilibrium theory as an ideal conception with the normative meaning and others treat it as a description in some attenuated sense and yet others distinguish very poorly between the two. Some see it as an ideal system worth examining because it is taken, perhaps mistaken, to be the system economic liberalism advocates; others see it as one element in a projected though as yet unexplained series of successive approximations to the working of actual economies.

> Some treat equilibrium theory as a study of the conditions for one or other kind of economic efficiency, such as the optimum allocation of resources or simply market clearing; others treat it as a handy framework for explanations and predictions of what actually goes on, perhaps on the grounds that people never fail to meet the efficiency conditions, or fail in a predetermined way.

Apart from this confusion of the meaning of equilibrium theory, the extreme restrictiveness of the assumptions that it requires, especially that of full information in all the varieties of this notion, renders it utterly useless for the understanding of the source and effects of innovation. It is therefore quite legitimate to base a theory of innovation, set within the fold of evolutionary economics, in an explicit refutation of the suitability of neoclassical economics for this task. Moreover, as the understanding of innovation in the 1980s came to match that of the classical economists of the nineteenth and early twentieth centuries, innovation theory progressed from a dissident analysis of a sector of industrialised economies to a more generic attack on mainstream theory. However, it is at this stage that confusion again arises, this time as to the exact nature of the countervailing discourse and it is here that the conflation of neoclassical and neoliberal economics becomes deeply problematic.

There have been numerous accounts of the development of neoliberal economics, but most of these accounts boil down to a description of the basic tenets of this school. These are mostly in terms of its assumption of the primacy of a simplistic version of the invisible hand in assuring the optimal coordinating mechanism for the general economy, with a restriction of the role of the state to the safeguarding of property rights and the correction of infrequent cases of 'market failure'. Most accounts also focus on the historical development of neoliberalism and its eventual hegemonic position over global economic policy formulation. The various trajectories of the evolution of neoliberal economics are also often traced with variations of interpretation across space and time. Rarely however is the distinction between liberal and neoliberal economics explored in detail. This is to some extent due to the blurring of the demarcation lines between the general policy advocacies of these two schools. The distinction between ordo-liberalism and anarcho-liberalism discussed by Foucault (2004), among others, points out a major divergence between the liberal and neoliberal schools, both in the theoretical positioning of state *vis a-vis* market and their contextual location through the middle to late twentieth century history.[20]

There is however another fundamental distinguishing factor which has not been sufficiently explored. We may discern this distinction by contrasting Hayek's (1942, 1943, 1944, and 1945) treatise on the encroachment of scienticism in the study of society and the theoretical and analytical emptiness of the neoclassical paradigm with the emergence of the standard microeconomics textbook, starting with Robbins' (1932) text which led to the consolidation of the neoclassical textbook in its current form with the flurry of textbooks coming out in the late 1950s and early 1960s. This text which has come to be the undisputed and totally exclusive tome in the teaching of undergraduate economics contains the whole array of neoclassical models drawn into the service of a neoliberal advocacy of free markets, in disregard of the fundamental theoretical incompatibility between the neoclassical and the liberal theoretical bases. This incompatibility is evident in every aspect of the neoclassical text, especially in the corruption of language evident in the word 'competition'. McNulty (1968) points out that the neoclassical models of perfect competition, monopoly and variations of oligopoly exclude, through assumption, any vestige of competitive behaviour. In fact, these models exclude the entrepreneur since in a perfectly known world all that is needed for optimal decision making is the computer. This is in contrast to Stigler (1957) who, in the same vein as Machlup's (1967) defence of marginalism in the depiction of the profit-maximising firm, argues that perfect competition is at the same time the most rigorous and most tractable model of competitive markets available to the economist. Machlup, almost casually, brushes aside critical contributions which introduced behavioural and organisational theories of firm behaviour[21] and consumer behaviour[22] as essentially cumbersome in comparison to the single objective/full information neoclassical theory of the firm. This insistence on the translation of equilibrium theory into an analytical portrayal of actual competitive behaviour and consumer decisions is disingenuous, and it can therefore only be read as an opportunistic claim for the scientific integrity conferred by the mathematics of neoclassical economics to validate libertarian ideology in the tradition of the Chicago School. This anomaly is most evident when we consider that the obvious normative implication of the full information general equilibrium model that the optimal coordination mechanism should be a centrally planned economy where the optimal allocation of resources would never be subject to the vagaries of markets and human agency. Instead, the perfect competition model has been used as the 'scientific' rationale for the support of free markets and the minimal state by the Chicago school which would eventually extend marginalist theory to explain all of human behaviour, thus laying claim to the status of an 'imperial science' for the hybrid (Stigler, 1984; Becker, 1996).

The thrust of the arguments for the enlisting of neoclassical economics in the service of a neoliberal agenda centres around the 'as if argument[23] proposed in the analogies of Friedman's (1953) billiard player and Machlup's (1967) automobile driver. Both Friedman and Machlup take care to avoid what Machlup calls the 'fallacy of misplaced concreteness'[24] by arguing that optimisation models were never meant to correspond to real life but were, in Machlup's words, the outcome of the application of Occam's Razor where a high degree of abstraction trimmed off empirical considerations which were superfluous to the requirements of predictive models aimed at tracing the effects of exogenous changes such as taxes or interest rates on market behaviour. Lundvall (2016: 238) makes the critical point that

> 'the most important weakness of neoclassical theory is not that it is too abstract. *It is rather that it makes the wrong abstractions.* In a context where knowledge is the most important resource and learning the most important process, neoclassical theory tends to abstract from the very processes that make a difference in terms of the economic performance of firms and for the wealth of nations.'

Analogies, unlike examples, can be dangerously misleading when called up in the cause of theoretical reasoning. Both the billiard player and the automobile driver are, specifically in their respective roles, decision makers driven by a single objective and making decisions in a fully known universe. To use these examples as useful analogies representing real life agents who are driven by multiple objectives, of different provenance and often contradictory, operating in a context which is marked by non-actuarial risk which grows along with ignorance as decisions and the envisaged consequences of those decisions stretch into the future, is a deeply flawed exercise. Reservations raised by the consideration of the actual object of study are brushed aside as essentially trivial specifics which do not affect the core principle of presumed behaviour on the basis of the 'as if assumption or by the argument that, regardless of flaws, the neoclassical theory of the firm is the best approximation to real life entities. The casual reference to the mechanical metaphor underlying neoclassical economics opens up to the syndrome best described by the term 'mechanomorphism' coined by Mittermaier (1986).[25] Mittermaier cautions against the easy dismissal of metaphors as a mere figure of speech when he says that 'they are more than mere expressions. They involve conceptions of the nature of economic affairs and consequently also certain attitudes of mind when economic questions are dealt with' (Mittermaier, ibid: 238).

The question that should be raised at this point is the level to which abstraction can be pushed before the distance from empirical reality fatally compromises not just the explanatory power but also the predictive capability of theoretical constructs. The neoclassical paradigm constitutes one of the more extreme examples of abstraction, offering as it does a fully determined closed logical construct of the economy which could provide unique optimisation solutions to the problem of the allocation of scarce resources. The critical issue here is whether neoclassical economics with the general equilibrium model at its core is amenable to adaptation and loose interpretation in the manner of neoliberal economists. The answer has to be unequivocally that it cannot. The neoclassical model is so completely specified and so dependent on this complete specification for its integrity that that any violation would negate the whole paradigm. Without full and perfect information (including probability values assigned to future possible outcomes) it would be impossible to derive continuous objective and constraint functions and thus say anything about allocation and constrained optimisation. The reason why the neoclassical model of the economy does not relate to empirical facts is fundamentally because it is not designed to do so. It is an extreme example of deductive reasoning, conceptually elegant in its mathematical rendition and useful as an exercise in logic, which cannot allow for approximations to its ideal state.

Neoclassical economics is quite incompatible with the study of political economy, presenting as it does a mathematical model of the national economy which is fully specified and designed to contain solutions to the model in the predetermined fashion of Hayek's (1945) depiction. The 'as if proposition of Friedman and Machlup is the *legerdemain* which implicitly justifies the neoclassical text as the basis for the understanding of economic life and the theoretical validation of a fundamentally libertarian normative position. This twinning of two incompatible theoretical corpuses is the hallmark of neoliberal economics, highly successful in its hegemony over the undergraduate text (Scerri, 2008) and across policy environments across the world, but fundamentally flawed as theory. This hegemony has constituted neoclassical economics as the discipline of economics, but the contradiction is that the neoliberal gambit which enabled this elevation violates, through its blurring of the demarcation lines between discursive formations, the primary requisite of exclusion as articulated by Foucault (1970) which specifies the limits of what can belong to a discipline.[26] The relationship between the discipline as neoclassical economics and the discourse as neoliberal economics violates the tenet set out by Foucault that '.. .(t)he discipline is a principle of control over the production of discourse. The discipline fixes limits for discourse by the action of an identity which takes the form of a permanent re-actuation of the rules' (Foucault, ibid: 61). In this sense, it is neoliberal economics which forms the mainstream discourse[27] while flouting the restrictions imposed by the neoclassical paradigm which it uses as its disciplinary base. Ironically, this hybrid is vulnerable to the charge that 'anything goes' which is often levied against pluralist economics. The apparently monist position of the hybrid as mainstream economics is not one of theoretical coherence but rather the outcome of power.[28]

The entrenchment of neoliberal economics, with a strong leaning towards anarcho-liberalism as the mainstream is reinforced over time through practice. Nelson and Winter (1982) and Nelson (2007) propose that research in economics tends to run along two linked but distinct tracks which they term formal and appreciative theory.[29] Formal theory stands in for the discipline of mainstream economics while appreciative theory in practice, or praxis, forms the discourse of economics as it is generally accepted. Thus, while formal theory in the mainstream is still neoclassical economics, appreciative theory — the way economics is 'done' and informs policy — has been largely formed by the neoliberal doctrine.

Appreciative theory is difficult to engage with theoretically. It is ephemeral, with a fluid positioning *vis-a-vis* its underlying base in formal theory, an essentially instrumentalist approach, with an easy adoption of *ex post facto* justifications for its predictive failures. In the world of prediction and prescription, instrumentalism is the unquestioned norm of practice. In the process the fundamental incompatibility between discipline and discourse in mainstream economics is forgotten or easily dismissed, and an implicit ideological agenda with its associated exercise of power, determines the shape and direction of the mainstream. The acceptance of the practice of appreciative theory can be highly problematic in the case of neoclassical economics which is so completely mathematically defined that it has little leeway for departures from its highly restrictive assumptions regarding information and the definition of economic agents.

One can justifiably argue that appreciative theory has become the vehicle for the usurpation of the mathematical validation of the neoclassical paradigm by neoliberal economics. The appeal to commonly perceived empirical reality as formative of research practice lays the discipline open to the dangers of adopting 'common sense' as a guiding principle for positing behavioural relations.[30] Evidence-based research and the normative implications of such research in the absence of a clear and unambiguous reference to the theoretical foundation of the research tend to result in a confusion of theoretical languages. When it comes to interpreting the world, evidence is meaningless without the theoretical lens, and it is the clear specification of the theoretical lens which often determines which empirical observations count as evidence and which are trivialised as 'noise'. Without this clear specification of the theoretical base for a research agenda, the choice of evidence itself often serves to reinforce a dominant discourse and its concomitant power relations.[31]

4. Possibilities

The entrenchment of the neoliberal hybrid as the discourse in economics, especially when reinforced by appreciative theory over successive generations of economists, means that this is the core against which other accounts have to be measured. This is clearly evident with the emergence of the system of innovation approach as a potential alternative general account of the economy. There is a hesitation in refuting the emerging neoliberal orthodoxy in its totality in Schumpeter's case as discussed earlier. Nelson and Winter (1982) still accord the orthodoxy central pace as far as static analysis is concerned. Nelson (2007) emphasises the need for evolutionary approaches to innovation and development to coalesce into a coherent body of formal theory which can act as an alternative reference point for a practice of an appreciative theory which is more appropriate to rapidly changing economies. However, the implicit concession that neoclassical economics is suited for static or comparative static analysis needs be questioned. From an evolutionary perspective, economies are always in a state of flux with periods of apparent stability occasionally, and often briefly, emerging as a resultant of a temporary balance of the myriad contending forces and tendencies which form the national and global political economy.

In this slippage in the identification of its counter-discourse, the system of innovation approach has as yet failed to develop a discursive formation which can challenge the mainstream account of the economy. In light of this, it is difficult to contest the assessment of Fine and Rustomjee (1996: 244) when they propose that the '(national system of innovation) framework is unduly descriptive in content, merely pointing to the various institutional components driving technical change, albeit breaking with received notions in orthodox economics'. Winter (2017: 739-740) is also dismissive of the explanatory power of system of innovation concept when he says that '(n)ational innovation 'systems' are generally more of a congeries than a system, if "system" is taken to imply a logically coherent structure. They reflect the accumulation of responses to relatively specific policy issues, but the impact of those responses may extend very widely.' To a large extent, the critiques of the system of innovation approach stem from the implicit adoption of a narrow version of the concept. The acceptance of the narrow version of the system of innovation opens up to the concern expressed by Schot and Steinmueller (2018) about the limited explanatory power and normative implications of the system of innovation framework due to areas of exclusion and the consequent limitations on the transformative potential of planning based on this restricted version. Lundvall (2023) effectively countered critiques of the explanatory limitations of the system of innovation approach; he had long emphasised the essential requirement to adopt the broad definition of the system of innovation as the base of its explanatory power.[32] Lundvall repeatedly interrogates the eligibility of the system of innovation approach for the status of theory, again measuring it up against the determinate mathematical articulation of causalities within the neoclassical paradigm. He proposes the system of innovation approach as a 'focussing device' (Lundvall, 2010, Ch. 15) and eventually uses the notion of a focussing device as explicitly synonymous with theory (Lundvall, 2016: Ch. 4). Lundvall (2010: 13) does in fact see the system of innovation framework as an alternative account of the national economy, as long as the broad version is adopted.[33]

An adherence to the narrow version of the system of innovation approach, even if implicitly through research and practice will inevitably retard the progress towards a comprehensive alternative general theory of the economy and the approach will. at best seen as a, often case-study based, contribution to a sub-sector of an economy often implicitly formed by the language of neoliberal economics. From a narrow perspective, the interpretation of the 'system' from an organisational perspective obviously would see severe theoretical limitations of the system of innovation concept and would ignore the fundamentally biological metaphor of the approach where a system of innovation is not necessarily, in fact rarely, something which is planned. Systems of innovation evolve organically, whether planned or not, and sometimes in spite of planning. They may thrive or falter and sometimes they may die out, and it is this interpretation of the 'system' which opens up the possibility of a new theoretical approach to the understanding of economies, at the national, sub-national, or supra-national levels.

Perhaps the starting point for the development of an alternative account of the general economy may be found in Lundvall's 1992 definition of the national system of innovation as '... the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge ... and are either located within or rooted inside the borders of a nation state' (Lundvall, 2010: 2). This particular definition is notable on two main issues. The first is the emphasis on knowledge rather than technology. The second is the reference to the institutional underpinning of the system of innovation in terms which allow for the whole gamut of formal and informal institutions and, by implication, the introduction of a significant degree of specificity in the study of systems of innovation. the allowance for institutional change, in itself, as innovation opens up considerably the explanatory power of the approach. In many respects it can offer accounts of the shifts in the evolutionary paths of systems at the local, national and global levels. It could consider the extinction of species of systems, as in the case of the, woefully under researched, Soviet systems of innovation, as well as the mutations leading to the emergence of new species, as in the case of the BRICS (Brazil, Russia, India, China and South Africa) group.

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There is one notable feature of the system of innovation approach which marks it out from other accounts of the general economy, and this is that it's theoretical base is ideologically neutral. The fundamental premises and assumptions of the neoclassical framework logically imply the centrally planned economy as the ideal coordination framework, best suited to avoid all types of 'market failure', given full and perfect information. Both anarcho-liberalism, which is synonymous with the usage of the label of neoliberalism, and ordo-liberalism, mostly associated with the planning framework of social democracies, have clear ideological bases. The system of innovation approach, grounded as it is in evolutionary economics, provides a theoretical framework which can be adopted by the whole gamut of ideological positionings.[34] This attribute, the ideological neutrality of the approach, should be one of its main claims to theoretical rigour.

The development of an alternative general theory of the economy could be built on three closely inter-linked pillars. The first is a revisiting of the theory of value, essentially re-articulating the labour theory of value as an innovation theory of value. A broad enough interpretation of innovation, going well beyond technology, would read all human economic activity, manifest in goods, services and experience, in terms of current innovation or as the embodiment of historical streams of innovation. This re-visiting of value would also help to revitalise the challenge to an exchange theory of value which implicitly runs through the mainstream discourse, where the wide range of local, national and global problems are classified as cases of 'market failure', still assuming that market clearing prices are indicators of economic value. The second foundation for an emerging discourse would be to anchor systems of innovation in specific accumulation regimes. Boyer (1988) provided an enticing prospect of the theoretical possibilities of this pursuit, more fundamental than the complementing of the study of the national system of innovation by the specification of a particular type of capital accumulation, as proposed by Fine and Rustomjee (1996). There is a range of post-Fordist accumulation regimes, including knowledge-led, finance-dominated, and dependency-led (Scerri, 2021) accumulation regimes which can be developed to contextualise systems of innovation. The third pillar would be the conceptual extension of the informal institutional and tacit knowledge base to permeate and ultimately define systems of innovation. This would entail the drawing in of traditional sociology and modern anthropology, and interpretative historical reading within a political economy theoretical framework of evolutionary economics.

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Notes

1 An earlier version of this paper appeared as a Preprint on Cambridge Open Engage, at https://www.cambridge.org/engage/coe/article-details/5eb5721e 279bd8001c8ed11b.

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3 Lundvall (2016: 234) states in retrospect that apart from a study of innovation, the national systems of innovation concept 'was also seen as constituting an alternative analytical framework and a challenge to standard economics when it comes to explain competitiveness, economic growth and development.'

4 'In Foucault's analysis the notion of discourse is the primary unit. A discourse can be understood as a system of possibility for knowledge. This involves questioning the type of rules that permit certain statements to be made; the rules that govern these statements; the rules that allow us to identify some statement as true and some as false; the rules that permit the formulation of models and classificatory systems; the rules that permit individuals to be identified as authors; and the type of rules that emerge when an object of discourse is transformed or modified. The identification of sets of these kinds of rules represents a discursive formation or discourse.' (Variava, 2020: 32)

5 This refers to classical liberal economists who were advocates of free trade. Early critics such as Nicholson (1909) accused List of distorting Smith's position on trade policy, ignoring his acknowledgement of the relevance of nations and setting him up as a straw man. Later commentators (Levi-Faur, 1997; Shafaeddin, 2000; Soete et al, 2010; Jun et al, 2016), while acknowledging List's combative tone and his occasional glossing over of Smith's reservations on the reality of nations, generally accept as correct his depiction of the theoretical position of the 'school' and its policy implications. It should be noted that List's critique of Smith and other related economists lays the foundation of the modern critical appraisal of the neoclassical and neoliberal economics, and of the Washington Consensus policy framework.

6 The concept of human capital is exemplified by Foucault (2004: 226) as 'Homo economicus is an entrepreneur, an entrepreneur of himself, which captures the eradication of the worker as a meaningful object of analysis, implicit in human capital theory.

7 It is worth noting that in his 1978-1979 lectures on the evolution of neoliberalism at the College de France Foucault never mentions neoclassical economics. Foucault sees the main difference between classical liberalism and neoliberalism as a shift in focus from exchange to competition as the core of the economic system (Read, 2009).

8 In List's case 'Christian religion, monogamy, abolition of slavery and vassalage, hereditability of the throne...' (List, 1841, Vol. II: 29)

9 See Lundvall (1992) Soete et al (2010).

10 'to the degree that large industry develops, the creation of real wealth comes to depend less on labour time and on the amount of labour employed than on the power of the agencies set in motion during labour time, whose 'powerful effectiveness' is itself in turn out of all proportion to the direct labour time spent on their production, but depends rather on the general state of science and on the progress of technology, or the application of this science to production.' (Marx, 1857-1861: 706)

11 '.. every individual ... generally, indeed, neither intends to promote the public interest, nor knows how much he is promoting it . . . he intends only his own gain, and he is in this, as in many other cases, led by an invisible hand to promote an end which was no part of his intention.' (Smith, 1776: 572). This excerpt from Smith's single most quoted passage on the invisible hand has been widely debated in the literature. See, among others, Persky (1989), Hill (2001) and Harrison (2011) for discussions on the theological and natural science

contexts of the concept. See Mittermaier (2020) for a thorough discussion of Smith's own qualifications about the restrictive institutional underpinning of markets required for the convergence of private and public interest as posited by the invisible hand.

12 This in spite of the antipathy between the Austrian and neoliberal schools.

13 Schumpeter (1943: 385) is harshly dismissive in his first footnote: "The religious quality of Marxism also explains a characteristic attitude of the orthodox Marxist toward opponents. To him, as to any believer in a Faith, the opponent is not merely in error but in sin. Dissent is disapproved of not only intellectually but also morally. There cannot be any excuse for this once the Message has been received." This reservation was also expressed by several Marxist academics, as for example in Jessop (2002: 22) who ".raises questions about the conditions under which accumulation can become the dominant principle of societal organization (societalization). For there are always interstitial, residual, marginal, irrelevant, recalcitrant and plain contradictory elements that escape subordination to any given principle of societalization and, indeed, serve as reservoirs of flexibility and innovation as well as actual and potential sources of disorder."

14 'The bourgeoisie, during its rule of scarce one hundred years, has created more massive and more colossal productive forces than have all preceding generations together' (Marx and Engels, 1848: 7).

15 'There is more "Schumpeter" in Marx's writings than many Marxists are willing to accept, and more "Marx" in Schumpeter's analysis than even Schumpeter was willing to recognize.' (Elliot, 1980: 45-46)

16 'Neoclassical economists attempt to construct a universal framework of socio-economic analysis but end up viewing the universe through the distorting lenses of a specific type of economic system. The universality of their alleged universal principles is thus questioned. Marx, on the other hand, knowingly reacts from this kind of approach and attempts to site his analysis of specific systems on specific concepts appropriate to that system. Yet, contrary to his own arguments he ends up relying on theories and concepts that are in fact universal. Neoclassical economics aspires to universality but ends up being specific; Marxism aspires to specificity but ends up relying on the general.' (Hodgson, 2002: 211)

17 Pitelis and Runde (2017: 679) succinctly capture the critical distinction between neoclassical and classical economics as being 'about the efficient allocation of scarce resources, rather than about resource creation and the creation and distribution of wealth as advocated by classical economists such as Adam Smith, David Ricardo and Karl Marx.'

18 Schumpeter (1934: 65-66) anticipates the classification of innovations between incremental and radical, at least, and opens the possibility for the consideration of techno-economic paradigm shifts (Freeman and Perez, 1988) when he states that 'To produce means to combine materials and resources within our reach. To produce other things, or the same things with a different method, means to combine these materials and forces differently. In so far as the "new combination" may grow out of the old by continuous adjustment in small steps, there is certainly change, possibly growth, but neither a new phenomenon nor development in our sense. In so far as this is not the case, and the new combinations appear discontinuously, then the phenomenon characterising development emerges.'

19 'the tyranny commenced which the methods and technique of the Sciences in the narrow sense of the term have ever since exercised over other subjects. These became increasingly concerned to vindicate their equal status by showing that their methods were the same as those of their brilliantly successful sisters rather than by adapting their methods more and more to their own particular problems. And although in the hundred and twenty years or so, during which this ambition to imitate Science in its methods rather than its spirit has now dominated social studies, it has contributed scarcely anything to our understanding of social phenomena, not only does it continue to confuse and discredit the work of the social disciplines, but demands for further attempts in this direction are presented to us as the

latest revolutionary innovations which, if adopted, will secure rapid undreamed of progress' (Hayek, 1942: 268).

20 See Foucault's (2004) tracing of the bifurcation of the evolution of liberal economics into ordo-liberalism which was at the core of Germany's post-war economic restructuring and subsequent policy and anarcho-liberalism which was the neoliberalism emerging from the Chicago school. See also Streeck and Yamamura (2001) for an exhaustive distinction between the two main varieties of capitalism which emerged in the post-war era.

21 See Simon (1959), Cyert and March (1963), March and Simon (1993), and Williamson (1985) for behavioural, managerial and organisational theories of the firm. Nelson (1991) laments the side-lining of these theories of firm behaviour from the core of economics.

22 See Stigler and Becker (1977) for the rationale for the theoretical dismissal of tastes and preferences as given in the analysis of consumer and other human behaviour.

23 'It is only a short step from these examples to the economic hypothesis that under a wide range of circumstances individual firm behave as if they were seeking rationally to maximize their expected returns (generally if misleadingly called "profits") and had full knowledge of the data needed to succeed in this attempt; as if, that is, they knew the relevant cost and demand functions, calculated marginal cost and marginal revenue from all actions open to them, and pushed each line of action to the point at which the relevant marginal cost and marginal revenue were equal.' Friedman (1953: 13)

24 Following Whitehead (1925) and Robbins (1932), Machlup (1967: 9) explains the fallacy as follows: "To confuse the firm as a theoretical construct with the firm as an empirical concept ... is to commit the 'fallacy of misplaced concreteness'. This fallacy consists in using theoretical symbols as though they had a direct, observable, concrete meaning."

25 '... an economist engages in mechanomorphism when he ascribes mechanical properties to what is otherwise recognized as part of human affairs or when he treats an economic system as though it were a mechanical system.' (Mittermaier, 1986: 237)

26 "a proposition must fulfil complex and heavy requirements to be able to belong to the grouping of a discipline; before it can be called true or false, it must be 'in the true', as Canguilhem would say ... one is 'in the true' only by obeying the rules of discursive 'policing' which one has to reactivate in each of one's discourses ..." (Foucault, 1970: 60)

27 'neoliberalism works to efface the fundamental division between worker and capitalist, between wages and capital, through the production of neo-liberal subjectivity. Neoliberalism is a discourse and practice that is aimed to curtail the powers of labour that are distributed across all of society—at the exact moment in which all of social existence becomes labour, or potential labour, neoliberalism constructs the image of a society of capitalists, of entrepreneurs.' (Read, 2009: 33)

28 See Harvey (2005), among others, for an account of the ascendancy of the Mont Pelerin Society in the major global and national economic policy spheres.

29 Nelson points out the "difference between ... 'appreciative' and 'formal' theory, with the former mostly expressed verbally, and much closer to the empirical details of the subject matter than the latter, and the latter articulated more abstractly, often in the form of a mathematical model, and more amenable to logical exploration and manipulation. While current use of the term 'theory' in economics has tended to identify with formal theory, ... in economics most of the empirical research and interpretation of empirical phenomena, was structured by appreciative theory.' (Nelson, 2007: 20-21)

30 'Common sense is constructed out of long standing practices of cultural socialisation.. .(It) can, therefore, be profoundly misleading, obfuscating or disguising real problems under cultural prejudice' (David Harvey, 2005: 39, citing Gramsci).

31 Hacking (1991: 181) captures the essential non-neutrality of evidence, in this case statistical evidence, in a distinctly Foucauldian manner when he proposes that '(s)tatistics has helped determine the form of laws about society and the character of social facts. It has engendered

concepts and classifications within the human sciences. ... It may think of itself as only providing information, but it is itself part of the technology of power in the modern state.'

32 Lundvall (2016: 224) is emphatic about this when he says that '(w)ithout a broad definition of the national innovation system encompassing individual, organizational and interorgani%ational learning, it is impossible to establish the link from innovation to economic growth'.

33 Lundvall (2010: 13) defines the broad version of the national system of innovation as including '.all parts and aspects of the economic structure and the institutional set up affecting learning as well as searching and exploring — the production system, the marketing system and the system of finance present themselves as sub-systems in which learning takes place.'

34 See, for example, Lewis (2021) for a highly persuasive argument for the theoretical and normative compatibility of the system of innovation approach with the Austrian school of economics.

2

Patent policy changes in India and its implications

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Abstract

This paper presents the historical account of the India's patent policy evolution. In view of the significant changes in the policy over the last two hundred years, research and development investments and patents have grown over a period. We present some of the key characteristics of such investments in innovation and its outcomes in India. Some of these trends are typical for developing economies. For instance, low relative investment in research, uninspiring private sector performance in terms of these investments with most patenting by non-residents. We also take stock of empirical research that focuses on the relationship between making provision for patents and motivating innovation and facilitating technology transfer.

Introduction

Patents enable people to financially gain from their creations and inventions (WIPO 2021). As a part of the formal intellectual property (IP)1, the state designs patent policy to confer the right to the inventors such that they can exclude others from imitating the protected technology. Patents have a long legal and economic history with evidence from the late 19th century from Germany and Switzerland signifying the role of these rights in protecting domestic industry (Kaufer, 1989). Over the next hundred years, patent policy has occupied "central place in debates over economic policy, national competitiveness, or social welfare" (Granstrand p. 266 2005). Alongside, the need for protecting patents in different jurisdictions was realized initiating the discussion on international treaties covering IP during the 19th century. The increase in the trade of patent- sensitive products in the 20th century linked IP and trade more closely in multilateral and bilateral international agreements.

The Agreement on Trade Related Intellectual Property Rights (TRIPS) as one of key agreements of the World Trade Organization (WTO), is a case in point.

In India, substantive legislation for "exclusive privileges" was enacted starting from 1856. Since then, patent laws have undergone minor and major amendments aligning with the political,[1] economic, and social context of that time, often with concomitant controversies. The initial policy, as per the interest of the colonial power was catering to the interest of non-natives with widespread patenting by non-residents. Post-independence, the trend was to give more emphasis to the social welfare of people by ensuring availability and accessibility of food and health. After 1995, the exogenous factors led to major changes in the patent policy as per the country's commitment under TRIPs agreement. India has witnessed increase in the research and patenting activity since the introduction of these changes. In the past two decades, extensive empirical literature has also emerged addressing the key rationales for providing patent policy including incentivizing innovation through monopoly profit and facilitating further technological change by ensuring public disclosure of the information. The evidence based on Indian data is in consensus with international results that underscores that there is no straight forward answer as the net impact of the patent protection on innovation is conditioned by different factors. The studies show that the influence of patents on innovation varies considerably across sectors. There is little evidence on the patent rights and technology transfer and strategic use of patents by firms in India. In this paper, we take stock of the previous literature on patent policy and its influence on the domestic economy of India through different channels, critically examines it, and identifies the existing gaps to outline research directions for future studies.

The rest of the paper proceeds as follows: Section two, after this introduction, provides the historical account of the patent policy's evolution in India. In section three, we exhibit data on research and development (R&D) investments alongside the information on patents to succinctly provide an overview of the India's innovation ecosystem. The fourth section reviews the academic literature that focuses on the impact of patent policy changes on innovation and technology transfer within the country. The different subsections bring forth analysis of specific sectors that have higher patenting propensity, impact of patents on market power and firm performance. The last section elaborates on the key characteristics of patenting in India that requires special attention, unexplored questions and outline future directions for research.

1. Indian patent act: The history[2]

The history of Indian Patent Act has four distinct phases. The first phase before 1947, when India got independence, was largely driven by the British policy, and is hence referred to as the Colonial Phase. After independence (1947-1995), in alignment with the overall economic mood of the country, the patent policy was designed “in a manner conducive to social and economic welfare, and to a balance of rights and obligations”, Article 83c of Patent Act of 1970. Racherla (2019) also noted that India’s patent policy attempted to “balance its social goals and priorities against the economic goals” before 1991. The last phase was largely driven by India’s commitments to conform with the TRIPs under WTO as its founding member. This phase has a brief sub-phase referred to as the Transition Phase (1995-2005) during which the legislative changes were introduced in the Patent Act of 1970. The second ongoing sub-phase begins after 2005 as India introduced the much-debated clause related to the introduction of product patent in all fields of technology as per TRIPs requirements. Interestingly, after 1995 the patent policy changes are also in sync with the overall country’s market driven policy. As per the National Intellectual Property Rights (IPR) Policy released in 2016, the first objective of the IPRs system is to “foster creativity and innovation and thereby promote entrepreneurship.” Evidently, the role of patent policy in the national innovation system to incentivize research and development (R&D) has gained prominence as the main concern of policymakers. Thus, “Indian patent regime reflects India’s journey in three different periods: colonization, post-independence, and globalization” (Racherla, 2019, p. 275). We consider each phase in turn.

The Colonial Phase (1856-1947)

The foundations for modern patent laws can be traced to the first patent code issued by the Venetian Senate in 1474. After the initial developments in the 15th century England, the patent system had spread widely. India, considering its colonial past, provided for the Act VI of 1856 based on the British Patent Law of 1852 to protect inventions and to ensure disclosure. This act was legislated before the Sepoy Mutiny[3] without the approval of the British Crown and was thus later repealed. Later in the same decade, Act XV of 1859 was introduced to provide exclusive privileges like making, selling, and using inventions of new manufacturers for a period of 14 years to the inventors. Further, design protection was added in 1872 and the Act of 1859 was consolidated as “The Patterns and Designs Protection Act” under Act XIII of 1872 along with amendment in 1883. In 1911, the Indian Patents and Designs Act replaced all the previous Acts and brought patent administration under the management of Controller of Patents for the first time. Further amendments were made in 1920, 1930 and 1945 that increased the scope and duration of the protection along with providing administrative ease of patenting.

The Restrictive Phase (1947-95)

In view of the economic and social realities of the country after Independence and with substantial changes in the political climate of the country, a dire need was felt to relook at the Indian Patents & Designs Act, 1911. Accordingly, the Government of India (henceforth, GoI) constituted a committee under the

Chairmanship of Justice (Dr.) Bakshi Tek Chand, a retired Judge of Lahore High Court, in 1949 to review the patent law in India to ensure that the patent system is conducive to the national interest. Interestingly, the terms of reference for the committee highlight the priority of the government at that time as the prevention of abuse of patent rights with specific focus on availability and accessibility of food and medicines. Based on the Committee's recommendations, an amendment was made to provide compulsory licence in relation to patents in respect of food and medicines, insecticide, germicide or fungicide and a process for producing substance or any invention relating to surgical or curative devices. The compulsory licence was also available on notification by the Central Government in 1952 (Act LXX of 1952). Based on the recommendations of the Committee, a bill was introduced in Parliament in 1953 (Bill No.59 of 1953). However, the Government did not press for the consideration of the bill, and it was allowed to lapse.

Another Justice N. Rajagopala Ayyangar Committee was constituted in 1957 by GoI to examine the question of revision of the patent law and advise government. The committee recommended retention of the patent system, despite its shortcomings, as it is a "universally adopted system". It is noteworthy that the Committee looked at the need to have a patent system for an under- developed country at that juncture and recommended the same with the expectation that "with the increasing emphasis on technical education and the number and quality of the research institutes that have been established in the country, together with the rapid industrialization that is proceeding, one may look forward to a time when the Indian research worker and inventor will take full advantage of the patent law," (Ayyangar Report, p. 20, 1959). The report recommended major changes in the law which formed the basis of the introduction of the Patents Bill, 1965. After some procedural delays, on the final recommendation of Joint Parliamentary Committee, the Patents Act, 1970 was passed. This Act repealed and replaced the 1911 Act and the provisions of the 1970 Act were brought into force on 20th April 1972 with the publication of the Patent Rules, 1972.

The Ayyangar Committee cited the need to develop research capabilities in the Indian pharmaceutical sector and gave an example of the German industry that had developed under process patents. Furthermore, the Committee noted the need of the then-underdeveloped India to provide affordable health care to the community as a major reason for removing product patents for medicines. The India Patents Act of 1970 included significant provisions to lower the social costs of patents owned by foreigners. Thus, the Patents Act of 1970 (a) prohibited granting of patents on goods that may be used as food and medicine (b), decreased the duration of patents on chemical processes (c), and greatly increased the scope of the use of compulsory licensing. Interestingly, then Prime Minister of India, Mrs. Indira Gandhi said at the World Health Assembly, Geneva in May 1982, "the idea of a better-ordered world is one in which medical discoveries will be free of patents and there will be no profiteering from life and death."

The Transition (1995-2005)

TRIPs agreement came into force in 1995 with minimum standards for seven types of IP for the member states of the WTO. India introduced changes in its domestic policy to conform to TRIPs through three key amendments in the Indian Patent Act 1970. The Patent (Amendment) Act 1999 provides permission to file applications for product patenting in the field of pharmaceutical, drugs and agro chemical industries though such applications were examined only after December 31, 2004. This amendment also makes a provision for granting Exclusive Marketing Rights (EMRs). The second amendment in the Act was made in 2002 whereby the term of protection was extended to 20 years, licensing rights were removed, publication of applications after 18 months began and provision of pre and post grant opposition was also initiated.[4] This Amendment also requires the complete description, including the source and geographical location, of the biological material if a patent is related to such materials.[5] Another provision requires an infringer to prove non- infringement of patent right in case of any dispute that is beneficial for the patentees as they may not have much knowledge about the infringers' processes. Further, this amendment also requires the publication of patent application in the patent gazettes after 18 months. The last provision is about filing patent application through Patent Cooperation Treaty (PCT).

The third amendment to the Act was made through the Patent (Amendment) Act 2004, implemented by January 1, 2005, which provides permission for product patents in all fields of technology. This amendment also creates provision of compulsory licensing for producing and exporting pharmaceutical products to any country having insufficient or no manufacturing policy to accommodate the Doha Round Mandate. The amendments made to the Patent Act of 1970 were fiercely debated in the Indian Parliament as it was feared that these changes can lead to "economic slavery" and the country being reduced to "a big market". The critiques also pointed out the possibility of misappropriating India's traditional knowledge by firms. In response to that GoI set up a Traditional Knowledge Digital Library (TKDL) as a prior art tool to protect Indian traditional medicinal knowledge and prevent its misuse[6]. There were also apprehensions about the role of MNEs and the increase in their monopoly power due to extensive patenting. The review of empirical literature in section 4, provides answers to a few of these apprehensions.

To sum, patent strength in India has increased after complying with the TRIPs agreement as the Ginarte and Park (1997) index value increased from 1.03 to 1.23 during 1985-1995 and later to 3.76 in 2005 following compliance by TRIPs agreement. Ginarte and Park (1997) and Park (2008) have shown that most economies have increased patent protection by making stipulated legislative changes. Thus, for India these changes are in accord with the international standards.

The Permissive Phase (2005 onwards)

As per Section 159 of Patent Act 1970, the Central Government of India, by notification in the Official Gazette, make rules for carrying out the purposes of the Act. After 2005, though the Act has not been amended, changes have been introduced in the Patent Rules 2003. We discuss these amendments briefly to highlight the ease of patenting that the IPO aims to achieve in recent times.

Collectively these changes signify an important progression in India's efforts to develop a vibrant and user-friendly IP regime that would facilitate and encourage creativity and innovation. We present a select few below:

Software patents have been a debatable issue and IPO has issued three guidelines for examining the Computer Related Inventions (CRI) in 2015, 2016, and in 2017 for the Patent Rules (2003). These guidelines are to clarify Section 3(k) of the Indian Patent Act 1970 that include "a compter programme *per se*" in the list of inventions not patentable. The amendment in 2015 shed light on the per se issue, with a reference to Oxford Advanced Learners Dictionary definition of '*per se*' as 'by itself' – to show that you are referring to something on its own, rather than in connection with other things. The second set of guidelines published in February 2016, broadened the exclusion rule (in the form of a three-step test) by stating that software of any nature, unless in conjunction with novel hardware, cannot be patented. The amendment in 2017 did away with this test and instead focuses on substance of the invention over the form, while examining the patent applications.

The basic fee for filing a patent application has been revised and is now determined by whether the application is filed electronically or physically with the Indian Patent Office (IPO). The basic e- filing fee is less than that of physical application filing in harmony with the overall objectives of the GoI of digitization of government services. Rule 6 of the Patents (Amendment) Rules 2019 is amended to waive the requirement to file original documents. Another incentive for Indian applicants to use the electronic filing system is the waiver of the transmittal fee for e-PCT filing and the fee for the certified priority document if e-transmission via WIPO DAS is used.

The Patent (Amendment) Rules 2016 are primarily concerned with startups[7]. Changes are being implemented to support startups and their patenting activities. For instance, provision is made for expedited examination for the start-ups, small entities, and government department to boost the start-up ecosystem. A faster patent grant is likely to support start-ups and academic institutions to signal the quality and industrial applicability of their technology.

For start-ups this implies easy access to funds from the venture capitalists and for academic institutions it means ease in technology transfer. The scheme has witnessed a growth of 67% within one year (2018-19 to 2019- 20) of the request received for expedited examination.

Indian patent law requires patentee to give details about the working of patent. Companies disclose the information about commercial working of newly invented products and processes and for this purpose the Patents Rules, 2003 specify Form-27 based on section-146 of the Patents Act, 1970. Form-27 contains the information about working and not working of patented inventions; reasons for not working; quantity and value of patented invention; if invented product is manufactured in India or imported among others. Form 27 must be filled within six months of the end of each such financial year, beginning with the financial year that begins immediately after the financial year in which the patent was granted. The Patents (Amendment) Rules 2020 amended Form 27 that eliminates the necessity for the patentee or licensee to provide a statement indicating whether the public requirement has been met, in addition to the requirement to submit license and sub-license information. The Patents Rules, 2003 have been amended further by the Ministry of Commerce and Industry in a notification dated September 23, 2021, to be known as the Patents (Amendment) Rules, 2021. The category of patent applicants has been expanded to include "educational institutions" in addition to a natural person, startup, and small entity.

In a recent report (Sanyal & Arora, 2022)[8], the Economic Advisory Council to the Prime Minister has noted that the average time taken for the first office action in India is 4.8[9] months as per the international practices. However, the final disposal of the application takes around 58 months that is the longest among the major patent offices across the globe. Sanyal and Arora (2022) highlight that initiatives are underway to invest more in the IP ecosystem of the country to strengthen the national innovation system.

Figure 1: Patent policy path timeline

2. India's innovation ecosystem

A robust patent regime is expected to enhance the scientific developments and technological innovations in an economy. In the Global Innovation Index, India's rank in 2015 stood at 81, which was the lowest amongst the 15 years that the index had been calculated. However, in 2022, India made it to the 40th position. The GII reports have observed that policy intervention was the driving force of this improvement in India's ranking over the years. In this section, we trace India's innovation journey to this current position in GII through key economic indicators of innovation. From the early days of independence, India has systematically strived towards developing science, technology, innovation ecosystem. India's Scientific Policy Resolution of 1958 that resolved to "foster, promote and sustain" the "cultivation of science and scientific research in all aspects," was the first step in that direction. Since, then the country has seen evolution of the Technology Policy Statement in 1983, Science and Technology Policy in 2003, and Science, Technology, and Innovation Policy (STIP) in 2013. STIP 2013 highlighted the need to increase private investment to commercialize R&D expenditure along with the need to explore public-private participation model. In December 2020, the GoI released the draft of the 5th National Science, Technology, and Innovation Policy (STIP)[10] for public comments. The primary objective of the fifth STIP is to create a robust ecosystem for innovation, technology, and science for an Atamnirbhar Bharat. The new policy is founded on the core principles of decentralization, evidence-informed decision- making, bottom-up, expert-driven decision-making, and inclusiveness. In this section, we present information on R&D and patenting to highlight some of the key characteristics of investments in innovation and its outcomes in India. Some of these trends are typical for developing economies and need specific attention of the researchers and policymakers. For instance, low relative investment in research, uninspiring private sector performance in terms of these investments with most patenting by non-residents. We elaborate on such trends now:

Figure 2 shows a persistent increase in the R&D investment by the public sector immediately after the independence. During 1980's, a sharp increase is noticed in the public funding of research that can be attributed to establishment of various institutions like Technology Development Board (TDB) and Technology Information Forecasting and Assessment Council following Technology Policy Statement in 1983. During 1990's India liberalized its economy and witnessed the flow of foreign investments along with increased openness to trade. However, public investments in R&D did not pick up until the first decade of 21st century when India also experienced overall economic growth. An important aspect of India's investment in R&D is the lower proportion of the private sector as compared to the public sector which is not in line with the major industrialised economies.

For instance, in the US and China, a large share of R&D spending comes from business enterprises - upwards of 60-70%. However, in India in 2016-17, as per the Department of Science and Technology (DST), India, only 42% of total R&D spend is by the private sector[11]. The number, though not comparable with international standards, has increased considerably from 19% in 2001-02. Another important worrying aspect of the investments made in research in India, is that the gross R&D expenditure is among the lowest in the world, at $43 per capita, according to the NITI Aayog's India Innovation Index 2021[12]. Additionally, the R&D expenditure as % of GDP between 1996 to 2018 is 0.73% (Figure 3). This percentage is stagnant between 0.60 - 0.80 over 1996 to 2018. Note that the ratio of R&D expenditure to GDP in India is low in comparison to many developed and developing countries. For countries like Brazil, Russia, China, and South Africa the percentage of R&D expenditure as GDP is 1.2%, 1.1%, over 2%, and 0.8% respectively. For the U.S., Sweden, and Switzerland the percentage is 2.9%, 3.2%, and 3.4% respectively. Evidently, the R&D budget is prioritised last because tax revenue is insufficient compared to the amount needed for constructing infrastructure and providing public services.

Figure 2: R&D Expenditure in India in million USD

Figure 3: Total R&D Intensity (% of GDP)

In terms of patenting activity, Chand (1950)[13] noted that 10692 patents were in force in India in 1949. The report further highlights that during 1856-1949 under different acts in total 2,99,22 applications were filed. Among these applications 21% originated from India and merely 15.15% of the total applications were filed by Indians. Most applications originated from the U.K. followed by the U.S. and Switzerland. Sagar (p. 316, 2020) concludes that it was "the interests of British patentees" that lead to "the first introduction and establishment of patent law," with the main objective of collecting royalties for their inventions patented in India. Considering the state of science and technology education in India, the capabilities of Indians inventors were limited, and the extent of rights were stronger as may be mandated by their technological capabilities.

To understand long run movements in patenting, we collected information from IPO from 1900 onwards. This data is for the applications filed in a particular year that were granted[14]. This information, presented in Figure 4a, reveals that the total average applications that were granted between 1900-1920 is 293 per year which increased to 952 for the period 1921-1940[15]. The overall trend, however, hides variations during the different phases that are evident from figures 4b and 4c that present data from 1947-1994 and 1995-2021 respectively. Figure 4b shows that after 1970, there is sudden decline in patent applications that can be attributed to key changes introduced in the act with respect to product patents. Now only process innovation can be patented in the fields of food and medicine for a period of seven years, whereas other fields of technology can be patented for a period of 14 years. The significant impact of this Act was on the MNEs leading to their exit from the Indian market (Chaudhary & Khanna, 2014). The exit of MNEs from the local market created an opportunity for the domestic firms to improve their capabilities through adaptive R&D following the Act. We will discuss about the influence of patent policy changes on the pharmaceutical sector of India, in a separate sub-section.[16]

We observe a constant trend in the patent applications between 1990 to 2004 whereas there is a sudden jump for the years 2004-2008 that further started declining after 2008. The Patent (Amendment) Act 1999 provides permission to file product patents in the field of pharmaceutical, drugs and agrochemical. However, such applications were examined and granted only after December 31, 2004[17] so the surge in patent issuance during 2007-09 was attributed to clearing a backlog of patent filings (Unnikrishnan, 2008). In the later years, IPO experienced an acute shortage of staff that is reflected in the sharp drop in patent grants during 2009-12. For instance, "about 55 Patent Examiners left the organization during 2004-09 and no recruitment took place during this period. Further, 47 patent examiners were promoted as Assistant Controllers during January 2009 and hence were not available for examination. This explains the comparative low figure of examination and grant during 2009-10," (Annual Report of IPO 2009-10).

Figure 4a: Patent applications (1900-2021)

Figure 4b: Patent applications (1947-1994)

Figure 4c: Patent applications (1995-2021)

Figures 5 and 6, chart patent applications and grants for the major fields of technology[18]. These fields are identified by IPO based on high patent concentration. The total number of patents applied for by Mechanical Engineering for the period of 2011-12 to 2020-21 is 107028. This sector is a leading sector in terms of patent applications. Moreover, there was a continuous increase in patent filing in other fields of technology. In terms of patent grant, 27997 patents are granted to Chemical field for the period of 2011-12 to 2020-21 which is highest among all fields of technology.

Figure 5: Number of patent applications under major fields of technology

Figure 6: Number of grants under major fields of technology

The international treaties covering IP have been negotiated since the 19th to ensure certain protection for the inventors in other jurisdictions.[19] Collectively, minimum regulations, national treatment and reciprocity as covered in the TRIPs agreement are likely to remove uncertainty for inventors and give them confidence to file patents in other jurisdictions. In India, historically non-resident patents have been high as revealed by Chand (1950), further, non-residents applications are still a large portion of the applications filed as evident from Figure 7. Though it seems that recently, there is a point of inflexion in India's patent filing history as *"for the first time in the last 11 years, the domestic patent filing has surpassed the number of patents filed by non-Indians at the Indian Patent office in last quarter (Q4) of 2021-2022."* (Sanyal and Arora 2022, p. 5).

Figure 7: Applications filed by residents and non–residents through various routes

Within the patents applied for by the residents, the top patentees include companies like Microsoft, Qualcomm, Huawei, Samsung, Ericsson, and GE are. Earlier researchers have also highlighted that among the resident patentee the number of foreign companies in India is rather large. This has been attributed to the companies' vast experience with patenting though their involvement in

R&D in the domestic economy is rather limited (Chaudhuri, 2012 & 2013; Basant & Srinivasan, 2016; Dhanora et al., 2021).

In consonance with the national Startup Mission, IPO has facilitated patenting by startups as now such firms can benefit from accelerated examination processes to obtain patents in about a year or two, and new rules permit a 50% fee reduction for startups starting in January 2021. Patenting by startups in India though low but have seen growth recently. For the year 2016-17 total number of patent filed by Indian startups is 160 which is further increased to 511, 801, 1650 and 1598 respectively in the years 2017-18, 2018-19, 2019-20 and 2020-21.

Another few aspects of patenting that we intend to bring forth are regarding the commercial working of patents, their quality and enforcement. Interestingly as per patent policy requirement, companies disclose the information about commercial working of newly invented products and processes by filling out Form 27 as per the Section 146 of the Patents Act, 1970. Figure 8 shows that there is an increase in the number of patents in force over the period in India. Patents in force between 2005-2014 are 30432 which increased to 62587 for the period of 2015-2021. There is about 105.67% increase in patent in force between 2005-2014 to 2015-2021. In the year 1989, only 289 patents were commercially working in India that is just 2.13% of the total in force patents at that time. The average of total commercially working patents for the period of 1990-1996 is 5.73% of total in force patents. However, this number increased to 11.23% in the year 2010. For the year 2017 and 2018, total commercial working of patents is 23.20% and 21.57%, respectively.

The surge in Indian patenting activity concomitantly raises issues about the quality of patents. Danish et al. (2019, 2022) investigated the quality of Indian patents using patent renewal information[20]. The findings of these studies show that the survival rate of Indian patents is low. Furthermore, patents filed in the field of instruments, mechanical and electrical, are of a higher quality. According to Danish et al. (2023), collaborative patents have a higher survival rate.

Figure 8: Commercially working patents

3. Assessment of the patent policy

Machlup (1958) establishes four reasons to advocate patents including natural-law thesis, reward- by-monopoly thesis, monopoly-profit-incentive thesis, and exchange-for-secrets thesis. A reward through monopoly rights is provided to the inventors for creating new products and enabling future inventions. Monopoly profits also incentivize creators to undertake research and development that is uncertain, risky, and expensive. The role of patents in incentivizing innovation is much debated and there is no simple answer. Many empirical studies, based on the Ginarte and Park index of patent policy (Ginarte

& Park, 1997; Park, 2008), take advantage of patent law differences across countries to explore the role of patent policy on innovation. These studies highlight the need to pay special consideration to the imitative, adaptive, and non-drastic nature of innovation and differential level of technological development among the developing countries. Also, one needs to understand the complexity of the relationship between making provision for patents and motivating innovation due to industry specific innovation propensity, availability of alternative means of appropriation and strategic consideration of firms (Sharma, 2022).

In the Indian context, due to non-availability of data from innovation surveys, most research relies on R&D and patenting as a measure of innovation. With respect to R&D as a measure of innovation, current studies have investigated factors such as firm size, market structure (Ghosh, 20009; Kumar & Aggarwal, 2005; Mishra, 2007), technology imports (Aggarwal, 2000), export intensity, and ownership related aspect (Ghosh, 2010) as its key determinants. Another set of studies focuses on the changes in the regulatory framework, particularly liberalization, and its impact on R&D activity of firms (Kumar & Aggarwal, 2005; Bas & Paunov, 2018). Sharma et al. (2018) use panel data for 1989–1990 to 2009– 2010 to find the specific impact of patent policy changes from 1999 onwards on innovation proxied by R&D expenditure in India. The results indicate that patent index does affect R&D intensity in a positive manner. However, while controlling for the general policy changes like delicensing and tariff reduction, that Indian government also undertook during the same time frame, the effect of patent index on research intensity becomes insignificant. Sharma et al. (2018) concludes that "since regulatory environment in India was generally restrictive to start with, any relaxation is seen as a big boost by businesses, much more than patent regulations." The study also segregates the patent policy changes into three time periods based on the policy amendments as mentioned earlier but does not find any consistent impact of any particular year. The study, however, does not take into account the technological capabilities of the firms that can impact the gains from strong patent regime. If some firms are adopting and adapting the technologies to the local requirements while a few are introducing novel products in the market, clearly the gains from strengthening patent rights in the industrial sector are going to be unequal.

Sharma et al. (2018) further probes the impact of specific policy changes namely the increase in the duration of protection to 20 years, enforcement mechanism, and membership into international convention on R&D intensity of firms. The results highlight that the firms respond to longer-term protection and strengthening of the enforcement mechanism by increasing their investments in R&D. Finally, as India became member of various international conventions firms engage in R&D as the patent protection is in line with international code of conduct.

Corroborating the thesis of industry-specificity of patents, Sharma et al. (2018) finds positive and significant impact of patent policy changes on manufacture of pharmaceuticals, medicinal chemical, and botanical products positive. Considering, that Indian patent policy since independence has focused on pharmaceutical sector, we have a separate sub section to elaborate the same.

Interestingly, in terms of patent policy changes and patenting as a measure of innovation, Ambrammal and Sharma (2014) find positive impact of the policy change on patenting by firms. Other studies, such as Chadha (2009), Haley and Haley (2012), and Jagadeesh and Sasidharan (2014), find that TRIPs related changes have a positive impact on the patenting in Indian firms and industries. However, studies based on patent data to examine the impact of policy changes on innovation may provide inflated results. As pointed out by Bryan and Williams (2021), the costs and benefits of patent filing alter with the changes in patent law. Under these conditions, it is difficult to distinguish if the propensity to patent is behind the increase in the filling or it is the real innovation.

Sectoral Analysis

Pharmaceutical

Indian pharmaceutical sector is a prominent player internationally as it supplies over 50% of the global demand for various vaccines and 40% of the generic demand for the U.S. (IBEF, 2022). Indian pharmaceutical firms are active in the production of formulations and bulk drugs activities. According to Bedi et al. (2013), the R&D by Indian pharmaceutical firms is involved in the development of new chemical entities, modifications of existing chemical entities to develop new dosage forms, forming new processes of manufacturing activities of existing pharmaceutical products and development of formulations for regulatory requirements. Prior to the Patent Act 1970, Indian pharmaceutical market was dominated by MNEs that controlled more than 75% of the market by importing the drugs (Duggan, Garthwaite and Goyal, 2016) leading to high market prices. The changes introduced in 1970 led to an exodus of foreign firms giving way to domestic firms to enter and develop capabilities and cater to the country's medical needs. Chaudhuri (2012), Kale and Little (2007), and Duggan et al. (2016) explain that Patent Act 1970 encouraged the entry of domestic firms in Indian drug market resulting in decrease in the prices of essential medicines. This Act improved the capabilities of domestic firms by increasing adaptive R&D expenditure. Eventually, India has emerged as a major supplier of cheap and quality generics to the global market (Goldar, 2013).

After the recent policy changes, the level of R&D expenditure by domestic firms has increased along with the number of patent applications. Goldar and Gupta (2010) noted that industry has also become more research-oriented as the ratio of R&D expenditure to sales has increased from 2% in 1996–1997 to about 6% in 2008–2009 based on the analysis of their sample firms. Mahajan (2011) also shows that the policy changes resulted in increased R&D efforts. Our analysis, based on 596 firms from CMIE Prowess data, shows that the Indian pharmaceutical industry's R&D intensity has been rising. The average R&D intensity of these firms was 1.49% in 1995, rising to 4.61% in 2005 and 6.62% in 2017. Similarly, the average R&D intensity of the top 5 R&D intensive firms in the sector is inching upward (currently at 12.3%) towards the international average of 16%.

In post TRIPs era, there is an increasing trend in patenting and patent enforcement in the Indian pharmaceutical industry. Chadha (2009) find that the patenting activity of the pharmaceutical firms increased after the TRIPs agreement. In 2001-02, total number of patent application filed for drugs were 871 and number of granted patents was 320, in 2010-11 this number increased to 3526 for application and 596 for grants (IPO 2014). Further, the number of product patent granted to pharmaceutical sector is 4486 for the period of 2005-06 to 2009-10; similarly, the number is 998 and 2824 for the period of 2010-11 to 2013-14 (upto 31-07-2013) and 2016 to 2019, respectively[21].

Figure 9: R&D intensity of Indian pharmaceutical industry

Nair (2008) explains that in post TRIPs era Indian pharmaceutical industry emerges as a global player exporting to developed countries like US and Europe which was initially limited to only least developed nations. Horner (2014) evaluates the impact of patents of Indian pharmaceutical industry in pre and post TRIPs era and find that during 1972–2005 local firms were mostly copying the MNEs' products resulting in the price reduction of the medicines in the domestic drug market. However, from 2005 onwards there is a positive impact of patent policy changes on R&D expenditure that is process oriented to serve the markets of high-income economies. Some researchers have also raised concerns with the product patent regime, pointing out that the foreign firms are again gaining market power in post- TRIPs era which result in high drug prices (Goldar, 2013; Chaudhuri, 2012 & 2015).

Using data from the Orange Book and CDSCO, Chaudhuri (2012) revealed that 50% of products patented after 1995 are marketed by foreign companies, accounting for approximately 20% of total patented product sales in 2010. This rising foreign company dominance has a detrimental effect on consumer welfare. Chaudhuri et al. (2006) investigates the welfare implications of TRIPs using data from the Indian drug market on quinolones. According to this study, the withdrawal of domestic product from the quinolones sub-segment costs the Indian economy approximately Rs. 13.70 billion in welfare. According to Bhaskarabhatla et al. (2016), India's pricing control policies are poorly implemented. They evaluate the impact of the Drug Price Control Order (DPCO) 2013 on limiting the cost of metformin, one of the most important oral diabetes medications. Using difference-in-difference methodology, this research highlights that pharmaceutical lobby raises the price of metformin prior to the price regulation period, which raises the price of metformin in the price regulation regime.

Information Technology

The role of software innovations is growing worldwide, and India has emerged as a global hub for information technology (IT) (Kumar & Puranam, 2011) that also contributes immensely to its domestic economy. India's IT sector accounted for 7.4% of India's GDP in 2021-22, and it is expected to contribute 10% to India's GDP by 2025 (IBEF, 2022). Eberhardt et al. (2016) examines the impact of various changes in the Indian patent law on the expected returns of software companies. Based on the event analysis, this study concludes that a softening of patenting restrictions in December 2004 resulted in a positive market response and a negative market response when these restrictions were reinforced in June 2005. Mani (2014) also points out that the share of software patents in total patents from India at the USPTO is steadily increasing. The study mentions that companies like Infosys, TCS, WIPRO, Ittiam Systems, Sasken, Ramco, L&T, and Mindtree are having a large share of patents granted by the USPTO. According to Mani's (2019), all the major patent holders in 4G and 5G mobile technology are foreign MNCs based in India.

Patent policy and technology transfer

Foreign Direct Investment (FDI)

Firms in developing countries acquire technology primarily through market-mediated channels such as trade in goods and services, foreign direct investment (FDI), licensing, or non-market channels such as employee turnover. Several studies investigate the link between changes in governmental regulation including patent policy on technology imports, and FDI[22] ( ). According to Ferrantino (1993), a strong IP regime lowers the costs of enforcing contracts between MNEs and their partners (affiliates or non-affiliates) for buying and selling technology. Studies find that IP regimes explain variations in FDI (Seyoum, 1996; Lee & Mansfield 1996; Lesser, 2002). Most studies use cross-country data to explore the role of patent regime on FDI instead of firm level information.

In India, with reference to few aspects of the patent system, a very sharp reaction of the MNEs has been noticed even after 2005. First is with respect to if a patent can be granted to minor variations of existing compounds in case there is enhancement in the efficacy. In a case law *Novartis v. Union of India & Others,* the Supreme Court decided that the substance that Novartis sought to patent was indeed a modification of a known drug as Novartis could not present evidence of a difference in therapeutic efficacy between the final form of Gleevec and the raw form of imatinib. Abbott (2013) pointed out that the judgment has received severe criticism from a number of originator pharmaceutical companies, including Novartis, and from the US Chamber of

Commerce. Another most discussed case is about the compulsory license that was issued in 2012 over Bayer's patented anticancer drug Sorefanib Tosylate (sold as "Nexavar") on the ground that it was exorbitantly priced about USD 4500 a month and hardly available to 2% of the patient population. The license was issued in favour of Natco, an Indian generic company, which then sold the drug (as "Sorafenat") about USD 150 a month. Following the judgement, the United States Trade Representative's Office (USTR) placed India in the priority watch list in its 2013 Special Report. The report pointed out that such developments raise questions about the "innovation climate in India". Such reactions highlight the close attention paid by MNEs to IP protection and its enforcement in a host economy.

Licensing

The creation and existence of technology market is pertinent for a developing economy as the purchase of technologies from the international market boosts technical capabilities while conserving resources. A patent regime opens the market for technology and facilitates its transfers between the owner and the buyer. Literature espouses that the impact of patent policy on licensing of technology by firms be either positive as it ensures economic returns or be negative due to the creation of monopoly power (Yang & Maskus, 2001). Studies based on licensing by the U.S. firms show that the impact of patent protection on licensing is conditioned by the existing level of protection (Yang & Maskus, 2003), is industry specific (Anand & Khanna, 2000) is relatively higher for developed countries (Park & Lippoldt, 2005). Kanwar (2012), based on licensing receipts by the developing countries, finds positive influence of the patent protection on the licensing of the technology by such economies.

Sharma and Ambrammal (2015) study the impact of patent policy on licensing intensity that is the foreign expenses made by firms in India as royalty payments, technical know-how fee and licensing fee. The study uses panel data for 51 industries for 1989-1990 to 2009-10 and isolates the general industrial policy changes in India after 1991 from the patent policy reform. This study does not find any significant impact of patent policy changes on licensing of technology. The study further enquiries into the industry-specificity of the technology transfer as in the sample on an average foreign licensing by patent sensitive industries is higher by 0.2 million Indian rupees. The empirical estimations provide a negative coefficient on the interaction term of patent sensitive industries and patent policy changes corroborating the monopoly power effect of increasing the strength of patent policy in favor of technology owners.

Patent Documents

The exchange-for-secrets thesis establishes an additional benefit of patent rights that is due to the disclosure requirement of patent applications. The disclosure requirement ensures that information is made available to other researchers and new knowledge has not been kept secret due to imitation threat. Mazzoleni and Nelson (1998) elaborated that disclosure requirements are important for furthering technological change of an economy, as a single inventor cannot exploit all possible uses of an invention. However, the empirical evidence of the role of information disclosed in patent documents and ensuing innovation is indeed mix (Magazzini et al., 2009; de Rassenfose et al., 2016; and Nagler & Watzinger 2021). Sharma (2019)[23] examines of 17,881 patents assigned to India from different patent offices that have 3,99,902 backward citations (examiner and applicant). A very small proportion of citations (9%) is made to patents with family patent in India. The study use case control approach for a sample of 19,775 citations that have family patent in India and 18,591 citations that do not have family patent in India. In terms of patents, the sample covered 39% of the patents that have at least one citation. The study finds that 98% of total patents and 99.7% of total citations in the sample are post 1999. The results of logit model show that the probability to cite domestic firms by another domestic firm is higher than the probability of domestic firm citing a foreign Indian firm. Moreover, the probability of knowledge gain from foreign parent firms that do not have a subsidiary in India is higher than knowledge gain from foreign parent firms that have a subsidiary in India. The author conclude that Indian firms are not using the information contained in patent documents. The possible reasons for this include (i) lack of awareness among the domestic firms to utilize the patent documents as a knowledge source, (ii) technological gap between foreign and domestic firms hindering the spillover process and (iii) limited sample particularly for case-control study that can be extended by including data on all citations.

Patents, Exports and Firm Performance

Investment in R&D strengthens the technological foundations of the firms, giving them confidence to explore international markets and export. Hasan and Raturi (2003) investigate the factors that influence exports in the Indian manufacturing industry, with a particular emphasis on the role of technology. According to the findings of this study, firms with technology imported via technology transfer and R&D are better positioned to enter export markets. Plane and Veganzones-Varoudakis (2019) confirm the positive impact of innovation on export in another study on the Indian manufacturing sector. Furthermore, Danish et al. (2021) investigated the impact of product and process innovation on export performance and revealed disparities. Studies like Goldar (2013), Tyagi and Nauriyal (2017), Mishra and Jaiswal (2017) and Bhat and Narayanan (2009) also explored the relationship between R&D and export and reported significant results. However, there is a lack of evidence on the impact of patent policy changes on the exporting capabilities of the Indian firms. Moreover, it is not studied if the changes in the policy in destination countries have impacted the firms' decision to export and its quantum.

The innovation activities of the Indian firms are expected to contribute towards productivity gains for the firms[24] R&D spending has been used in the studies by Goldar (1986), Raut (1995), Sharma (2010), and Sharma (2012) as an indicator of firm-level innovation activity. Ambrammal and Sharma (2015) and Khachoo et al. (2018), on the other hand, examine patent data for the industrial sector. Employing productivity, profitability, and Tobin's q ratio as performance indicators, the study by Ambrammal and Sharma (2015) quantifies the effects of patenting on the performance of the firms. This study uses a relatively new source of data, firm-level patent granted, that has not previously been investigated in the context of India. The study reveals that patenting by firms improves their performance. The study also provides evidence of patenting's positive benefits for financial performance, with clear distinctions between international and domestic enterprises. Another study by Dhanora et al. (2021) analyzes the impact of technological innovation on productivity of Indian pharmaceutical firms. This study utilizes firm-level panel data for Indian pharmaceutical industry for the time 2000–2013. This study suggests that both product and process have positive and significant impact on firms' productivity. However, this relationship varies with the ownership structure of firms. MNEs are enjoying market benefits as they are efficient and productive.

Patents and Market Power

Firms can sustain their market dominance through new products and processes that provide means for large and old firms to create high entry barriers. The dominant designs developed by a firm deter the entry of new firms and increase merger activities, which then results in high market power (Utterback and Suarez 1993). According to empirical research, MNEs in India perform more innovatively than domestic enterprises (Ambrammal & Sharma, 2016; Dhanora et al., 2018; Khachoo et al., 2018). The size and dominance of MNEs is a result of their technological prowess and access to capital. In terms of investment capacity, absorption capacity, technological profile, and productivity score, MNEs also have an advantage over local enterprises (Cohen & Levinthal, 1989; Patel & Pavitt, 1997; Sharma, 2012).

A recent study by Dhanora et al. (2021) investigate the relationship between MNEs market power and their patenting activity. This study investigates the effects of new product and process development on the market strength of 168 Indian pharmaceutical companies between 2000 and 2013. To capture firm-level innovation activity, this study calculated product and process patents stock. Results of this study imply that firms' market power is positively influenced by both product and process innovation. The results also show that MNEs have a stronger position in the Indian pharmaceutical sector, particularly firms from the U.S. and Europeans countries are dominating the drug market in India. Additionally, the impact of a firm's product group on market power varies but patenting enhances business performance in the Indian pharmaceutical sector. Interestingly, the relationship is not linear as shown by Dhanora et al. (2018).

This study based on pharmaceutical companies in India support the inverted U-shaped relationship between technological advancements and market dominance as operationalized by the Lerner index. The findings are unaffected by profitability as an alternative measure of market dominance.

4. Caveats and new frontiers

In the concluding section, after summarizing the paper, we briefly mention a number of other patent policy issues that need attention of the researchers in India.

India's innovation landscape has gained momentum in the first two decades of the 21st century. The key indicators of such dynamism are (i) steady increase in the private sector participation in the research with increasing share in the total investments made in R&D nationally, (ii) overall growth of patenting activity that is not only supported by surge in the application by non-residents but also that of residents, (iii) recently, residents' patenting activity has increased manifold and is likely to overtake that of non-residents and (iv) the entrepreneurial activity has also been witnessing a renewed energy as startups are growing manifold with an enabling ecosystem including patent policy support. After the economic reforms including the removal of heavy state regulation and opening to the rest of the world, GoI has also created R&D tax credit incentives for the private sector along with an overhaul of the patent system. Clearly, relaxation in the regulatory environment is seen as a big boost by businesses that are now investing in research to sustain competition.

From an emerging economy perspective, like India, in accord with the empirical results based on other countries, evidently there is no straightforward answer if patents incentivize innovation and facilitate technology transfer. There is a need to understand the complexity of the relationship between making provision for patents, motivating innovation, and creating markets for technology. Innovation in certain industries gains from patents. However, the current empirical strategies of the studies cannot capture the inventions that were scientifically feasible but were never brought to market due to insufficient patent policy terms (Budish, Roin, and Williams 2016). As no clear answer has emerged from the research of the past three decades on the role of patents on innovation, once again the discussion on the utility models has emerged in the policy circles. Sanyal and Arora (2022) noted, "a new legislation granting protection to incremental innovation through utility models can be considered to be brought about in India." The need for such an act is realized due to the incremental nature of innovation in India and to support the start-ups and small-scale enterprises.

There are other aspects of patents that remain understudied in the Indian context like scope and disclosure function of the patents. For instance, not much evidence is available about the impact of patents on sequential innovations.

Such evidence is much needed given the specific characteristic of patenting in India whereby majority patent are granted to non-residents and even within residents' patents, foreign firms are most active. The studies centering around the effects of such patents on sequential innovation by residents, market competition and monopoly power are, therefore, much needed. The strategic use of patents by firms in India has also not gained much traction by the researchers. Interestingly, the data available on the working and non-working of patents can be employed to study the strategic considerations of firms while patenting.

Considering the relative ease in the availability of patent data from IPO as compared to few years ago, we also view the abovementioned issues as ripe for future work. Such availability of data is further supported by developments in the techniques like deep-learning based text understanding for extracting the information. The need of the hour is to harness data in different patent documents to understand patterns of innovation and various facets of inventions like the role of collaborations, patent quality, knowledge spillovers and many more.

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Notes

1 Other forms of IP are copyright and related rights, trademarks, industrial design, and geographical indications.

2 The information is based on History of Indian Patent System | About Us | Intellectual Property India | Government of India (ipindia.gov.in)

3 The Sepoy mutiny had prompted the then British Parliament to transfer the powers of Indian government, territories, and revenue from the East India Company to British Crown.

4 If a patent is filed or granted on unfair ground, one can challenge its validity.

5 A patent can be revoked if there is wrong information about the source and geographical origin of the biological material.

6 See the website Council of Scientific & Industrial Research | CSIR | GoI for more details.

7 A start-up is defined as any innovative entity that was incorporated or registered within the last five years and has less than $3,736,060 in annual gross revenue. A startup, according to the Patent (Amendment) Rules, 2017, can be any Indian entity recognised as a startup by the competent authority under the Startup India Initiative or a foreign entity that meets the Startup India Initiative's turnover and period of incorporation criteria.

8 Report by The Economic Advisory Council to the PM titled, "Why India needs to urgently invest in its patent ecosystem?" (PDF File)

9 The time take for first office action is 4.5 months for the European Patent Office and 15.4 for the U.S.

10 Draft is available at: https://dst.gov.in/sites/default/files/STIP_Doc_1.4_Dec2020.pdf

11 See: Research and Development Statistics 2017-18, Department of Science and Technology (DST), December 2017, http://www.dst.gov.in/research-and-development-statistics-2017-18-December-2017.

12 More details are available at https://www.niti.gov.in/sites/default/files/2022-07/India-Innovation-Index-2021- Web-Version_21_7_22.pdf

13 B. T. Chand, Report of the Patents Enquiry Committee (1948–1950) (Delhi: Government of India, 1950).

14 Current studies rely on either application or grant data to capture the patenting activity of a country. However, the platform by IPO for data download is designed such that we could get data only for applications that are granted later with the year relating to the time of filing the application.

15 These figures do not align with the numbers from Chand (1950) due to following reasons: (i) these numbers include the application filed in a particular year that were granted. So, the applications that were not granted are not part of this information and (ii) the data on inPASS is dynamic, particularly from earlier periods which is updated regularly as more digital records are made available. This also explains the missing information between 1900-1912.

16 See, Duggan et al. (2016), Goldar (2013) and Kale and Little (2007).

17 These patent applications are commonly known as mailbox patent applications.

18 For this analysis, we focus on recent data due to consistency in definitions and availability.

19 National treatment and reciprocity were introduced in international treaties with Paris Convention (1883) and Berne Convention (1886). National treatment implies that "each Member accord to the nationals of other Members' treatment no less favourable than that it accords to its own nationals with regard to protection of intellectual property," (Article 3 of TRIPs). Reciprocity signifies that as a signatory country of an international treaty provides national treatment to inventors of other member countries, her own inventors receive national treatment in return (Scotchmer, 2003).

[20] The information on patent's renewal is one of the measures of patent quality available in the literature (Schankerman & Pakes, 1985; Arora et al., 2001; Lanjouw et al., 1998; Bessen, 2008).

[21] See the list
http://www.ipindia.nic.in/writereaddata/Portal/Images/pdf/Drugs_Patent.pdf
https://www.ipindia.gov.in/writereaddata/images/pdf/revised-list-of-pharma-patents.pdf

[22] See for instance Dunning, 1979; Horstmann & Markusen, 1987; Wang & Blomstrom, 1992; Kabiraj & Marjit, 1993; Smith, 2001; Kabiraj & Marjit, 2003; Maskus, 2004.

[23] An unpublished project report submitted to Indian Council of Social Science Research (ICSSR) in 2019.

[24] See, for instance, Goldar (1986); Fikkert (1996); Khachoo et al. (2018); Raut (1995); Sharma, (2010 & 2012) and Ambrammal & Sharma (2016).

3

Knowledge-driven development through national innovation systems: a comparative analysis of global south versus global north

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Abstract

Existing literature emphasizes that innovation, technological development, and knowledge (especially foreign technological knowledge) are critical economic growth and development factors. Most of the developed nations obtained economic transformation through knowledge-based innovations. The growth of East Asian tigers (Particularly, South Korea, Taiwan, and Singapore) are the best example. They have achieved rapid industrial and technological catch-up through the effectiveness of their National Innovation System (NIS). Therefore, this study investigates the NIS interrelated dimensions such as Patent applications, R&D expenditure, and High-Tech exports of Selected three East Asian Tiger countries (South Korea, Singapore, and Taiwan) and compares them with Sri Lanka. Furthermore, this study investigates how these factors (Patent applications, R&D expenditure, and High-Tech exports) impacted growth for different income levels. For that, the study uses a quantitative methodology, depending on secondary data, relying on the data period from 2000- 2021; the study empirically estimated pooled OLS, panel Fixed effect, and Random Effects estimation using 20 Developed countries and 22 Developing countries.

The results indicate that High-tech exports, the number of patent applications, and R&D expenditure on science and technology are significant measures of a country's growth. The results are significant for the developed sample but not for the developing sample. Furthermore, in Sri Lanka, NIS is weak and needs more attention to sustain growth.

Key Words: *National Innovation System (NIS), Knowledge, Innovations, Sustain Growth, Global North, Global South, Sri Lanka*

1. Introduction

Existing literature has discussed the importance of Technological development on growth through the National Innovation System (NIS) Lundwal 2007, Malerba, 2005, Lee (2001, 2016, 2018), Joseph (2021), Singh (2010) and many others. Although not the only pillar of innovation, technological development is both part of the innovation process and a result of it. Innovation involves much more than knowledge of the relevant science and technology. (Schumpeter, 2000) has accepted a distinction between the formulation of a working idea for a product or process (an invention) and the application of that idea to the economy (an innovation). The literature stresses that innovation, the improvement of existing or the creation of entirely new products, processes, services, and business or organization models, drives long-run economic growth and quality-of-life improvements (Becker & Knudsen, 2002).

The view is that innovation is a crucial sustainability driver, and many scholars have emphasized it. Hence, Sustainable development is a pressing issue that requires immediate action and changes from governments, industry, and society (Tirca & Silvestre, 2019). In the context of globalization, the marketplace is undergoing rapid changes in competition, technological advancement, and a shift to knowledge-based economies. Against this background importance of knowledge as a competitive weapon has increased dramatically (Dierdonck, Debackere, & Engelen, 1990). Furthermore, Mansell (2002) stated a more substantial knowledge base for knowledge-driven development. Research enables advancement in knowledge and technology and thereby creates an environment conducive to innovation which is considered the driving force behind economic development (Esham, 2008).

In the late 1980s, the systematic view of innovation at the national level attracted much attention. Freeman (1987) and Nelson (1993) are significant contributors to the perspective of the National Innovation System (NIS). The National Innovation System (NIS) is a concept aimed at interpreting the phenomena of current growth. The miraculous economic development experienced in the 1900s by East Asian countries (such as Japan, South Korea, and Taiwan) has been critical to many other developing countries. It has attracted much attention in development studies (Amsden, 1994).

However, many developing countries fail to reach knowledge-based development because most developing countries need proper NIS. Furthermore, they need more technology, innovation, and knowledge, especially in high-tech industries. Instead of technological innovation-based industries, developing countries still have mostly labor- intensive industries. At the same time government spending meager amount for R&D. Therefore, the main research questions are why is it essential to have better NIS for developing countries? Moreover, what is the role of National Innovation Systems in Sustainable Growth in developing countries; what are the development indicators of NIS? Finally, how innovations and knowledge-based development could enhance growth, and what are the determinants of it?

First, this study conducted a comparative analysis of global South and northern countries to find answers to the following questions. Mainly, this study researched three East Asian countries, namely South Korea, Taiwan, and Singapore. We then compared it with Sri Lanka in selected indicators. Furthermore, using the quantitative methodology, depending on secondary data, relying on the data period from 2000- 2021, the study conducted a pooled OLS, panel Fixed effect, and Random Effects estimation for global north countries (20 selected developed countries) and Global south countries (22 selected developing countries).

This paper has organized as follows. Section two discusses related literature; Section three shows the methodology, data, sample, and empirical framework. Section four shows the comparative and empirical analysis with empirical results and Interpretations. Finally, section five concludes the study by providing policy suggestions.

2. Literature review

Concept of Innovation

Innovation is a significant business challenge, seen as increasingly essential for growth and viability (Tidd, 2001). However, it is challenging for companies to know what is necessary for successful innovation (Christensen, Raynor, & McDonald, 2013). Innovation adoption is 'the generation, development, and adaptation of novel ideas on the part of the firm' (Damanpour 1991; Higgins 1995). In the 1930s, an Austrian-American economist Schumpeter (1934), realizing the importance of innovation or novelty in an economic system, defined innovation means the commercial or industrial application of something new such as goods, a new style of manufacturing, the opportunity for a new marketplace, detain of a new transport source, polishing off a new institute or the association of any industry (Usman, Liu, Hameed, Bi, & Wu, 2015). According to Lewis, (2009), innovation has become the engine of the universal economy nowadays. It is widely discussed as the core driver of countries' competitiveness, trade, and industry growth.

Origin of the Concept of NIS

The innovation system concept was developed in Europe and the US in the 80s. Undoubtedly, the collaboration between Christopher Freeman and the IKE group in Aalborg at the beginning of the eighties was important in coining and shaping the earliest versions of the concept (Freeman 1982 and Lundvall 1985). Hence, the essential ingredients and inspiration may be found in the work of many other innovation scholars before that (Lundvall 2007). Freeman brought a deep understanding of innovation processes, historical insight, and wisdom to the collaboration. His reference to Friedrich List was crucial since it linked the concept to the state's role in catching-up processes. The IKE group, inspired by French structuralist Marxists and development economists, contributed ideas about 'national production systems' and 'industrial complexes' where vertical interaction was crucial for performance and outcome and linked this to the analysis of international specialization and international competitiveness (Lundvall, 2007). However, the NIS is a concept aimed at interpreting the phenomena of current growth and has primarily been analyzed in the literature of the 1990s.

Furthermore, NISs have become indispensable, both in academic circles as well as in international institutions. Moreover, the literature on 'regional systems of innovation' has proliferated since the middle of the nineties (Malmberg, 1997), while Franco Malerba and colleagues developed the concept of 'sectoral systems of innovation' (Breschi & Malerba, 1997). Some of the critical ideas inherent in the innovation system concept (vertical interaction and innovation as an interactive process) appear in Porter's industrial clusters and Etzkowitz & Leydesdorff's Triple Helix-concept (Etzkowitz & Leydesdorff, 2000).

The Model of Taiwan

Wong (1999) describes Taiwan's path and the NIS, which supported it as the Reverse Value Chain. In essence, this technological capability development strategy involves developing process capabilities, then extension into product design capabilities, and finally, new product creation/branding activities. This reverses the typical sequence of value chain activities pursued by large, established, high-tech firms in advanced countries. Most Taiwanese firms that pursued the Reverse Value Chain strategy started as SMEs engaging in labor-intensive manufacturing activities. Because of their limited resources, they could not invest much in R&D efforts. Hence, the state played an essential role in diffusing process technologies to the SMEs through public research institutes (PRIs) in the early stage and later by establishing various product technology consortia (Poh-Kam 1995). Shyu and Chiu discussed government innovation policies' role in advancing Taiwan's competitive advantage in more detail. The authors described how tools such as the alleviation of taxation, loan subsidy, technological assistance, government procurement, and workforce cultivation have increased incentives based on the supply, demand, and environmental sides (Shyu & Chiu, 2002).

The Model of South Korea

In contrast to Taiwan, the Korean innovation system model is characterized by large conglomerates, the Chaebols. Their large size and ready access to finance give them an enormous opportunity to undertake the reverse product life cycle. This can be seen in the rapid technological catch-up of the large Korean chaebols in such sectors as automobile, steel, consumer electronics, semiconductors (especially DRAM), and Active Matrix LCD. In all these cases, the giant Korean chaebols have moved aggressively from late followers to fast followers. In the case of DRAM technology, to become the global technological leader overtaking the USA and Japan (Kayal, 2008). To achieve their rapid catch-up via this strategic route, Korean firms have resorted to aggressive capacity investment to accelerate the learning effect, accepting thin margin or loss bearing to build volume and gain market share, and deep investment in R&D (Wong, 1999). After huge state investments in education and public Research and Technology Organizations (RTOs) during the 1960s and 1970s to increase the supply side of technology, the industrial sector needed more demand for R&D despite the government's strong encouragement and incentives. In other words, the supply of R&D and the linking mechanism were present, but the demand side was missing. Industries largely ignored the linking mechanisms due to the absence of a felt need to invest in R&D given the relatively easy means of acquiring and assimilating foreign technologies then available from many sources. It was only in the 1980s when technology was regarded as one of the essential underlying variables in market competition, that the situation changed. To fix this shortfall, the government introduced new policies designed to strengthen the industry's need for R&D. One of which was a list of import-substitution of major import items. The government designated specific target machinery, parts, and new materials to be localized for import substitution. It then offered tax incentives, preferential financing, and R&D subsidies to those who developed the designated items. Through 1987, the government has designated 1,555 such items (Kim & Dahlman, 1992)

The Model of Singapore

In contrast to Taiwan and Korea, Singapore adopted a model of a national innovation system that can be characterized as one emphasizing government facilitation of technological learning from Multi-National Corporations (MNC). Ever since the government embarked on a strategy of encouraging foreign investment to jump-start industrial development in the 1960s, the Singapore government has continued to encourage MNCs to upgrade their manufacturing processes and to bring in successive waves of new and more advanced products to be manufactured in Singapore. Research evidence has shown that these MNC operations have spawned a large supporting industry in Singapore and induced substantial technological capability development among many local subcontracting and contract assembly firms. This was also facilitated by the movement of experienced technical professionals and managers from the MNCs to start their contract manufacturing firms (Wong 1997). Although the Singapore government established PRIs to promote the diffusion of process technologies to local small and medium-sized enterprises (SMEs), it has probably done less in facilitating the diffusion of product design know-how than Taiwan and Korea (Kayal, 2008). To support a shift to another route of technological development, the government has accelerated the establishment and funding of PRIs/university R&D to encourage MNCs to start product R&D operations in Singapore and recently launched an ambitious Technopreneurship Program to promote the growth of new technology start-ups. Besides promoting the development of new supporting infrastructure such as a venture capital industry and IPR support services, the government is reviewing changes to existing business regulations (e.g., stock exchange listing regulations, stock option rules, and tax incentives for business angel investment) to facilitate the growth of technopreneur-ship (Wong, 1999).

National Innovation Systems in Sri Lanka

According to Wickremasinghe (2006), the NIS concept is novel for Sri Lanka, where interaction among various actors and institutions involved in technological innovation remains weak and emphasizes the importance of paying attention to how the government policy framework, R&D activities, education system, culture, history, traditions, etc., play their roles in this network system. Developing a robust innovation system in a country requires a robust network of government institutions, regulators, research institutes, universities, enterprises, consulting firms, and professional/ business groups. It is not just creating the right environment for this network to operate but also proving the right government interventions to ensure that a productive nexus develops from this (Wijesinha & Perera, 2012). NIS is weaker in Sri Lanka (Ramanayake 2022).

3. Methodology

As a methodology, this study uses quantitative methodology using secondary data. First, the study conducted a comparative analysis of NIS trends in the global South and global North. In this study global South is represented by the case of Sri Lanka; South Korea, Taiwan, and Singapore represent the global North.

The secondary data on innovations, especially patents applications, high-tech exports, and R&D expenditure, were compared. Using World Bank online data, WIPO data, Country websites, and journal articles, we collected the data.

Data Analyzing Techniques

For analyzing data, we conducted an empirical analysis of panel data by Pooled OLS, FX, and RE estimations with the Houseman test using STATA software. Further, some graphs and tables are drawn to identify data trends using MS Excel.

Empirical Framework and the Sample

This study conducted a panel data regression using 20 developed and 22 developing countries as an empirical analysis. The data period was taken annual data from 2000 to 2021. In this empirical analysis, we considered the key indicators NIS impacted and its impact on growth. Therefore, the impact of patent applications, R&D expenditure, high- tech exports, and foreign direct investments on the country's GDP growth was tested using Pooled Ordinary Least Square (POLS) estimation. Moreover, panel Fixed Effect and Random Effect were also tested as a robustness check. Finally, Housman Test was done to distinguish the difference between the fixed effect (FE) and the random effect (RE). Table 1 indicates the selected sample countries.

Table 1: Selected Sample list for Developed and Developing Countries

Developed Countries		Developing Countries	
Canada	Finland	Kenya	Indonesia
Germany	Austria	Jordan	Israel
Portugal	Norway	Singapore	Thailand
Belgium	Netherland	Hong Kong	Columbia
Italy	Poland	China	Saudi Arabia
Denmark	France	Pakistan	Brazil
United States	United Kingdom	Korea, rep	Sri Lanka
Japan	Switzerland	Argentina	Egypt
Spain	Luxemburg	Bangladesh	Mexico
Greece	Sweden	Malaysia	South Africa
		Vietnam	India

Source: Country Classification – World Economic Situation and Prospects 2022

The growth equation for multiple regressions used as follows.

$\hat{y} = B0+\beta 1x1+\beta 2x2+\beta 3x3+\beta 4x4+ Ui$

$\hat{y}$ = Gross Domestic Product (GDP)

$x1$ = Total Patent Applications

$x2$ = Research and Development Expenditure (R&D)

$x3$ = High – Tech Exports

$x4$ = Foreign Direct Investments (FDI)

Ui = Error term

4. Comparative and empirical analysis, empirical results and interpretations

4.1 Comparative analysis of north versus south in selected indicators of nis

According to Carvalho, Carvalho, & Nunes, (2015), the most significant measures for innovation performance in a country are the number of patents, private and public R&D, and percentage of innovation firms. Furthermore, Sahin (2019) stated that high-technology exports with their high-added value are considered a determinant of economic growth. According to Kengatharan & Jeyan Suganya (2022), foreign direct investments would also play an active role in economic growth, positively leading to the GDP. Therefore, the number of patents, R&D expenditure, and high technology exports are significant measures of the country's economic growth through innovation performance.

This section discusses the sleeted indicators necessary for innovation and growth through NIS.

4.1.1 Global North: South Korea, Taiwan, China and Singapore

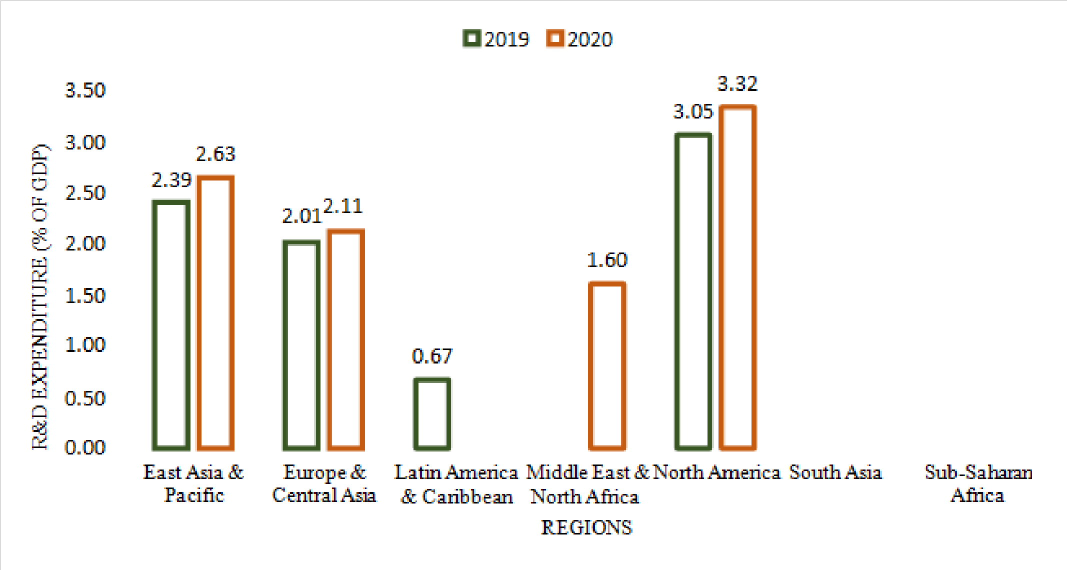
This section discusses the R&D intensity (expenditure on GDP), Patents and patent applications, Trademark and Industrial design applications, and High-Tech exports in selected East Asian countries, namely South Korea, Taiwan, China, and Singapore. We included China because most of Taiwan's statistics are included under China.

- ***R & D Expenditure on GDP***

Ildırar, Ozmen, and İşcan (2016) reported that Research and Development (R&D) is an essential variable affecting the country's economic growth and development through increasing the technology capabilities and enlargement of the resource base and promoting the capability of resource utilization. Countries that innovate by conducting R&D activities always have high economic growth. Since 2000, total global R&D expenditures have more than tripled in current dollars, from $676 billion to $2.0 trillion in 2018.[1] (Global Research and Development: Fact sheet, 2020)

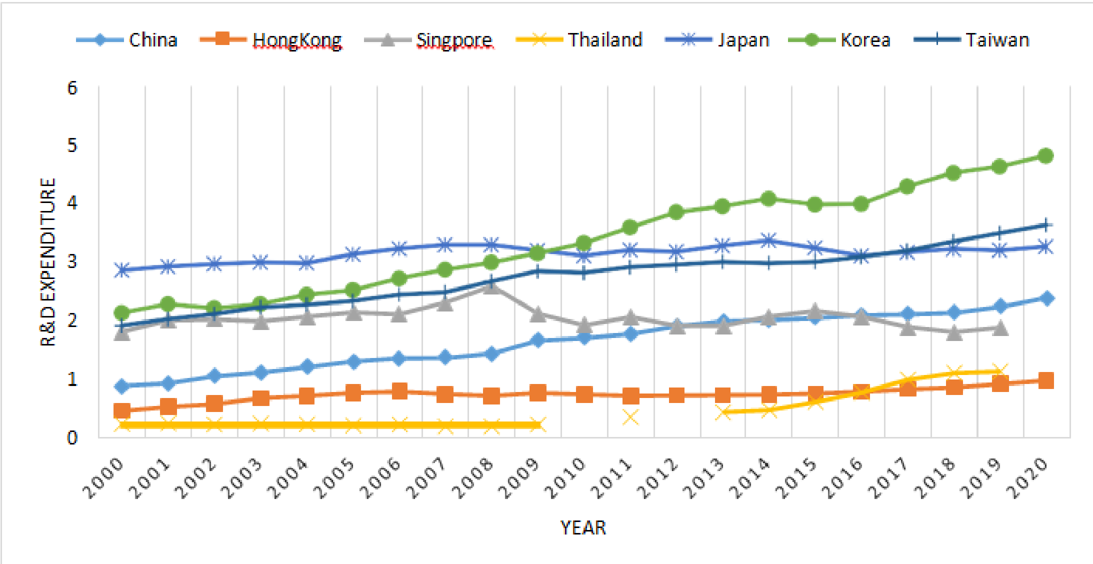
Figure 1 indicates that the most on R&D (% of GDP) in the past two years, 2019 and 2020, is the North American region, which is 3.05% in 2019 and 3.32% in 2020. The second highest is from East Asia, 2.39% in 2019 and 2.63% in 2020.

Figure 1: R & D Expenditure on GDP in regions -2018 and 2019



Source: WorldBank Data (South Asia and Sub-Saharan Africa data is not available)

Figure 2: R & D Expenditure on GDP in East Asia (2000-2020)



Source: World Bank Data (Taiwan data is from OEDC and statista.com)

Figure 2 indicates R&D expenditure on GDP in selected East Asian countries. According to that, the highest from South Korea spent 4.63% on R&D in 2019 and 4.81% in 2020. According to the Federation of Korean Industries (FKI) descriptions, South Korea's R&D expenditures reached 93.1 trillion won ($75.4 billion) in 2020, up from roughly 89 trillion South Korean won in the previous year. Taiwan remains the second largest, spending 3.49% and 3.63% of R&D on

GDP in 2019 and 2020, respectively. Japan also spent 3.26% of its national GDP in 2020.

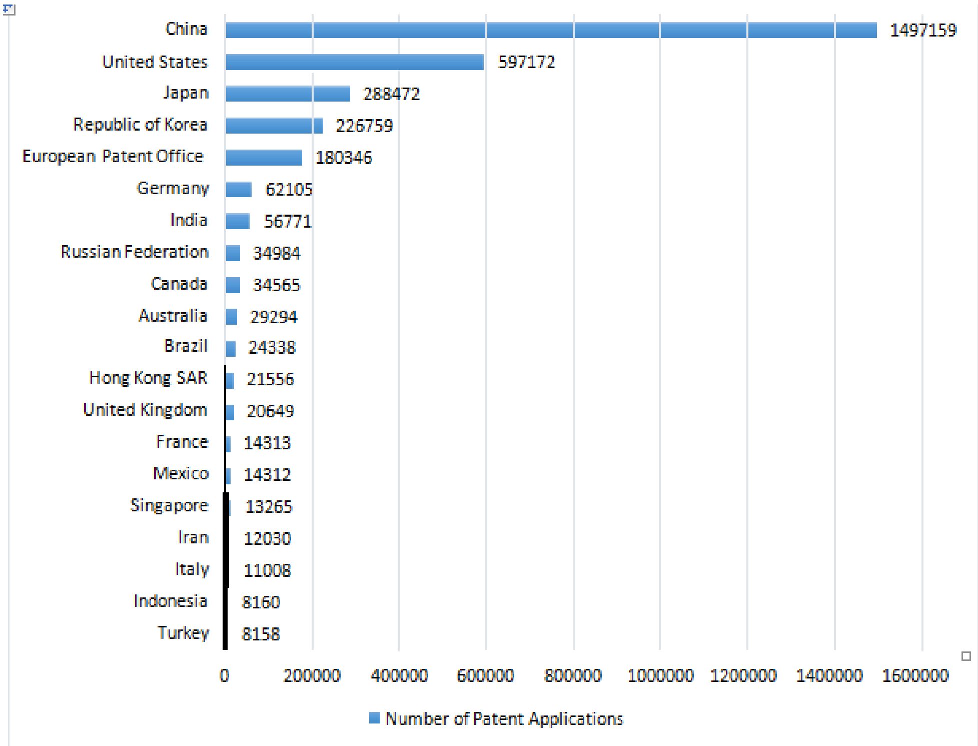
Moreover, China increased its R&D intensity by spending 2.24% of GDP in 2019 and 2.4% in 2020. According to the Chinese National Bureau of Statistics, the total public and private science and technology expenditures in 2019 rose 12.5% over the previous year to 2.21 trillion Chinese yuan ($322 billion). Spending on basic research accounted for 6% of the total; applied research, 11.3%; and development, 82.7%. The spending amounted to 2.23% of GDP, an increase of 0.09 percentage points from 2019. China's increasing investment in R&D has contributed to its growing innovation power, mainly focusing on high-tech areas such as artificial intelligence, quantum information, and semiconductor manufacturing. After China, Thailand also showed significant growth in expanding R&D on GDP marking 1.14% in 2019.

- **Number of Patent Applications**

According to the WIPO (2023), in 2021, Patent filings grew by 3.6% in the Word. Trademark and industrial design filing activity grew by 5.5% and 9.2%, respectively. Patent filings worldwide exceeded 3.4 million, trademark filing activity totaled 18.1 million, and industrial design filing activity amounted to 1.5 million. Furthermore, Applications for utility models, a particular form of a patent right, dropped by 2.5% to 2.9 million applications (WIPO, 2023).

World Intellectual Property Office (WIPO) stated that patents are the engine of economic growth. Based on the WIPO reports, China's IP office received 1.5 million patent applications in 2020 of a total of 3.4 million filed worldwide in 2021; China was followed by the offices of the United States (597,172), Japan (288,472), the Republic of Korea (226,759) and the European Patent Office (180,346). Together, these five offices accounted for 85.1% of the world total. Figure 3 shows the top 20 countries in Patent applications worldwide.

Figure 3: Patent Applications at the top 20 Countries in 2020



Source: World Intellectual Property Indicators-2021

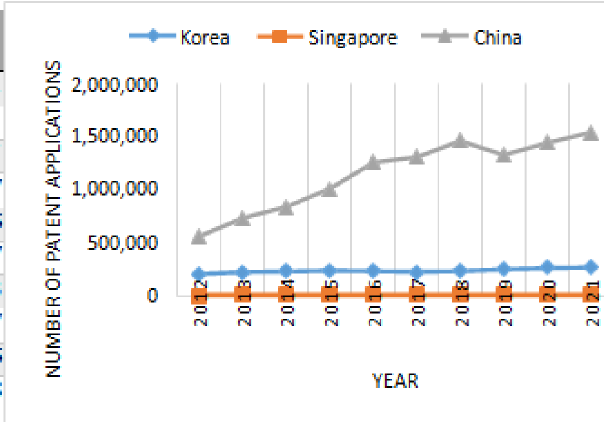
Furthermore, in 2021 Patents in force worldwide grew by 4.2%. China has become the top and followed by the US (3.3 million), Japan (2 million), the Republic of Korea (1.2 million), and Germany (877,763). China (+17.6%) saw the fastest growth in patents in force in 2021, followed by Germany (+5.2%) and the Republic of Korea (+5.2%).

Comparing the number of patent applications of South Korea, Singapore & China, China has been leading the number of patent applications compared with other countries (see Figure 4 and Table 2).

Table 2: Patent Applications

Year	Korea	Singapore	China
2012	203,880	4,905	561,472
2013	223,560	5,489	734,115
2014	230,583	5,937	837,857
2015	238,229	6,192	1,010,557
2016	233,834	6,745	1,257,466
2017	226,614	6,951	1,306,077
2018	232,022	7,414	1,460,243
2019	248,550	7,378	1,328,067
2020	260,614	7,946	1,441,086
2021	267,517	9,764	1,538,558

Figure 4: Patent Applications



Source: (WIPO, 2021). *Taiwan data is not available*

However, TIPO Statistics Report showed the Patent and Trademark Applications in 2018. while Taiwan (ROC) is not a member of the United Nations, and the number of patents filed in Taiwan is not reported separately from China in the indicators. Therefore, the number of patent applications filed with the Taiwan Intellectual Property Office (TIPO) in 2018 was 73,4319, placing it in sixth place worldwide for that year, or second place per capita.

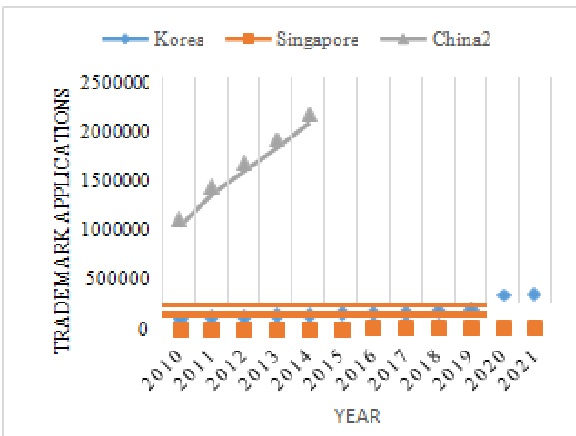
- **Number of Trademark Applications**

According to WIPO's Trademark Statistics Report 2021, an estimated 13.9 million trademark applications covering 18.1 million classes were filed worldwide in 2021. The number of classes specified in applications grew by a remarkable 5.5%. The trend of Trademark Applications worldwide from 2000 to 2021 is indicated in Figure 5. Trademark Applications increased from 2.6 million in 2000 to 13.9 million in 2021.

Table 3: Trademark Applications

Year	Korea	Singapore	China
2010	128672	16929	1056563
2011	132506	18202	1386776
2012	141838	19265	1618432
2013	157139	20033	1847938
2014	160311	21297	2104414
2015	183005	21380	
2016	181889	22758	
2017	180427	24155	
2018	199518	25974	
2019	218591	26581	
2020	256834	26560	
2021	285274	30639	

Figure 5: Trademark Applications



Source: (WIPO, 2021) *(Note: Taiwan data is not available)*

China's IP office had the highest volume of filing activity of Trademark Applications with a class count of around 9.5 million, followed by the USPTO (899,678), the European Union Intellectual Property Office (EUIPO) (497,542), and the offices of India (488,526) and the UK (450,815). Table 4.2.1.2.2 and Figure 4.2.1.2.3 compare Trademark applications of selected East Asian countries Korea, Singapore, and China (as Taiwan data is not separated from China).

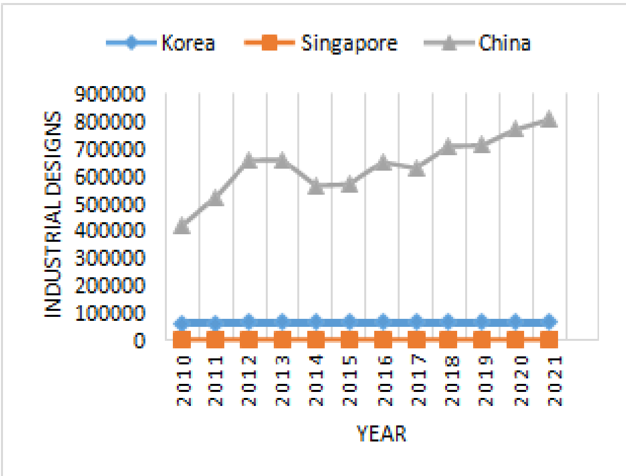
- **Number of Industrial Designs**

An estimated 1.2 million industrial applications containing 1.5 million designs were filed worldwide in 2021. The number of designs grew by 9.2% in 2021. As shown in Figure 10, the trend line of total Industrial Designs Applications increased continuously from 0.3 million in 2000 to 0.9 million in 2013 and declined to 0.85 in 2014. However, it increased to 1.2 million in 2021. Table 4 and Figure 6 compare several industrial designs in Korea, Singapore, and China. China has been leading the Number of Industrial Designs applications for an extended period.

Table 4: Industrial Design Applications

Year	Korea	Singapore	China
2010	57187	1977	421273
2011	56524	2167	521468
2012	63135	2182	657582
2013	66940	2434	659563
2014	64620	2360	564555
2015	68236	2411	569059
2016	65656	2221	650344
2017	63425	2389	628658
2018	63797	2043	708799
2019	65311	2365	711617
2020	67381	2063	770362
2021	64925	2554	805710

Figure 6: Industrial Design Applications



Source: WIPO online Database

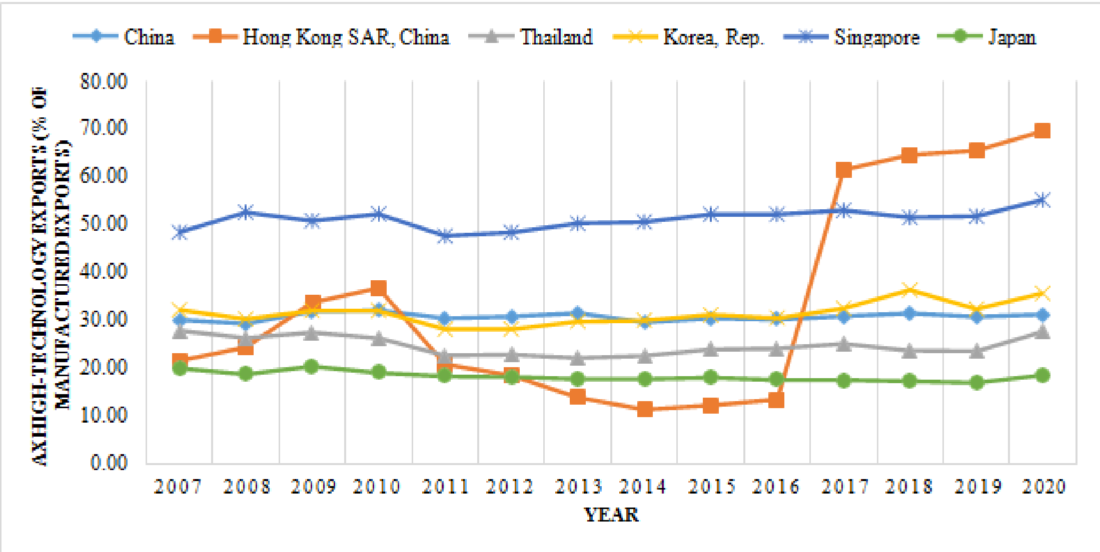
- **High-Technology Exports**

High-Technology Exports are products with high R&D intensity, such as computers, scientific instruments, electrical machinery, pharmaceuticals, consumer electronics, and aerospace products. According to the OECD, High-technology goods have been among the most dynamic components of international trade over the last decade. Therefore, a country's ability to compete in high-technology markets is essential to its global economic competitiveness. Many developing countries need more R & D to reach this industry, which requires high technology and knowledge (Ramanayake 2022). These positively impact economic growth, while low-tech exports negatively impact high- technology product exports leading to increased productivity between domestic and foreign competition (Lee 2020, Sofuoğlu, Kizilkaya, & Koçak, 2022).

Moreover, according to Sahin (2019), high-technology exports, with their high added value, are considered one of the determinants of growth in recent years. The increasing competitiveness of developing countries in international markets depends on the country's capacity to produce and export high-tech products. Therefore, exporting high technology products is a critical engine of the country's economic growth and development.

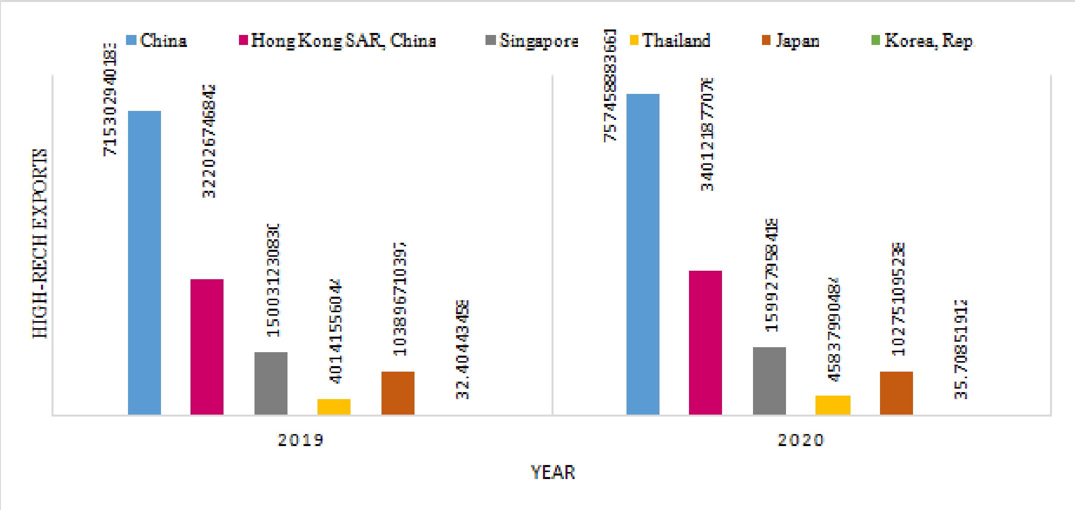
According to World Bank data, high-tech exports worldwide increased from 2.21 trillion in 2007 to 2.85 trillion in 2019. Figure 7 shows the trend in High-tech exports (% of manufactured exports) in selected East Asian countries. Hong Kong, China, Korea, and Singapore are at the top in East Asia and the world. This shows 2016 China's significant acceleration of high-tech exports, particularly with China's Belt and Road Initiatives (BRI) started in 2013 mainly.

Figure 7: High-technology exports (% of manufactured exports) of selected East Asian Countries



Source: Using World Bank Online Data created by the Authors

Figure 8: High-technology exports (current US$)) of selected East Asian Countries in 2019 & 2020



Source: Using World Bank Online Data created by the Authors

Figure 8 shows that China's High – Tech exports (current US$) were highest in 2019 and 2020. In 2021 also, China was the highest, accounting for 942314.82 million US dollars, followed by Hong Kong with 431628.78 million dollars.

In Taiwan's case, according to Taiwan's Ministry of Economic Affairs, Taiwan-based makers received export orders for high-tech products worth US$400.47 billion in 2021, amounting to 59.41% of the total value for all export orders and an increase of 22.9% in the year. Moreover, Taiwan shipped $477.8 billion worth of exported products around the globe in 2022. That dollar reflects a 43% gain compared to $334.2 billion in 2018. The biggest export of Taiwan is electronic integrated circuits and related micro assemblies, especially semiconductors. That represents almost four-fifths (38%) of total shipments. According to the data by Taipei-based research firm Trend Force, Taiwan dominates the foundry market or outsourcing of semiconductors manufacturing. That is 60% of the total global foundry revenue.

4.1.2 Global South: Sri Lanka

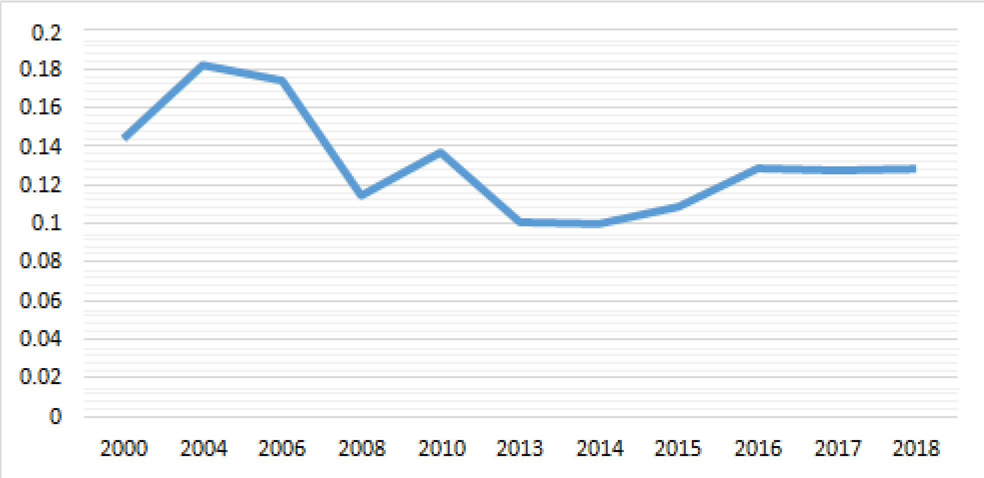
To compare with the Global North, we took Sri Lanka as a country representing the Global South. One of the limitations of this study is that we only consider Sri Lanka. Later we will include a few more developing countries to this comparison. Similar to section 4.1.1, this section researches R&D intensity, Patents, Trademarks and Industrial designs applications, and High-Tech exports in Sri Lanka.

- **Research and Development Intensity (R&D) in Sri Lanka**

Sri Lanka's Research and Development Expenditure: % of GDP data was reported at 0.144% in 2000 and increased to 0.182 in 2004. As of 2013, the R&D

expenditure of Sri Lanka decreased to 0.10%. The latest value of the Gross Domestic Expenditure on Research and Development (GERD) of Sri Lanka in 2020 was. Rs. 18,174.60 million was 0.12% of the country's GDP. Figure 9 indicates the trend line of R&D expenditure in Sri Lanka from 2000 to 2018.

Figure 9: R&D Expenditure share of GDP from 2000 to 2018



Source: World Bank Database

Sri Lanka spent the highest of Rs. 14854.59 million for re-current expenditure (81.62%) and Rs. 3320.01 million for capital expenditure (18.38%) on R&D 2020. According to the R&D statistics of the National Research and Development Survey 2020 conducted by the National Science Foundation (NSF), Sri Lanka, the highest gross expenditure on Research and Development (GERD)[2] was acquired by Business Enterprises (37.94%), followed by Government Research Institutes (34.12%), Higher Education Sector (26.7%), and Private Non-Profit Organizations (1.25%).

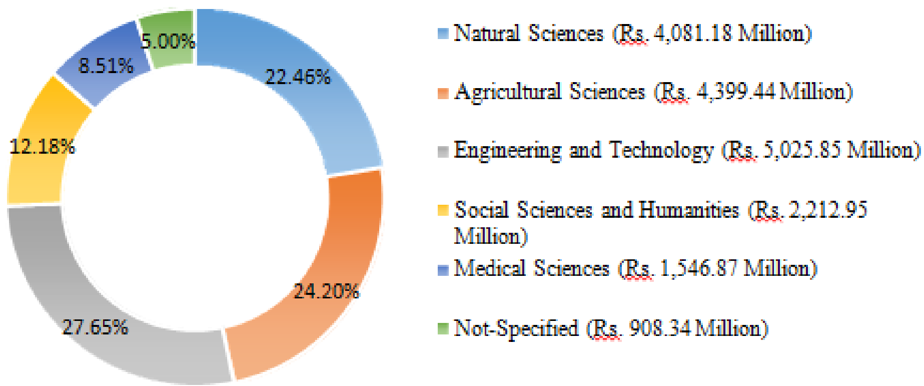
The highest proportion of funds for R&D was devoted to Applied Research, 47.45% of GERD, while Basic and Experimental Developments accounted for 29.30% and 23.25% of GERD, respectively. At the same time, the top three fields of science which have the highest GERD are Engineering and Technology (27.65%), Agricultural sciences (24.20%), and Natural sciences (22.46%). The Social Sciences and Humanities field has a lower value of 12.18% when compared with other fields (See Table 5 & Figure 10). In Sri Lanka, 6,064 Researchers (Head Count) are employed in domestic R&D activities, and their Full-Time Equivalent value was 2267. Researchers per millions of population were 103.43 in full-time equaled (FTE).

Table 5: Time Trend - GERD by Field of Science (Rs. Million)

Discipline	2014	2015	2016	2017	2018	2020
Natural Sciences	2,666.19	3,170.30	3,020.67	3,060.19	3,350.26	4,081.18
Engineering and Technology	2,447.55	2,991.80	4,913.90	3,432.84	5,986.74	5,025.85
Medical Sciences	371.85	1,019.10	930.77	1,588.50	1,558.03	1,546.87
Agricultural Sciences	4,077.77	3,746.10	4,349.42	6,080.86	4,372.72	4,399.44
Social Sciences and Humanities	603.85	647.8	1,390.84	1,561.81	2,654.95	2,212.95
Not Specified	182.87	329	813.7	1,279.14	421.23	908.34
Total	10,350.08	11,904.10	15,419.30	17,003.34	18,343.92	18,174.63

Source: National R&D Survey of Sri Lanka 2020 (NSF)

Figure 10: Gross Domestic Expenditure on Research and Development (GERD) by Field of Science 2020



Source: National R&D Survey of Sri Lanka 2020 (NSF)

Moreover, from the point of view of Lee (2013), middle-income countries or developing countries generally present low ratios of R&D. That is true in the Sri Lanka context as the R&D expenditure on GDP in Sri Lanka has a relatively low value when compared with selected East Asian countries like Korea, Taiwan, and Singapore and also in China and Japan. While Korea is at the top by spending the highest GDP on R&D of 4.81% in 2020,

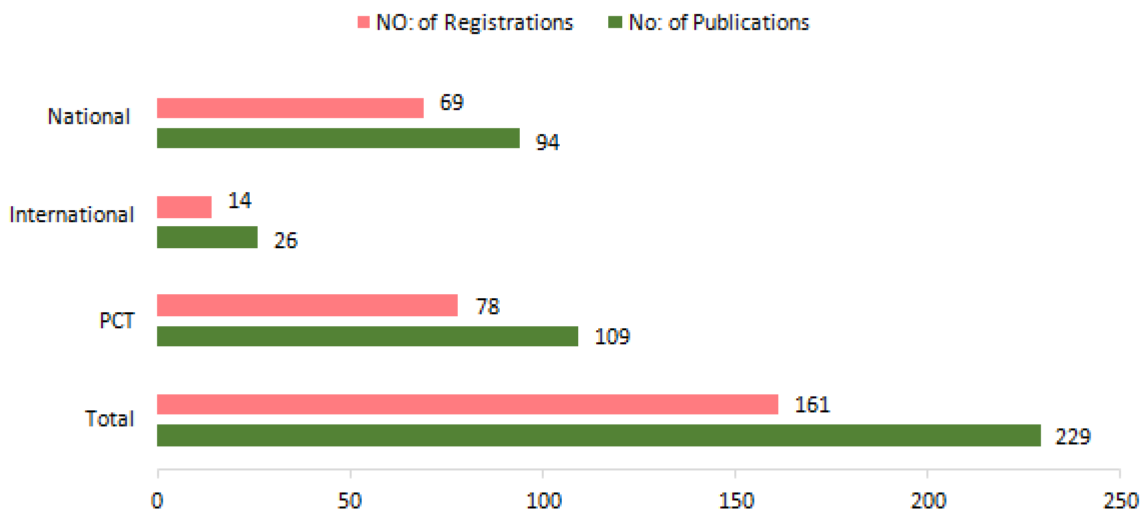
93.1 trillion, and Taiwan remains the second largest by spending 3.63% of GDP on R&D, followed by Japan spending 3.26%, China has 2.4% of R&D of GDP and also Singapore spending 1.9% in 2019. Hence, Sri Lanka only spends

0.12% of its GDP on R&D. Ramanayake (2022) indicates that Sri Lanka shows a decreasing trend of R&D expenditure and Government spending on education.

- **Patent Applications in Sri Lanka**

As stated by the National Intellectual Property Office (NIPO) in Sri Lanka, Patents protect inventions and ensure the inventors the benefits resulting from the inventions, thereby providing incentives for inventiveness, encouraging other inventions, and promoting investment. This will spur the economic and technological development. According to the NIPO statistics, Sri Lanka had 161 registrations and 229 publications of total patents in 2020 the registrations and publications of National, International, and PCT. Figure 11 show the patent applications in Sri Lanka in 2020.

Figure 11: Patent Applications of Sri Lanka in 2020

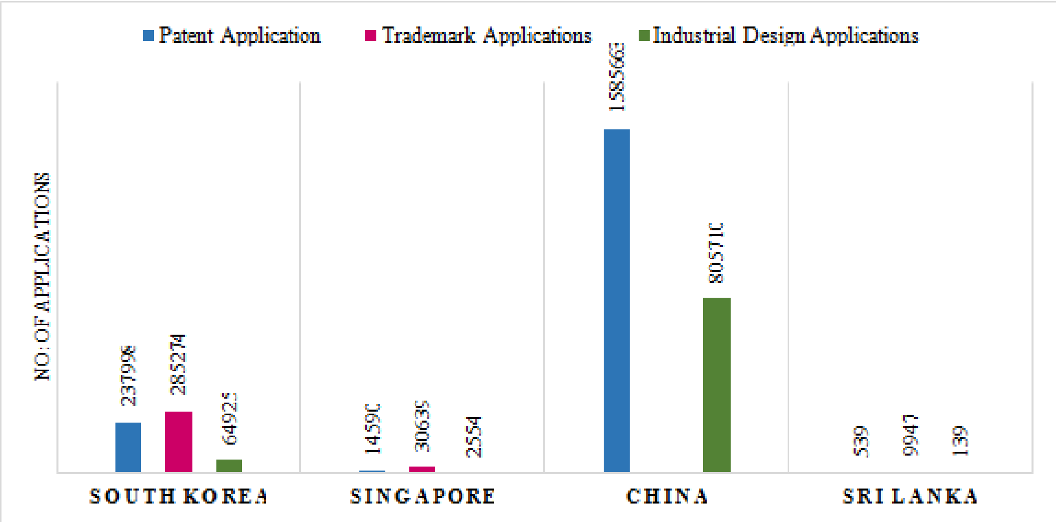


Source: Using NIPO Statistics created by the Authors

Figure 4.2.2.2.2 shows the Comparison of Patents, Trademarks & Industrial Designs Applications of selected East Asian countries, including Sri Lanka, in 2021. When comparing Patent applications, Trademark applications, and Industrial design applications of Sri Lanka with selected East Asian countries South Korea, Singapore, and China, Sri Lanka has significantly low numbers.

According to the WIPO statistics, in Patent applications, the highest is from China at 1585663, South Korea accounted for 237998, and Singapore has 14590 patent applications, while Sri Lanka owned only 513 patent applications. Moreover, South Korea reported 285274 trademark applications, Singapore reported 30639 trademark applications, and Sri Lanka reported only 9947. In the case of Industrial design applications, China owned the highest by achieving 805710 applications, followed by South Korea having 64925 and Singapore which marked 2554. However, Sri Lanka took only about 139 industrial design applications in 2021.

Figure 12: Comparison of Patent Applications, Trademark & Industrial Designs Applications in EA and Sri Lanka



Source: Using WIPO Data created by the authors

- **High-Technology Exports in Sri Lanka**

High-Tech exports in Sri Lanka are relatively low compared to other East Asian countries. Sri Lankan exports are limited to a few labor-intensive primary export industries, such as textiles, garments, and agricultural products. Sri Lankan export basket is mainly filled with textiles and garments (52% of total exports) and tea (17%); others include spices, gems, coconut products, rubber, and fish since the 1980s till now (Marwah and Ramanayake 2021; Ramanayake & Wijetunga, 2018).

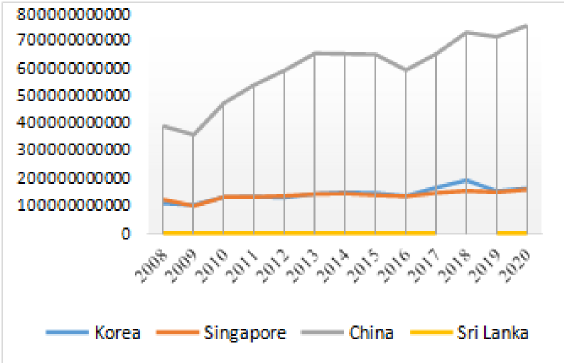
High- Tech exports (current US$) have declined in Sri Lanka since 2008. It was 103 million in 2008, declining to 63 million in 2015. However, in 2021 it shows an increment, and it was 94 million (current US$) 2021. Furthermore, a High-Tech export (% of manufactured exports) of Sri Lanka was also very low; it was 1.9% in 2008, declined to 0.89% in 2015 and 1.04% in 2021.

When comparing the High-tech exports in Sri Lanka with selected East Asian countries South Korea, Singapore, and China (Taiwan data is unavailable), Sri Lanka has very low and is in its initial stage (See Figure 13). China led the field by accounting for 757459 million, followed by South Korea and Singapore, having 163987 million and 159927 million, respectively, in 2020, and Sri Lanka only accounted for 83 million. Therefore, Sri Lanka is incapable of competing in the global market, which affects the country's economic growth as unable to sustain economic growth. According to these statistics and trends, the growth dream for Sri Lanka needs to catch up.

Table 6: High-technology exports (% of manufactured exports) of Korea, Singapore, China & Sri Lanka

Year	Korea	Singapore	China	Sri Lanka
2010	32.07	52.32	32.12	1.13
2011	28.18	47.72	30.48	1.04
2012	28.22	48.45	30.85	0.95
2013	29.82	50.32	31.57	1.04
2014	30.06	50.63	29.70	0.95
2015	31.21	52.21	30.42	0.89
2016	30.52	52.23	30.24	0.94
2017	32.55	53.07	30.91	1.02
2018	36.39	51.56	31.55	
2019	32.40	51.81	30.82	1.10
2020	35.71	55.26	31.28	1.26

Figure 13: High-technology exports (current US$) of Korea, Singapore, China & Sri Lanka



Source: Using World Bank data created by the authors

4.2 Empirical Analysis: Comparison of Global North versus Global South

Here this study discusses the descriptive statistics of two samples. According to the descriptive statistics using 20 developed countries, the mean GDP of developed countries is 1.89, the maximum value is 2.14, and the minimum value is 2.12. The mean of the total patent applications of developed countries is 52014.21, the maximum value is 621453, and the minimum value is 413. In R&D expenditure mean value is 2.0566, the maximum is 3.8738, and the minimum value is 0.5273, and high-tech exports have a 15.2994 mean, while the maximum value is 29.87957 and the minimum value is 3.77465. Also, FDI has a 1.28 mean, and maximum and minimum values are 2.18 and -3.45, respectively (See Table 7).

Table 7: Descriptive Statistics table for Developed Countries

Variable	Mean	Standard deviation	Minimum value	Maximum value	No: of Observations
GDP	1.89	3.48	2.12	2.14	420
Total Patents	52014.21	130328.8	24	621453	413
R&D expenditure	2.0566	0.83538	0.5273	3.8738	398
High-Tech exports	15.2994	6.55836	3.77465	29.87957	280
FDI	1.28	5.57	-3.45	2.18	411

Sources: Authors calculations

Table 8: Descriptive Statistics table for Developing Countries

Variable	Mean	Standard deviation	Minimum value	Maximum value	No: of Observations
GDP	7.50	1.76	1.47	8.46	462
Total Patents	44069.33	176792.7	72	1542002	452
R&D expenditure	1.13466	1.200887	0.423	5.43562	326
High-Tech exports	16.79151	16.45854	0.194923	69.6469	284
FDI	-1.12	2.27	-2.32	4.17	462

Sources: Authors calculations

According to the descriptive statistics using 22 developed countries, the mean GDP of developed countries is 7.50, the maximum value is 8.46, and the minimum value is 1.47. The mean of the total patent applications of developed countries is 44069.33, the maximum value is 1542002, and the minimum value is 72. In R&D expenditure mean value is 1.13466, the maximum is 5.43562, and the minimum value is 0.423, and high- tech exports have a 16.79151 mean, while the maximum value is 69.6469 and the minimum value is 0.194923. Also, FDI has -1.12 mean and maximum and minimum values of 4.17 and -2.32, respectively (See Table 8).

4.2.1 Empirical Results for Developed Countries

Table 9 indicates the results on POLS, FE and RE for the sample of developed countries.

Table 9: Effect of Patent applications, R&D, High-tech exports and FDI to the GDP of developed countries.

Dependent Variable: GDP	Constant Variance	Total Patents	R&D Expenditure	High-Tech exports	FDI	R square value (R^2)	No: of observations
Pooled OLS $\hat{y}$	7.05** (0.043)	2.650*** (0.000)	2.11** (0.036)	-2.90** (0.005)	-1.266*** (0.002)	0.8708	269
Fixed Effect(FE)	6.60*** (0.010)	2.65*** (0.000)	2.62** (0.011)	-3.37*** (0.002)	-1.201*** (0.004)	0.8674	269
Random Effect (RE)	7.05*** (0.0043)	2.65*** (0.000)	2.11** (0.036)	-2.90*** (0.005)	-1.266*** (0.002)	0.8708	269

Sources: Authors calculations

Pooled OLS model:

$\hat{y}$ = 7.05 + 2.650 $x1$ + 2.11 $x2$ – 2.90 $x3$ - 1.266 $x4$ + Ui

According to the POLS model, the R square value (R2) is 0.8708. That is, the independent variables cover 87% of the variation of the dependent variable. Thus the constant coefficient is shown to be 7.05. When one unit of total patent applications is increased at the constant level of R&D expenditure, High-tech exports, and FDI, the GDP will increase by 2.650. At the same time, when the R&D expenditure is increased by one unit with the constant total patent applications, high-tech exports, and FDI, GDP will have increased by 2.11. Hence R&D expenditure is not significant for growth for developed countries.

Moreover, results indicate that, for developed countries, High-tech exports negatively impact growth. In other words, GDP will decrease by 2.90 when the one unit of High- tech exports increases while total patent applications, R&D expenditure, and the FDI are constant. FDI also shows negative impacts on growth for developed countries.

Fixed Effect (FE) & Random Effect (RE):

FE: $\hat{y}$ = 6.60 + 2.650 $x1$ + 2.62 $x2$ – 3.37 $x3$ - 1.201 $x4$ + Ui

RE: $\hat{y}$ = 7.05 + 2.650 $x1$ + 2.11 $x2$ – 2.90 $x3$ - 1.266 $x4$ + Ui

According to the fixed effect (FE), the R square value (R2) is 0.8674. That is, the independent variables cover 87% of the variation of the dependent variable. Thus the constant coefficient is shown to be 6.60. At the same time, according to the RE estimation, the R square value (R2) is 0.8708. That is, the independent variables cover 87% of the variation of the dependent variable. Thus the constant coefficient is shown to be 7.05. Therefore, robustly POLS, FE, and RE results show the same significance.

Housman Test

In panel data regression, the Housman test is carried out to distinguish the difference between fixed effect (FE) and the random effect (RE). Here, if the P value is more significant than 0.05 random effects is applicable, and if the P value lesser than 0.05 fixed effect is more significant. Therefore, for the developed sample, Housman test results in P values displayed 0.00, indicating that the fixed effect is more suitable.

4.2.2 Empirical Results for Developing Countries

Table 10 indicates the results on POLS, FE, and RE for the sample of developing countries. The results indicate that R&D expenditure and High-tech exports are insignificant for developing countries. This results in line with many existing pieces of literature. Many developing countries have very low R&D intensity and low High-Tech exports.

Table 10: Effect of Patent applications, R&D, High-tech exports and FDI to the GDP ofdeveloping countries

Dependent Variable: GDP	Constant Variance	Total Patents	R&D Expenditure	High Tech exports	FDI	R square value (R^2)	No: of observations
Pooled OLS $\hat{y}$	3.65*** (0.000)	824646*** (0.000)	6.73 (0.172)	-1.62 (0.491)	-8.665*** (0.000)	0.9549	207
Fixed Effect (FE)	2.56*** (0.004)	797502*** (0.000)	1.95*** (0.002)	-9.33 (0.702)	-7.423*** (0.000)	0.9310	207
Random Effect (RE)	3.65*** (0.000)	824646*** (0.000)	6.73 (0.172)	-1.62 (0.491)	-8.665*** (0.000)	0.9549	207

5. Concussions & policy suggestions

With the continuous rapid technological change and the emergence of globalized markets, all the developed and developing countries are hurrying to become more innovative. The concept of National Innovation Systems plays a significant role in growing a country's economy.

According to the literature, Wong (1999) stated that, among small-late industrializing economies in the world, three of East Asia – Korea, Taiwan, and Singapore- have achieved significantly faster high-tech industrial growth over the last three decades than all other developing countries. More interestingly, they have evolved distinctly different models of national innovation systems. Furthermore, China is escaping the middle- income trap by following the same path through NIS. However, most low- and middle- income countries like Sri Lanka cannot sustain economic growth as they have paid little attention to the NIS. Moreover, they are weak in developing technology and innovation outputs. According to Lee (2016), and Ramanayake (2022), most middle-income and developing countries failed to sustain growth because they specialized in low- technological industries and the inability to upgrade their specialization to more advanced technologies.

High-tech exports, the number of patent applications, and R&D expenditure on science and technology are significant measures of a country's ability to innovate.

When comparing above mentioned NIS interrelated dimensions of Sri Lanka with selected East Asian countries with rapid technological catch-up, Sri Lanka has deficient and in its initial stage of NIS. In Sri Lanka, the number of patent applications, trademarks, industrial designs, and R&D expenditures on S&T is remarkably low compared with other Asian countries. Sri Lanka's weak performance on innovation is a symptom of the low priority given to S&T and R&D investments over the past several years. Compared to other developing and developed countries, the University-Industry collaboration are not substantially established in Sri Lanka. Very few industry-research linkages are existing in today.

Furthermore, High-Tech exports in Sri Lanka are also comparatively low and limited to a few labor-intensive primary export industries.

Based on the results of the panel data regression, it is clearly stated that the NIS interrelated dimensions such as Patent applications, Research & Development expenditure, High-Tech exports, and Foreign Directs Investments positively impact the GDP of developed countries but do not in developing countries. These indicators are relatively low in developing countries than in developed countries.

According to the data collected in this study, it can be seen that the growth-driven- NIS- associated indicators could perform better in Sri Lanka. Therefore, Sri Lanka must take an integrated approach to innovations or science and technology to benefit from NIS. In there, the government of Sri Lanka needs to take action by developing new policies to expand and uplift NIS to sustain the country's economy.

5.1 Policy Suggestions for Sri Lanka

Based on the study's findings, the following suggestions can be made.

1. The government of Sri Lanka should prioritize Science and Technology in its path toward economic development and need to increase the country's technological development fund. Sri Lanka's GERD has remained under 0.12% of the GDP in 2020 compared with others – Korea (4.81%), Taiwan (3.63%), and China (2.24%). Therefore, increasing the GERD to at least 1% is recommended.
2. Promoting university-industry R&D cooperation can be an excellent strengthening of the NIS. Unlike developing and developed countries, the University-Industry collaboration is not substantially established in Sri Lanka. Universities and higher education centers should increase their existing collaboration with industries. Moreover, that should include more than essential student internships but more research-oriented ones.
3. Moreover, Sri Lankan government should take the necessary steps to allow industries to do joint R&D with the academic sector.

4. The country's future is mostly based on the upcoming generation or youth; therefore, it is necessary to develop the country's educational system. We need to increase general science and technology literacy among every level of students to
5. build up a critical mass of scientists, researchers, and people with innovative and critical thinking.
6. In Sri Lanka, Exports are mainly limited to a few labor-intensive primary export industries such as textiles, garments, and some agricultural products. Therefore, more expertise in these fields must be needed to compete in the global market. Moreover, economic activities like high-tech exports in Sri Lanka need to be more knowledge-intensive to benefit from international trade.
7. Furthermore, in the export industry, Sri Lanka should introduce and develop new innovative industries other than textile and agriculture to gain higher profits. Moreover, relevant policies need to be taken from the government side to encourage the private sector to global market competition with higher profits.
8. Moreover, encouraging people towards innovations and entrepreneurs with appropriate policy support for "techno-entrepreneurship" is also significant in commercializing technical innovations.

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Notes

[1] Global Research and Development: Fact sheet, 2020

[2] Gross Domestic Expenditure on Research & Development

4

Family involvement, innovation and product market competition

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Abstract

The paper constructs a theoretical framework suggesting a moderating impact of product market competition in determining the relationship between family ownership/control and innovation. We argue that the elimination of 'career concerns' of CEOs in firms with greater family share may explain the mechanism followed to encourage R&D investments. Empirical testing of the hypotheses is performed using data from the Indian manufacturing industry for the period 2001-2018. The findings suggest that the domestic product market competition complements the relationship between family ownership/control and R&D investments. This indicates that family firms tend to invest more in R&D as domestic product competition increases. The data suggest that the effect of family involvement on innovation is due to the reduction of managerial career concerns, as we find that managerial turnover (conditional on poor performance) is lower if family involvement is higher. This effect is significantly stronger under higher degrees of competition.

Introduction

Innovation is crucial for industrial growth (Mansfield 1962; Scherer, 1965; Mowery 1983; Colombelli et al. 2013), but what factors determine a firm's ability to innovate? To answer this question, a large body of research emerged. Several studies discussed the role of ownership and control of families on firms' innovation (Ortega-Argilés, Moreno and Caralt, 2005; Okamuro and Zhang, 2006; Kellermanns et al., 2008; Kim, Kim and Lee, 2008; Chen-Lung et al., 2009; Eddleston, Kellermanns and Zellweger, 2012; Lodh, Nandy and Chen, 2014; Ashwin, Krishnan and George, 2015). Another strand of research highlighted the role of product market competition (see Arrow 1962; Schumpeter 1943; Aghion et al. 2005). Nonetheless, there exist very few studies addressing the moderating effect of market competition on family involvement[1] while analysing the latter's effect on innovation (Ugur and Hashem 2012; Buchwald and Thorwarth 2015). In this paper, we address this issue in the context of an emerging economy, India.

The literature on family businesses follows from the work of Coase (1937) which states that the firm is not a black box, but rather an organization in which the contribution of several stakeholders plays an important role in productive activities. Following this view, family involvement plays a leading role in the analysis of innovation, because not only the physical resources but also the behavioural characteristics and integration of human resources are crucial to the R&D investments of the firms. Stewardship theory (Davis, Schoorman and Donaldson, 1997) and the Socio-Emotional Wealth perspective (Berrone, Cruz and Gomez- Mejia, 2012) suggest that family owners and controlling members in a firm focus on the continuity of the business in the long run; hence they tend to invest more in R&D. A recent empirical study on Indian pharmaceutical industry finds that Indian family firms act as stewards and invest more in R&D (Ashwin, Krishnan and George, 2015).

Literature on product market competition finds a direct relationship between competition and innovations. Arrow (1962) argues that increased product market competition provides firms with an incentive to innovate. In a monopoly, the firms tend to delay innovations to maximize benefits from previous innovations while their managers enjoy a quiet life and become lazy (Hicks, 1935; Aghion and Howitt, 1992). An increase in product market competition tends to discipline these lazy managers to work harder and introduce new innovations in the market (Hart, 1983; Schmidt, 1997; Bertrand and Mullainathan, 2003; Raith, 2003; Karuna, 2007). Nonetheless, we suggest that based on the objectives of owners and managers, they may respond differently to increased product market competition, particularly in the case of strategic long-run investments such as R&D. For instance, family-owned firms care about their socio-emotional wealth and generational succession. Consequently, they tend to focus more on longevity than short-run benefits. Managers of these firms may also feel more secure in pursuing long-term goals (Cater III and Justis, 2009). Thus, the increased competition may induce family firms to invest more in R&D to sustain in market in the long term. In other words, the stewardship behaviour of the firm becomes even more prominent as the business is threatened by increased competition. In contrast, the shareholders and managers of non-family firms may not be directed substantially by factors such as socio-emotional wealth and concerns about the longevity of the business. The managers of non-family firms may also have to focus on short-term goals for securing their job.

Although the preferences of family firms towards investments in innovations under high competition can be stated in the aforesaid way, it is important to understand the mechanism that leads them to this outcome. For this, we test whether family owners eliminate the career concern of their managers to increase R&D investments under higher degrees of competition. The 'career concern' model suggests that the managers' short-term concerns about their jobs may restrict riskier but profitable long-run strategic R&D investments (Holmstrom, 1989). Aghion et al. (2013) suggest that more sophisticated shareholders with long-term vision may provide greater job security to CEOs/managers even if they perform poorly[2]. This way job protection enables the managers to take up risky but profitable R&D investments.

To the best of our knowledge, no existing study has explicitly explored the moderating role of product market competition in determining the relationship between family involvement and product market competition. To fill this gap, we address this issue in this paper in the context of manufacturing firms in India using Panel Tobit estimation. The results are checked for robustness using the System-GMM estimator. The findings reveal that the domestic product market competition complements the relationship between family ownership/control and R&D investments of the firm. Additionally, using the Panel Probit model, we test whether family firms eliminate the career concerns of their managers to encourage greater investments in innovations. The findings suggest that the effect of family involvement on innovation is due to the reduction of managerial career concerns, as we see that managerial turnover (conditional on poor performance) is lower if family involvement is high.

The next section discusses the relevant literature to construct a theoretical framework for further empirical investigation. The third section provides methodological details along with information related to data and variable construction; preliminary observations have been given in the fourth section; the fifth section elaborates on the empirical results and finally, the sixth section concludes and provides some policy suggestions.

2. Review of literature

The present paper argues that family firms invest more in R&D activities in response to increased competition. It is because families, concerned about generational succession, take a long-term perspective on their businesses. The long-term perspective results in a relatively stable tenure for the CEOs. A relatively stable tenure allows CEOs to be free of short-term performance concerns and invest in R&D with the aim of higher long-run growth. The next two subsections use the existing literature to establish these linkages and provide a theoretical underpinning for the present study.

2.1 Family firms, innovation and product market competition

Several studies investigated the relationship between family involvement and innovation in the previous decades (Bushee 1998; Coriat and Weinstein 2002; Lazonick and O'Sullivan 2000; Tylecote and Ramirez 2006; Munari, Oriani, and Sobrero 2010; Choi, Park, and Hong 2012). Many of them support the argument that there is a positive relationship between family ownership and innovation. A perspective related to the relationship between family ownership and innovation is drawn from the stewardship theory (Davis, Schoorman and Donaldson, 1997; Le Breton-Miller and Miller, 2009; Ashwin, Krishnan and George, 2015). It suggests that the family members have a long-term perspective of their business and therefore are concerned about generational succession (Munari, Oriani and Sobrero, 2010). This may motivate them to invest more in R&D activities to improve their competitive advantage and ensure the long-term survival and growth of their firm.

Socio-Emotional Wealth (SEW), which involves the non-economic goals of family firms, plays an important role in the decision to put efforts into innovations (Berrone, Cruz, and Gomez-Mejia 2012). SEW is defined as "the ability to exercise authority, the enjoyment of personal control, "clan membership", a sense of belonging, affection, intimacy as well as an active role in the family dynasty" (Gomez-Mejia, Makri and Kintana, 2010). SEW in family firms has some indirect role to play in taking such decisions regarding innovation, a strategy which will help the firm to sustain itself in the long term and remain competitive (Levenburg, Schwarz and Almallah, 2002; Classen et al., 2014). Recent evidence in India finds a positive relationship between family involvement and innovations in Indian firms and finds support for stewardship and SEW perspectives (see Ashwin et al., 2015). It should be noted that the combined impact of family ownership and family control over the management of the firm is found to be even stronger. Based on these observations, it can be argued that the concentration of family ownership and control can be an important determinant of innovations.

Product market competition is also an important determinant of innovation. Arrow (1962) argues that the incentives due to increased competition level encourage the firms to innovate. Product market competition reduces managerial slack by disciplining managers and hence, promotes innovation. Product market competition helps to induce efficient management to help the firm control a large market share through the strategy of investments in innovations (Allen and Gale, 2000). If the managers are not working hard, the company will lose market share and the managers will face the threat of job loss and bankruptcy. Leibenstein (1966) has shown that the role of the decision-maker, i.e. manager, is critical for the firm's financial situation. When managers have certain preferences due to which they may be maximising their private benefits at the cost of firms' profits, so-called X-inefficiencies may arise. When there is a rise in competition, the financial situation of the firm deteriorates as there is downward pressure on the overall profits. This may force the managers to cut down their slack by reducing individual monetary and non-monetary benefits to ensure the firm's survival.

The role of product market competition in determining the ownership-innovation relationship can also be analysed in the context of family involvement. Chen and Steinwender (2020) argue that family managers show distinctive preferences that include more than maximising private monetary benefits. The family managers have a strong desire to sustain and build a legacy for their descendants. The SEW perspective on family firms suggests that family members also enjoy taking pride in the firm. Moreover, a successful business enables them to use the monetary benefits for personal purposes. These monetary/non-monetary benefits will be lost if the firm ceases to exist due to rising competition. This may encourage the family owner/managers to deal with the competition with vigour to ensure survival. Chen and Steinwender (2020) find that a rise in import competition resulted in greater productivity in family-managed firms than in non-family firms in Spain. The productivity improvements are found to be stronger in multi-generational firms. The study suggests that firms with concentrated family ownership/control are likely to be more concerned about the survival and continuity of the business as the competition increases. Based on the arguments it can be hypothesized that the higher the market competition, the stronger the relationship between family involvement and innovation should be.

2.2 Career concerns of CEOs and innovations

Several scholars argue that investment in innovation will increase if firms do not terminate their CEOs even in a situation of bad income realization. Manso (2011) constructed a theoretical model where shareholders and CEOs have different horizons with respect to innovation. In his model, payoffs from innovation can only be realized in the long term whereas CEOs have a relatively short-term concern because of their career goals. Manso (2011) argues that to encourage more investment in innovations, firms should not terminate their CEOs due to failures in R&D which will motivate the CEOs to keep a long-term goal.

Holmstrom (1989) also develops a model where he argues that CEOs' compensation, wealth, and career concerns are related to the performance of firms and hence they are prone to reject those projects which involve some risks but at the same time have positive net present value. He also suggests that firms should provide job security to their CEOs to boost innovation and inspire them to go for risky investments like innovation. Recent works which corroborate the arguments of Manso (2011) and Holmstrom (1989) are Aghion et al. (2013) and Luong et al. (2017). They find that more institutional investor ownership results in more innovation. According to them, this happens because institutional investors do not terminate CEOs even when performance is poor.

Aghion et al. (2013) draw insights from two models viz. the lazy manager hypothesis (Hart, 1983; Bertrand and Mullainathan, 2003) and the career concern model (Holmstrom, 1989). According to the first model, managers prefer a quiet life but institutional investors force them to innovate. The second model argues that managers will not be very keen to invest in innovation which involves risk because if the project fails they will be fired. However, the incentive to innovate will increase if the contracts are such that managers are not terminated even in the consequences of bad income realizations. Aghion et al. (2013) build a model that nests these two models and then test the interaction between institutional ownership and competition on innovation. They show that the predictions of the two models differ. The prediction that follows from the career concern model is supported in their study. Their findings show that, as competition increases, the positive effect of institutional investment on managerial incentives also increases. It becomes stronger when CEO turnover is less even in a situation of declining profitability. Thus, institutional ownership and competition are complements in this model whereas they are substitutes in the lazy manager model. However, both models predict that institutional ownership increases innovation but their interaction effects are different in Aghion et al. (2013).

Drawing insights from the above studies we argue that family involvement increases incentives for innovation because family ownership insulates CEOs against career risk even in the consequences of bad income realizations. We argue that this effect operates mainly through the channel of bequest motives. Bequest motive within the family firms encourages family members to promote long-term goals over managerial prejudice. Long-term goals, on the other hand, help to promote the sustainable development and reputation of firms. Innovation plays vital for long-term success in many businesses and thus helps to improve the reputation of firms (Ganguly et al., 2020). Therefore, family members have strong motivations to encourage innovation. To achieve sustained control of the firm over generations, family members would like to maintain the affluence of both the family and the firm and hence they will follow a long- term strategy. Thus, family involvement would have a positive attitude toward innovation (Tan, Liu and Geng, 2021).

Family involvement in management also leads to emotional attachment to the business. In family firms, employees are provided with a sense of professional security (Cater III and Justis, 2009) which is conducive to innovation. R&D is a risky investment and has a long-term goal and is subject to failure in many instances which will result in the generation of losses. In such situations, family CEOs are naturally insulated from career risk because of their family involvement. However, family owners will protect the career risk of the non-family CEOs too so that they can think in the long-term and get motivated to innovate. It would help to improve the reputation of the family which would help to pass on the firm to the next generation and to leave the business in good condition. We argue that the risk of CEO turnover will be less as a consequence of bad income realization which will encourage more innovation in the context of family ownership. Thus, family ownership increases firm innovation, and this happens due to the reason that family owners do not terminate CEOs even when their performance is poor. Additionally, in line with the arguments by Aghion et al. (2013), our model predicts that more intense product market competition should reinforce the positive impact of family ownership on managerial incentives to invest more in innovations.

3. Data and methodology

The firm-level data of manufacturing firms registered with BSE (Bombay Stock Exchange) and NSE (National Stock Exchange) has been extracted from the PROWESS database managed by the Centre for Monitoring Indian Economy. The firms with a greater share of foreign promoters than Indian promoters have been removed as the key decision on R&D are likely to be influenced by foreign partners. Finally, after eliminating the firms with a greater share of state or central governments, we are left with an unbalanced panel of 777 companies for the period 2001-2018. The use of Tobit modelling is appropriate when the dependent variable is censored (Greene, 2003). Our dependent variable, R&D intensity, is left censored at zero as any value less than this level would be meaningless.

First, we use the random effect panel Tobit regression model as our main explanatory variables representing family ownership and control do not change substantially over time (Kennedy, 2008). As suggested in earlier studies, one-year lagged values have been used to avoid possible endogeneity (Girma, Gong and Görg, 2008). Our model specifications are as follows:

$$RD_{it}=\sum\beta_k FI_{kit-1}+\sum\lambda_j Controls_{jit-1}+\mu_i+\delta_t+\varepsilon_{it} \quad (1)$$

$$RD_{it}=\sum\beta_k FI_{kit-1}+\theta COMP_{it-1}+\sum\lambda_j Controls_{jit-1}+\mu_i+\delta_t+\varepsilon_{it} \quad (2)$$

$$RD_{it}=\sum\beta_k FI_{kit-1}+\theta COMP_{it-1}+\sum\eta_k(FI_{kit-1} \square COMP_{it-1})+\sum\lambda_j Controls_{jit-1}+\mu_i+\delta_t+\varepsilon_{it} \quad (3)$$

In the above specifications, the subscripts i and t denote the firm and time respectively. Our dependent variable is R&D intensity. FI represents the family involvement indicators viz., the share held by the family (FAM), family CEO/MD (FAMCEO) and the dual role of family CEO and chairperson (DUAL). COMP represents the level of product market competition. As control variables, we include some firm characteristics such as the degree of independence enjoyed by boards of directors (IND), size of the firm (SIZE), age of the firm (AGE), the prior performance of the firm (ROA), leverage (LEV), export intensity (EXP), financial slack (FS), foreign institutional shareholdings (FII), domestic institutional shareholdings (DII) and group affiliation (GROUP). The coefficients μ, δ and ε capture industry-fixed effects, time-fixed effects and random disturbances respectively. To test the robustness of our results, the System- GMM estimator has also been used. The approach helps to control for any potential endogeneity by incorporating lagged values of dependent and independent variables as a system of instruments in the model (Arellano and Bond, 1991; Blundell and Bond, 1998). The results from the System-GMM estimator are presented in Appendix.

Additionally, we test whether the effect of family involvement stems from improvements due to different preferences of family shareholders than other types of shareholders. For this, we test whether the concentration of family ownership, conditional on bad performance, increases/decreases the probability of CEO resignation[3]. The following panel Probit models are used to test the hypothesis:

$$CEORESIGN_{it} = \alpha + \beta_1 \Delta ROA_{it-1} + \varepsilon_{it} \quad (4)$$

$$CEORESIGN_{it} = \alpha + \beta_1 \Delta ROA_{it-1} + \beta_2 FAM_{it-1} + \beta_3 (FAM * \Delta ROA)_{it-1} + \mu_i + \delta_t + \varepsilon_{it} \quad (5)$$

The CEORESIGN is a dummy variable that takes the value 1 when the CEO resigns before retirement and 0 otherwise. Independent variables ΔROA_{it-1} and FAM represents a change in prior performance (measured by return on assets) and family shareholding respectively.

Variable construction

Dependent variable: In models (1), (2) and (3), R&D Intensity (RD) is the main dependent variable and is measured by the ratio of R&D expenditure and aggregate sales. The R&D intensity is an input variable and is extensively treated as a proxy for technological innovations happening within the firms. As R&D investments may or may not fully reflect innovations, some of the studies prefer to use other output measures of innovation such as patent count or change in Total Factor Productivity (TFP). However, these output-based indicators may also be inadequate to represent innovative activities (Singh and Chakraborty, 2021). Our dependent variable, as an input variable, is more likely to capture the innovative efforts of the firms irrespective of the outcome. Therefore, we consider R&D as a better indicator of 'intent to innovate' than other output-based measures. It should also be noted here that R&D is considered highly risky and uncertain (Gupta, Wilemon and Atuahene-Gima, 2000), therefore making the output-based indicators a relatively less precise measure of 'intent to innovate' or 'innovative efforts'. This observation is important in the context of this study considering the behavioural analysis of family firms focuses on how they behave instead of how they perform.

In models (4) and (5), the dependent variable is a dummy variable that takes the value equal to 1 if the CEO resigns before retirement and 0 otherwise.

Independent variables: The independent variables in the model represent various aspects of family involvement and product market competition. In particular, the following variables are used: (1) *Family shareholding (FAM)* is defined as the percentage of shares held by Indian individuals and Hindu undivided families (HUF) as promoters. The literature suggests that concentration of ownership may affect the innovative activities of the firms (see Matzler et al. 2015). (2) *Family CEO/MD (FAMCEO):* The role of the CEO as a determinant of the innovative efforts of the firms has also been recognised extensively (Diéguez-Soto, Garrido- Moreno, and Manzaneque 2018). Following Ashwin, Krishnan, and George (2015), we assume that the CEO/MD belongs to the family owning the firm when the CEO/MD of the firm is also a promoter. The variable takes the value equal to 1 when CEO/MD is from the family, and 0 otherwise. (3) *Family CEO-chairperson duality (DUAL)* variable has been incorporated to test the impact of family control on investments in innovations when both the CEO/MD and chairperson belong to the owner family. The literature suggests that the dual presence of the family CEO and chairperson enhance the impact of family control over the firms' strategic decisions such as R&D (Li and Yang 2019). The dummy variable takes the value equal to 1 when both CEO/MD and the chairperson belong to the family.

The competition variable is included in the model considering it may determine the R&D investments of the firms (Aghion et al., 2005). For more insights, product market competition variables are derived using two different indicators of market structure i.e. HHI (*Herfindahl-Hirschman Index*) and PCM (Price-cost Margin). HHI is measured as a sum of the square of the market share of each firm at the 3-digit National Industrial Classification (NIC) - 2008.

$$HHI_{mt} = \sum_{i=1}^{N} S_{it}^{2} \qquad where,\ S_{it} = \frac{sales_{it}}{\sum_{i=1}^{N} sales_{it}}$$

PCM represents overall price competition and is calculated as follows:

$$PCM = \frac{total\ output - total\ inputs - payro}{total\ output}$$

The values of HHI and PCM lie between zero and one. The values equal to zero and one represent perfect competition and monopoly respectively. By definition, HHI measures concentration in the domestic market. It does not take into account competition from foreign firms. However, PCM reflects the overall price competition that a firm faces, including the competition from foreign firms. To transform HHI and PCM from explicit measures of market concentration into measures of competition, we subtract them from one. It should be noted that for a simpler interpretation of the results throughout this paper, the product market competition variables derived from HHI and PCM indices are referred to as DCOMP (domestic competition) and PCOMP (price competition) respectively. Additionally, interaction terms of family involvement variables (FAM, FAMCEO and DUAL) with the product market competition variables have been introduced in the models to empirically test the complementarity between the two.

Apart from the aforementioned variables, some important controls have been used in the model. *Board Independence (IND*) is an important factor that can influence the extent to which firms may invest in R&D. The degree of governing board's independence is measured as the ratio of independent directors to the total number of directors present in the board. *Size of the firm* (SIZE) may be an important determinant of its R&D investments (Mowery, 1983). A larger firm may be financially more capable and resourceful to invest in R&D. Contrary to this, it can also be argued that smaller firms have indivisibilities in favour of their smaller scale, providing them with greater scope to grow faster. The size of the firm in our model has been measured as the log of the deflated value of reported revenue from sales. *Age of the firms (AGE)* may also affect their R&D investments. Coad et al. (2016) argue that younger firms grow faster as they grow older. The age of the firm has been calculated by taking the log of the values obtained by subtracting the incorporation year from the year to which the data belongs. *Return on assets (ROA*), in our model, is a proxy for the prior performance of the firm. The performance in the past is likely to encourage and assist the firm to invest more in R&D. On the other hand if performance is poor, the firms may exhibit rigid and conservative behaviour towards strategic R&D investments (Ahuja, Lampert and Tandon, 2008). The variable is measured as the ratio of profit before depreciation, interest, tax and amortisation (PBDITA) and total assets. *Leverage (LEV)* indicates the financial situation of the firm. It is calculated as the ratio of debt to equity of the firm. The firms with a higher debt-to-equity ratio may be more concerned about paying off the debt using current cash flow instead of investing in R&D (Munari, Oriani and Sobrero, 2010). *Exports intensity (EXP)* is defined as a ratio of exports and aggregate sales. The technological spillovers from the foreign markets and the need to compete with other multinationals provide the exporting firms with an incentive to learn and invest in technological up-gradation. Therefore, it can be argued that the firms with a higher export share in the total output are likely to invest more in R&D (Solomon and Shaver, 2005; Neves, Teixeira and Silva, 2016). *Financial slack (FS*) is another important determinant of industrial R&D. The current ratio is a liquidity ratio that is used to measure a company's ability to meet its short-term obligations, i.e. to pay off its short-term liabilities. A ratio of current assets divided by current liabilities measures the adequacy of the company's short-term assets to meet its short-term liabilities. A ratio below one implies inadequacy and a ratio just above one would indicate a "just-about" adequate ability to meet current liabilities. But, a ratio that is much above one would indicate too much of a short-term asset on hand that could be deployed for better long-term use. It has been established that financial adequacy in the short- run allows the firms to invest more in discretionary strategic investments like R&D (see Kim, Kim, and Lee 2008). Foreign institutional shareholding (FII) serves as an active monitor, provides the firms with insurance in case of innovation failures, and encourages technological spillovers from high-innovation economies (Luong et al. 2017). Foreign investors, in this way, are likely to boost the innovative efforts of the firms. In our model, the percentage of promoter shares held by foreign institutional investors is used as a control variable. Domestic institutional shareholding (DII) defined as the percentage of common shares held by domestic institutional investors is another important control variable in the model. It has been observed that institutional ownership acts as a pressure resistance for managers and results in greater investments in R&D (Bushee, 1998). Finally, a dummy variable Group-affiliation (GROUP) takes the value equal to 1 when the firm is affiliated to a business group, and 0 if the firm is a standalone firm. The literature observes group affiliation as an important determinant of the innovative activities of the firms (see Guzzini and Iacobucci 2014).

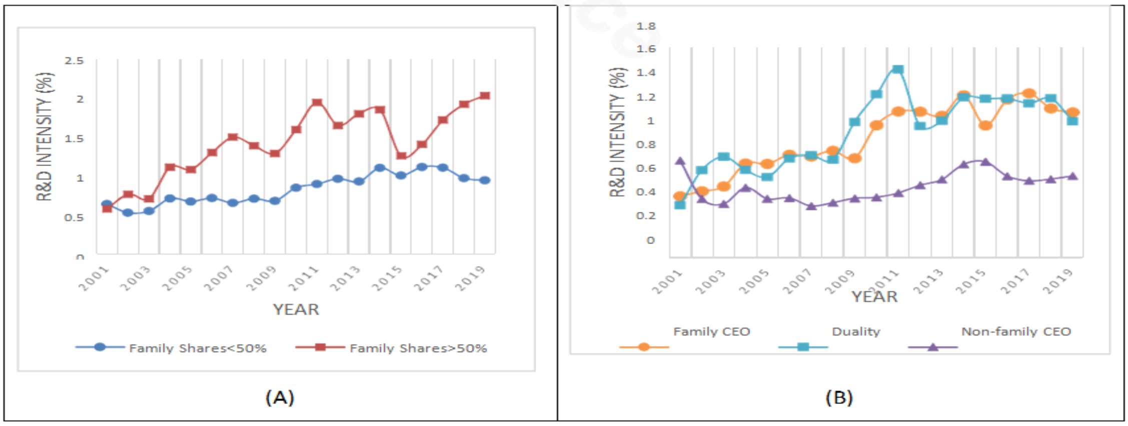
4. Empirical results

4.1 Preliminary observations

The preliminary observations reveal that R&D investments are significantly greater in firms with concentrated ownership. Figure 1 shows that throughout our study period, the R&D intensity in the firms with highly concentrated family ownership remained higher than in the firms with less concentrated family ownership[4]. Similarly, the family firms which are controlled by the family CEO or family CEO and chairperson invested more in R&D. The gap between the R&D intensity of the firms with a greater degree of family involvement and less degree of involvement appears to have widened during the last two decades.

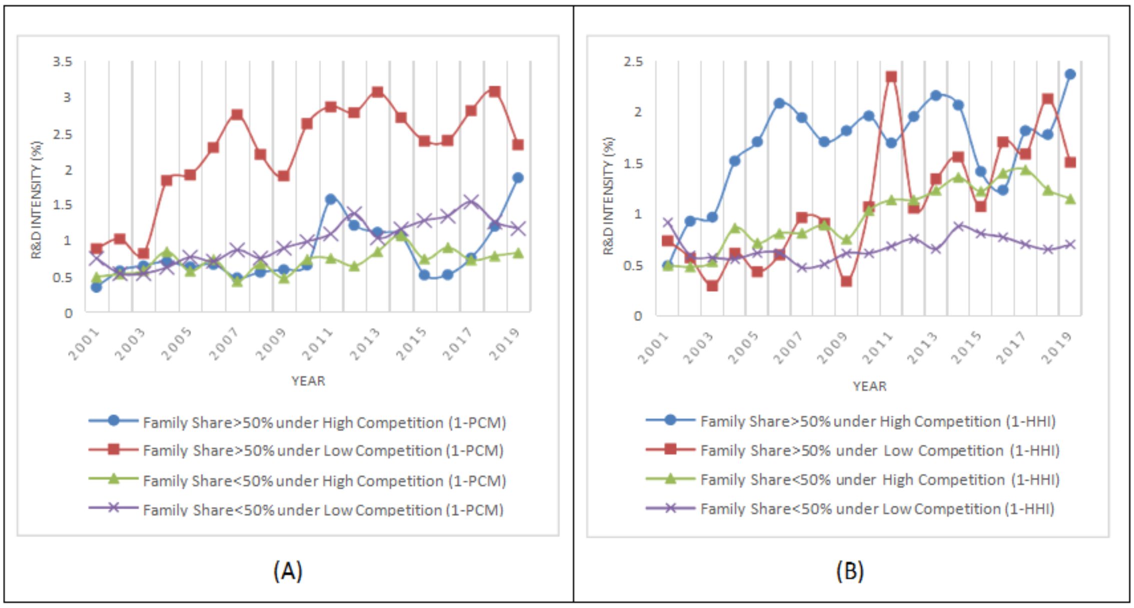
Figure 2 segregates more and less concentrated family firms based on the degree of competition they face. Figure 2(A) exhibits that firms with concentrated family ownership have increasingly invested much more under lower price competition (PCOM). Firms with less concentrated ownership also perform somewhat better under lower price competition. Although high price competition seems to be a limiting factor that restricts the R&D investments of all the firms, the influence of competition appears to be much more pronounced in the case of firms with concentrated family ownership. Surprisingly, we find contrasting observations when the domestic competition (DCOMP) is used as an indicator of product market competition (Figure 2B). The R&D investments of all the firms are higher when the competition is high. Nonetheless, the firms with concentrated family ownership have increasingly more R&D intensive under intense domestic competition.

Figure 1: R&D intensity of the firms with more and less family involvement



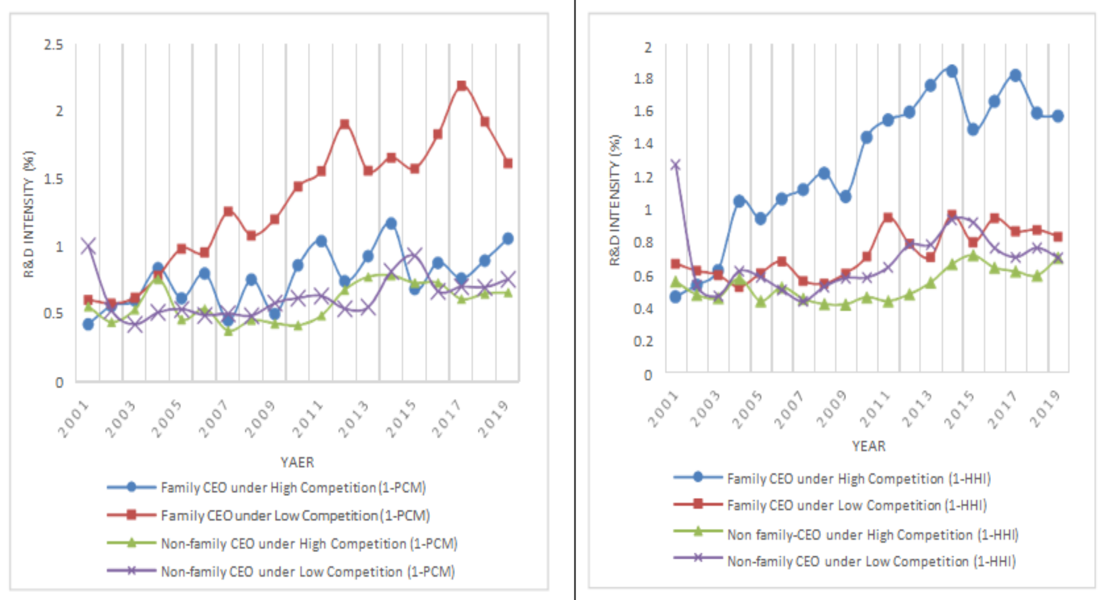
(Source: Authors' calculations using CMIE-Prowess data)

Figure 2: R&D intensity of the firms with more and less family involvement under high and low competition



(Source: Authors' calculations using CMIE-Prowess data)

Figure 3: R&D intensity of the firms controlled by family/non-family-CEOs under high and low product market competition levels

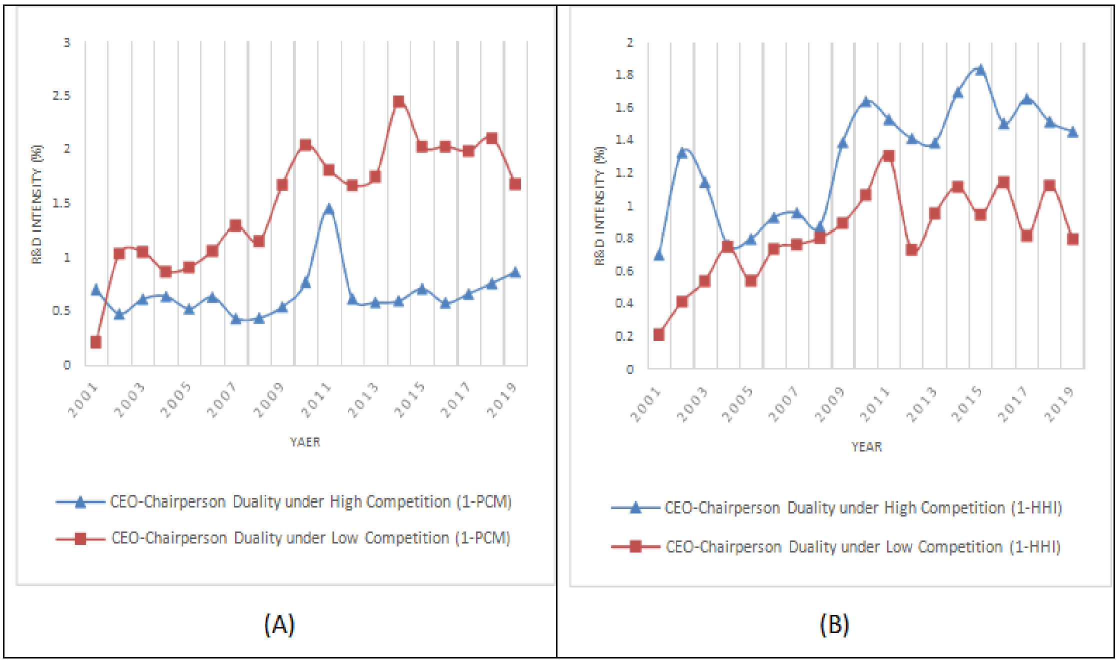


(A) (B)

(Source: Authors' calculations using CMIE-Prowess data)

Figure 3 and Figure 4 show that observations on R&D intensity remain largely comparable when sample disaggregation is performed using family control variables instead of concentration of family ownership under different degrees of price/domestic product market competition. Overall, the preliminary observations suggest that family involvement may be an important determinant of industrial innovations. Additionally, the level of product market competition could play a moderating role in the determination of the relationship between family involvement and innovations.

Figure 4: R&D-intensity (%) of the firms controlled by family CEO and chairperson under high and low product market competition levels



(Source: Authors' calculations using CMIE-Prowess data)

4.2 Econometric results

4.2.1 Family involvement and innovation

The estimation results of the Tobit model are presented in a systematic way to observe how the inclusion or exclusion of important independent variables related to family involvement and product market competition affect the dependent variable. In Table 1, Model 1.1 estimates equation (1) and finds that the factors representing family ownership and control over management are statistically significant. The higher ratio of independent directors is also significantly positive suggesting a more independent board allows the firms to put in greater financial efforts towards R&D. Among the control variables, size of the firms, exports and financial slack, are found to be positively associated with R&D intensity, whereas, the share of domestic institutional promoters and group-affiliation affect the R&D-intensity of the firms' negatively. Other control variables such as age, ROA, and FII are statistically insignificant. Model 1.2 includes the domestic competition variable (DCOMP) as mentioned in equation (2) and finds that domestic competition is a significant variable that may affect the R&D investments of the firms. Other variables largely remain unchanged. Therefore, the results from Model 1.1 support the hypothesis that the theory of stewardship and SEW is valid in the Indian context.

In Model 1.3, Model 1.4 and Model 1.5, we include the interaction terms between the domestic competition and family involvement variables namely family shareholding, family- CEO and CEO-chairperson duality. The significance of interaction indicates that there may exist a moderating effect of market competition on the family involvement indicators viz. FAM and FAMCEO in influencing the R&D investments of the firms. The sign of the coefficient suggests that the marginal effect of a greater competition level on the R&D intensity of the firm is greater when the family ownership is concentrated or the CEO belongs to the family. In other words, the interaction term suggests that under higher domestic competition, as family ownership or degree of family control increases, the R&D intensity of the firm also rises. It is interesting to find that apart from explicitly affecting the innovative efforts of the firms, domestic competition may also encourage the firms with concentrated ownership/control to invest more in R&D. The interaction between competition and CEO-chairperson duality, however, is statistically insignificant. Model 1.6 finds similar results when all the interaction variables are included in the model. Overall, the results suggest market competition may complement the relationship between family involvement indicators and R&D investments. The value of the Wald chi-square statistic is highest in Model 1.6 indicating that it is the best model.

Likewise, Table 2 presents the estimation results after replacing the measure of competition with PCOMP. The results confirm the significance of family ownership variables. However, contrary to the results we found in Table 1, the interaction terms between the family ownership variables, FAM, FAM and FAMCEO with PCOMP are insignificant. The correlation matrix and Variance Inflation Factor (VIF) show that the estimates do not suffer from the issue of multi-collinearity[5]. The System-GMM estimations find the results from the Tobit model robust (see Table A2 and Table A3 in the Appendices section).

Table 1: Panel Tobit Estimation (Measure of Competition: DCOMP)

	Model 1.1	Model 1.2	Model 1.3	Model 1.4	Model 1.5	Model 1.6
FAM	0.021*** (0.001)	0.023*** (0.0011)	0.0218*** (0.0045)	-0.0019 (0.001)	0.0002 (0.002)	0.0234*** (0.0045)
FAMCEO	0.055*** (0.009)	0.0554** (0.022)	0.0531 (0.092)	0.074** (0.031)	0.057 (0.092)	0.073*** (0.014)
DUAL	0.018*** (0.006)	0.019*** (0.006)	-0.015 (0.036)	-0.0195 (0.0361)	0.134*** (0.008)	0.189 (0.199)
IND	0.781*** (0.056)	0.785*** (0.056)	0.787*** (0.056)	0.784*** (0.056)	0.786*** (0.056)	0.787*** (0.056)
DCOMP		1.453*** (0.266)	1.027*** (0.279)	2.081*** (0.393)	1.42*** (0.268)	1.817*** (0.396)
FAM*DCOMP			1.026*** (0.052)			1.028*** (0.053)
FAMCEO*DCOMP				0.915** (0.421)		1.245*** (0.427)

DUAL*DCOMP					-0.177 (0.225)	-0.237 (0.227)
Size	0.0717*** (0.019)	0.076*** (0.019)	0.0744*** (0.019)	0.077*** (0.019)	0.076*** (0.019)	0.074*** (0.019)
Age	0.117 (0.11)	0.121 (0.13)	0.1046 (0.131)	-0.131*** (0.013)	0.120 (0.17)	0.116 (0.12)
ROA	-0.054 (0.037)	-0.049 (0.037)	-0.0515 (0.037)	-0.048 (0.037	-0.049 (0.037)	-0.0503 (0.036)
LEV	0.0001 (0.0002)	0.00011 (0.00028)	0.000108 (0.00028)	0.00011 (0.00028)	0.00011 (0.0002)	0.00011 (0.0002)
EXP	0.05*** (0.008)	0.036*** (0.0086)	0.036*** (0.008)	0.035*** (0.008)	0.036*** (0.008)	0.036*** (0.008)
FS	0.047*** (0.01)	0.036*** (0.012)	0.037*** (0.012)	0.037*** (0.013)	0.036*** (0.0011)	0.033*** (0.016)
FII	-0.0002 (0.0017)	-0.00028 (0.0017)	-0.0005 (0.0017)	-0.00023 (0.0017)	-0.0002 (0.0017)	-0.00046 (0.0017)
DII	-0.0017* (0.0010)	-0.0019* (0.0011)	-0.0021* (0.0011)	-0.0019* (0.0011)	-0.0019* (0.0011)	-0.0021** (0.0011)
GROUP	-0.054*** (0.011)	-0.052** (0.021)	0.0535 (0.1005)	0.0477 (0.1005)	0.052 (0.10)	- 0.0479*** (0.003)
Constant	-0.475* (0.256)	0.89** (0.358)	0.577* (0.293)	1.423*** (0.434)	0.868** (0.359)	1.251** (0.434)
Observations	8582	8582	8582	8582	8582	8582
Wald Chi-Square	599.94	630.55	656.61	635.82	631.2	666.63
Log-likelihood	-26188.6	-26173.7	-26161.3	- 26171.43	- 26173.48	- 26156.85

Notes: The dependent variable is R&D intensity defined as the ratio of R&D expenditure and aggregate sales of the firms.

****, **, and * denote significance levels at 1 percent, 5 percent and 10 percent respectively. The values in parentheses are standard errors. Standard errors are clustered at the firm level.*

Table 2: Panel Tobit Estimation (Measure of Competition: PCOMP)

	Model 2.1	Model 2.2	Model 2.3	Model 2.4	Model 2.5	Model 2.6
FAM	0.021*** (0.001)	0.011*** (0.0014)	0.001 (0.0018)	-0.016*** (0.0011)	0.019*** (0.0019)	0.026*** (0.0018)
FAMCEO	0.055*** (0.009)	0.052*** (0.09)	0.053** (0.012)	-0.096 (0.121)	0.052 (0.092)	0.137*** (0.012)
DUAL	0.018*** (0.006)	0.021*** (0.0036)	0.022*** (0.0041)	0.025 (0.0362)	0.214** (0.099)	0.256** (0.101)
IND	0.781*** (0.056)	0.783*** (0.056)	0.783*** (0.056)	0.785*** (0.056)	0.781*** (0.054)	0.783*** (0.056)
PCOMP		0.142* (0.079)	0.111 (0.094)	-0.067 (0.134)	0.206*** (0.083)	-0.072 (0.139)
FAM*PCOMP			0.0018 (0.014)			-0.0013 (0.0031)
FAMCEO*PCOMP				0.297 (0.253)		0.379 (0.457)
DUAL* PCOMP					0.42 (0.46)	0.511* (0.26)
Size	0.0717*** (0.019)	0.0561*** (0.0217)	0.057*** (0.021)	0.053** (0.021)	0.051** (0.021)	0.048** (0.022)
Age	0.117 (0.11)	0.126 (0.131)	0.127 (0.131)	0.142 (0.13)	0.122 (0.131)	0.141 (0.131)
ROA	-0.054 (0.037)	-0.053 (0.037)	-0.053 (0.037)	-0.052 (0.037)	-0.052 (0.037)	-0.052 (0.037)
LEV	0.0001 (0.0002)	0.0001 (0.0002)	0.00011 (0.0003)	0.0001 (0.0003)	0.00021 (0.0002)	0.0001 (0.0002)
EXP	0.05*** (0.008)	0.034*** (0.008)	0.034*** (0.0087)	0.034*** (0.0087)	0.034*** (0.008)	0.033*** (0.008)
FS	0.047*** (0.01)	0.04*** (0.011)	0.05*** (0.0012)	0.04*** (0.0011)	0.04*** (0.001)	0.04*** (0.0015)
FII	-0.0002 (0.0017)	-0.00023 (0.0017)	-0.00017 (0.0077)	-0.0002 (0.00174)	-0.00028 (0.0017)	-0.00021 (0.0016)
DII	-0.0017* (0.0010)	-0.0019* (0.0011)	-0.00188* (0.0010)	-0.00191* (0.0011)	-0.00201* (0.0011)	-0.00193* (0.0011)
GROUP	-0.054*** (0.011)	0.063 (0.101)	-0.063*** (0.008)	0.061 (0.101)	0.065 (0.101)	0.061 (0.1007)
Constant	-0.475* (0.256)	-0.515** (0.257)	-0.510** (0.257)	-0.42* (0.261)	-0.522** (0.257)	-0.403 (0.261)
Observations	8582	8582	8582	8582	8582	8582
Wald Chi Squ.	599.94	602.98	603.22	606.62	610.27	616.6
Log-likelihood	-26188.6	-26187.1	-26186.8	-26185.1	-26183.7	-26180.6

Notes: The dependent variable is R&D intensity defined as the ratio of R&D expenditure and aggregate sales of the firms.

***, **, and * denote significance levels at 1 percent, 5 percent and 10 percent respectively. The values in parentheses are standard errors. Standard errors are clustered at the firm level.

Overall, the findings provide greater support to the stewardship theory and SEW perspective on family firms. The estimations result from Table 1 and Table 2 corroborate the findings of the erstwhile Indian studies that Indian family firms are more R&D oriented. As an important addition to the existing literature, we find the possible complementarity of product market competition in influencing the relationship between family ownership/control and investments in innovation. However, the validity of the findings is conditional upon the indicator of product market competition.

To explain somewhat dissimilar results when two different indicators of the product market competition are used, we have to consider how these are defined. DCOMP, as discussed earlier, defines competition in terms of the distribution of domestic market share and mainly represents competition from the firms in the domestic market. High competition in terms of firms' domestic market shares may not necessarily worsen the firms' financial situation (Cattó, 1980; Anderson, Fornell and Lehmann, 1994). According to economic theory, zero economic profits are possible in a situation when there are a large number of buyers and sellers producing homogenous products under the condition of free entry and exit. However, that's generally not the situation in most manufacturing sectors. Therefore, despite high competition measured using DCOMP, a firm may earn more than normal profits making them financially capable of investing in costly R&D projects. In this case, the firms with greater family involvement have the incentive to invest the retained earnings in long-run R&D projects to acquire greater market share and gain market power in the long term. Additionally, when the domestic competition is higher (i.e. larger number of competitors), there is a greater risk of imitation by the domestic rivals (Singh 2022). Considering family firms suffer less from agency problems and are more informed of the management quality (Sirmon et al., 2008), risk from imitation becomes less significant in the firms with greater family share. This further results in greater investments in innovations in more concentrated family firms as the domestic competition increases.

On the other hand, PCOMP is a measure of overall price competition that represents overall competition including competition from foreign firms. Unlike DCOMP, intense price competition reduces the firms' profits more explicitly (Porter, 1980). Higher price competition implies that the firm has zero market power i.e. the firm is incapable of charging more price than marginal cost. Theoretically, this means zero economic profits. Thus, intense price competition implies that firms are unable to retain earnings to further invest in R&D. Under this financial pressure, the firms are likely to prioritise short-term survival goals over long-term strategic investments.

Overall, all these results point in the direction of a positive effect of family involvement on innovation in response to domestic product market competition. The following section explains these results from the perspectives of CEO turnover.

4.2.2 Family ownership and CEO turnover and innovation

The estimation results of Equation (4) and Equation (5) are presented in Table 3. Model 3.1 suggests that change in returns from assets does not have a significant effect on CEO turnover. The results in Model 3.2 point out that the concentration of family ownership reduces the likelihood of CEO turnover. This suggests that the CEOs in firms with concentrated family ownership are relatively more protected against job loss and therefore may encourage greater R&D investments. This observation is in line with the results discussed in previous sub- sections. Further, the interaction term between variables ΔROA and FAM is significantly positive. This suggests that if the performance of the CEO is poor (i.e. ΔROA is negative), there is less probability of the CEO being fired in the more concentrated family firms. The elimination of job-related concerns may encourage CEOs to invest in riskier yet profitable R&D investments.

The observation that performance does not affect CEO turnover is probably because several family families appoint family members as CEOs who naturally enjoy longer tenures regardless of performance (Cater III and Justis, 2009). Therefore, we perform a similar analysis with a dependent variable defined as 'Non-family CEO turnover'. The dependent variable takes the value one when a non-family member CEO resigns before retirement. The results in Model 3.3 and Model 3.4 show that performance improvement may reduce the chances of CEO turnover. The interaction term between FAM and ΔROA suggests that firms with more concentrated family ownership may protect even the non-family CEOs against job loss.

Family firms may offer a higher degree of job protection to CEOs after a bad performance. Nonetheless, the degree of job protection may vary depending on levels of product market competition. In our model, concentrated family firms offer more job security when they face a higher degree of competition. First, it is easier for the CEOs to justify bad performance when the product market competition is intense, which is generally not possible if the CEO perform poorly without any significant competition in the market. Second, eliminating job concerns could be a mechanism to ensure the longevity and protection of the family business when the threat from competition in the market is immediate and intense. In other words, family firms may have a greater incentive to offer job security to CEOs under a higher degree of competition.

Table 3: Panel Probit Estimation

	Dependent Variable: CEO Turnover		Dependent Variable: Non-family CEO Turnover	
	Model 3.1	Model 3.2	Model 3.3	Model 3.4
ΔROA	-0.006 (0.10)	-0.005 (0.06)	-0.28*** (0.021)	-0.24*** (0.021)
FAM		-0.71*** (0.18)		-0.27** (0.11)
FAM* ΔROA		1.21*** (0.18)		0.98*** (0.13)
Constant	-2.12	-1.21	-2.23	-1.17
Observations	13281	13281	3969	3969
Log-likelihood	-336.21	-223.19	-345.65	-227.65
Wald Chi-squ.	13.39	87.12	15.34	91.16

Notes: The dependent variable "CEO turnover" is a dummy variable that takes the value equal to one when the CEO resigns before retirement, and zero otherwise. The dependent variable "Non-family CEO turnover" is a dummy variable that takes the value 1 when a non-family CEO resigns before retirement, and zero otherwise.

****, **, and * denote significance levels at 1 percent, 5 percent and 10 percent respectively. The values in parentheses are standard errors. Standard errors are clustered at the firm level.*

To test this hypothesis empirically, we segregate samples based on low and high levels[6] of domestic/price competition faced by the firms. Table 4 suggests that when the domestic competition is weak, performance is an insignificant determinant of CEO turnover. However, in the case of non-family CEOs, good performance may reduce the chances of CEO turnover to some extent. The degree of family ownership is also a significant factor that decreases the likelihood of CEO turnover. The coefficients of interaction terms between FAM and ΔROA in Model 4.3 and Model 4.4 suggest that family share conditional on bad performance is an insignificant determinant of CEO turnover under low domestic competition. The observation suggests the elimination of career concerns to facilitate long-run strategic investments does not occur when firms face low domestic competition. However, the interaction term is significantly positive in Model 4.6 and Model 4.8 indicating that under high domestic competition, the firms with greater family firms may provide more job protection to poorly performing CEOs.

Table 4: Panel Probit Estimation under Low and High Domestic Competition

	Low Domestic Competition				**High Domestic Competition**			
	Dependent Variable: CEO Turnover		Dependent Variable:Non-family CEO Turnover		Dependent Variable:CEO Turnover		Dependent Variable:Non-family CEO Turnover	
	Model 4.1	Model 4.2	Model 4.3	Model 4.4	Model 4.5	Model 4.6	Model 4.7	Model 4.8
ΔROA	-0.03 (0.11)	-0.15 (0.31)	-0.05** (0.02)	-0.02* (0.01)	-0.04* (0.02)	-0.091* (0.06)	-0.13*** (0.02)	-0.15** (0.02)
FAM		-0.96** (0.39)		-0.35** (0.16)		-0.64*** (0.21)		-0.46* (0.24)
FAM*ΔROA		0.19 (0.23)		0.42 (0.48)		0.53*** (0.11)		0.61*** (0.13)
Constant	-2.54	-1.01	-2.56	-1.65	-2.11	-2.91	-2.13	-2.85
Observations	6663	6663	2077	2077	6618	6618	1892	1892
Log-likelihood	-398.23	-211.1	-389.45	-198.65	-365.22	-234.17	-386.12	-276.17
Wald Chi-squ.	29.19	123.89	43.01	123.19	31.09	137.76	49.67	111.76

Notes: The dependent variable "CEO turnover" is a dummy variable that takes the value equal to one when the CEO resigns before retirement, and zero otherwise. The dependent variable "Non-family CEO turnover" is a dummy variable that takes the value 1 when a non-family CEO resigns before retirement, and zero otherwise.

****, **, and * denote significance levels at 1 percent, 5 percent and 10 percent respectively. The values in parentheses are standard errors. Standard errors are clustered at the firm level.*

Similarly, Table 5 presents the estimation results of the samples segregated based on low and high-price competition. The results suggest that good performance and concentration of family ownership reduce the chances of CEO turnover under both low and high-price competition. The interaction term between family ownership and change in ROA points out that under high competition, the firms with greater family share are less likely to experience CEO turnover when the performance is poor. The effect is absent in the sample of firms facing low-price competition. The comparison of coefficients of the interaction term in Table 4 and Table 5 indicates that the reduction in the chances of CEO turnover conditional on bad performance is substantially more under high domestic competition than high price competition.

The career concern model discussed by (Aghion et al., 2013) uses product market competition as a proxy for imitation. As imitation is more likely to occur when domestic product market competition is high (Singh, 2022), domestic competition is a better proxy of imitation as compared to price competition. It may also be argued that in response to imitation (or say, domestic competition), a firm with a higher degree of family involvement exhibits better resource management in response to the threat of imitation (Sirmon et al., 2008). This explains why the positive effect of family ownership on managerial innovation through the elimination of CEOs' job concerns is stronger under higher domestic competition as compared to higher price competition.

Table 5: Panel Probit Estimation under Low and High Price Competition

	Low Price Competition				**High Price Competition**			
	Dependent Variable: CEO Turnover		Dependent Variable:Non-family CEO Turnover		Dependent Variable: CEO Turnover		Dependent Variable:Non-family CEO Turnover	
	Model 5.1	Model 5.2	Model 5.3	Model 5.4	Model 5.5	Model 5.6	Model 5.7	Model 5.8
ΔROA	-0.03** (0.01)	-0.07** (0.03)	-0.12*** (0.004)	-0.14*** (0.021)	-0.35*** (0.054)	-0.43*** (0.11)	-0.37*** (0.041)	-0.41*** (0.062)
FAM		-0.82*** (0.27)		-0.63*** (0.21)		-0.62** (0.26)		-0.66*** (0.19)
FAM*ΔROA		0.35 (1.07)		0.32 (1.18)		0.013*** (0.002)		0.016*** (0.002)
Constant	-1.54	-0.87	-1.45	-0.74	-1.43	-0.91	-1.43	-0.76
Observations	6250	6250	2093	2093	7031	7031	1876	1876
Log-likelihood	-435.68	-298.45	-514.01	-276.85	-487.04	-301.98	-476.21	-312.75
Wald Chi-squ.	38.18	98.17	37.15	91.04	29.15	99.16	38.17	93.6

Note: Notes: The dependent variable "CEO turnover" is a dummy variable that takes the value equal to one when the CEO resigns before retirement, and zero otherwise. The dependent variable "Non-family CEO turnover" is a dummy variable that takes the value 1 when a non-family CEO resigns before retirement, and zero otherwise.

****, **, and * denote significance levels at 1 percent, 5 percent and 10 percent respectively. The values in parentheses are standard errors. Standard errors are clustered at the firm level.*

5. Concluding remarks

The literature on family businesses draws upon the principal-principal agency theory, stewardship perspective, behavioural agency model and family's socio-economic perspective to observe how strategic decisions and performance of the firms are influenced by the family's involvement. In this paper, the empirical exercise corroborates the findings of earlier studies on Indian industries (see Ashwin, Krishnan, and George 2015; Lodh, Nandy, and Chen 2014). As an important contribution to the literature in this stream, we find that product market competition is an important moderating factor that may interact with family involvement related variables such as family ownership and control to influence the R&D investments of the firms. The findings suggest that firms with a greater family involvement become more R&D intensive with an increase in domestic market competition. This finding holds when we deconstruct family influence into two components viz. ownership and management. Our findings suggest that Indian family firms and their managers are willing to spend more on innovations due to their stewardship nature and to avoid the loss to their SEW with increasing competition. The moderating effect of market competition is contingent upon the measure of product market competition. A higher domestic competition induces the family firms to invest more in R&D, higher price competition remains an insignificant factor. We also test the 'career concern' hypothesis and find that the effect of family involvement on innovation is due to the reduction of managerial career concerns, as we see that managerial turnover (conditional on poor performance) is lower if family involvement is high. This effect is significantly stronger under higher degrees of competition.

Considering that India has gradually rolled out market-friendly reforms starting from 1991, the competition in the Indian manufacturing industry is expected to have significantly increased. The reforms largely aimed at improving productivity for faster growth. The innovation activities were also expected to boost due to greater incentives. In this context, our findings may have important implications for a developing country like India that strives to encourage the participation of the private sector to boost R&D investments (STI Policy, Government of India 2013)[7]. We suggest that Science, Technology and Innovation (STI) policy should not be seen in isolation from the effects of family ownership and competition. The presence of family-owned firms along with increased domestic competition would be beneficial in increasing R&D expenditure in manufacturing firms. This would, in turn, help these firms to increase productivity, and sustain for long as the competition increases. More importantly, the promotion of domestic competition is more desirable than price competition to achieve desired objectives of innovation policies. This argument explains to some extent the reason why the R&D intensity in the Indian manufacturing industry remained stagnant and low after the 1991 reforms. The 1991 reforms aimed at increasing overall price competition.

Whereas, an increase in domestic competition seems to have remained relatively less impressive in the subsequent period as the size of large firms increased disproportionately (Kato, 2009). Moreover, the entry barriers for new domestic firms effectively increased due to the reforms, therefore, making it difficult to increase competition in the domestic market (Babu, 2002). Our findings suggest that policy measures that can increase domestic competition through an increased number of smaller and medium-sized firms can boost R&D investments. Considering that family-owned firms comprise a majority share of the Indian manufacturing industry (Pant and Pattanayak, 2007), the promotion of domestic competition is likely to have a substantial impact.

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Appendices

Table A1: Descriptive statistics and correlation matrix

	Mean	Std. Dev.	Min	Max	RD	FAM	FAM -CEO	DUAL	IND	DCOMP	PCOMP	Size	Age	ROA	LEV	EXP	FS	FII	DII	GROUP	VIF
RD	0.52	1.947	0	50.161	1																
FAM	18.46	21.38	0	99.37	0.042	1															1.22
FAMCEO	0.701	0.457	0	1	0.047	0.26	1														1.44
DUAL	0.211	0.408	0	1	0.056	0.14	0.33	1													1.05
IND	0.252	0.278	0	1	0.19	-0.008	-0.024	0.17	1												2.87
DCOMP	0.852	0.167	0.022	0.87	0.015	0.039	0.031	0.04	0.024	1											2.34
PCOMP	0.507	0.224	0	0.91	0.0003	0.148	0.095	0.099	0.11	-0.013	1										2.11
Size	2.948	1.099	-1.38	6.293	0.046	-0.053	-0.030	0.13	0.37	0.047	0.29	1									1.23
Age	1.465	0.285	0	2.193	-0.021	-0.095	-0.12	0.06	0.21	0.029	0.04	0.30	1								1.98
ROA	0.126	0.306	-5.24	27.35	0.0003	0.031	-0.021	0.002	0.042	0.022	0.006	0.092	0.015	1							2.56
LEV	1.987	39.35	0	110.49	-0.003	-0.006	-0.018	-0.006	-0.013	0.003	0.012	0.012	-0.006	-0.0081	1						2.43
EXP	15.494	22.604	0	100	0.086	0.117	0.14	0.092	0.071	0.004	0.12	0.12	-0.11	0.022	-0.008	1					2.87
FS	1.629	11.408	0	91.61	0.006	-0.002	0.0075	-0.005	0.006	0.004	-0.005	-0.031	-0.017	-0.014	-0.003	-0.011	1				1.56
FII	5.674	16.342	0	90	-0.005	-0.243	-0.25	-0.102	0.011	0.041	-0.044	0.14	0.12	0.032	0.025	-0.048	0.0032	1			1.33
DII	22.396	22.824	0	94.07	-0.037	-0.442	-0.13	0.003	0.14	-0.02	0.083	0.26	0.17	-0.0005	-0.001	-0.047	0.0011	-0.22	1		1.34
GROUP	0.514	0.499	0	1	-0.009	-0.24	-0.15	0.021	0.12	0.016	-0.036	0.26	0.21	-0.007	0.003	-0.075	-0.0052	-0.096	0.38	1	2.99

(Source: Authors' calculations using CMIE-Prowess data)

Note: The values of VIF less than 10 indicate there is no serious problem of multi-collinearity (Nachane, 2006)

Table A2: GMM Estimation (Measure of Competition: DCOMP)

	Model A2.1	Model A2.2	Model A2.3	Model A2.4	Model A2.5	Model A2.6
FAM	0.32** (0.15)	0.43*** (0.11)	0.53** (0.25)	0.12*** (0.011)	0.13 (0.002)	0.54*** (0.0045)
FAMCEO	0.013*** (0.0011)	0.014** (0.027)	0.013 (0.062)	0.014** (0.031)	0.017 (0.092)	.023*** (0.014)
DUAL	0.021* (0.010)	0.020*** (0.0011)	-0.019*** (0.0033)	0.021 (0.0041)	0.051*** (0.0011)	0.061*** (0.014)
IND	0.091** (0.036)	0.078*** (0.016)	0.077*** (0.015)	0.074*** (0.016)	0.078*** (0.015)	0.077*** (0.015)
DCOMP		0.045*** (0.006)	0.03*** (0.008)	0.031*** (0.003)	0.041*** (0.008)	0.017*** (0.006)
FAM*DCOMP			0.003*** (0.0001)			0.002*** (0.0001)
FAMCEO*DCOMP				0.12*(0.05)		0.245 (0.427)
DUAL* DCOMP					0.011* (0.005)	1.11 (1.67)
Size	0.317* (0.017)	0.36*** (0.012)	0.47*** (0.032)	0.36*** (0.023)	0.36*** (0.032)	0.34*** (0.021)
Age	-0.0017 (0.011)	-0.002*** (0.0003)	-0.006*** (0.0011)	-0.00011 (0.0013)	-0.0002* (0.0001)	-0.116*** (0.021)
ROA	0.041*** (0.011)	0.049*** (0.012)	0.05* (0.027)	0.048* (0.02	0.042*** (0.007)	0.053*** (0.021)
LEV	-0.00021* (0.0001)	-0.00023 (0.00028)	-0.00021 (0.00028)	-0.00023 (0.00028)	-0.00022 (0.0002)	-0.00023 (0.0002)
EXP	0.08*** (0.001)	0.07*** (0.0015)	0.072*** (0.0011)	0.051*** (0.0002)	0.061*** (0.00011)	0.06*** (0.021)
FS	0.047*** (0.01)	0.036*** (0.012)	0.037*** (0.012)	0.037*** (0.013)	0.036*** (0.0011)	0.033*** (0.016)
FII	-0.0002 (0.0017)	-0.00028 (0.0017)	-0.0005 (0.0017)	-0.00023 (0.0017)	-0.0002 (0.0017)	-0.00046 (0.0017)
DII	-0.0017* (0.0010)	-0.0019* (0.0011)	-0.0021* (0.0011)	-0.0019* (0.0011)	-0.0019* (0.0011)	-0.0021** (0.0011)
GROUP	-0.054*** (0.011)	-0.052** (0.021)	0.0535 (0.1005)	0.0477 (0.1005)	0.052 (0.10)	-0.047*** (0.003)
Constant	-0.475* (0.256)	0.89** (0.358)	0.577* (0.293)	1.423*** (0.434)	0.868** (0.359)	1.251** (0.434)
Observations	7647	7647	7647	7647	7647	7647
Wald Chi-Square	599.94	630.55	656.61	635.82	631.2	666.63
Hansen Test	22.21	22.22	22.28	23.01	23.22	25.67
AR(1)	-2.11***	-2.13***	-2.51***	-2.41***	-1.99***	-2.56***
AR(2)	-0.21	-0.23	-0.27	-0.28	-0.29	-0.23

Notes: The dependent variable is R&D intensity defined as the ratio of R&D expenditure and aggregate sales ofthe firms.
****, **, and * denote significance levels at 1 percent, 5 percent and 10 percent respectively. The values inparentheses are standard errors. Standard errors are clustered at the firm level.*

Table A3: GMM Estimation (Measure of Competition: PCOMP)						
	Model A3.1	Model A3.2	Model A3.3	Model A3.4	Model A3.5	Model A3.6
FAM	0.32** (0.15)	0.31*** (0.0014)	0.27*** (0.0018)	0.26*** (0.0011)	0.29*** (0.0019)	0.26*** (0.0018)
FAMCEO	0.013*** (0.0011)	0.02*** (0.09)	0.023** (0.012)	0.026*** (0.0012)	0.052*** (0.002)	0.07*** (0.012)
DUAL	0.021* (0.010)	0.01*** (0.0036)	0.03*** (0.0041)	0.013 (0.003)	0.021* (0.01)	0.025* (0.01)
IND	0.091** (0.036)	0.07*** (0.021)	0.06*** (0.012)	0.07*** (0.013)	0.07*** (0.013)	0.07*** (0.014)
PCOMP		0.02* (0.01)	0.01*** (0.0001)	0.022* (0.11)	0.011* (0.005)	0.012 (0.139)
FAM*PCOMP			1.18 (0.31)			0.15 (1.31)
FAMCEO*PCOMP				-0.297* (0.153)		-0.379** (0.157)
DUAL* PCOMP					-0.425*** (0.166)	-0.511*** (0.169)
Size	0.317* (0.017)	0.51*** (0.0217)	0.47*** (0.021)	0.53** (0.021)	0.51** (0.021)	0.48** (0.022)
Age	-0.0017 (0.011)	-0.0021* (0.001)	-0.007*** (0.0001)	-0.0001 (0.001)	-0.006*** (0.0001)	-0.006*** (0.0001)
ROA	0.041*** (0.011)	0.049*** (0.012)	0.05* (0.027)	0.048* (0.02	0.042*** (0.007)	0.053*** (0.021)
LEV	-0.00021* (0.0001)	-0.00032* (0.00015)	- 0.00041* (0.0002)	- 0.0003** (0.0001)	-0.0003** (0.0001)	-0.0003** (0.0001)
EXP	0.08*** (0.001)	0.06*** (0.0015)	0.06*** (0.0011)	0.062*** (0.0002)	0.054*** (0.00011)	0.064*** (0.001)
FS	0.047*** (0.01)	0.016*** (0.012)	0.018*** (0.012)	0.019*** (0.013)	0.018*** (0.0011)	0.017*** (0.016)
FII	-0.0002 (0.0017)	-0.00076 (0.0011)	-0.00065 (0.0011)	-0.00041 (0.0011)	-0.00051 (0.0012)	-0.00065 (0.0012)
DII	-0.0017* (0.0010)	-0.0069 (0.011)	-0.0061 (0.011)	-0.0069 (0.011)	-0.0069 (0.011)	-0.0061 (0.011)
GROUP	- 0.054*** (0.011)	-0.042** (0.011)	-0.043*** (0.015)	- 0.047*** (0.015)	-0.042*** (0.001)	-0.049*** (0.003)
Constant	-0.475* (0.256)	0.89** (0.358)	0.577* (0.293)	1.423*** (0.434)	0.868** (0.359)	1.251** (0.434)
Observations	7647	7647	7647	7647	7647	7647
Wald Chi Squ.	599.94	665.98	599.98	646.62	632.17	678.1
Hansen Test	22.21	26.22	25.18	24.11	28.12	25.69
AR(1)	-2.11***	-2.73***	-2.81***	-2.49***	-2.99***	-2.89***
AR(2)	-0.21	-0.32	-0.35	-0.33	-0.37	-0.38

Notes: The dependent variable is R&D intensity defined as the ratio of R&D expenditure and aggregate sales ofthe firms.

****, **, and * denote significance levels at 1 percent, 5 percent and 10 percent respectively. The values inparentheses are standard errors. Standard errors are clustered at the firm level.*

Notes

[1] The *family ownership and family control* respectively emphasize on two separate aspects related to the firms'
ownership and management. In the subsequent text, beside using these two terms appropriately, a term family involvement is used while referring to both family ownership and family control collectively.

[2] Aghion et al. (2013) explores the role of institutional shareholders in the career concern model. However, the
same argument can be extended to other types of shareholders, such as family shareholders.

[3] The idea is inspired from Aghion et al., 2013 that uses the similar methodology to estimate the impact of
institutional ownership on CEO firing conditional of bad performance. As the data on CEO firing is unavailable, we use data on CEOs who resigned before retirement.

[4] The high concentration of family ownership for preliminary observations is defined using minimum 50 percent as benchmark criteria. It is likely that 50 percent benchmark helps us to identify a level that is significantly important in terms of having control over the firms. The family with majority shareholding (i.e. more than 50 percent) typically should have more say when it comes to strategic investments such as R&D. It should be noted that we have used different levels (such as 5 percent and 20 percent) and observed comparable results.

[5] Table A1 in Appendix section presents that the correlation matrix, VIF and other descriptive statistics.

[6] High and low levels of competition are defined by the median values of competition variables

[7] The draft of the recently proposed Science, Technology and Innovation policy (2020) also suggests that the country's technological goals will be achieved through private sector's support

5

New industrial and innovation policies in the context of recent productive and innovative global transformations

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Abstract

The deepening of the financialization process and the reduction of the world trade and world GDP growth rates had caused changes in the production and innovation dynamics in the last twenty years. These trends have characterized the global economic scenario since the international crisis of 2007/08 and were exacerbated by the Covid 19 Pandemic crisis.

The paper has the objective of analysing the impacts of the global economic scenario on the implicit industrial and innovation policies of developed countries, especially the increase in protectionism and in the use of foreign direct capital screening. The paper also analyses some features of the process of reconfiguration of the global value chains and the adoption of reshoring strategies by multinational companies and governments of some developed countries from the mid-2010s on, that were strengthened after the crisis of the Covid 19 pandemic.

The main expected result of the paper is to suggest analytical inputs for the debate on the design of a new set of industrial and innovation public policy in developing countries. This new industrial and innovation policy must consider the international context of increasing protectionism for the domestic firms of developed countries and the need to develop new systemic approaches for industrial and innovation policy.

Introduction

The paper uses the innovation system approach to analyse the systemic character of the recent innovation policy adopted by developed countries and to reflect upon the design of new industrial and innovation policy in developing countries.[1]

The innovation system approach is an analytical framework that proposes an appropriate definition to the innovation process and shows its contribution to the process of economic and social development. At the same time, the innovation system approach constitutes a practical tool for the design and implementation of innovation policy (Lundvall, 2007).

The complementarity between the innovation system approach and the Latin American structuralist approach proposed by Cassiolato and Lastres (2008) contributes to the definition of a systemic innovation policy.

In this context, the importance of implicit industrial and innovation policies and the coherence of these policies with explicit industrial and innovation policies within a national development project becomes fundamental. According to Herrera (1995), implicit industrial and innovation policies are those that, although not designed to affect the productive and innovation dynamics, often have a greater effect than explicit policies, which are the actual industrial and innovation plans and policies. In this sense, systemic industrial and innovation policy should consider both explicit and implicit instruments and policies, as well as the coherence between these two groups of policies. According to Coutinho (2005), the macroeconomic policies, the trade policies, the public procurement policies and the regulatory policies are examples of implicit industrial and innovation policies that may have significant impacts on the productive and innovative dynamics of a country.

This article aims at analyzing the changes of implicit industrial and innovation policies of the most developed countries and China as a result of the recent transformations on the global dynamics of production and innovation from the point of view of the innovation system approach.

The methodology of the paper is based on two main axes. The first will be based on the mapping of references about the changes in the role of the State since the international crisis of 2007/08, as well as about the main characteristics of the industrial and innovation policies of the most developed countries. In this case, bibliographical research in international information sources was carried out. The main international information sources to be consulted are the Organization for Economic Cooperation and Development (OECD) and the United Nations Conference on Trade and Development (UNCTAD).

The second axis of analysis of this paper is based on the use of databases to analyse in greater detail the use of protectionist instruments (tariff and non-tariff barriers) in industrial and innovation policies of selected developed countries. For this, the Global Trade Alert database will be used (www.globaltradealert.org). This database gathers, since 2009, information on protectionist and liberalizing measures in relation to international trade adopted by a set of developed and developing countries. This information allows for an analysis of the growth of protectionism in the context of industrial and innovation policies, as well as the main instruments used to protect domestic industry.

The paper has three main objectives:

(i) To analyse the characteristics of industrial and innovation policies of developed countries, with respect to: increase in protectionism and increased in the use of instruments aimed at controlling the entry of foreign capital.

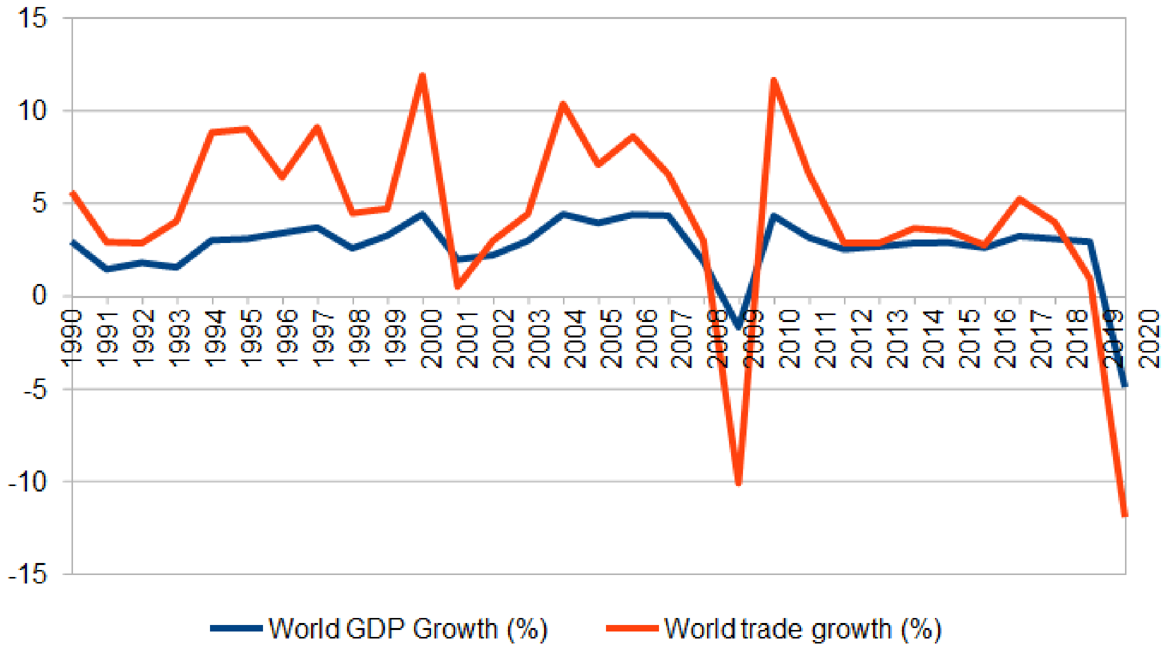
(ii) To analyse the reshoring strategies (mechanisms aimed at the internalization of stages of the production process previously displaced to countries with lower production costs) adopted by multinational companies and governments of some developed countries from the mid-2010s on strengthened after the crisis of the Covid 19 pandemic.

(iii) To suggest inputs for the design of an industrial and innovation policy in developing countries considering the recent transformations in the global dynamics of production and innovation and in the public policies focused on industrial and innovation development of developed countries.

In this sense, this paper has the objective of contributing with inputs to new designs of industrial and innovation policies in developing countries (especially Brazil), which take into account the new global trends in terms of productive and innovative dynamics and the new characteristics of the industrial and innovation policies from developed countries and contribute to economic and social development.

The deepening of the financialization process and the reduction of the world trade and world GDP growth rates had caused changes in the production and innovation dynamics in the last twenty years. These trends have characterized the global economic scenario since the international crisis of 2007/08 and were exacerbated by the Covid 19 Pandemic crisis. Figure 1 shows the world gross domestic product growth rate and the world trade growth rate from 1990 to 2020.

Figure 1: Evolution of World GDP and trade growth rates (1990-2020)



The global economic scenario has caused changes in the public policies focused on the productive and innovative development of most of the developed countries and China since the international crisis of 2007/08.

The main changes in the role of the state related to industrial and innovation policies are related to the increase in the protectionism of the most developed countries. The government of most countries, especially of the G-20, have significantly increased the use of barriers (tariff and non-tariff) to minimize the impact of changes in the global dynamics of production and innovation and of international crises on productive structures and to protect domestic companies.

Another policy instrument increasingly used by the most advanced countries since 2016, especially since the Covid 19 pandemic, is related to the control of foreign capital in strategic economic activities related to national security. The sectors related to health systems (pharmaceutical products and medical equipment, for example) are increasingly subject to control of direct foreign investment entry.

This paper is going to examine the impacts of the reduction of the world GDP and trade growth rates on the industrial and innovation policies of the developed countries. It will also bring some reflections in terms of the necessary changes on the industrial and innovation policies of developing countries.

The next session will address some of the general characteristics of industrial and innovation policies in developed countries and China. The increase in the use of mechanisms to protect domestic industry and domestic companies within the scope of industrial and innovation policies will be discussed, in special: the use of tariff and non-tariff barriers, the use of subsidies to local companies, and the increased restrictions on foreign capital in activities considered strategic. The third session will examine the reconfiguration of the global value chains and the reshoring process, which is being supported by public policies of some countries. The last session brings the final remarks of the paper.

2. The return of protectionism, the use of subsidies to local companies and the adoption restrictions to foreign capital

This section will analyse three characteristics of the industrial and innovation policies of the more developed countries. Section 2.1 will discuss the return of protectionism, section 2.2 will show that the main protectionist measure adopted by those countries is the subsidy award to domestic firms and section 2.3 will show that the adoption of foreign investment screening is increasing in the last years.

2.1. The return of protectionism

Industrial policy returned (or was strengthened) to the agenda of most countries a result of the 2007-2008 economic and financial crisis. This return presents several characteristics, among which the use of traditional trade policy instruments stands out.

Besides the sharp increase in inequality in almost all countries and the growing dominance of finance in the strategies of large transnational corporations in the West (and even in several Asian countries such as Japan and South Korea), the deepening of the global crisis since then has been characterized by a decrease (and almost stagnation) in the importance of international trade as shown in figure

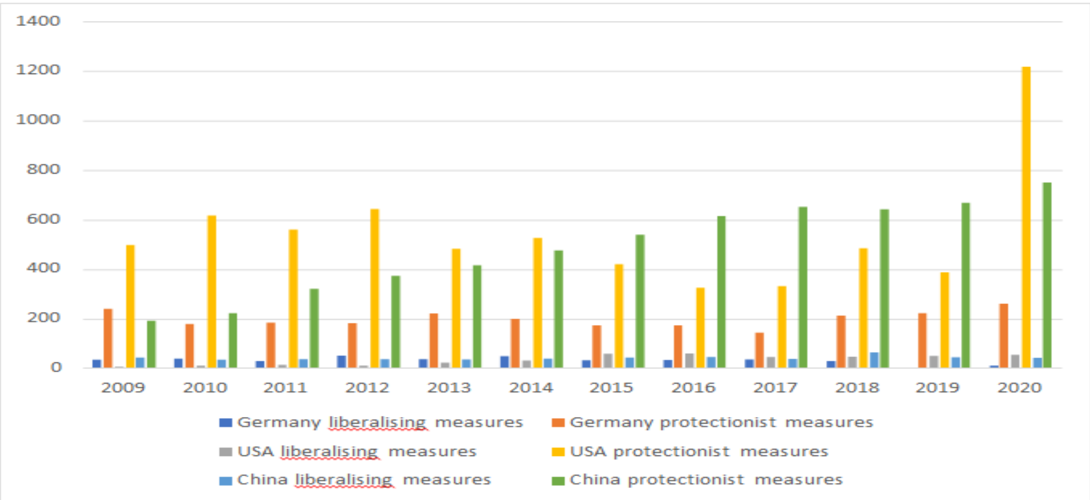
1. In this context of chronic crisis, the return of industrial policy is characterized by a significant increase in protectionism already from 2009, which was strengthened in the Covid-19 crisis. The governments of most countries, especially in the G-20, have significantly increased the use of barriers (tariff and non-tariff) to minimize their impact on productive structures. Table 1 presents the number of protectionist measured adopted by selected group of countries.

Table 1:					
Year	World	G20	US, China and EU	Share of G20/world	Share of US, China and EU/world
2009	2097	1528	1262	72,87	60,18
2010	2091	1595	1239	76,28	59,25
2011	2088	1652	1286	79,12	61,59
2012	2418	1902	1405	78,66	58,11
2013	2518	1920	1368	76,25	54,33
2014	2508	1965	1465	78,35	58,41
2015	2562	2018	1494	78,77	58,31
2016	2375	1848	1448	77,81	60,97
2017	2626	2132	1492	81,19	56,82
2018	2904	2466	1714	84,92	59,02
2019	2545	2129	1632	83,65	64,13
2020	4668	3541	2902	75,86	62,17
2021*	2310	1783	1357	77,19	58,74
Total	33710	26479	20064	78,55	59,52

Notes: (*) until December 20th.
Source: Own elaboration with data from Global Trade Alert

Protectionism increases in practically all countries and has been of special importance in the three main ones: the US, China, and Germany, as can be seen in figure 2. In this aspect, the Global Trade Alert data present a counterpoint to the evidence presented by international organizations, which supports that there is no return of protectionism. However, the data shows that there is an increase in protectionism through protectionist measures in favour of local firms.

Figure 2: Number of Protectionist and Liberalizing Measures Implemented - Germany, US and China (2009-2020)



Source: Own elaboration with data from Global Trade Alert

The type of protectionism adopted by larger developed economies differs from traditional trade restrictions and is closer to less transparent forms of state discrimination against foreign commercial interests (Evenett, 2019).

The more developed countries, with larger domestic markets, generally implement actions aimed at strengthening domestic companies through a series of measures. Besides greater tax exemptions, different kinds of subsidies, and restrictions on foreign capital, the main measures that have been adopted are: restrictions on direct imports, which include tariff increases, import quotas, and import bans; public procurement where government contracts are transferred from foreign to local companies; export taxes and restrictions on foreign firms; and export incentives, including subsidized trade financing for domestic firms.

It should be noted that, according to data collected by Global Trade Alert, pharmaceutical products are among the five products that have received the highest number of protectionist measures adopted in the period 2009 to 2021 (1,618 protectionist measures in the period 2008- 2021). Among the 20 most affected sectors is also medical and surgical equipment and orthopedic appliances with 1,013 protectionist measures implemented in the period. It is important to mention that China was the country that implemented more protectionist measures in the pharmaceutical sector.

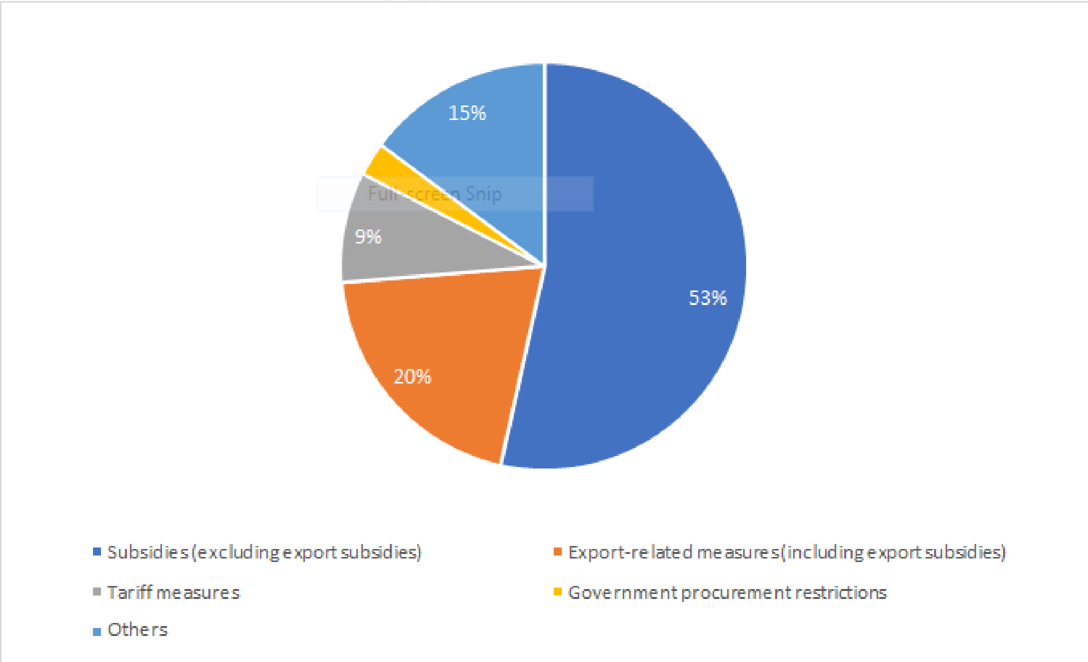
The increased protection for the pharmaceutical industry is in recent years is not limited to China. For example, countries like Germany and Spain use protectionism for the pharmaceutical industry in a significant way. In the Spanish case, several food-related sectors are among the most protected, given the well- known specialization pattern of that country. However, we also observe pharmaceutical products in the group of the ten sectors most affected by restrictive interventions in Spain, as observed in the case of China. In the case of Germany, which has a different specialization pattern, among the sectors that have received more protection are aircraft and spacecraft, chemicals, electricity, some food-related sectors, plastics, and pharmaceuticals.

The increasing protection of the pharmaceutical sector is a phenomenon that should be highlighted, especially in the context of the Pandemic Covid 19 crisis. In general, the most developed countries have increased the degree and form of protection for the pharmaceutical industry through various policy instruments targeted at protecting domestic firms.

2.2: The use of subsidies for local firms

The main protectionist measure to domestic industry adopted by countries in the period of 2009-2021 is the subsidy award. Figure 3 shows that this instrument represents 53% of total protectionist measures adopted.

Figure 3: Main protectionist instruments for domestic companies adopted by the countries in the period from 2009 to 2021.



Source: Own elaboration with data from Global Trade Alert

Table 2 shows the evolution of the number of subsidies implemented between 2009 and 2021 by the US, China and European Union, in addition to the number of subsidies awarded in the world. Together US, China and European Union accounted for over 76% of the subsidies implemented in the global economy. In 2019, 84% of good imports into China, 85.3% of goods imports into the European Union, and 66.4% of goods imports into the US were in products where subsidies had been received by local rivals (Evenett and Fritz, 2021).

The subsidies awarded by China, the European Union, and the United States are not limited to the crisis years (specifically, those associated with the COVID-19 pandemic and the Global Financial Crisis). US, China and European Union A total of 1439 subsidy awards and policy changes were implemented during 2009- 2010, 3496 during 2020 and 2021, and 8889 during 2011-2019.

There is evidence that the increasing use of subsidies in industrial policies is being challenged more frequently. In the WTO, the number of trade disputes related to subsidies has increased sharply since 2010, as well as investigations about subsidized imports have been initiated. The most advanced countries lead this issue. US subsidy and countervailing duty practices have been contested 43 times in 2020. In the case of China and the EU, the same indicators are 19 and 22 respectively in 2020. No other WTO member comes close to such figures.

Despite the difficulty in obtaining data about the total amount of subsidies provided by different countries, Evenett and Fritz (2021), estimates that in the 2010s the total value of such subsidies exceeded $400 billion. Such (imperfect) evidence supports the assertion that subsidies are growing under industrial and innovation policies.

National governments are not solely responsible for the subsidies awarded by China, the European Union, and the United States. A total of 677 subsidies awards and policy changes were implemented by subnational government agencies, and a total of 3,446 subsidy changes were made by supranational bodies, in particular by the European Investment Bank (Evenett and Fritz, 2021). The economic activities that received more subsidies from these countries are pharmaceuticals, with a total of 1421 subsidies, and medical devices and optical and precision instruments with 926 subsidies, representing 17 percent of the subsidies awarded to all economic activities.

2.3. Increase in the foreign direct investment screening mechanisms

In recent years a large number of governments have established or strengthened mechanisms to review foreign direct investment in their jurisdictions (Evenett, 2021). This process has intensified especially since the pandemic crisis and the intensification of technological-military disputes between China and the US. Such policy is related to concerns about the role of foreign capital, especially in activities that are more sensitive to national security.

The well-known limits on the establishment of foreign companies within the respective national spaces or the restriction of bids by foreign companies to acquire local rivals for competition reasons have been extended by the various governments. The governments have set up institutional mechanisms to review the ongoing operations and strategic choices of foreign companies already established in the countries. National Treatment measures for access to local markets as well as regulation of conduct after establishment or acquisition are now possible (Evenett, 2021).

The sectors related to health systems (pharmaceutical products and medical equipment, for example) are increasingly subject to control of direct foreign investment entry.

The most common explanation for doing this has been related to national security, but it can be observed that the protection of domestic firms and the strengthening of the domestic productive base have also been stimulating more developed countries to increase control of foreign capital inflows (especially foreign direct investment).

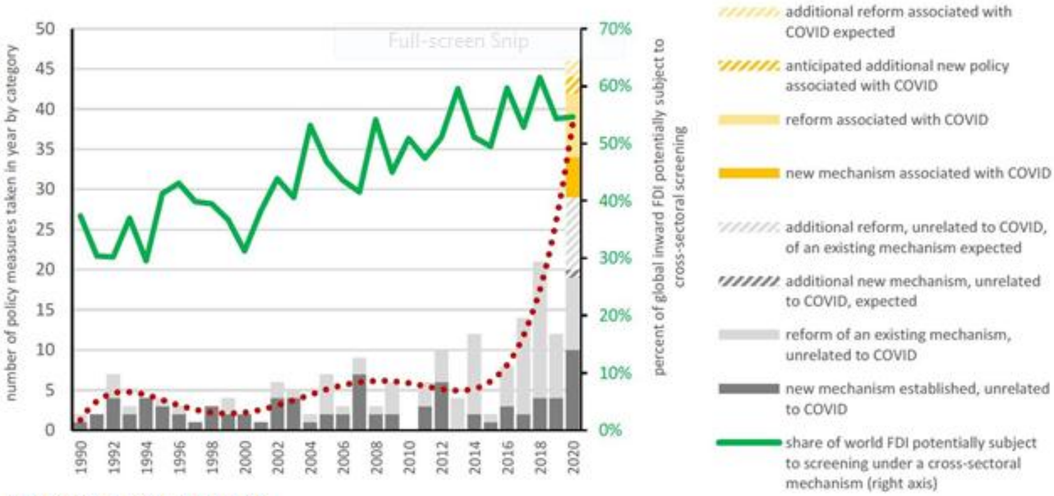
OCDE (2020) shows that only since 2018 have more than half of the 37 OECD countries put in place a cross – or multi sectoral investment screening mechanism, compared to less than a third a decade earlier. According to Evenett (2021), at least 30 governments have introduced or strengthened policies that screen foreign investments ostensibly on national security grounds.

The percentage of OECD members with FDI screening regimes increased further after 2018, before the COVID-19 pandemic. The OECD (2020b) argues that the economic situation caused by the COVID-19 pandemic crisis has further accelerated policymaking in this area. It is important to highlight that some of the countries have introduced such rules still in the 1960s. However, until very recently many countries did not have investment screening mechanisms in place. For many years, few countries had legislated in this area (introduced new mechanisms or reformed existing ones) until policymaking activity surged considerably in and after 2016 (OECD, 2020b). Evenett (2021) suggests that the spread of digital general-purpose technologies and growing geopolitical rivalry are enduring factors that account for the strengthen of FDI screening, prior and besides the pandemic crisis.

In addition to the increased number of policy mechanisms aimed at controlling the inflow of foreign investment, important qualitative changes are also occurring in the screening mechanisms. Most mechanisms now allow for intervention on a much broader basis. Indeed, a much larger number of transactions are now potentially subject to scrutiny. Rules have become more detailed and sophisticated and are geared towards routine applications. Implementation practice has also changed in many countries, with more frequent use of the instruments. Greater depth of regulation and transparency about policy practice are further indicators of a transformational change that has emerged over the past decade in many countries, deepening markedly from 2016 onwards (OECD, 2020b).

Figure 4 below from OECD (2020b) presents data on the introduction of policies related to foreign ownership and acquisition for a panel of 62 countries participating in the “Freedom of Investment Roundtable” organized by OECD for the period 1990 to 2020. Two pieces of information are worth highlighting. First, the percentage of global FDI subject to control by recipient governments grows significantly from 25% in the 1990s to almost 60% in recent years. Second, the number of FDI control-oriented policy measures taken per year grows over the period as a whole but shows a significant increase from 2015 and exponentially in 2020, when governments explicitly justify their introduction, at least in part, with the pandemic or its consequences.

Figure 4: Introduction and reform of acquisition and ownership-related policies to safeguard essential security interests (1990 to 2020)



Source: OECD, 2020b.

Indeed, the exceptional health and economic situation caused by the COVID-19 pandemic has further accelerated policymaking in this area, as documented by various reforms and temporary adjustments of existing policies. In some European countries this acceleration was further boosted by a European Commission Communication issued in March 2020. Australia, France, Hungary, and Italy have explicitly made temporary adjustments that apply stricter rules to a wider range of transactions than previously. In addition, France, Germany, Japan, Poland, and Spain have made permanent changes to their investment screening mechanisms in response to the new situation. Slovenia has introduced a new review mechanism motivated, at least in part, by the arrival of the pandemic. Germany, the Netherlands, New Zealand, and the United Kingdom accelerated reforms of their policies that had been initiated before the onset of the crisis (OECD, 2020b).

Governments of emerging economies have also increased their use of foreign investment screening mechanisms. India and Romania have explicitly justified recent adjustments in their foreign investment control rules by the pandemic or its consequences. China and Russia approved reforms to their foreign capital regime in the first half of 2020.

Adjustments to foreign direct investment screening mechanisms, directly associated with COVID-19, fall into one of two groups that correspond to specific concerns and objectives:

- Reforms that add assets to the scope of screening mechanisms that are crucial for the pandemic response (health-related industrial sectors and associated supply chains) or that strengthen controls in these areas;

- Measures that introduce or improve FDI screening mechanisms across the board to prevent acquisitions in any sector where assets present temporary financial problems and value distortions under the exceptional economic condition associated with the pandemic.

With regard specifically to health-related industrial sectors, foreign participation in health infrastructure is currently subject to screening in 21 OECD countries for security reasons, up from 14 in 2019. Acquisitions of biotechnology companies or medical equipment companies are also now subject to screening in 21 OECD countries compared to 11 countries that performed it before the pandemic (OECD 2020b).

3. Reconfiguration of global value chains and some considerations about the reshoring strategies and policies

The first section will present some aspects about the reconfiguration of the global value chains and the reshoring strategies and policies associated to this process. The second section will show some considerations about the limitations of the reshoring process.

3.1. The reconfiguration of global value chains

An important change observed in recent years in the industrial and innovation policies of developed countries and in the strategies of multinational companies is related to the efforts to bring back important parts of the productive chain that were previously displaced, mainly to Southeast Asia. Such processes, treated in the literature as "reshoring", were already a policy objective since the middle of the last decade, but received a greater impulse with the pandemic that demonstrated the importance of relying on local production in a series of strategic activities, especially the health-related industrial sectors.

In general, the reshoring process is characterized by a change in the strategies of multinational companies that, with the support of industrial and innovation policies in more developed countries, promote and encourage the internalization of activities previously developed in other countries.

The expansion of global production chains is a phenomenon recognized and widely discussed in the economic literature. Since the 1990s, the production of large multinational companies has been organized around global production chains, which are characterized by the fragmentation and displacement of stages of the manufacturing process to countries with lower labor costs. This process, made possible by the diffusion of information and communication technologies, was marked by the deverticalization of production with the fragmentation of activities accompanied by intense international transfer of production stages. The main objective was to reduce costs, together with gains in economies of scale and scope, made possible by the expansion of markets and the coordinated management of geographically dispersed activities (Hiratuka and Sarti, 2017).

The new global production pattern was characterized by the worldwide dispersion of production with functional integration of economic activities. Timmer et al (2016) highlight a significant increase in the global import intensity index (which measures the imports required in all stages of production of a final good or service) in the period from 2000 to 2008 which, according to the authors, characterizes the deepening of the process of international fragmentation of production. This same indicator analyzed by Timmer et al (2016) indicates that from 2011 there was a stagnation in the process of fragmentation of production, indicating the end of the long period of expansion of GVCs.

The Covid 19 pandemic, which aggravated uncertainty about the supply of inputs and products within global value chains, further contributed to the reduction of trade within the chains and to the reshoring process of the most developed countries.

Many multinational companies were weakened due to the exposure resulting from the disruption of supply chains during the Covid 19 pandemic crisis, bringing to the fore issues associated with the importance of countries reducing their dependence on imports of inputs and products from other countries and acquiring self-sufficiency in products and strategic chains (Barbieri et al, 2020).

In this sense, the Covid 19 pandemic contributed to one of the recent factors that triggered or strengthened decisions by European companies to relocate stages of their production processes previously shifted to China and other Asian countries. This relocation process was determined by the goal of reducing dependence on imports of inputs, intermediate goods, and products in periods of increased uncertainty and crisis.

The perception of the need for productive and technological autonomy in strategic areas, the need of increasing skilled work and the need to increase innovative capability by bringing together the core activities and manufacturing activities led multinational companies to make efforts to bring back activities in the production chain (in general manufacturing-related activities) that had previously been transferred to countries with lower production costs, especially low wages. In some cases, the countries of origin of these companies have supported the companies through public policies to support reshoring.

Moreover, the pandemic has revealed supply chain vulnerabilities in health - related industries in many countries. As a consequence, the call for more productive and innovative autonomy in strategic supply chains has been highlighted in the public policy debate, spurring the adoption of measures to better protect, strengthen, or even restore domestic production of those goods.

Barbieri et al (2020) points out that, as a response to the Covid 19 pandemic crisis, reshoring strategies were adopted by individual companies or sets of companies (production chain). According to the authors, some actions were adopted in a short-term horizon and others in a long-term horizon. In some cases (especially in the joint actions of firms), actions aimed at restructuring production chains are supported by the state through specific policies aimed at stimulating reshoring initiatives for strategic supply chains.

Some authors (Barbieri, 2018) associate the reshoring process with strategic elements, as opposed to the previous process of offshoring manufacturing stages that were motivated by cost elements. The strategic elements of reshoring are related to the co-location of R&D, engineering, and manufacturing activities, and responsiveness to customer demands (Barbieri et al, 2018).

Regarding the connection between reshoring efforts and consumer demand, Cosimoto and Vona (2021) state that sustainability issues constitute a central driver of reshoring decisions. In particular, the ecological dimension of sustainability has been showing increasing importance in companies' reshoring decisions. In this regard, firms in sectors known as traditional, such as textiles and footwear, mechanical products and furniture, have been showing a growing concern with sustainability issues and, therefore, are more predisposed to reshoring processes than other sectors. Firms in more dynamics sectors, such as electronics, have also adopted reshoring efforts. In this sense, the production of semiconductors, which during the pandemic crisis became a bottleneck for the automobile and electronics industries, is one of the areas that has been the focus of incentives for companies and governments in the European Union. The supply problems of inputs, intermediate goods or products during the covid 19 pandemic crisis may have highlighted the vulnerabilities of the organization of production around global value chains.

According to Lee (2021), value chains are undergoing a reconfiguration process with a focus on resilience. One of the factors contributing to this reconfiguration is the changing role of China in the global economy and some resulting factors are causing firms to leave China. The growing digitalization of production and tensions with the United States have been contributing to this movement.

Digitalization of production is an important factor to understand some reshoring efforts. Some companies are considering building highly digitized factories (“smart factories”) in their home countries and closing older production lines in China (Lee, 2021).

This aspect is linked to the growing need to incorporate new technologies (Internet of Things, blockchain, robotics, artificial intelligence, big data, etc.) into the production process. In general, the most advanced technologies are more widely available and easier to access in the home countries of multinational companies, which constitutes a stimulus factor for reshoring efforts. In this case, Cosimato and Vona (2021) states that some firms are implementing reshoring strategies to compensate for the lack of capabilities and efficiency losses of the offshore production base, bringing back productive activities that are developed in smart factories with the use of new technologies.

Another factor that must be considered to understand the loss of dynamism of global value chains is the recognition of the importance of proximity between innovation and manufacturing activity. In this sense, with regard to the US, some authors suggest that the manufacturing outsourcing process has advanced excessively, bringing the perception that it is necessary to strengthen innovation systems (Hiratuka and Sarti, 2017).

3.2. Potential limits to the reshoring process

Despite the efforts of multinational companies and the policies of governments that support the reshoring process highlighted above, it is important to consider some issues associated with such a process that may limit its reach.

As suggested by Williamson (2020) there are a number of reasons why reshoring strategies may have limited effects.

First, there is no certainty that reshoring and localized production will have significant impacts on improving the robustness of a supply chain. In other words, there is no evidence that the reshoring process will lead to the development of capacity to maintain operations and product supply during a crisis (Miroudot, 2020). In principle, as a result of intensified reshoring, the capacity to supply a given local market will necessarily be smaller in scale, with limited options to quickly increase production in response to a crisis. In this way, reshoring would have limited capacity to reduce the vulnerability of supply chains in periods of crisis.

China has built huge capacities in recent decades, which cannot be replicated, efficiently and quickly by other countries. Yu et al (2020) showed how these capabilities - and also more flexible labor legislation, allowed the medical equipment manufacturing company Zoncare to respond quickly, as early as February 2020, to an explosion of demand from several countries, by taking advantage of the huge and flexible domestic input supply base, while also being able to operate for twenty hours a day and increasing its monthly output by 600%. This shows that, in order for the reshoring process to have an impact from the point of view of reducing the vulnerability of production chains in the face of health crises (or those associated with natural and environmental disasters), it would be necessary to implement a broader strategy of creation and endogenization of productive and innovative capacities.

Another reason why reshoring impacts can be expected to be limited is related to production and distribution costs (Buckley, 2019). Williamson (2020) points to several examples in this direction. For example, the Best Buy chain, one of the most important retailers of electrical products in the US warned that attempts to bring back several of its global suppliers would dramatically increase economic inefficiency. Rathke & O'Connell (2020) estimate that Apple would have at least a 30% increase in production costs if it pulled iPhone production from China. For these reasons, Williamson (2020) concludes that firms have strong incentives to avoid the different cost and quality problems and inefficiencies by resisting the implementation of reshoring processes that could lead to changes in the organization of production based on the fragmentation of production.

Finally, one should not forget that the strategies of large Western multinational companies for short-term profit maximization tend to conform their pattern of global organization of production activities and the negative impact of reshoring attempts can be significant. If, for example, reshoring means transferring productive activities that are carried out in China, such companies may be reluctant both because of technological factors, availability of skilled work, and the possibility of restriction in terms of access to the main major world market with significant growth prospects. In this sense, China is the largest consumer market for a wide range of goods and services. As analyzed in Cassiolato et al (2021), without the Chinese market, the world automobile market would be stagnant, with a downward trend since 2005. It is unlikely that Western multinationals, which have demonstrated low investment capacity in this millennium, will choose to invest significantly in re-locating production when growth in demand for their products and services is almost exclusively coming from countries like China.

There is some evidence that the global value chains are going through a reconfiguration process in the last years because of many factors, including the impacts of the pandemic crisis. Nevertheless, it is not possible yet to find out the reach and the results of this process.

4. Concluding remarks

This paper explored some recent trends related to the changes in the role of the state in the most advanced countries and China in the context of the recent transformations in the global production and innovation dynamics.

Based on the recent transformations in the global dynamics of production and innovation discussed in Cassiolato et al (2010), it was suggested that since 2011 the most advanced countries have been increasingly using trade policy in the context of their industrial and innovation policies with the aim of protecting domestic industry and domestic firms from competition from foreign firms. A set of information supporting this argument was presented, and it was also highlighted that most of the instruments to protect domestic industry are associated with subsidies awarded to domestic firms. Besides the increase in trade protection instruments and subsidies to the local industry, the most developed countries have also been increasing the use of foreign direct investment screening mechanisms in strategic areas.

In addition to such trends observed within the policies of more advanced countries and China, this paper also analyzed the process of reconfiguration of global value chains and the resulting reshoring process. The latter has been undertaken within the strategies of some multinational companies, with the support of industrial policies of more advanced countries (and some developing countries) aimed at the relocation of production activities previously transferred to countries with lower production costs.

The paper also highlighted the limitations to the reshoring process. In general, efforts aimed at reshoring are relatively recent processes and, for this reason, it is not yet possible to accurately assess the impact of these processes on global productive and innovative dynamics.

Although it was not the objective of the paper, it is also important to consider that the developed countries are implementing industrial policies and programmes. Germany, France, US, Japan and many other developed countries are investing billions of dollars in the reindustrialization process, with focus on the strengthening of the national productive base and firms. The generation and diffusion of the new technologies associated with the so-called industry 4.0 is in the centre of the industrial policies.

However, it is important to reflect on what are the impacts of such changes for developing countries, especially regarding industrial and innovation policies.

First of all, it is suggested that the so-called industrial policies oriented to global value chains (including the attraction of foreign direct investment) based on trade liberalization measures recommended over the last years by international organizations to developing countries should be definitely left aside from the debate on industrial and innovation policy. In a context in which developed countries have been increasing protection of domestic industry and domestic companies and implementing efforts to bring back productive activities previously transferred to countries with lower production costs, the space for State action and public policies in developing countries need to be rethought.

In this sense, this paper had the objective of contributing with inputs to the debate about new designs of industrial and innovation policies in developing countries, which considers the new global trends in terms of productive and innovative dynamics and the new characteristics of the industrial and innovation policies from developed countries and contribute to economic and social development. In this case, the research agenda includes the development of new systemic approaches to industrial and innovation policy that are focused on solving national challenges and seek to articulate social demand with the economic dimension. The traditional sectorial and horizontal industrial policy approach are not anymore useful, considering all the recent transformations in the global productive and innovative dimension.

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Notes

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6

Does national innovation capacity lead to reduction in income inequality? Empirical evidence from panel data analysis

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Abstract

The inequalities within and between countries have been on the rise, especially since globalisation. In this context, the reduction of inequalities has been featured in the Sustainable Development Goals (SDGs), indicating policy efforts to arrest growing inequalities. This study empirically analyses the role of innovation in income inequality in fifteen developed and developing countries for twenty years, from 2002-2021. Four indicators, top 1%, top 10%, middle 40%, bottom 50%, and the Gini index from World Inequality Database, are used for inequality. The number of patent applications, spending on research and development, and the number of researchers per million as the innovation variables are used as measures of innovation. The empirical results based on panel data methods showed that innovation helps in reducing top income inequalities while it had a positive impact on the bottom 50 per cent. The findings are consistent with alternative specifications and measures of innovation. Apart from innovation, the governance/quality of institutions plays a significant role in reducing inequalities.

I. Introduction

Inequality may be the law of the universe from its very existence, but the word "equality" finds its importance in every aspect of a society that paces development. Income inequality refers to the unequal distribution of income among the population, and the resulting gap between the rich and poor is called the disparity. It highlights the lack of mobility of income and opportunities within that community and thus reflects the persisting disadvantage for a particular segment of society.

Cowen and Tabarrok (2021) defined income inequality as "the unequal distribution of income across the population," which may be caused by the advantaged groups possessing more resources and income than the other sections of society. Widening inequality has significant implications for the deterioration of the socioeconomic balance, which includes the concentration of power in decision-making in the hands of a few, raises the crisis risk, may hamper poverty eradication, and causing political and economic imbalance.

Innovation refers to the introduction and execution of new ideas and technologies that would result in developing new goods and services or enhancing existing ones. Innovation in various sectors may lead to novel solutions for traditional problems or improve the existing solutions in their metrics; this way, innovation furnishes betterment in society. But do these innovations address the income disparity? If yes, how? The effect of a nation's innovation on income disparity is one of the important research questions to be answered in economics. This study attempts to find the answer by adopting an econometric approach.

We first reviewed the relevant literature to find the persistent income distributional discrepancies that manifest in various ways across the entire economy. While it is acknowledged that innovation is a crucial link between sustainability and inequality, its effects on social mobility and the eradication of poverty need to be scrutinised. A significant observation is that the interaction of financial development and globalisation has a favourable impact on income inequality. It is impossible to disregard the long-standing bidirectional relationship between income disparity and innovation potential, as well as their concurrent evolution.

We gathered data for the study from the World Bank data, the World Inequality Database, and the UIS statistics. Panel data regression methods were applied to the cross-sectional data that we collected from fifteen countries, chosen using simple random sampling from two categories- the high-income and upper or low middle- income countries and the impact of various innovation factors we used (R&D as a per cent of Gross Domestic Product (GDP), Number of patent applications from residents, Worldwide Governance Indicators (WGI) index, the expense on education, the spend on tertiary education, GDP per capita and the number of researchers per million inhabitants) are measured for the income inequalities (Top one, Top ten, Middle forty, Bottom Fifty & Gini index).

Plotted for these years are the various trends and patterns in these inequality levels and innovation values and a correlation chart showing the relationships between these variables. The innovation aspects are noted to negatively contribute to the Gini index, suggesting that they promote equality.

II. Literature review

Heated discussion surrounds the distribution of income between national populations and the global community that economies produce. Does equitable economic growth exist? Are low- income countries catching up with richer ones? The World Inequality Report (2022) gives us figures and estimates that provide some insights into the global inequality levels and the distribution of income among the global top 10%, top 1%, middle 40%, and bottom 50%, along with mapping the movement in global inequality and within-country inequalities from the year 1820 to 2020. Yang (2020) analyses these movements and pinpoints the increase and decrease in income inequality in Asia from the year 1993 to 2019 using data from the simplified Asia Distributional National Account (DINA). For the past three decades, despite dissimilar growth and inequality patterns within the countries, a significant decline in Asian inequality at the regional level has been seen. From 1993 to 2019, Asia's inequality patterns showed considerable convergence. But it is important to highlight that within-country inequality in China and India has increased since economic liberalisation in the 1980s and has continued to be higher than in Western European nations, the world's least unequal area. This gives rise to the need to examine the factors contributing to the income gap.

Napolitano et al. (2020) recognise innovation as a critical channel linking sustainability and inequality and identify strong correlations between countries' environmental degradation exposure and income inequality and poverty levels. Hailemariam et al. (2020) investigated its primary causes and discovered that positive innovation shocks initially have a negative impact on income disparity, but after a certain amount of time, this effect turns around and becomes favourable. Further, the work points out the beneficial impact of per capita GDP on income disparity. Further, Hailemariam et al. (2020) suggested that the influence of innovation on income inequality varies over time. Hu and Mathews (2005) conducted an extended study on a work by Furman, Porter, and Stern (2002), which framed a concept of National Innovation Capacity by the measure of patenting rates and established a country's innovation capacity as the driving force behind its economic performance.

What has been the trend and pattern of innovation capacity through time if we assume it is a major cause of wealth inequality? Is the trend that it notices consistent with income inequality? How is the ability to invent influenced by various factors? Innovation is highly correlated with the epochs and the peculiarities of specific countries and regions. Susan et al. (2008) made an attempt to provide a framework to study the relationship between innovation and capability building with poverty and inequality. The relationship between innovation and inequality is mediated by the term 'globalisation', characterised by the increased flows of components like knowledge, products, and values. Globalisation is identified as the factor that stimulated technological changes but eventually caused uneven effects on inequality. Their principal argument is that even if innovation does not directly affect inequality, it is connected with poverty and inequality through several social, economic, and political processes (Susan et al., 2008). Further, innovation and inequality have a bidirectional relationship and do co-evolve.

Fan et al. (2012) focus primarily on innovation disparity in China from 1995 to 2006 at the interregional and intraregional levels. The authors observed diverse trends at different times at different levels within the nation and identified population, economic development level, R&D, location, and openness as significant elements that affect innovation at these levels. Analysing five capability, (iii) service innovation capability, (iv) product innovation capability, and (v) marketing estimated levels of innovation capability convergence.

The first empirical research to explore the link between innovation activity in a panel of nations and government redistributive policies at the top of the income distribution by Brzezinski (2022), utilising the patent-based indicators of innovation, found no indication of a detrimental redistributive effect on innovation. Law et al. (2020) examined the influence of innovation capacity by considering cross-sectional dependence. The Standardised World Income Inequality Database development with innovation capacity have a positive effect on income inequality. Using Hatemi- J cointegration, the ARDL limits test, and VECM Granger causality techniques, Cetin et al. (2021) examine the relationship between technological advancement and economic disparity in Turkey. The findings confirmed the applicability of the Financial Kuznets Curve (FKC) to the Turkish economy, the beneficial impact of technological innovation, and the adverse impact of economic development on income disparity. They also discuss the relationship between technological innovation and income inequality. Włodarczyk and Julia (2017) conducted a regression analysis synthetic measure, the Creative Economy Index, in measuring innovation. Kanwal and Eyisi (2022) add to the body of knowledge on income inequality by looking at how Front End Innovation (FEI) affects it. They discovered a negligible connection between FEI and economic inequality from fixed effect panel regression on annual country-level data for thirty-one frontier markets over a 15-year (2003–2018) period. Inequality is suggested to be caused by FEI in this research as well.

The schumpeterian growth model with heterogeneous households, employed by Chu and Cozzi (2018), studied patent protection and R&D subsidies' effects on innovation and income inequality. The main finding was that whereas increasing R&D subsidies promotes a relatively big fall in income and consumption inequality, improving patent protection causes a slight increase in inequality in both consumption and income.

The impact of innovation on income inequality is analysed by Ozan (2012) when patents with a finite length cover innovations and offer a Schumpeterian theory of the non-linear relationship between income distribution and inventive activity in a dynamic general equilibrium environment. Concerning global statistics, a negative association between innovation ability and income disparity was found, albeit this correlation cannot be verified across all nations. Furthermore, provided the gap in purchasing power between the rich and the poor is not too great, they claim that income redistribution may favour the capacity for innovation.

Aghion et al. (2015) conducted extensive research on the impact of innovation-led growth on top salaries and social mobility. They have used cross-state panel data to show a positive and significant correlation between various measures of innovation and top-income inequality in the United States over the past few decades. They have successfully demonstrated positive and significant correlations between innovativeness or frontier growth on the one hand and top income shares or social mobility on the other hand. This suggests that these correlations at least partly reflect the repercussions of innovation on top-income shares. Additionally, it is interesting how innovativeness affects top income inequality: for instance, when evaluated by the number of patents per capita, innovativeness accounted for an average of 17% of the growth in the top 1% income share across US states between 1975 and 2010. In their further study in 2019 using the cross-state panel and cross-U.S commuting-zone data, along with pointing out the positive effect of innovation capacity on social mobility, they found a causality between innovation capacity and top income inequalities (Aghion et al., 2015). They also point out the positive effect of innovation capacity on social mobility.

III. Data and methodology

Our study is based on secondary panel data gathered from various sources such as the World Bank data, the World Inequality database, and the UIS Statistics (The UNESCO Institute for Statistics) from 2002 to 2021.

Two categories of countries are chosen for our purpose- the high-income countries and the upper or low-middle-income countries. Simple random sampling is performed among them, and fifteen countries are selected for further analysis and study. Austria, Finland, Hungary, Netherlands, Norway, Poland, United Kingdom & Slovakia from the high-income nations, and Argentina, Brazil, Ecuador, Mexico, Philippines, Russian Federation & South Africa from the low upper or low middle-income nations.

Table-1 lists the factors that are taken into consideration for our analysis as they have an impact on the national innovation capacity.

Table 1: List of independent variables taken to measure innovation and economic factors

Variables	*Definition*	*Source*
GDP per capita	*GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for the depreciation of fabricated assets or for the depletion and degradation of natural resources. Data are in current U.S. dollars.*	*World Bank Data*
The percentage of GDP spent on research and development	*Specifically, "is the gross domestic expenditures on research and development (R & D), expressed as a percentage of GDP," according to the world bank database. They cover both capital and ongoing costs in the four major industries of business, government, higher education, and private non-profit. Basic, applied, and experimental research are all included in R&D.*	*World Bank Data*
The percentage of GDP spent on education	*General government spending on education is expressed as a share of GDP, including current, capital, and transfers. It comprises expenses paid for by government transfers from external sources. Local, regional, and national governments are typically included under the general government umbrella.*	*World Bank Data*
Expenditure on tertiary education	*Tertiary education spending is expressed as a share of all general government education spending. Local, regional, and national governments are typically referred to as general governments."*	*World Bank Data*
World governance indicators	*Perceptions of the calibre of public services, the calibre of the civil service and the extent of its independence from political influences, the calibre of policy formulation and implementation, and the credibility of the government's commitment to such policies are all included in the category of government effectiveness. The estimate provides the nation's score on the overall indicator, which ranges from around -2.5 to 2.5, in units of the standard normal distribution. This is how the variable WGI estimate is defined by the World Bank.*	*World Bank Data*
The number of researchers per million inhabitants		*UIS Statistics*
The number of patent applications submitted by the residents of the country in a year		*World Bank Data*

Table-2 lists the variables considered for measuring income inequality:

Table 2: Variables considered for measuring inequality variables

Variables	*Definition*	*Source*
Top 10%	*This is the top ten per cent of income inequality in a country. It is the percentage of the total income of a country that goes to the top 10% of the richest people in that country.*	*World Inequality Database*
Top 1%	*It gives the percentage of the total income that goes to the top 1% of the richest.*	*World Inequality Database*
Middle 40%	*The percentage of income that is accumulated by the middle 40% of the richest people in the country.*	*World Inequality Database*
Bottom 50%	*This is the percentage of the total income that goes to 50% of the poorest in the country.*	*World Inequality Database*
Gini index	*the quantitative measure of income inequality is 0 under complete equality and 1 under complete inequality.*	*World Inequality Database*

III. I Descriptive analysis

Descriptive analysis is the process of seeking out the pattern using current and historical data. It is frequently referred to as the most rudimentary type of data analysis because it only describes patterns and connections without going any further. Thus, it aids in gaining an understanding of the data's distribution, assists in the identification of errors and outliers, and allows the finding of correlations between variables, enabling us to prepare for upcoming statistical analyses.

III. ii Panel Data regression

To study the effect of the innovation factors in the inequality variables, we use the method of panel data regression following Philippe et al. (2015), a beneficial regression model to control the dependencies of unobserved independent variables, which can cause bias in the traditional regression models. In general, it is the amalgamation of cross-sectional data and time-series data where the cross-sectional data is observations of multiple objects at a single time point and time-series data is the observations of a single object at different time points.

In most cases, panel data provide us with ample observations, enhancing the degrees of freedom and decreasing collinearity among explanatory factors and hence increasing the effectiveness of econometric estimates as a result (Hsiao, 2014). Panel data can deal with the problem of homogeneity and the resulting endogeneity. The general panel data regression is given by Biørn (2016).

$$Y_{it} = \alpha_{it} + \beta X_{it} + \varepsilon_{it}$$

Where Y is the inequality variable, X is the vector of variables that are listed in Table-2,

α is the intercept, β is the individual errors, ε is the idiosyncratic errors, i is the countries, and t is the year.

The following are the basic three-panel regression models.

1. Pooled OLS

The simple OLS used on the panel data ignores time and individual attributes in favour of concentrating just on the relationships between the individuals. Simple OLS requires exogeneity for no correlation between the unobserved independent variable(s) and the IVs. Even if the aforementioned assumption is true, the problem with PooledOLS is that alpha might show a serial correlation with time.

$$cov\ (\alpha i, \alpha i) = (\alpha i) = \sigma 2 > 0$$

2. Fixed Effects (FE) Models

The FE model treats the individual impacts of each of the unobserved, independent variables as a constant ("fix") across time. Endogeneity, also referred to as the relationship between unobserved independent variables and the IVs, can occur in FE models:

$$Yit = \alpha i + \beta Xit + \varepsilon it$$

$$i = 1, 2, 3. . . \quad \& \qquad t = 1, 2, 3. . . T$$

Only the idiosyncratic error remains, which has to be exogenous and non-collinear (represented by my = unobserved factors that vary over time and among units).

This approach does, however, permit heterogeneity to exist within the model because it can be managed. Dependencies can, unfortunately, only be seen within the individuums because individual effects are fixed.

3. Random Effects Model

RE models identify the individual effects of unobserved, independent variables as random variables over time. They have the ability to "switch" between OLS and FE and can therefore concentrate on both inter- and intra-individual dependence. RE-models select the suitable model based on the serial correlation of the error terms. To accomplish this, the model uses lambda.

$$\Lambda = 1 - \left(\frac{\sigma_{\varepsilon}^{2}}{\sigma_{\varepsilon}^{2} + T \cdot \sigma_{\alpha}^{2}}\right)$$

Lambda, in essence, determines how large the variation of alpha is. If it is 0, there won't be any fluctuation in alpha, indicating that PooledOLS is the best option. On the other hand, if lambda tends to become one and the variance of alpha tends to become very large, it might be sensible to drop alpha and stick with the FE model.

III. iii Hausman test

When there are two estimators available, one of which is known to be consistent and effective under the null hypothesis but inconsistent under the alternative, and the other of which is consistent under both hypotheses, the Hausman principle can be used to solve the problem, without always being effective Pesaran (2015).

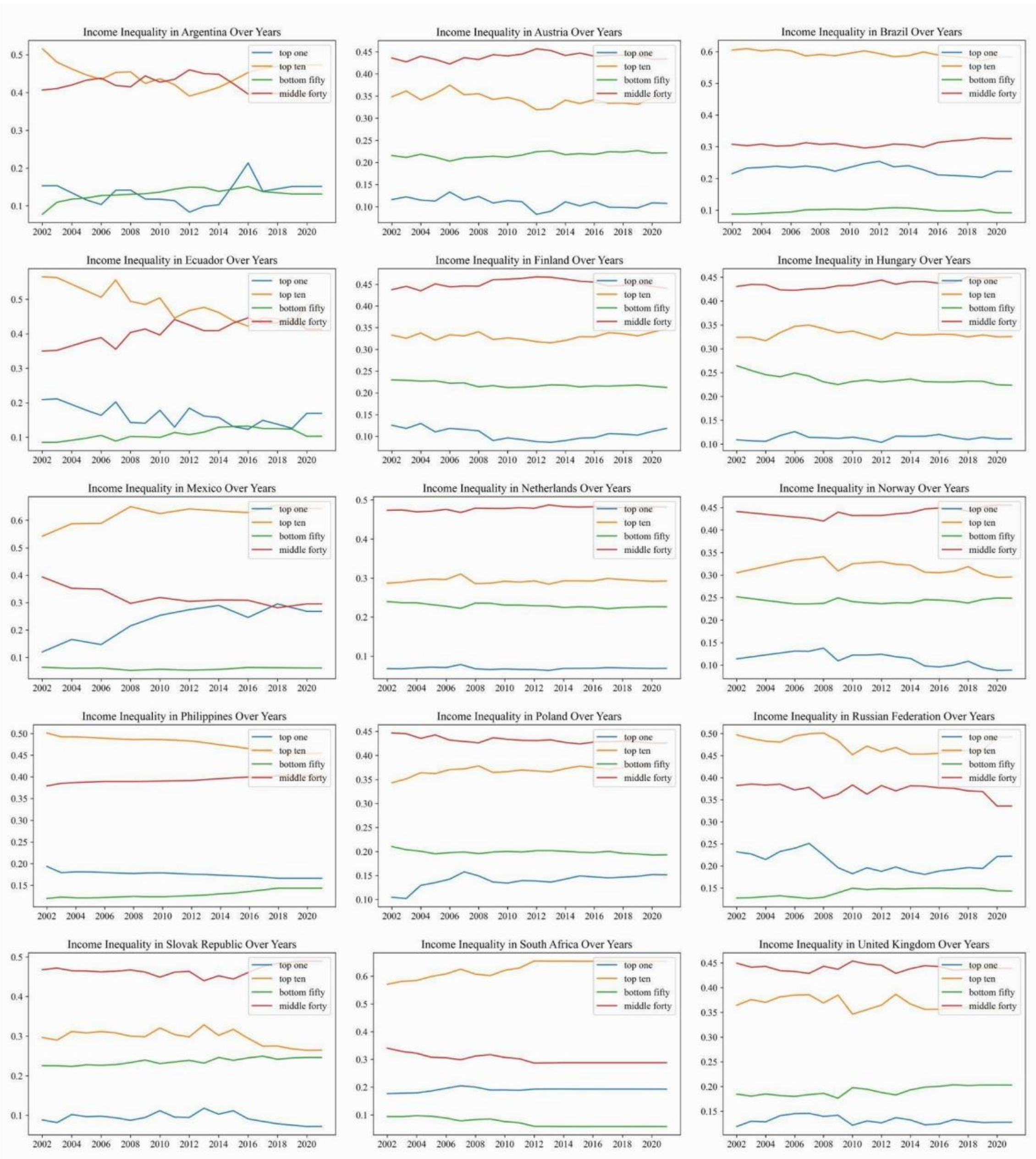
The test differentiates between fixed and random effects. It detects the endogenous regressors in a regression model. In essence, it examines the relationship between the unique errors and the regressors; the null hypothesis is that they are not.

IV. Results and discussions

A descriptive analysis is conducted on the numerical data to identify the patterns of various variables under consideration for the study. All nations have seen an increase in their GDP per capita during these years. The spending on research and development seems to be increasing in almost every high-income as well as middle-income country. In high-income countries, an average of 1.756% of the GDP is spent on research and development, whereas it shrinks to 0.627% in middle-income countries. The mean number of patent applications from residents in high-income countries is around 3380.69. The middle-income countries have a mean number of 4745.40 patent applications with a maximum of 29269. The WGI governance shows a decreasing trend in most countries except Argentina, Russian Federation, Ecuador & Philippines in developing countries. The minimum value for WGI Governance in the high income is 0.29277, whereas, in the middle income, it is -1.0376. The high-income countries spend an average of 5.4092% of their GDP on education, of which 25.60% is spent on tertiary education. Middle-income countries spend about 4.367% of their GDP in the education sector, of which a mean of 19.6897% is on tertiary education. A significant difference can be observed between the high and middle income in the case of the number of researchers per million inhabitants as well as the GDP per capita. Even though there is a growth in the number of researchers, this is not reflected in the number of patent applications. The high-income countries contribute an average number of 4139.17 researchers per million inhabitants with a minimum number of 1471.87, while at the same time, the middle-income countries contribute around 859.78. The middle-income countries hold only a mean value of 11864.97 dollars as their GDP per capita, whereas the mean GDP per capita in the high-income countries is found to be about 35588.01 dollars.

While considering the income distribution from Figure-1, in high-income countries, 33.08% of the income is accumulated in the hands of the top ten per cent of the population, of which 10.91% goes to the top one per cent. The middle forty handles about an average of 44.78% of the income and 22.12% goes to the bottom fifty per cent. This disparity is not alarming as that found in upper or middle-income countries.

Figure 1. Innovation inequality over the years



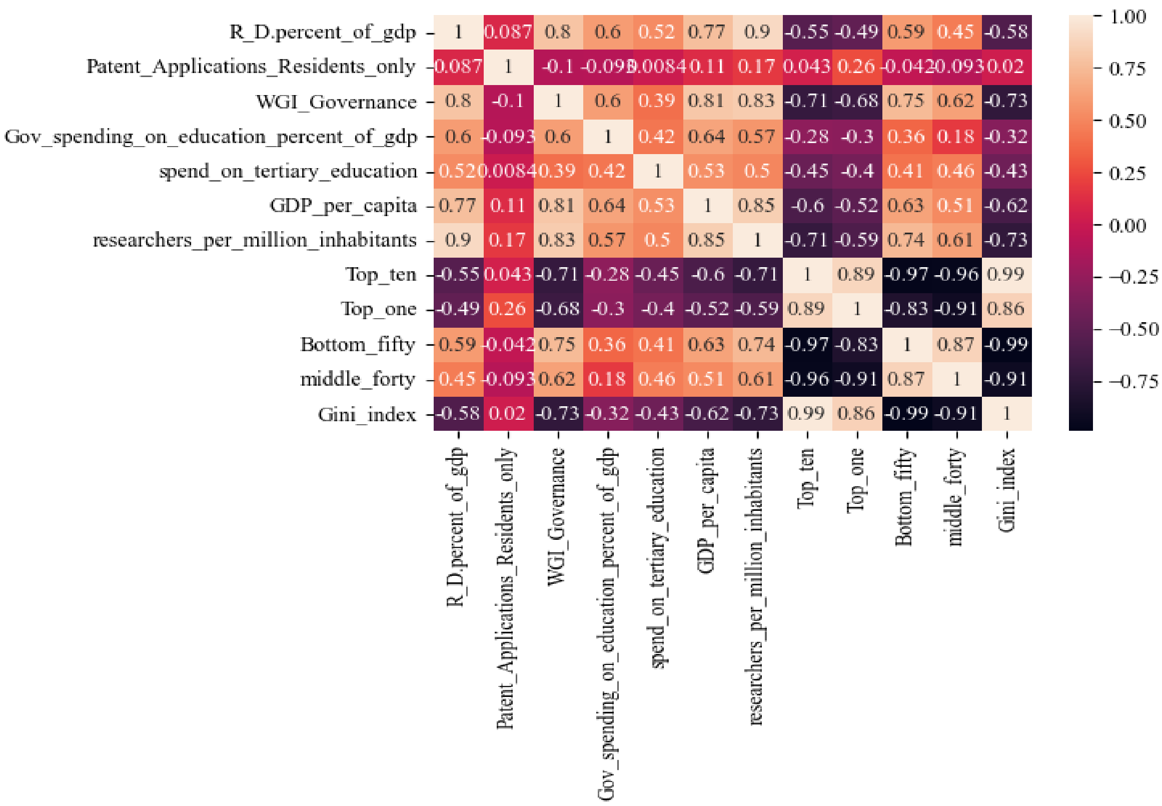
In middle-income countries, the top ten per cent of the population handles about 53.28% of the income. Inequality of income exists in nearly every aspect of the economy, and it is evident that in the majority of cases, middle-class individuals are in charge of the top 1%.

In high-income countries like Austria, Finland, the Netherlands, Norway, and the United Kingdom, as can be observed from Figure -1, there has been no significant change in the inequality gaps. The gap that exists between the rich and poor in each country remains constant, even after many years.

Contrary to the case in high-income countries, the major share of income in middle-income countries is accumulated in the hands of the top ten per cent, beyond some exceptions. The bottom fifty per cent of the population continues to be a population that is less beneficial in case of income distribution except in Poland and, at some point, in Argentina.

It is clear from Figure-1 that a major portion of the income in these countries also accumulates in the hands of the top ten per cent in most cases and the income gap between the top ten and bottom fifty remains to be constant or increases with some exceptions.

Figure-2 is the heatmap representing the correlation between various determinants of innovation capacity and income inequality in the selected countries



Almost all innovation capacity parameters exhibit negative relationships with the top one and top ten inequalities, with the exception of the number of resident patent applications. All the factors that show a positive relationship between the middle forty have an implication for the advantageous group of society. Weak or strong, the bottom fifty positively correlate with the innovation capacity parameters except for the patent applications.

The regression analysis method is adopted to understand the nature and degree of the relationship between innovation factors and income inequalities. First, we conducted the Levin–Lin–Chu unit- root test to check the stationarity of the data. Table-3 shows the result of the Levin-Lin-Chu unit root test.

Table-3: Results of unit root test

Levin–Lin–Chu unit-root		
Variables	***Statistics value***	***p-value***
The percentage of GDP spent on research and development	-4.1080	0.0000
The number of patent applications submitted by the residents of the countryin a year	-3.0573	0.0011
World governance indicators	-1.3643	0.0862
The percentage of GDP spent on education	-1.4826	0.0691
Expenditure on tertiary education	-5.2317	0.0000
GDP per capita	-2.4495	0.0072
The number of researchers per million inhabitants	-9.5959	0.0000
Top 10%	-2.9136	0.0018
Top 1%	-3.1840	0.0007
Bottom 50%	-2.2676	0.0117
Middle 40%	-1.9119	0.0279
Gini index	-2.6215	0.0044

It is evident that most of the variables are significant and the data is stationary. Hence, it is appropriate for our panel regression models. The panel data regression methods have been opted and the Hausman test is chosen to conduct a trial between the random effects and fixed effects models.

Table-4 presents the results of the regression analysis. The p-values for the Hausman test were observed below 0.05 and thus the fixed effects models.

Table 4: Result of panel data regression for top ten inequality

Top Ten				
Variables	***Estimate***	***Std. Error***	***t-value***	***Pr(>|t|)***
The percentage of GDP spent on research and development	-0.0126**	0.0066	-1.9204	0.0558
The number of patent applications submitted by theresidents of the country in a year	0.0025	0.0036	0.6972	0.4863
World governance indicators	-0.0277***	0.0071	-3.9037	0.0001
The percentage of GDP spent on education	-0.0083***	0.0022	-3.8739	0.0001
Expenditure on tertiary education	-0.0002	0.0003	-0.8334	0.4053
GDP per capita	0.0106**	0.0050	2.1209	0.0348
The number of researchers per million inhabitants	-0.0152***	0.0059	-2.5790	0.0104

It's important to highlight the negative relationships between the top ten inequality and the innovation elements of government performance & GDP share of education spending as well as the number of researchers per million inhabitants. This percentile of the income distribution is positively influenced by the number of patent applications and the GDP per person.

Table 5: Result of panel data regression for top one inequality

Top one				
Variables	***Estimate***	***Std. Error***	***t-value***	***Pr(>|t|)***
The percentage of GDP spent on research and development	-0.0076	0.0072	-1.0499	0.2947
The number of patent applications submitted by theresidents of the country in a year	0.0167***	0.0039	4.2404	0.0000
World governance indicators	-0.0150**	0.0078	-1.9200	0.0559
The percentage of GDP spent on education	-0.0054***	0.0024	-2.2945	0.0225
Expenditure on tertiary education	0.0001	0.0003	0.1628	0.8708
GDP per capita	0.0148***	0.0055	2.6859	0.0077
The number of researchers per million inhabitants	-0.0178***	0.0065	-2.7292	0.0068

The model has a well-established strong and positive association between variables of the number of patent applications & the GDP per capita and the top one per cent income disparity, whereas the betterment in the field of knowledge can affect the accumulation of income in the top one per cent in a negative way as shown in Table 5.

Table 6: Result of panel data regression for middle forty inequality

Middle forty				
Variables	*Estimate*	*Std.Error*	*t-value*	*Pr(>|t|)*
The percentage of GDP spent on research and development	0.0088*	0.0048	1.8390	0.0670
The number of patent applications submitted by theresidents of the country in a year	-0.0066***	0.0026	-2.5321	0.0119
World governance indicators	0.0145***	0.0052	2.8193	0.0052
The percentage of GDP spent on education	0.0043***	0.0016	2.7608	0.0062
Expenditure on tertiary education	-0.0001	0.0002	-0.5777	0.5639
GDP per capita	-0.0225***	0.0036	-6.2217	0.0000
The number of researchers per million inhabitants	0.0249***	0.0043	5.7956	0.0000

It is evident from Table-6 that those factors (the number of patent applications & GDP per capita) that positively contributed to the top one and top ten inequalities seem to have eminently negative associations with the middle forty per cent. The role of government effectiveness, the percentage of GDP spending on education and the number of researchers in fostering the middle forty per cent cannot be ignored. The spending on R&D also contributes to the enhancement of income accumulation in the middle forty.

Table 7: Result of panel data regression for bottom fifty inequality

Bottom fifty				
Variables	*Estimate*	*Std.Error*	*t-value*	*Pr(>|t|)*
The percentage of GDP spent on research and development	0.0047	0.0031	1.4882	0.1378
The number of patent applications submitted by theresidents of the country in a year	0.0044***	0.0017	2.5683	0.0107
World governance indicators	0.0125***	0.0034	3.6931	0.0003
The percentage of GDP spent on education	0.0039***	0.0010	3.8545	0.0001
Expenditure on tertiary education	0.0003**	0.0001	2.1074	0.0360
GDP per capita	0.0061***	0.0024	2.5811	0.0104
The number of researchers per million inhabitants	-0.0062**	0.0028	-2.1942	0.0290

Table 7 depicts the influence of various factors on the bottom 50% of the population. Even though all the innovation factors except the number of researchers per million inhabitants have positive intercepts with the bottom fifty per cent of income inequality, the contribution of government effectiveness and the government spending on education is implausible. The increase in the GDP per capita and the number of patent applications also seem to affect the flow of income to the bottom layers positively.

Table 8 represents the regression analysis results taking the Gini index as the dependent variable.

Gini Index				
Variables	***Estimate***	***Std.Error***	***t-value***	***Pr(>|t|)***
The percentage of GDP spent on research and development	-0.0117	0.0062	-1.8796	0.0612
The number of patent applications submitted by the residents of the country in a year	-0.0025	0.0034	-0.7421	0.4587
World governance indicators	-0.0279	0.0067	-4.1585	0.0000
The percentage of GDP spent on education	-0.0072	0.0020	-3.5526	0.0004
Expenditure on tertiary education	-0.0004	0.0003	-1.4276	0.1545
GDP per capita	-0.0018	0.0047	-0.3849	0.7006
The number of researchers per million inhabitants	-0.0010	0.0056	-0.1856	0.8529

The implication is that since every innovation component has a negative intercept with the GINI index, they all lead to equality. It is important to recognise and consider the significant relationship between WGI governance and educational spending in policy-making and implementation.

IV. Conclusion

Since innovation tends to foster economic growth, there is a growing body of study on how it affects income disparity and the mechanisms that connect them. This research focuses on the relationship between innovation capability and income inequality and how these variables influence different levels of income distribution. To achieve our goals, we used panel data for 15 countries from high-income, upper and low-middle-income countries.

The literature section notes a significant decline in Asian inequality at the regional level over the past three decades, although the region still has high inequality when compared to Western European nations, the region with the least inequality in the globe. The study also examines the bidirectional relationship between income inequality and innovation inequality and how these two variables have evolved simultaneously.

The findings corroborate that income inequality is real, and the resulting gap in the socioeconomic conditions of our society will only prove detrimental to a sustainable future. The empirical findings reveal significant wealth disparity, which is driven by the number of patent applications while spending on R&D and education has the opposite effect. We find that the middle-40 per cent is the most advantageous of all income groups. The Gini Index shows that practically all innovation- related factors have a negative impact on it, showing the path to equality.

In summary, the analysis reveals that all nations have seen an increase in their GDP per capita during the years under consideration, and spending on R&D is increasing in both high-income and middle-income countries. However, high-income countries spend a higher percentage of their GDP on R&D and education, having more researchers per million inhabitants and higher GDP per capita than middle-income countries. Further, income distribution is more unequal in high-income countries than in middle-income countries.

The inadequateness of the data significantly hampered the effort to discover the relations through this study. It is challenging to establish a causal link between innovation and economic disparity. Whether innovation directly contributes to changes in income disparity or whether income inequality drives innovation is a question that is frequently difficult to answer. It is difficult to adequately measure both economic disparity and innovation. Technology advances, patent applications, and investment in research and development are just a few examples of how innovation can manifest itself. The Gini coefficient or income percentiles are two examples of metrics that can gauge income disparity. It might be challenging to compare results across research since varied assessment strategies can produce inconsistent results.

An economy must have a fair income distribution to grow sustainably, and new technologies must reach all levels to promote harmonious development. Lack of equitable opportunity may result from the concentration of wealth in a few hands, which may show in various ways. Consequently, we might fail to utilise our complete intellectual wealth for progress. Future studies need to explore this aspect of the relationship between innovation capability and income inequality. Future research must carefully investigate the innovation elements and determine which has the greatest impact on reducing inequality by selecting a large number of nations, including those with low incomes, over a longer period of time. Recognising these elements may aid governments in formulating and implementing policies that would strengthen the weaker sections of society by lowering disparities.

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7

Performance of networks - The proposal of a managerial tool based on social network analysis

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Abstract

Innovation networks supported by public funds are considered critical instruments of public policy and they are very relevant to promote the creation and strengthening of robust innovation systems. Therefore, considering both the relevance of these networks, and its heavy public investment, there is a growing need to assess their development in order to ascertain their potential for innovation and performance. Unfortunately, the literature on conceptual frameworks for evaluating these networks is scarce and fragmented. In this sense, this paper describes a social network based tool to measure innovation networks. This tool is part of an ongoing project related to the construction of a model for evaluating innovation networks. This work aims to contribute to the study of networks, through a systemic, dynamic, flexible and transparent approach. The research conducted in this study was exploratory and based on cases, to this, it was taken as a case study three segments of the Brazilian Network for Nanotechnology and it was constructed an evaluation tool. Nanotechnology has been chosen as the application area by its dynamic character, for being an intensive knowledge area and for having high an innovative potential. The data used was based on the public register of national curricula of researchers from Brazil (CV-Lattes). Among the results obtained in this work, one of the most important is that in the area of nanotechnology in Brazil, networks are not very connected. It is realized that these networks still are in a growth stage and they are not yet mature or consolidated with a few exceptions.

Keywords: *innovation networks, network performance, nanotechnology, network metrics, social networks, innovation performance.*

Introduction

Innovation networks financed by public funds are considered critical public politic instruments to promote the creation and consolidation of robust innovation systems. They can even be converted into learning platforms (Lundvall, 1998;Kava, 2020) to participating actors and relevant mechanisms to promote technological development and competitiveness of a country (Thursby, Thursby,2011. Therefore, considering both the relevance of these networks, and its heavy public investment, there is a growing need to assess their development to know their potential for innovation and performance. Unfortunately the literature on conceptual frameworks and tools to evaluate these networks is scarce and fragmented.

This paper aims to present a proposal of social networks based tool for assessing innovation networks. Social networks are very useful for dynamically analyzing elements of a network and the relations among elements as well as its different phases: growth, consolidation and maturity. This tool is part of an ongoing project related to the construction of a model for evaluating innovation networks presented in (Escalante, 2008). It is hoped this will contribute to the assessment of networks, through a systemic, dynamic, flexible and transparent approach. It is intended to evaluate the innovation network at various stages of its life cycle. This proposal is focused on innovation networks supported by public funds.

The research conducted in this work was exploratory and based on cases (Vergara 2010; Yin 2004). To do this, it was taken as a case study three segments of the Brazilian Nanotechnology network and it was built an assessment tool. Nanotechnology has been chosen as an area of application by being dynamic, knowledge intensive and high innovative. Also the reason for the choice comes from the growing importance that many countries around the world have been giving to this potential industry (Selin, 2011; Huang; Wu, 2011; Mangematin, 2012, . They are considering the Nanotechnology as a strategic area with great impacts for the economic and social development (Yawson & Kuzma, 2010; Arifi 2023)Nanotechnology involves several areas of knowledge, needs multidisciplinary teams and, thus, is highly related to innovation networks.

This papers is organized as follows: Section 2 presents the theoretical framework of this work; in Section 3, is presented the research methodology that has been performed in this work; Section 4 describes an assess tool using the national register of curricula of researchers from Brazil (CV- Lattes), and the social networking methods there were used in order to evaluate these networks; in Section 5, some of experimental results are presented and discussed. Section 6 presents the conclusions and guidelines for future work.

2. Theoretical framework

This section begins by presenting some fundamentals of networks and their importance in organizations; then it will be described a specific type of network called innovation network but in the context of National innovation System. As follows, it is described a very useful concept for the evaluation of the networks known as social networks analysis and, finally, a review of the literature on the evaluation of innovation networks will be presented.

2.1. Innovation networks and national innovation system

The term network is used in different fields of knowledge (sociology, management, marketing, etc.) and with different meanings. Academically, the term is used in social networks (Uzzi 1997), from the perspective of inter-organizational networks (Powell et al. 2005) and the industrial network approach (Håkansson, Ford 2002), among others. Because each approach studies a particular aspect of the network, there are very few researches focused on the study of networks as a whole (Provan, Kenis, 2008; Vonortas, 2012).

Regarding the definition of a network, it is considered as a strategy (Jarillo 1998) as a structure of governance (Powell, 2005; Arifi, 2023)), or even as instruments of social change (Pyka, Saviotti 2005). In the literature of innovation systems (Lundvall, 1992; Malerba, 2002, Kava, 2020), networks are seen as key policy instruments to promote innovation.

Following are some definitions. Jarillo (1998) defines networks are long-term agreements with defined purposes, between different organizations, although based on intense interaction and allow them to establish or sustain their competitive advantage. Guarau (2005) states that a network consists of relations connecting actors (individuals, groups of individuals, parts of companies, firms or groups of firms) that are cooperating to acquire resources that could not be get on individual level. In the words of Debresson (1991), networks are a useful way to analyze the phenomenon of innovation (the subject of innovation in networks will be detailed in the next section).

In this study, innovation networks are defined according Rampersad et al (2010):

> *A relatively loosely tied group of organizations that may comprise of members from government, university and industry continuously collaborating to achieve common innovation goals.*

About the motivations for the formation of a network, it is possible considers different aspects like: product complexity, access to external knowledge, organizational learning and dissemination of information, faster demands attention, protection against technological uncertainty, etc (Powell et al. 2005; Mangematin, 2010, 2012; Pandza, 2011; Shapira, Maso, 2020).

With regard to classification of networks, there are several classes. The types vary according to fields of knowledge and the author. For the purpose of this research, there will be highlight innovation networks supported by public funding (Gauna Vonortas, 2012).

2.2. Innovation networks and innovation systems

To understand the theme of networks and their relation to innovation systems it is considered appropriate to start by the term innovation. Today, innovation is considered by many authors as one of the most important competitive and strategic elements of an organization in the dynamic environment of organizations (Rothwell, 1994; Chesbrough, 2004; Christensen, 2000); even being considered a mantra (Plonski, 2004).

The definition of innovation has evolved over the past 40 years. In the 60s and 70s innovation has been regarded as the fundamental process to develop a new idea, since concepts such as effectiveness, profitability and customer satisfaction have been integrated. The inclusion of the marketing process in the meaning of innovation is probably the result of customer focus and increased business competitiveness (Christensen, 1997; Rothwell, 1994; Kava, 2020).

On the other hand, it is appropriate to mention that there is a large amount of literature related to the process of innovation and economic development from different theoretical perspectives: geographical, based on general theory of location; studies of the role of location in competitiveness (Porter, 1994); learning regions; and the perspective of Innovation Systems, in its different levels: national (SIN), regional / local and sectorial; technical systems, including the Triple Helix (Lundvall, 1992; 1998 ; Nelson, 1993; Malerba et al. 2001; Carlsson, 2002). This list is certainly not complete, but gives an overview of the topic.

Within these perspectives, and considering the opinion of many experts about the interactive nature of the innovation process at both the intra-organizational and inter-organizational level (Chesbrough, 2004; 2017), arises the need for analysis of the innovation process from a systemic perspective (Lundvall, 1992 Pyka, 2002; Vonortas, 2012, Maso, 2020).

Considering degrees of innovation (or also called Generations of Innovation), Amidon (1997) defines five levels:

- Level 1: Technology Transfer - where tangible outputs are transferred.
- Level 2: Knowledge Sharing - That means people are a transfer mechanism.

- Level 3: Collaboration of Knowledge – i.e. joint innovation, for example, with customers, suppliers, etc.
- Level 4: Knowledge of Innovation - including the management of systemic processes
- Level 5: Innovation Networks - look to innovation as a dynamic network of knowledge flows, which becomes the source of advantage. At this level, innovation is regarded highly dynamic, where different Strategic Business partners are needed

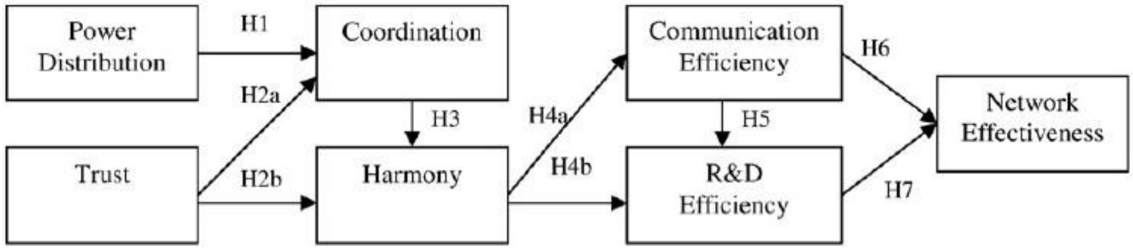
The research related this work focuses on level 5, i.e., in innovation networks. To Pyka (2002), an innovation network is a tool for social change, whose main purpose is to promote technological development through the creation, generation and dissemination of knowledge. He says that the higher the changing needs of customers and markets, the greater are the challenges of innovation networks.

In the opinion of Carayannis (2006) innovation networks are real and virtual infrastructures that serve to promote creativity, enhance their ability to catalyze invention and innovation in a public or private domains in the context of open systems perspective. For this author, networks are useful in the formation and growth of technological entrepreneurship. In this context, innovation intensifies the technological entrepreneurship and is viewed as a central element of innovation systems.

Regarding the role of innovation networks, these are seen as crucial to promote technological development and have the following potential benefits: they decrease costs (of products, key services, etc.); they build, enhance or complement technological capabilities; they help control the technological uncertainties; they facilitate faster development of new products and services; they capture knowledge from outside sources, helping to the access to information resources and global knowledge; they facilitate organizational learning and the communication skills of network partners; they optimize investments in research and development (R & D), among other advantages (Bullinger et al. 2004; Gulati, 1998, p. 1442, Carayannis, 2006; Germunden et al. 1995; Waserman; Faust, 1994; Rampersad et al, 2010; Managematin, 2012, Maso, 2020)

Small and medium sized companies also need to participate in innovation networks to attract or outsource the resources necessary for the proper development of their projects (Guaraú, 2005). The complexity of the product development cycle forces firms, regardless of size, to participate in several networks. They develop various roles in these networks. See fig1 about management of innovation networks

Fig.1 Rampersas (2010) management of innovation networks



2.3. Social networks and innovation networks

All social conglomerated is built around relationships; the performance of an individual cannot be fully understood unless we relate it with the actions of others to whom she/he is connected through different social connections (Granovetter 2005; Maso, 2020). This conglomerate formed by individuals and their connections is called a social network (Wasserman, Faust, 1994). The study, visualization and characterization of these networks are known in literature as social network analysis (SNA). Several researches in the areas of network theory and graph theory have been developed in SNA (Berkowitz, 1982). These studies established several metrics to analyze different features of a social network.

When representing a social network as a graph, it is possible to apply the concepts of graph theory to analyze the network structure. Concepts such as degree of a node (number of edges connected to it), may be useful to see if the relations are uniformly distributed on the network and to know the network density (Matheus; Silva, 2009). These two indicators describe the level of integration of actors in the network and the maturity level of the network. A disconnected network or a low density network may show a network that still has to mature to take advantage of its full potential. Considering the modeling of social networks using graphs, it is possible to define some metrics that are important to understand its structure. Among these metrics it is possible to mention the centrality or prestige (Matheus; Silva, 2009).

The centrality is associated to the relationships that a node has. The number of relationships that a node has represents its importance. Metrics of products generated by the network as published articles, patents generated, etc., allow assessing the network in a limited way. With the analysis of social networks and its metrics it is possible to have a more complete evaluation of the innovation network.

2.4. Evaluation of innovation networks

This section analyzes the literature related to the processes, mechanisms and evaluation metrics of networks from a systematic perspective. In this sense, first, it is reviewed some fundamentals of the evaluation process in networks and then the subject of assessment is reviewed in various areas of knowledge.

2.4.1 Fundamentals of evaluation networks

What is the meaning of efficiency and effectiveness in innovation networks?

Efficiency in innovation networks is related to the speed in the development of products and services, and besides to the more rational use of resources for R&D, among others characteristics. On the other hand, the effectiveness of a network is related to the ability to reach the desired goals and objectives. Thus, in this research, to evaluate performance of networks of innovation it is necessary the assessment of efficiency and effectiveness of the network in terms of innovative potential.

Why is it important to evaluate networks?

The evaluation of networks, although it is a complex process (Ziggers et al, 201;Mangematin, 2010, 2012; Pandza, 2011), is relevant for the following reasons (Vinnova, 2006, Maso, 2020):

- The learning becomes essential, and the process of learning can be of three forms Operational learning - evaluation provides lessons on how things can be done better;
- Feedback policy - serves to check the extent in which networks have achieved their goals and furthermore contributes to the design of future strategies;
- Impact of networks - the intention is to help improve the efficiency and effectiveness of national innovation system, determining the results and impact of pre-established indicators.

b) Simplifies network planning, as it helps to measure progress and to propose solutions to problems. This requires the network to be adaptable. Some networks have difficulties to change their focus, processes and partners. Strategies to develop flexibility involve use the assessment process in order to have a broad thematic focus and flexible structures according to changes of the environment.
c) Allows having parameters of comparing and monitoring. That lets you analyze how the network is developing its work and how this can be improved. Also, it makes easy to compare it with other similar networks.

According to Lengrand (2006), studies oriented to the evaluation of programs and innovation networks, have the following characteristics:

- There are countries that underutilize the focus of evaluation;
- In more advanced cultures, the assessment goes beyond simple performance audit, and increasingly is becoming an integral part of a learning-based approach for policy-makers;
- There is no single method that can answer all evaluation questions and can be applied to all types of studies (this is corroborated by Gregersen and Johnson (2005)). Typically, evaluations need a combination of various assessment methods;
- It is necessary users well informed that understand the limitations of any assessment.

What types of evaluation of innovation can be done?

The assessments vary in shape, methods used, the scale, scope, and the extent to which the results are disseminated and used; but, according to Lengrand (2006), there are three basic types of evaluation, oriented to the evaluation of innovation programs:

- **Ex-ante evaluation** - conducted prior to implementation and focuses on your goals and how they should be achieved. Evaluations of this type are used to provide answers to questions of risk and uncertainty. For example, what are the impacts of network implementation? Examples of these assessments are studies (forecast) foresight, the techniques based on cost and benefit, etc.
- **Intermediate evaluation** - involves reviewing the progress and results at some point in its development.
- **Real-time evaluation** - consists of the detailed monitoring of its operation.
- **Ex-post evaluation** - examines the results after they have been developed (can be more than once). Semi-quantitative and qualitative methods can be used.

In these assessments, Lengrand (2006) considers the networks in order to analyze the structure of cooperation between actors.

In the literature of networks, the issue of performance evaluation is analyzed in a piecemeal fashion. Several authors consider certain elements of their networks as determinants of innovative performance, such as the network structure and components as its centrality (position of the firm on the network), connectivity, kind of links, etc (Powell et al. 2005 , p. 30; Ahuja, 2000, p. 428). Other authors consider that what affects the performance of the network is the network dynamics. This involves issues such as the evolution of the network, the entry of new actors, the output of others, the network collaborative process and its intense interaction in order to exchange knowledge flows, learning process and absorption capacity, etc. (Leydesdorf, Ezowitz, 1998, p. 198; Cohen, W.M.; Levinthal, 1989, p. 574; Benkler, s/d). For some authors is the type of network that has effects on performance (Provan &, Kenis, 2008).

Regarding the governance of networks and how this affects the performance of networks, we highlight the work of Provan and Milward (2001) and Provan and Kenis (2008); Ziggers et al, (2010); Rampersad et al,(2010), which value the evaluation of networks, but they say that it is a complex work and often neglected in the literature. They offer a discussion about the effectiveness, relevance of network governance and their impact on performance, but in the context of the public sector.

Gassmann and Enkel (2005, p. 123) are other authors in the field of networks that contribute to the thematic about evaluation. They determine the factors that affect the performance of networks, such as: funds (considered to be key), the network structure (here argue that various elements can be evaluated, since the literature has not offered a structure that can be the best for innovation networks, for example, membership and selection of members, their roles, network management, level of research spending and type and quality of results), connectivity and interaction of the actors (the relationship among the members based on their connectivity is a crucial success factor for the innovative results of the network, for example, trust, culture, network reciprocity, density and integration, flexibility, relationships, etc.) network and the influence of the member institutions of origin (absorption capacity of the members when they return to their place of origin).

From the literature it is possible to identify several factors that affect the performance of innovation networks (Escalante, 2008): communication (intensity, frequency, etc.); typology of the network; management (strategy, and mechanisms for implementation); network structure (centrality, commitment to actors.); coordination; collaboration (joint action of actors at various levels); social capital (collective learning and collective ability); strategic direction of the network (defining the future); funds (financial resources); public policy and instruments of innovation (innovation environment); network competence (skills and attitudes of the actors of the network); governance (administrative structure of the network management and support mechanisms); international visibility (international recognition); and innovation culture and technological trajectory of the country.

2.4.2. Traditional metrics for innovation versus contemporary

Innovation as a complex and multidimensional activity cannot be measured with a simple indicator, or even with indicators that do not reflect its dynamics. So, today, it is necessary new ways and metrics to evaluate innovation from a dynamic, multidimensional and systemic point of view that can go beyond inputs and innovation outputs, considering also the innovation process itself, but in the context of networks. Thence, it is necessary to reflect about the dynamics of innovation in today's global networked economy in such a way that assists both policy makers and firms in improving their business strategies and evaluation process not only in the context of firms, but also in the network level (Milbergs; Vonortas, 2004; Coccia, 2007; Rampersad et al, 2010; Vonortas, 2012). Some interesting works has studied metrics about innovation network in different industries (Malerba; Vonortas, 2009; Vonortas, 2012), and others about metrics but related network governance (Ziggers et al, 2010; Rampersad et al, 2010),

A key component of an effective innovation policy is to measure the factors that guide innovation performance and monitoring of results. However, today the indicators reflect the industrial age but not the contemporary dynamic (based on ideas and processes). According to Vonortas (2012) dynamic performance metrics that are also timely and multidimensional are required. For this author the concept of additionality is an useful concept when is analyzed the public support for R&D in the context of networks:

- *Input additionality: Has public expenditure created additional funds to be spent and on what?*
- *Output/outcome additionality: Has public expenditure generated additional private and social returns?*
- *Behavioural additionality: Has public expenditure created sustainable effects beyond the infusion of resources and outputs such as improving the knowledge, capabilities, organization and strategies of firms (OECD, 2006)*

The Behavioural additionality, is for some authors like Vonortas (2012), the main network approach that can make its greatest contribution, because provides a new lens to examine important aspects of the longer lasting, more sustainable contributions of public policy in affecting organizational and national regional capabilities to innovate.

In this sense, advances in construction of metrics to assess the dynamic nature of innovation are emerging slowly, but they are still scarce especially in high technology areas, with some exceptions, like the research of Chang Yuan Chieh, et al (2012.Xu, 2023). These authors considers that exist a positive relationship between organizational capabilities and radical innovation performance. Their work analyzed four capabilities: (1) openness capability, (2) autonomy capability, (3) integration capability and (4) experimentation capability. The research was mainly focused on measurement of the magnitude of the output of radical innovation, such as nanotechnology.

Otherwise, it was possible to identify some empirical cases in the literature review concerning to nanotechnology such as: the VINNOVA agency and the

Nanothecnology Brazilian network. The VINNOVA agency (2006) developed a scheme of bi-annual assessment of competence centers. To develop this process, they invite peer reviewers from both national and international academia (researchers and graduate students), industry (as listeners) and the assessment is made according to phases of implementation (maturity) of these networks. At each stage the focus of assessment changes. Another important aspect is that the evaluation is done in several dimensions (ex-ante, during and future) and also examines the attractiveness of the network nationally and internationally. As for criticism of this model is that only evaluates the innovation networks in terms of inputs and outputs, but does not consider the analysis of the innovation process, i.e., their dynamics and structure. It is an assessment based on traditional and static aspects of innovation.

The paper of Wartburg, Leichert, (2008) extended the current evaluation considerations of patented technology from a static perspective to include a dynamic view using nanotechnology as an example. An interesting study about indicators for nanotechnology is the research from Yawson &Kuzma (2010, Chandler, 2021), they studied the Agrifood sector using dynamic systems. Some indicators are: numbers of nano products in R&D, number of nano consumers accepting, number of nano consumers purchasing, number of nano products of the market, number of nano people aware etc. They considers that dynamic systems is very useful because the complexity exists, partly due to the uncertainty of risks and benefits of using nanotechnology, follows some considerations of these authors:

> *"Through system dynamics, policy makers and other stakeholders in the agrifood sector may gain insight into the causal factors influencing consumer acceptance. Knowledge of how causal factors influence public perception and consumer acceptance patterns may assist industry, academics, and policy decision makers in strategic planning" (Yawson &Kuzma, 2010).*

Another work but with focus to the relationship between faculty -industry (including also biotechnology) belong to Thursby, Thrusby (2011), their contributions are about the proposal of some indicators related with the collaborative nature and characteristics of nanotechnology. So, they make the proposal of some indicators like: co-patenting, co-publication, funding from industry to faculty, and faculty consulting). In this context Thursby, Thrusby (2011) considers that:

> *"The prevalence of patenting by firms and universities, as well as the interaction of these institutions, has been cited as important distinguishing features of the nanotechnology and biotechnology revolutions but identifying faculty collaboration and its impact, both on the industry and university side, is challenging because data on the interaction is not generally available. Indeed, most of what we know about the influence of academic research on industry comes from studies of patent citations to university-assigned patent""*

Regarding evaluation of networks in Latin American countries, we can mention Brazilian case. In this national networks the evaluation is made by the Ministry of Science and Technology in terms of reports (every two years) and it is based on oral presentations supported by reports results for each network. The content of the assessment is traditional in terms of results generated as if they were research groups (outputs) and not exactly networks. It has been known that in the last evaluation the intention was to evaluate the Brazilian network of nanotechnology through its achievements as networks.

Finally, regarding the research about evaluation of networks in nanotechnology, they are still in their infancy, there are some works that try to evaluate some aspects of innovation in this area related to bibliometric analysis, and analysis of patents (Meyer, 2006, Chandler, 2021).

2.4.3. Tools to support the evaluation of innovation networks

Some of the tools used to support the evaluation from the perspective of inputs and outputs, as well as the dynamic process of innovation in the network are described in this section. According to Lengrad (2006) there are different methods to assess the potential for innovation:

- Methods to access and generate data - data production techniques that are used in primary and secondary research.
- Methods for structuring and explore interventions.
- Methods for data analysis - they are ways of processing and definition of conclusions from statistical material and qualitative approaches and more sophisticated modeling and simulation.
- Methods to draw conclusions, including impact assessment.

There are also methods to analyze networks from another perspective:

- Bibliometric analysis - The bibliometric data provides the opportunity to calculate the relevant indicators of interest to the new theories of innovation, specifically of networks within the framework of innovation systems.

- Scientometric analysis using a series of indices of input and output with greater focus on scientific production and funding for research mainly public (Coccia, 2007).

- Analysis of patents and co-patents (Kim; Song, 2007, Sanchez et al 2021).

- Analysis of collaboration between universities and industry and the proposal o some indicators such as co-patenting, co-(Thursby, Thursby,2011, Chandler, 2021)

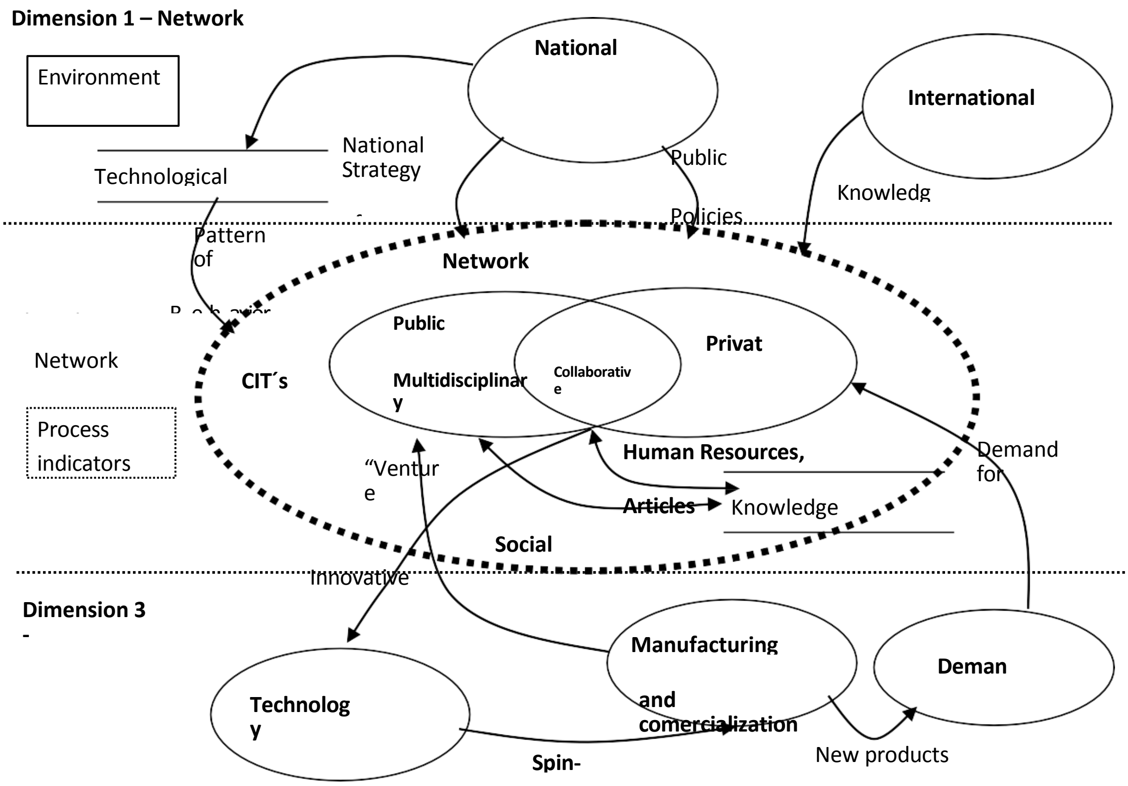
- Analysis of technology ventures such as spin-offs.
- Analysis of the dynamics of networks, based on techniques of social networks (Wasserman; Faust, 1994; Agapitova, 2003, p.12; Rycroft, 2003; Vonortas, 2010, 2012) and supported by software such as Cytoscape (Smoot, et al, 2011, Xu, 2023), which serves to find the characteristics of the network graphically.

It is noteworthy that an author who has researched extensively on support tools to evaluate networks is Church (2003, Chandler, 2021, Xu, 2023). Several tools were developed: communication channels in networks, tools for appraising the contribution of networks, tools for networks monitoring, check list of networks, among others. Many of such tools are in the experimental stage. Another important author is Vonortas (2012), his contribution is related to the introduction of the social network methodology as a tool for evaluating important aspects of research and development (R&D) programs. Two examples of network methodology application were described.

2.4.4. Toward an analytical framework

Escalante (2008, 2012) tries to contribute in a modest way to overcome this gap in the literature mainly in the area of nanotechnology, with a proposal of a model for evaluating innovation networks in nanotechnology. From the literature, it is clear that evaluating networks is a complex process that includes many dimensions, factors and indicators, especially when you want to evaluate these networks in a systematic way. Doing an exercise in abstraction is possible to try to define some dimensions that might reflect this evaluation process, it is clear that classification is not definitive, but it is a rigorous exercise that aims to contribute to the literature of innovation networks. It is possible to classify critical factors of performance, in a preliminary way, in three dimensions (see Figure 2):

Fig. 2 Framework for evaluating innovation networks



Follows the dimension of the proposal:

- **Network environment dimension :** Includes all those factors that are inputs to the network and affect its performance;
- **Dimension of the process of the network:** It is one of the contributions of this work, because it tries to evaluate the black box of the innovation process in a network and it is a starting point for understanding network management.
- **Technology transfer dimension:** Includes all those factors related to the outputs of the network, i.e., the innovations generated by network and how they are marketed to be generating wealth.

Other aspects of the innovation process are the production, distribution, and demand analysis, are not considered in this framework, because it is focused on public networks. A more detailed description of this previous framework can be found in (Escalante, 2012).

3. Nanotechnology in brazil.

To do our research we chose as a field of study the nanotechnology area and specifically in Brazil. Latin American's activities in nanotechnology area, are also increasing and they are being supported by several mechanisms of public policies (Salamanca-Buetello, et al, 2005; Kay and Shapira, 2009). In 2001, when the nanotechnology policy in Brazil started with the creation of four institutional, multidisciplinary (innovation) networks and four Millenium Institutes aimed at promoting research in the field were invested by the Science and Technology Ministry (MCT) about US$8 million for the period 2001-2003.

In 2003, a Program for the Development of Nanoscience and Nanotechnology was elaborated and later incorporated into the MCT´s Multi-year plan for 2004-2007 (Kay, et. al, 2009). This program was designed based on the problem generated by the inevitable loss of competitiveness of Brazilian industry and specifically in the area of nanotechnology (MCT, 2003). The program was strengthened in 2005 with a bigger budget and was better aligned to the Industry Policy, Technology and Foreign Trade (MDIC, 2005). In the context of convergence between research and industrial policies, ten new research and innovation networks were created. These networks were more oriented to industrial application and involve cooperation with the productive sector.

Since the first program was created in 2004 to 2009, the MCT has invested resources in the order of 314 million reais (about 182 million dollars at today's exchange rate) (Invernizzi, 2011). The Brazilian nanotechnology policy has been fundamental in strengthening the research infrastructure in nanotechnology and the networks have connected researchers from virtually the entire country. In a study of groups of CNPq (Invernizzi, 2011) were recorded 3,502 researchers in 469 groups from 24 states (almost all from Brazil) and 104 institutions. According Albornoz et al (2010), “Brazil is the most prominent country for nanotechnology in Latin America: in 2006, it ranked 18th in the world for publications related to nanotechnology, with 827 articles indexed by the SCI.” However, with respect to the supply of products).

Currently there are nine research networks and innovation, seven national institutes of science and technology (INCTs) and six strategic laboratories supported by the Program for Nanotechnology of the MCT. By edict MCT / CNPq 74, 2010, was supported the creation of more 17 cooperative networks integrated of basic and / or applied research, and the edict MCTI / CNPq 17, 2011 is expected to support two more networks for research and development in Nanotoxicology and Nanoinstrumentation.

As regards international collaboration, most networks have international partnership. For example, the nanocosmetics network has partnership with two French institutions, two Swiss, one Swedish, one German, one Dutch and one from England, and the network RENAMI has partnership with institutions of the United States, France, Holland and Germany.

4. Research methodology

The research conducted in this work was exploratory and based on cases (Vergara, 2010; Yin 2004). To do this, it was taken as a case study three segments of the Brazilian Nanotechnology network and it was built an assessment tool. Nanotechnology has been chosen as the area of application by its dynamic character, knowledge intensive and high innovative potential.

Regarding the data, it was used data from the Brazilian register of curricula of researchers (CV- Lattes), which gathers information on publications, research projects, among others, to assess these segments. For Brazil, the CV-Lattes is the official repository to access the scientific productivity of researchers.

A tool was developed for extracting data, as will be presented in Section 4. The extracted information from the CV-Lattes was used as an input of a social network analysis tool which evaluates the networks through time. For this, a longitudinal analysis was done starting from the beginning of the network until today. It was possible to assess how these networks have evolved and the level of integration and collaboration of the networks' actors. These actors can be researchers from universities, research centers, public or private. This tool allows you to view both the network of actors (researchers) and the network of institutions (aggregated information). The software used to visualize the network was NetworkX. There was also an extensive theoretical study on innovation networks and evaluation of these networks using secondary data such as books, articles, theses, etc. The developed tool is part of an ongoing project related to the assessment of innovation networks and support tools.

5. The development of a tool for the evaluation of innovation networks based on social network analysis

This Section presents the developed tool for evaluating the performance of networks based on scientometrics and patent data from the Lattes Platform (http://lattes.cnpq.br/). This tool extends a prototype developed by Digiampietri and Silva (2011). The Lattes Platform, an initiative of the Brazilian National Council for Scientific and Technology Development (CNPq), is a database from curricula, institutions and research groups involved in Science and Technology. The developed tool intends to facilitate the analysis of networks structure and dynamics. The goals of this tool are not only to evaluate an innovation network in the traditional point of view (outputs), but also the structure, evolution and dynamicity. It, starting with a list with researchers' names, extracts, organizes, and summarizes the researchers' information using social networks technologies. The process executed by the tool is described as followed and summarized in Figure 2.

1) At first, the tool searches, using search APIs (Application Program Interfaces), the URL (web address) of Lattes curriculum of each

researcher using the keywords *"currículo lattes"* (lattes curriculum) combined with the name of each researcher. The first search is made using the Google search API. If the researcher' curriculum is not found, the tool executes a new search using Microsoft Bing search API. In both cases, the results of the searches are validated, the web site pointed by the URL is downloaded, and it is verified, using regular expressions, to guarantee the curriculum belongs to the queried researcher;

2) After finding the curricula's URLs, the tool download all the curricula HTML files and store them temporarily;

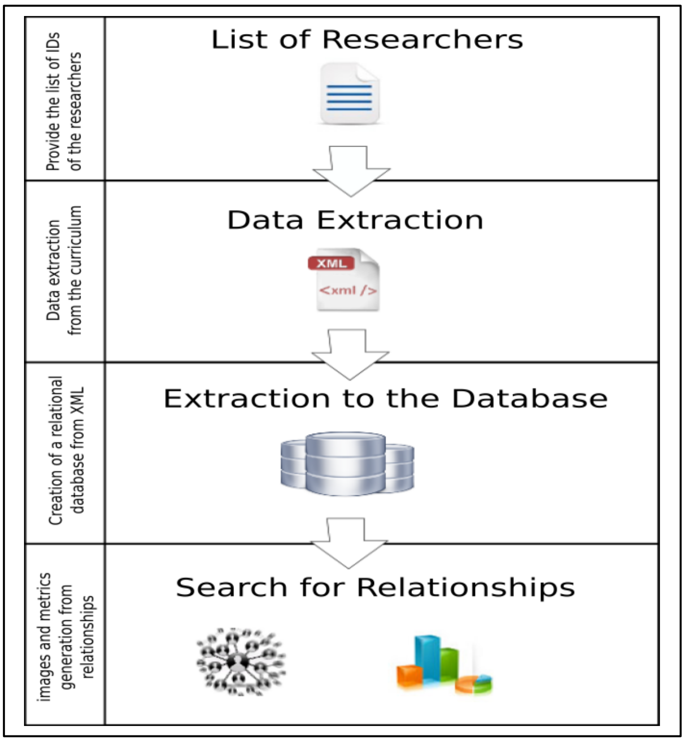
3) The third task of the tool is to extract the relevant data from the HTML files and export this data to XML files using a script;

4) The following task is to convert the XML files to store them in a relational database. During this process, the redundant productions are removed.

5) The fifth task consists in calculating the weight of the relations between each pair of researchers. This weight is calculated according with the collaborative production of each pair (journal and conference papers, books, chapters, projects and patents). The same process is used to calculate the weight of relations between institutions.

6) After the weights were calculated, the weighted graphs are produced using *Cytoscape* software (Smoot et al. 2011). This software is used to create the networks for each kind of production considered and a network with all kinds of productions. These networks are created for all the years in a given interval, thus it is possible to analyze their evaluation and dynamicity. The *Cytoscape* software also produces metrics to describe the networks.

Fig. 2 Summary of the Network Production Process



In this paper, the relations between researchers are initially studied evaluating three kinds of production: journal papers, patents and projects. The proposed model considers different weights for each kind of production. The idea is that different kinds of production requires different amount of the effort of the group (or team), thus each kind of production will receive a weight proportional to the effort required by the group. In this paper, it is proposed an automatic way to calculate the weights for each relation, considering the kind of production and the analyzed community (network).

Being Ri the studied network; Wi,j the weight of production j in the network i; Ni,j the number of productions of kind j in network i; Ai the number of authors in the network i; Ai,j the number of authors in the network i who have productions of kind j; and Āi,j the average number of authors in the network i who have productions of kind j. The weight of production ok kind j in the

$$W_{ij} = \frac{A_{i,j}}{N_{i,j}} * \frac{A_i}{\bar{A}_{i,j}}$$

network i is given by the formula:

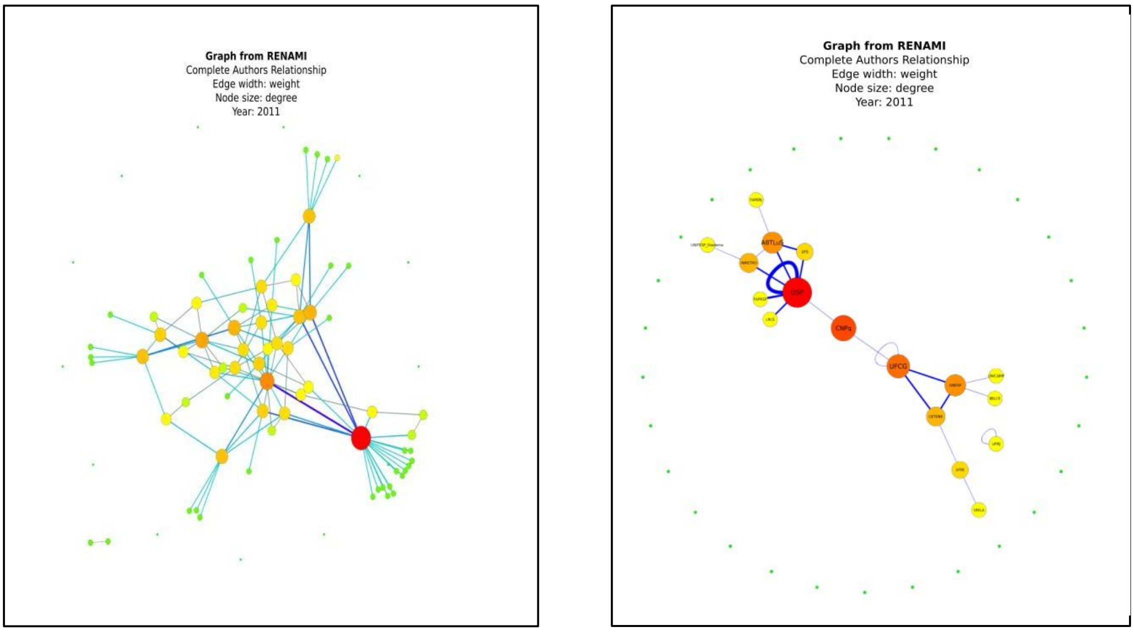
6. Experimental results based on the nanotechnology innovation networks: Brazilian case

In order to test the developed tool, three case studies where used: two nanotechnology networks and one institute created by the Science and Technology Ministry to incentive the nanotechnology research. The Brazilian government believes in the potential of the emergent nanotechnology industry to increase the economic and social national development. One of the mechanisms developed to improve the nanotechnology national program is the creation of the national research institutes and the national research networks.

The case studies of this paper used data from this three networks: RENAMI (*Rede de Nanotecnologia Molecular e de Interfaces* - http://www.renami.com.br/) created in 2001, the *Nanocosmetics Network* (http://www.ufrgs.br/nanocosmeticos/) created in 2005 and the *Nanobiosimes National Institute* (http://www.nanobiosimes.ufc.br/) created in 2009. Network with different levels of maturity where chosen in order to confront the differences and similarity of them across the years.

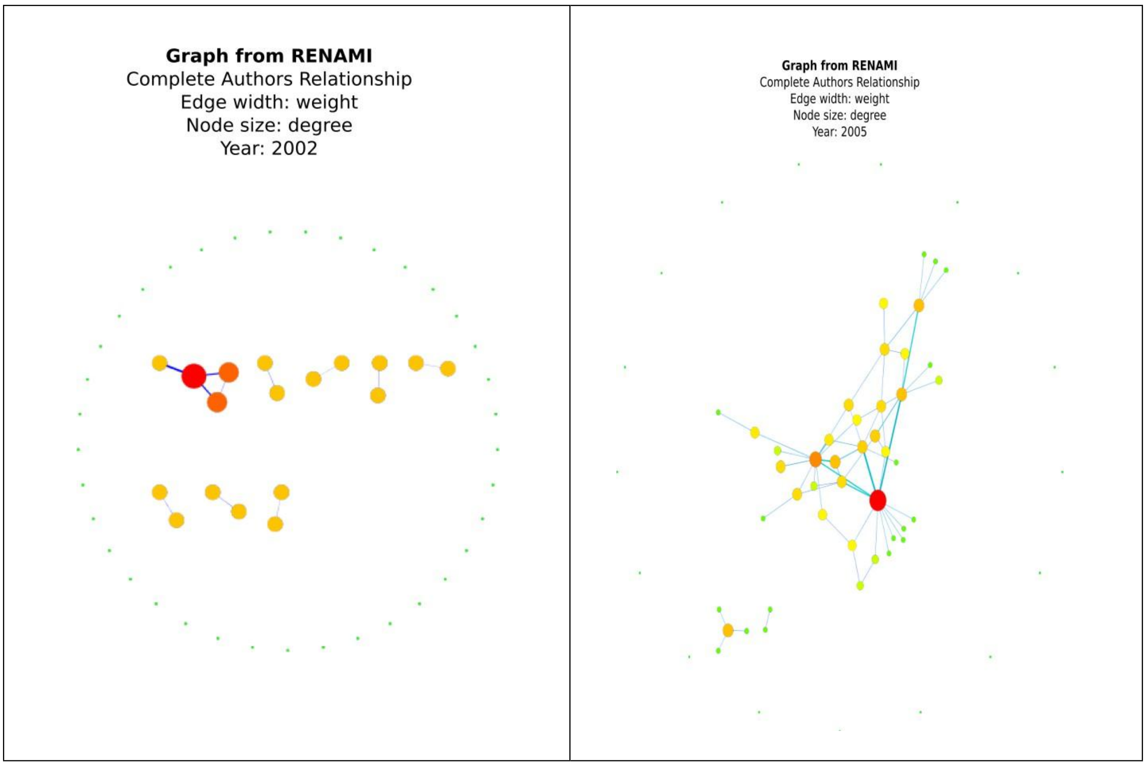
Following, it will be presented some graphs produced using the process presented in Section 4. These graphs are used as the basis from the networks evaluation. Figure 3 presents the RENAMI networks, considering the three productions analyzed (journal papers, patents and projects). The left graph presents the relations between researchers/authors and the right graph presents the relations between the institutions in the network.

Fig. 3 RENAMI network – Researchers' relationships (left) and Institutions' relationships (right)



RENAMI network: in Figure 3, the graph nodes represent the researches (left) and the institutions (right), each node representing one researcher or institution will be called actor. Bigger nodes mean actors with bigger production, and the edges represent the collaborative production between researchers or institutions. Thicker edges mean bigger weight between the two nodes. In this figure, it is possible to notice: the existence of isolated nodes, i.e., researchers that do not work with the other members of the network (in a future work, it will be studied the relations between these researchers and researchers outside the network); and there are many actors with weak relations with the rest of the network. When comparing these graphs with only the patents graphs, it is possible to notice the bigger integration in the network occurs among the actors who produce patents; the institutions are working in networks with few exceptions; and the centrality of the network is concentrated in a small number of actors, i.e., few actors are responsible for the majority of the productions.

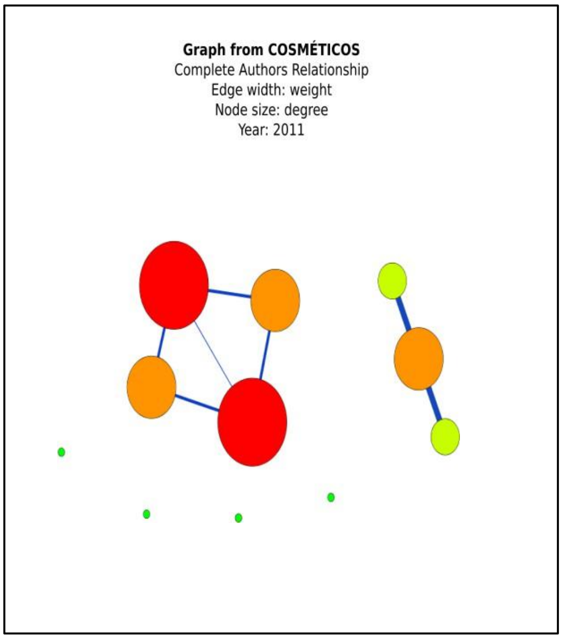
Fig. 4 Dynamics of RENAMI's network from 2002 to 2011

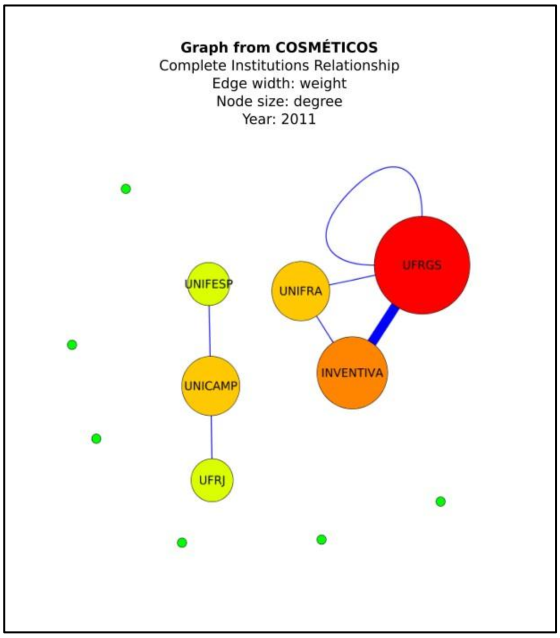


Analyzing the network along the years, it is possible to see the network evolution through the years: actors and sub-graphs that where disconnected of the network start to have relations with the network, increasing the network connectivity (See the figure 4). Even noticing that this network is not full connected; it is possible to say this network achieved a good level of maturity due the high productivity of the network and of its actors.

Nanocosmetics Network: this network is young and has only 13 main actors. 50% of them are isolated and the others are grouped in two groups. When analyzing the journal paper and patents networks it is possible to identify that the major integration involves the journal paper production, and the patents are produced by actors individually. Actually, these patents can be produced in a collaborative way by the authors, but they were declared individually in the curricula, thus, this information requires future investigation, eventually an extension of the network can identify new relationships that, indirectly, connect the authors of this network. In despite of the high productivity of the network, the collaborative production is still low, revealing a lack of integration among the actors. The maturity level of this network is not high, as showed in Figure 5.

Fig. 5 Nanocosmetics Network – Researchers' relationships (left) and Institutions' relationships (right)





Nanobiosimes Institute: in the Nanobiosimes Institute, the relationships among researchers occur, mainly, considering the production of journal papers and, in a smaller degree, considering the development of projects. The patents were created by the actors in and isolated way and, possibly, with external actors, meaning that, even increasing the size of the network; it will not be possible two identify indirect relationships among the actors inside the original network. Despite of the fact that it is a young network, it has a good integration of the authors considering the production of journal papers, but the integration in the patent production still have to increase. This information can be observed in Figure 6.

Finally, we use the data to show the interactions of the networks with other areas of research. In Figure 7, we present the distribution of research interest areas from the researches of the three networks evaluated in this paper and their co-authors (actors that does not belong to the network). These areas where extracted from the researchers and co-authors curricula. In this figure, it is important to note that 91% of the RENAMI's researchers and 73% of the Nanobiosimes' researchers work with Exact Sciences (Physics, Chemistry, Mathematics, etc.) or Engineering but only 26% of the Nanocosmetics' researchers work with these areas. On the other hand, 86% of the Nanocosmetics' researchers are interested in Biological and Health Sciences. It is also possible to note that, for each group, the co-authors interest areas are similar but broader then the interest areas from the researchers in the groups. These facts are predictable and were validated by the curricula's data.

Fig. 6 Nanobiosimes Institute – Researchers' relationships (left) and Institutions' relationships (right)

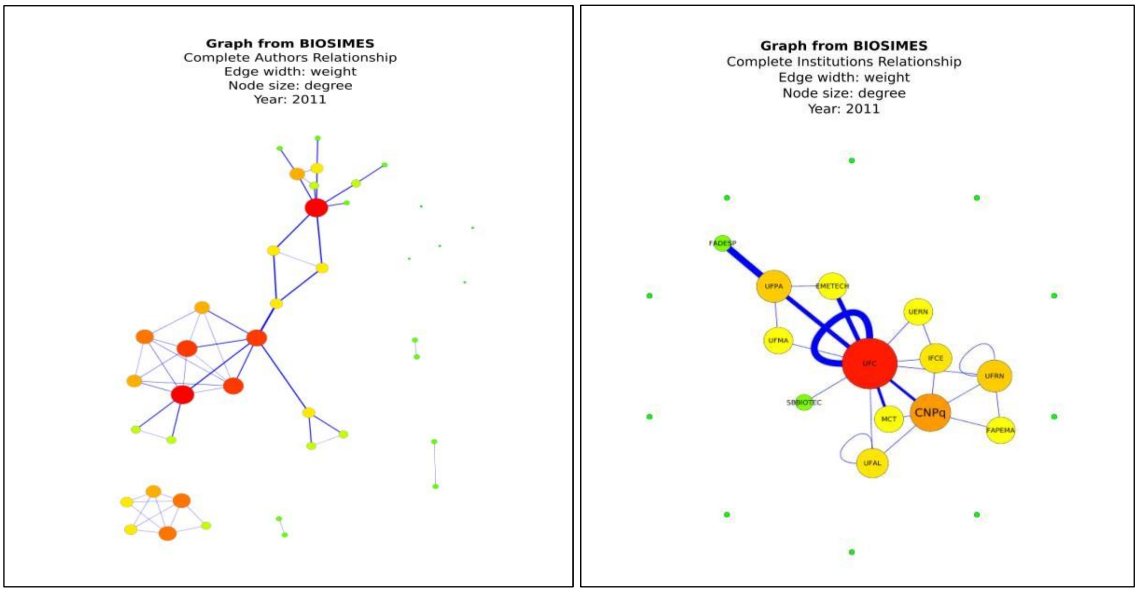
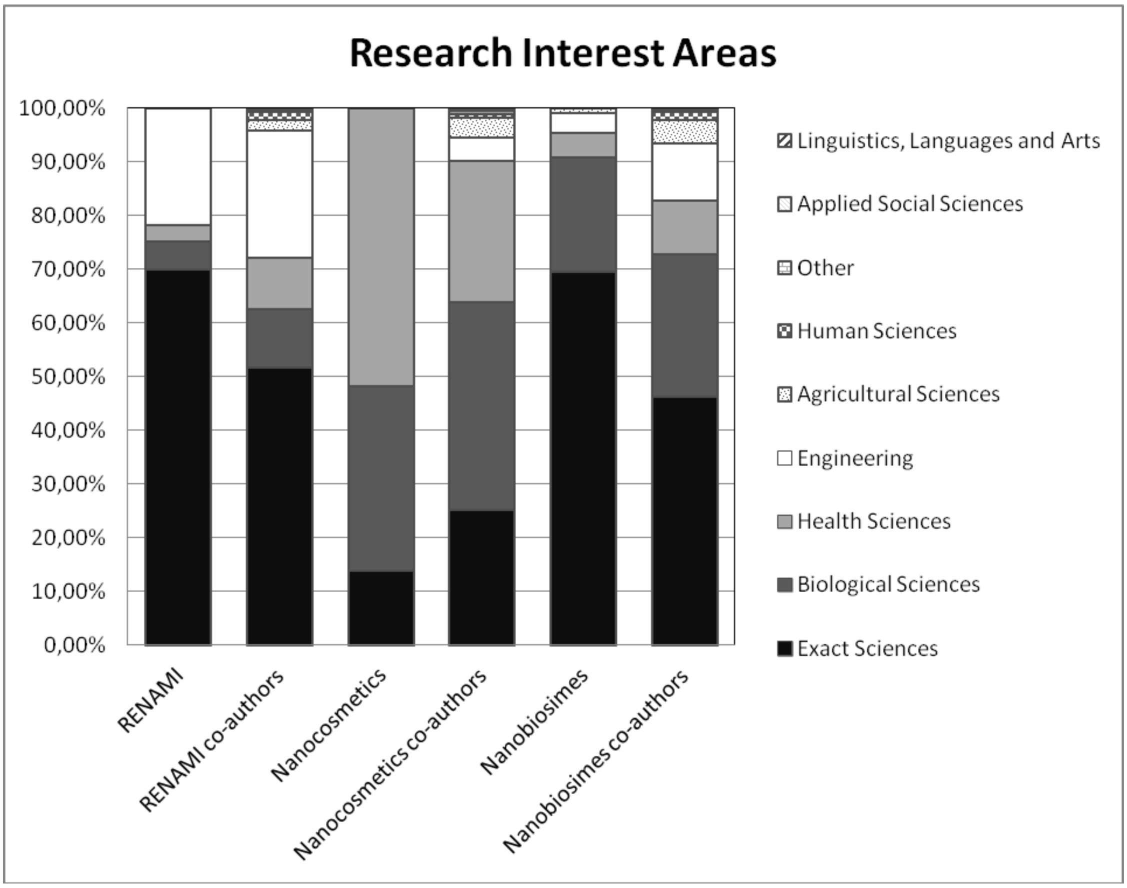


Figure 7 – Distribution of Research Interest Areas



7. Social network analysis related work

There are some similar researches that extract information from the CV-Lattes and make analysis of this information through social networking tools, but none has been used for the analysis of innovation networks in nanotechnology and specifically in Brazil. Among the existing studies are:

- Digiampietri and Silva (2011) featured a study and implementation of a system for the analysis of social networks of researchers. Curriculum Lattes were used for the identification of researchers' relationships. The results of the analysis of these curricula were combined with the criteria used by area committees of the CAPES (the Brazilian Coordination for the Improvement of People from Higher Education) for the evaluation of the publications of researchers. It brought greater automation to this process that is often carried out manually during the evaluation of graduate programs;
- Silva et al (2006) also conducted a study on a social network of research that focuses on the co-authorship network of teachers PPGC / UFMG (Graduate Program in Information Science at the Federal University of Minas Gerais) in order to identify characteristics inherent to

relationships between the actors involved in this network (network density and collaboration among different teachers from different lines of research);

- Mena-Chalco and Marcondes Junior (2009) developed an open source system called scriptLattes that starting from the Lattes database provides information, graphs / networks of collaboration and academic reports about groups of researchers. This tool is used by institutions like the University of São Paulo (USP), the Research Foundation of the State of São Paulo (FAPESP) and others;
- Finally, another study on the extraction of data from the Lattes curriculum is being developed by Alves, Yanasse and Soma (2009) and is related to the creation of an object- oriented API (Application Programming Interface) called Lattes Miner. The main objective of the tool is to allow the extraction of scholarly information through the web, to measure performance of researchers, professors and graduate programs.

8. Conclusions and future work

This paper deals with the problem of evaluating innovation networks. There were presented basic concepts about organizational networks, innovation and innovation networks. The paper introduced a discussion about the importance of evaluating innovation networks, specifically the public ones. These subjects, the evaluation of the performance of networks and, mainly, the innovation networks are still being disregarded in the literature, with few exceptions (Enkel; Gassmann, 2005, p. 7; Provan; Milward, 2001; Church, 2002; Vonortas, 2012; Pandza, 20122, Ziggers et al, 2010).

Although this panorama, it is emerging a growing interest for this theme, and for the definition of new models to evaluate networks and to monitor the evolution and production of the networks in real time (Enkel; Gassmann, 2005; Pandza, 2011; Alharakhia, 2012; Mangematin, 2012; Vonortas, 2012). Moreover, there are a new interest in the definition of innovation metrics (however with few researches in network metrics). In general, the metrics are based on traditional measures of inputs and outputs, without considering the detailed information about the network, such as the structure and dynamicity, characteristics very important in innovation networks. This paper presented the first version of the social network analysis based tool, which evaluates the collaboration among the members of the network and the network evolution. This tool is part of an ongoing project about an evaluation model of innovation networks and support tools. The tool was applied on some segments of the Brazilian network of nanotechnology, a strategic area to the development of the country. Among the results produced in this work, we highlight that, in the area of nanotechnology in Brazil, the sub-networks, or segments, are not so related. It was noticed that they're still in a growth stage and they are not yet mature or consolidated, with few exceptions. Only the network RENAMI has a very significant level of connectivity. As future work, the tool will be extended in order to evaluate aspects such as the influence of the network environment (the relationships between the network and external authors), the generation of well qualified human resources (master and PhD students), and start-ups. Another study that should be done is the introduction of semantic techniques (Mika, 2007) to analyze the production of researchers and suggest, for example, the link between actors working on related issues, this similarity could be implemented using ontologies (Staab, S.; Studer, R 2009). This could encourage the intellectual output of the network participants and resource sharing.

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8

Synergies across innovations obstacles in emerging economies: Evidence from chile

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Abstract

This research explores the effect of synergies across innovation obstacles on the inventive activity of Chilean manufacturers. Empirical analysis over the 2013-2018 period highlights the prevalence of two types of synergies: one comprising financial, network, knowledge and demand constraints and, another pairing regulatory obstacles to internal resistance to innovate. The presence of either set of obstacle synergy reduces the likelihood to innovate and weakens other innovation determinants such as R&D intensity, firm size, and the use of instruments for intellectual property protection. Firms accessing public support for innovation are found to respond differently from the rest. They tend to react to such constraints by tightening their scientific interaction with other private entities at the expense of links with public research institutions. Our results provide ample ground for policy making as they underscore avenues to jointly tackle innovation impediments while pointing out differences among various types of cooperative arrangements and flag the presence of innovation deterrents stemming from rigid policy settings.

Keywords*: Innovation Obstacles, Innovation surveys, Innovation policies, PCA, Chile.*

1. Introduction

This paper explores the mechanism by which financial and non-financial barriers to innovate can influence both firms' innovation determinants as well as their probability to pursue strategies for technological innovation (process and product innovation). Addressing the influence exerted by obstacle synergies over these processes, tackling endogeneity concerns that are derived from the link between impediments to innovate and scientific activity, in addition to studying the role played by government aid in mitigating such constraints herein encompass the three major contributions of this work.

Chile is regarded as a relevant case study given its outstanding performance as one of Latin America's inventive economy. According to ECLAC (2022), this country has not only consistently reported one of the highest R&D investment in the region (as a proportion of GDP) but has also stood out as the economy with the greatest scientific productivity in relation to their peers. A pooled sample of Chilean firms reporting information on their corresponding inventive activity from 2013 to 2018 comprises our main source of micro-level data for this empirical assessment.

Our general results are summarized as follows. In accordance with the outcome generated by a logistic principal component analysis, obstacles to innovate in Chile can be clustered around two groups: one batch highlighting interdependences across financial, knowledge, network and demand barriers and, a second one stressing complementarities between regulatory obstacles and factors linked to internal resistance to innovate. Multivariate probit regressions and additional correspondence analysis further corroborate these latter groupings.

The impact of these two groups of obstacles over propensity to pursue technological innovation is later examined in the context of a probit estimation. Acknowledging issues of reverse causality, our instrumental variable approach includes (as an exogenous predictor) a firm-level indicator for the intensity of impediments to innovate. Within this regression, each obstacle synergy is observed to negatively influence likelihood to innovate. Other innovation determinants also included in the regression (such as size and the use of intellectual property rights) seem to weaken their relevance for firms' inventive activity in the presence of either interrelation. Firm-level factors like R&D intensity and cooperative agreements with other private entities, on the other hand, are found to become inessential when the interdependence between financial, network, knowledge and demand barriers prevails.

Further insights are unfolded once we split our sample to separately consider firms with and without access to government aid for innovation. Despite the presence of synergies across obstacles, government funding and tax credits for R&D are empirically highlighted as pertinent policy tools nurturing private scientific interactions. Firms accessing these types of public support (SMEs with a lower-than-the-average R&D investment) and that face either group of impediments are able to heavily rely on cooperative projects with other private entities as a critical factor shaping its propensity for technological innovation. Nonetheless, additional room for policy intervention is here deemed as strongly necessary since, by the same token, cooperative agreements with public entities are found as an element negatively shaping probability to innovate regardless of obstacles synergies and access to government support.

This work is structured as follows. Section 2 outlines our conceptual framework on the elements that define interactions across obstacles to innovate. Section 3 describes our micro-level data for Chile, while section 4 introduces our empirical approach to identify groups of impediments. Section 5 presents our main econometric results on the impact of obstacle synergies over likelihood to innovate. Section 6 briefly discusses policy instruments for innovation in Chile and shows additional econometric results for the case firms accessing such type of public support. Section 7 concludes this research.

2. Conceptual framework

Firm's inventive outcome can be negatively affected by the presence of financial and non-financial constraints. Prohibitive costs and budgetary limitations on firms' cash flow account for the set of financial impediments, while knowledge, demand, market an even regulatory related restrictions comprise the non-financial ones.

Given the recent large-scale availability of innovation surveys, the impact of these impediments has been empirically analyzed in relation to various indicators of inventive activity. These comprehend the use of variables signaling the pursuit of technological innovation (product and process innovation strategies), the quest for the non-technological one (organizational and marketing), indicators of inventive performance (the percentage ratio of new products and services being sold at the market with respect to total revenue), measures for firms' willingness to engage on scientific effort (R&D investment) and even indicators for the extent through which such expenditures takes place inside the organization (the ratio of R&D to sales).

Blanchard et al. (2012) argue that the negative repercussions over innovation activity induced by either kind of obstacles can be particularly observed if the group of non-inventive firms is excluded from the corresponding sample being assessed. Concurring with these considerations, Pellegrino and Savona (2017) further expanded such quantitative appraisal. They created a subsample of potential innovators which not only focused on firms aiming to innovate but that also filtered out for those units that struggled to engage on inventive efforts. By following this approach, these authors were then able to stress on the relevance of non-financial constraints. Market related barriers (such as concentrated market structure and lack of potential consumer demand) were identified as being as detrimental for innovation as the respective negative effect generated by financial constraints.

Two recent empirical studies make a case for obstacles to innovate in Chile. On the one hand, Ortiz and Fernandez (2022) explored the individual impact of impediments over the execution of different innovation strategies for a sample of firms comprising the agricultural, mining, manufacturing and services sector from 2006 to 2017. According to their results, financial restrictions stand as the single barrier with the highest negative influence over process innovation, while market and demand impediments play a more active role in discouraging product as well as organizational strategies. Knowledge, market and demand obstacles prevail as elements negatively configuring marketing innovation.

On the other hand, also with regard to Chile, Zahler et al. (2022) further emphasized the predominance of financial and demand barriers as the most detrimental factors reducing likelihood to innovate. In line with their findings, other particular impediments negatively shaping technological and non-technological innovation (such as knowledge constraints) only seem to become significant once these financial and demand constraints are explicitly excluded from the econometric regression. Just like the previous study, these authors focused on every major sector of economic activity in the country (including primaries and mining) but restrict their analysis to the years between 2009 and 2016.

In our view, despite such pertinent results, three central elements also configuring innovation constraints seem to not have been comprehensively explored thus far. These include the interdependence across different types of obstacles and their corresponding joint impact over scientific activity, the potential endogeneity (reverse causality) governing the interaction between such impediments and inventive outcomes, as well as the expected role of government aid in alleviating the negative repercussion that stem by the presence of those constraints.

Given their specific features, innovation obstacles tend to reinforce and complement one and other. For instance, the lack of qualified personnel can be tightly linked to insufficient financial funds. Such scarcity of knowledge and expertise can even allow for a growing uncertainty with respect to the potential resulting demand for the firms' inventive outcome. Shedding light on these synergies across innovation barriers is of high relevance as it underscores the need to devise policy instruments that seek to jointly tackle their complementarities instead of approaching them individually.

While carrying out Principal Component Analysis (PCA) and additional econometric tests, Mohnen and Rosa (2002) determine a number of complementarities among the set of innovation impediments faced by French firms within the service sector. These include the presence of high interdependences across barriers pertaining to economic risks (issues of appropriability, feasibility and marketing), strong correlations between the shortage of qualified labor and the unavailability of special machinery and equipment, as well as important linkages between internal resistance to innovation and administrative procedures, just to name a few.

Galia and Legros (2004) pursued a similar empirical assessment to determine potential synergies across those obstacles that induce either the suspension or deferment of scientific projects. In consonance with their correspondence analysis, the postponement of inventive projects can originate due to complementarities between organizational rigidities and information shortages as well as by the interdependences combining economic risks and sources of finance, among others. Synergies pairing lack of skilled workers and financial risks coupled with complementarities pertaining to institutional inflexibility and limited customer responsiveness seem to make a case for the decision to abandon projects.

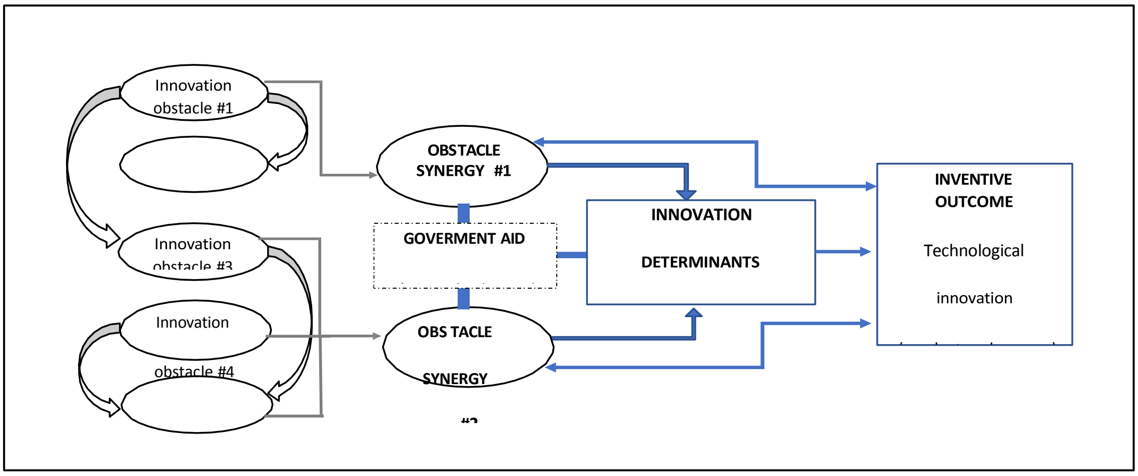
Previous research has already underscored the idea that obstacles of any sort are likely to be endogenous on their relationship with innovation. For instance, Savignon (2008) argued that financial obstacles can lower the probability to execute scientific projects in the same way as innovative activity might induce economic difficulties for the firm. The same could be implied for other innovation barriers such as scarcity of expertise or inability to cooperate. Limited innovation capabilities might not only seriously compromise firms' competences to effectively exchange intangible knowledge but also undermine their participation on inventive projects with other key players operating elsewhere. Bivariate probit models and instrumental variable regression encompass the econometric tools that have been primarily utilized to correct for the above-mentioned endogeneity of innovation constraints.

A final note regards to the role of government aid. Policy instruments like direct access to public resources along with the granting of tax credits for R&D can too be considered as additional elements influencing impediments to innovate. In our view, they can do it so by strengthening the relevance of innovation determinants (say R&D intensity) on top of alleviating (or even suppressing) the adverse consequences that are observed in the presence of these restrictions. Nevertheless, to the best of our knowledge, the extent through which those instruments of public support can actively participate over these processes has not yet been empirically explored.

Having introduced these general discussions, we now proceed to outline the conceptual framework that will govern our quantitative appraisal as well as define our empirical expectations. Such scheme is herein briefly summarized in figure (1).

As a result of persisting synergies with one and other, individual financial and non-financial obstacles to innovate can also jointly burden firms' inventive activity. To evaluate the effect exerted by those synergies, groups comprising various individual barriers can be formed conditional on their attributes and the specific nature of their interdependence. Financial, knowledge and cooperation impediments might, for instance, be clustered around a single category since low cash flows tend to limit the acquisition of skilled labor thus eventually obstructing ability to cooperate with other enterprises. The same analogy results compatible for the rest of obstacles. The sole presence of such complementarities is herein foreseen to influence innovation activity by way of two channels; a direct impact over propensity to innovate and, an indirect one affecting other firm-level determinants of innovation (R&D intensity, size, instruments of intellectual property and, so forth). Following existing literature, we expect the direct impact to negative shape likelihood to innovate. With regard to the indirect one, we predict an ambiguous result. Depending upon the specific features of innovation determinants, the presence of obstacle synergies might either increase (or diminish) their importance over firms' probability to pursue scientific outcome.

Figure (1): Conceptual framework on the impact of obstacle synergies on innovation determinants and inventive outcome



Source: Authors

Access to public support for R&D is herein anticipated to act as an element mitigating the effects triggered by innovation constraints. These could be observed either by a reduction (or even suppression) of the above mentioned direct and indirect effects.

Endogeneity issues are to be reckoned and remedied within this framework given evident concerns of reverse causality between innovation activity and their respective obstacles. An instrumental variable approach is then deemed as highly necessary to properly validate the ideas and conclusions posed by this work.

3. Data

Chilean innovation surveys biannually divulged by the country's statistical office *(Instituto Nacional de Estadísticas, INE)* consitute our main source of micro-level information. Such datasets report a large number of innovation related variables including predominant type of innovation strategy being pursued (product, process, organizational and marketing), composition of R&D expenditures, availability of skilled workers, individual obstacles to innovate being faced by firms, policy instruments to support scientific activity, among others.

Our research will rely on a recent pooled sample of firms (generated by INE) which contains standardized micro data from the 9th, 10th and 11th waves of the country's innovation datasets and that range the period between 2013-2018. Aside from addressing a more recent and shorter time span, our research differs too from the recently advanced works on Chile in that we solely focus on the dynamics within the manufacturing sector.

In line with the general guidelines outlined in our conceptual framework, a subsample of inventive firms is hereby produced. Following Blanchard et al. (2012) and Pellegrino and Savona (2017) we filtered out the initial pooled of Chilean firms sample to solely consider those entities reporting innovation activities of any sort, that had ongoing or abandoned scientific projects and that have also faced at least one obstacle to innovate over time. Firms not meeting either of these criteria were then explicitly excluded from the analysis.

4. Complementarities across impediments to innovate.

As per the information provided within our innovation surveys, economic units in Chile face the follow set of constraints on their inventive activity;

- Financial obstacles (FINOBS) which are comprised by the lack of internal and external sources of funding as well as by prohibitive cost to innovate.
- Knowledge obstacles (KNOBS) which resemble shortage of highly skilled labor and insufficient firms' awareness with respect to available technologies and current market trends.
- Network obstacles (NETOBS) highlighting inability to cooperate on scientific projects with other entities.
- Demand obstacles (DEMOBS) that relate to the market predominance of well-established producers and the resulting uncertainty on the future potential demand of given inventive outcome.
- Regulatory obstacles (REGOBS) signaling bureaucratic burdens and excessive administrative procedures to formalize R&D projects.
- Other general obstacles (OTHER) comprehending the lack of interest to innovate due the prevalence of already well-functioning solutions and/or the absence of a specific market niche to position an invention.

As can be observed, correlation table (1) reveals a high level of complementarities across two groups of individual obstacles: one important association between financial, knowledge, network and demand barriers and, a second interdependence connecting regulatory constrains and other general impediments to innovate. In order to formally aggregate these latter correlations into general categories of obstacle synergies, our research executed a Logistic Principal Component Analysis (LPCA). This statistical technique is here implemented as it represents a unique data reduction method when binary information is only available. This is our particular case given the fact that obstacles to innovate in Chile are solely reported using a dummy variable format.

Table (1). Correlation between obstacles to innovate

	FINOBS	KNOBS	NETOBS	DEMOBS	REGOBS	OTHER
FINOBS	1					
KNOBS	**0.565**	1				
NETOBS	**0.476**	**0.542**	1			
DEMOBS	**0.544**	**0.509**	**0.454**	1		
REGOBS	0.313	0.323	0.394	0.374	1	
OTHER	0.208	0.244	0.243	0.303	**0.452**	1

Computed correlation used pearson-method with listwise-deletion.

The main results from our LPCA approach are shown in table (2). For the ease of simplicity, we only introduce the first two components generated by this analysis, their corresponding cumulative variance, along with the respective loadings reported by individual obstacles within each of these two dimensions. As anticipated, and in line with those loadings, we observe that financial, knowledge, network and demand can indeed be aggregated into a single category (here labeled as "OBS1"), while regulatory and other type of obstacles are also clustered around a second tier (here named "OBS2"). Also in line with these results, we note that components OBS1 and OBS2 are able to explain a large proportion of the variability across individual impediments to innovate given the fact that their joint percentage of cumulative variance is found to be of nearly 70%.

	Table (2). Logistic PCA	
Obstacle	**OBS1**	**OBS2**
FINOBS	**0.197**	0.157
KNOBS	**0.204**	0.116
NETOBS	**0.189**	0.015
DEMOBS	**0.201**	0.074
REGOBS	0.111	**0.317**
OTHER	0.098	**0.321**
PDE	**0.51**	**0.69**

To more accurately validate the main results derived from our logistic PCA method, a few supplementary analyses are next provided. These will seek to further justify our choice to merely utilize the first two LPCA components as well as better corroborate the grouping of individual obstacles there contained.

Standard PCA methodology typically exhorts scholars to only utilize those PCA dimensions whose eigen values are found to be higher than 1 (the Kaiser criterion). Nevertheless, since the LPCA approach does not report such information, our research decided to validate our choice for two dimensions through the execution of multiple correspondence analysis. This particular method follows the same rationale behind standard PCA and is too well suited to account for the presence of binary observations. The resulting associations across innovation barriers that stem from the correspondence analysis are introduced in figure (2) through a coordinate plot.

Figure (2). Multiple correspondence analysis: coordinate plot of binary responses to innovation impediments

From such a graph, we detect a clear pattern whereby different responses to innovation barriers tend to be clustered together. Positive and negative answers over financial, knowledge, demand and network constraints form a respective group of their own. This pattern is too observed when other and regulatory barriers are examined. Even more so, the cumulative variability explained by each dimension within this figure accounts for nearly 100% of the total variance across impediments. Therefore, based on these additional results, we uphold our decision to solely rely on the first two general components generated by our logistic PCA approach (OBS1 and OBS2).

Our final appraisal to corroborate interdependences across innovation barriers relates to an additional correlation assessment through the implementation of Multivariate Probit Analysis (MVP). This econometric procedure entails examining the resulting correlation between generalized residuals that originates after individually regressing each impediment to innovate with respect to common explanatory variables. Following Galia and Legros (2004) and Mohnen and Rosa (2002), we conducted our MVP analysis based on the next set of independent regressors: size, type of ownership (domestic or foreign owned), general type of R&D expenditures (intra-mural and extra-mural), presence of cooperation agreements with other firms, and existence of training activities for workers. Appendix A.1 outlines the operationalization of each variable employed on these regressions along with their respective descriptive basic statistics. Conversely, appendix A.2 shows the main MVP econometric results.

Table (3) introduces the resulting correlation across generalized residuals singly reported per innovation obstacle. As can be inferred, our initially presumed interdependence across two main groups of obstacles (one batch comprising financial, knowledge, network and demand barriers and a second group connection regulatory and other constraints) still prevails even when the effect of various explanatory variables over each individual barrier is accounted for.

Table (3). Disturbance covariance matrix derived from MV Probit regression: all inventive firms

	FINOBS	KNOBS	NETOBS	DEMOBS	REGOBS	OTHER
FINOBS	1					
KNOBS	0.379	1				
NETOBS	**0.466**	**0.486**	1			
DEMOBS	**0.484**	**0.428**	0.384	1		
REGOBS	0.351	0.210	0.379	0.401	1	
OTHER	0.196	0.144	0.316	0.281	**0.529**	1

Computed correlation used pearson-method with listwise-deletion.

Complementarities comprising components OBS1 and OBS2 thus constitute the two main type of obstacle synergies influencing innovation activity across Chilean manufacturers. The rationale behind the interactions contained in OBS1 stand as straightforward. Tight monetary resources largely explain the inability to acquire skilled labor (which also prevents firms to effectively exchange tangible and intangible knowledge with other entities) thus resulting on an increasing unawareness with regard to the pressing trends in consumer demand. On the other hand, the logic behind the interaction between regulatory impediments and obstacles pertaining to internal resistance to innovate deserves a more detailed explanation. Excessive and rigid bureaucratic procedures that seek to regulate and promote R&D activity might also dissuade firms' intention to pursue inventive projects within its own area of expertise. For instance, limiting public support for R&D to a few priority sectors (explicitly excluding risky projects as well as those that provide alternative solutions to already existing industry-level problems) might induce firms to not intend innovation activities as they neither operate nor possess the necessary skills to engage on those publicly supported sectors. In this way, regulatory obstacles can further contribute to internal resistance to innovate as they intend to foster private R&D investment in areas outside the immediate competence and interest of given firms.

5. Econometric analysis

This section depicts our econometric strategy to describe the impact of innovation determinants and obstacles synergies over firms' likelihood to innovate. A dummy variable signaling either the presence of product or process innovation strategies (i.e., technological innovation) represents our dependent variable. As independent predictors, we include the following variables that typically configure firms' inventive activity: R&D intensity, informal methods of intellectual property (IMIP), size, cooperation agreements with other private firms (COF), as well as the existence of collaborative projects with other research institutions (CREO). Appendix A.3 shows descriptive statistics along with the respective operationalization of each of these regressors.

Logistic PCA scores for components OBS1 and OBS2 are too included within our probit regression. Such scores were generated in the last empirical section and, thus, embody the firm-level effect of existing synergies across financial, knowledge, network and demand obstacles (OBS1) as well as that between regulatory constraints and other obstacles to innovate (OBS2). In order to gain additional insights over the effect exerted by such synergies, our research will conduct four different probit estimations: a pure regression model exclusively examining innovation determinants; a second and a third model now including the impact of synergies OBS1 and OBS2, respectively, and; a fourth probit estimation accounting for the simultaneous presence of these two.

In light of endogeneity concerns derived from the relationship between barriers to innovate and inventive activity, an instrumental variable approach will be followed for the case of the probit regression models 2 to 4. As an instrument, we will compute an indicator initially proposed by Zahler et al. (2022) which seeks to capture the exogeneity of innovation barriers. Given the fact that innovation constraints can vary depending on geographical, sectoral and time-related factors, these authors built an empirical measure for the average intensity of these barriers that explicitly incorporates such considerations. Our research, nonetheless, slightly adapted this indicator to only consider groups of obstacles according to their above-described complementarities. Appendix A.7

formally introduces the construction of this latter instrument along with our proposed alteration.

Table (4) presents our econometric results. Following previous argumentations, column (1) refers to our pure model, while columns (2) to (4) denote instrumental variable regressions[1]. Year and sectoral dummies are included on each respective specification. By observing column (1), it can be concluded that in the absence of innovation obstacles, nearly all of the independent regressors there considered positively increase likelihood to execute technological innovation. Cooperation agreements with other research institutions (CREO) represents the sole exception since it reports a negative but non- significant coefficient.

As per the ideas set by our conceptual framework, direct and indirect effects stemming from the inclusion of obstacles synergies are largely observed. Since either obstacle complementarity studied in columns (2) and (3) shows a statistically negative coefficient, we confirm the direct detrimental role that these two play in reducing likelihood to innovate. The expected unambiguous indirect effect over innovation determinants that is derived from the presence of OBS1 and OBS2 also prevails. For instance, according to column (3), existing complementarities between regulatory factors and internal resistance to innovate seem to reduce the relevancy of R&D intensity, IMIP, size, and private cooperative agreements as elements positively shaping technological innovation. These latter synergies embodied in OBS2 appear likewise to heighten the negative impacted exerted by collaborative projects with research institutions.

Complementarities between financial, market, knowledge and network barriers (OBS1), on the other hand, are perceived to yield a more profound effect. Due the inclusion of these synergies in column (2), size and instruments of intellectual property remain as the sole statistically significant determinants of technological innovation when compared to initial pure model introduced in column

(1). The influence that synergy OBS1 exerts over these two, nonetheless, does not seem to be homogenous since the size variable is now perceived of higher relevance while the initial positive effect of intellectual property is reduced. Such situation seems to largely persist even when both groups of obstacles synergies (OBS1 and OBS2) are simultaneously accounted for (column 4). In addition, as too predicted by our conceptual, financial obstacles (here embodied in OBS1) can indeed come across as elements offsetting the respective impact induced by other less detrimental barriers. This is empirically confirmed by the fact that the corresponding coefficient for OBS2 is found as non- significant once synergies in OBS1 are also incorporated in regression output at column (4).

Table (4). Instrumental variable probit regression elements influencing likelihood of technological innovation

DV: Technological innovation	(1)	(2)	(3)	(4)
R&D_intensity	0.074***	0.001	0.049**	0.001
	(0.02)	(0.01)	(0.01)	(0.01)
IMIP	0.411***	0.335***	0.326***	0.336***
	(0.12)	(0.09)	(0.09)	(0.09)
Size	0.109***	0.137***	0.071**	0.137***
	(0.03)	(0.02)	(0.02)	(0.02)
COF	0.668***	0.165	0.573***	0.156
	(0.13)	(0.09)	(0.10)	(0.09)
CREO	-0.256	-0.204	-0.404***	-0.182
	(0.15)	(0.10)	(0.11)	(0.11)
OBS1		-0.184***		-0.185***
		(0.00)		(0.01)
OBS2			-0.200***	0.018
			(0.01)	(0.01)
Constant	0.035	-0.831***	0.685***	-0.895***
	(0.16)	(0.14)	(0.14)	(0.15)
Pseudo R^2	0.063	--	--	--
Wald test (Chi^2)	--	201	113	219
Wald test (p-value)	--	0.000	0.000	0.000
Cragg-Donald(F-st)	--	75.464	192.076	40.913
Sectoral dummies	YES	YES	YES	YES
Year dummies	YES	YES	YES	YES
Observations	1,531	1,531	1,531	1,531
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$				

6. The role of public support for innovation

Direct financial provisions and tax credits comprise the main policy instruments to support private inventive projects in Chile. Monetary resources for innovation are granted through a wide array of government schemes conditional on performance and on the fulfillment of program specific pre-requisites. Some of the major public sponsors for this type of investment include Chile's Economic Development Agency (CORFO), the country's Innovation Authority (CONICYT), government programs targeting the development of the agro-industrial and fishery sectors (FIA and FID, respectively), as well as the support provided by centers for excellence research under the framework of the Millennium Scientific Initiative (ICM). On top of this, Chile's R&D law provides a 35% tax credit for firms pursuing R&D investment, which is therein computed considering such entities' total inventive expenditure over a given year. Economic units engaging on collaborative projects with other domestic or foreign owned firms are particularly eligible for these types of fiscal credits.

Since our innovation surveys contain information on each of the recently advanced lines of financing for innovation, we decided to split our initial sample of inventive enterprises in Chilean manufacturing to separately account for those with and without access to such government aid. Entities within our dataset that report receiving either type of R&D grant or tax credit are regarded as publicly supported firm, while the opposite will hold for enterprises reporting none of the above.

Information per type of public support considering size, R&D intensity and inventive strategy is herein introduced through appendix tables (A.4) to (A.6). As can be observed, public schemes advocating private R&D investment in Chile have mainly targeted small and medium sized firms that mostly followed a combination of product and process innovation strategies and, that generally scored a lower-than-the-average R&D intensity. In comparison, our sub-sample without public aid is primarily comprised of medium-sized and large firms mostly pursuing other general strategies (marketing and organization) with a relatively higher-than-the average R&D to sales ratio.

Table (5) shows our econometric results for the influence of government aid over obstacle synergies and innovation determinants. Panel (a) reports regression output for the case of firms accessing R&D grants and fiscal credits, while panel (b) shows the corresponding results for entities without such support. Within each respective panel, columns (1) to (4) follow the same logic as initially described in table (4).

For the case of publicly supported firms, in the absence of innovation obstacles, probability to innovate is exclusively affected by size (column a.1). Even though policy instruments for innovation were previously described to mainly target SMEs, firms of larger size appear to be the ones widely benefiting from such aid when no constraints to inventive activity are being considered. This latter effect, nonetheless, does not seem to prevail as we shift our analysis to the next immediate columns in panel (a).

Two innovation determinants show highly contrasting effects once obstacles synergies are included in these regressions. Firms accessing government aid seem to increase their interaction with other private entities at the expense of limiting their links with public research institutions. On the one hand, in line with columns (a.2) to (a.4), we observe that regardless of the occurrence of either obstacle synergy, publicly supported firms tend to primarily rely on private cooperative agreements as the predominant element influencing their propensity to perform technological innovation.

This latter outcome can be indubitably linked to the specific requirement set by the Chilean government whereby firms eligible for tax credits are explicitly asked to engage on collaborative projects with other private entities as a condition to access this type of support.

On the other hand, cooperative projects with public institutions are found to reduce probability to innovate across the same sub-sample of firms. When compared to the baseline regression (column a.1), the presence of obstacle synergies appear to accentuate the negative of effect of CREO since their respective coefficients (being shown at columns a.2 to a.4) tend to become more profound and statistically significant. Factors related the persistence of bounded innovation capabilities across public institutions (which prevents them from successfully commercializing scientific output) coupled with the presence of government incentives that seek to prioritize collaboration among private agents unequivocally explain these issues.

Table (5). Instrumental variable probit regression elements influencing likelihood of technological innovation.

	Panel (a): Firms with access to public support				**Panel (b): Firms without access to public support**			
DV: Technological innovation	**(a.1)**	**(a.2)**	**(a.3)**	**(a.4)**	**(b.1)**	**(b.2)**	**(b.3)**	**(b.4)**
R&D_intensity	0.079	-0.051	0.016	-0.068	0.079***	0.009	0.054**	0.009
	-0.05	-0.05	-0.04	-0.04	-0.02	-0.02	-0.02	-0.02
IMIP	0.501	0.217	0.399	0.268	0.440***	0.384***	0.314**	0.389***
	-0.3	-0.2	-0.2	-0.2	-0.13	-0.1	-0.11	-0.1
Size	0.263***	0.123	0.001	0.084	0.087**	0.140***	0.068**	0.140***
	-0.07	-0.07	-0.06	-0.06	-0.03	-0.02	-0.02	-0.02
COF	0.453	0.491*	0.720***	0.565**	0.742***	0.113	0.571***	0.11
	-0.29	-0.23	-0.2	-0.21	-0.16	-0.10	-0.12	-0.1
CREO	-0.142	-0.421*	-0.635***	-0.539**	-0.394*	-0.115	-0.517***	-0.088
	-0.29	-0.21	-0.19	-0.2	-0.19	-0.14	-0.15	-0.14
OBS1	-0.203***			-0.206***		-0.182***		-0.184***
	-0.01			-0.01		-0.01		-0.01
OBS2			-0.290***	-0.057			-0.189***	0.022
			-0.01	-0.04			-0.01	-0.02
Constant	-1.031	-1.409***	0.938**	-1.098**	0.244	-0.753***	0.737***	-0.827***
	-0.41	-0.32	-0.33	-0.39	-0.18	-0.16	-0.16	-0.17
Pseudo R^2	0.204	--	--	--	0.058	--	--	--
Wald test (Chi^2)	--	40	72	133		172	86	183
Wald test (p-value)	--	0	0	0		0.00	0	0
Cragg-Donald(F-st)	--	15.508	20.338	10.614		64.835	162.139	34.506
Sectoral dummies		YES	YES	YES	YES	YES	YES	YES

Year dummies		YES	YES	YES	YES	YES	YES	YES
Obs.		241	241	241	1290	1290	1,290	1,290

Following the same stream of ideas, we also observe that, despite particularly targeting firms with lower-than-the-average inventive expenditures, access to government aid does not seem to increase the relevancy of R&D intensity on propensity to innovate. Instruments of intellectual property are not deemed either as pivotal elements for technological innovations by these publicly supported entities.

Finally, for the case of enterprises not receiving government incentives for innovation (presented at panel b), we note no major discrepancies with respect to trend initially described on table (4) which corresponds to the entire sample of Chilean manufacturing inventive firms. Complementarities across innovation obstacles tend to reduce propensity to innovate (direct negative effect) and, in most cases, they also weaken the statistical significance of innovation determinants (indirect ambiguous effect). Barrier synergies under component OBS2 are too offset by the interplay between financial, knowledge, market and network impediments to innovate.

7. Conclusions and points for discussion

This paper aimed to evaluate the mechanism through which innovation activity is negatively affected by the presence of impediments to conduct scientific activity across Chilean manufacturers. Previous research has extensively addressed this issue by exclusively focusing on the individual impact from given obstacles to innovate. Our empirical work deviates such from existing literature in that we consider the role played by obstacle complementarities in conditioning innovation determinants as well as likelihood to innovate. These analyses were herein performed through the lenses of a recent pooled sample of inventive enterprises which was compiled and produce by Chile' Statistical Office for period 2013-2018. Our general conclusions can be summarized as follows.

Financial, network, knowledge and market barriers (OBS1) reinforce one and other and, thus, they can jointly discourage innovation outcome. Inventive activity can also be daunted by virtue of the high interdependence between regulatory restrictions and factors pertaining to internal resistance to innovation (OBS2).

While the sole presence of these two synergies directly reduces propensity to pursue technological innovation (process and product innovation strategies), their indirect effect over innovation determinants appears as less straightforward. Firm-level factors such as size and the use of instruments for intellectual property protection still positively influence innovation regardless of the presence of either obstacle synergy. R&D intensity and the existence of inventive projects with other private firms only seem to become essential when the complementarities under OBS2 are only considered. Cooperation activities with other research institution come across as an element severely discouraging likelihood to innovate also in the sole presence of this latter interdependence. Even in the simultaneous presence of OBS2, the direct and indirect effects exerted by constraints in OBS1 are found to largely prevail over innovation propensity and their determinants.

Splitting the sample of inventors between firms with and without access to government aid allowed us to unravel additional insights with respect to the indirect effect over innovation determinants that is generated from the occurrence of such complementarities. Firms eligible for R&D tax credits (or that receive some sort of public funding for innovation) tend to heavily rely on private cooperation agreements as the single critical element positively shaping its probability to conduct technological innovation regardless of the incidence of any synergy. Such interesting empirical conclusion can be explained by a specific policy measure devised by the Chilean government whereby firms accessing public support for innovation are required to engage on scientific projects with other privately owned economic units.

Nevertheless, as a potential side effect, access to government aid also seems to conversely discourage collaborative projects between inventive private firms and public institutions. These specific types of cooperative agreements are found to negatively condition private scientific activity in the presence of any type of obstacle synergies and regardless of the granting of public support.

Finally, with regard firms to without government aid for innovation, we noted that their response to synergies across impediments largely resemble the direct and indirect mechanism initially described for the case of all inventive Chilean firms.

Beyond recommendations to jointly tackle innovation obstacles in accordance with the potential complementarities here outlined, this empirical work also underscore the need to better adapt existing policy incentives to not only target private agents but also other relevant public entities operating within the country's national system of innovation. Government aid for innovation in Chile should not merely prioritize increasing collaboration across private entities but also aim for a closer interaction of these with public research institutions. As it the case for the average developing economy, such institutions produce and absorb the vast majority of highly qualified labor and execute most of the R&D investment in the country. Including incentives for scientific collaboration between public and privately owned entities as part the general conditions to access government aid will surely reinforce scientific research across wider segments of the national innovation system and even assist on the country's efforts to boost private R&D investment.

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Appendix

Table A.1. Descriptive statistic and operationalization of the variables included on the Multivariate probit regression.

.Variable	Name in regression	Mean	Std. Dev.	Coef. Var.	Max.	Min.	Operationalization
Financial obstacles	FINOBS	0.79	0.41	0.52	1.0	0.0	Binary variable for the presence of limited monetary resources, lack of external funding and occurrence of prohibitive costs.
Knowledge obstacles	KNOBS	0.73	0.44	0.61	1.0	0.0	Binary variable for the lack of qualified personnel as well as shortages of technical and market knowledge
Network obstacles	NETOBS	0.58	0.49	0.85	1.0	0.0	Binary variable for the occurrence for the lack of cooperation agreements
Demand obstacles	DEMOBS	0.72	0.45	0.63	1.0	0.0	Binary variable for the existence of market- related uncertainties such as target market being dominates by well-established producers
Regulatory obstacles	REGOBS	0.38	0.48	1.29	1.0	0.0	Binary variable for the presence of regulatory difficulties
Other type of obstacles	OTHER	0.43	0.50	1.15	1.0	0.0	Binary variable of the presence of lack of prospective demand for innovation outcome and the existence of well-functioning solutions
Size	Size	3.81	1.41	0.37	9.68	0.00	Total labor employed by the firms
Multinational firm	MNE	0.10	0.30	2.99	1.0	0.0	Binary variable for the presence of foreign owned investment inside the firm
R&D intra-mural	R&D intra-	0.69	0.46	0.67	1.0	0.0	Binary variable for presence of intra-

	mural						mural R&D.
R&D extra-mural	R&D extra-mural	0.39	0.49	1.26	1.0	0.0	Binary variable for presence of extra-mural R&D.
Cooperation activities	Cooperation	0.19	0.39	2.04	1.0	0.0	Binary variable existence of cooperation activities with other firms or institutions
Training activities	Training	0.20	0.40	2.02	1.0	0.0	Binary variable for the execution of training activities for the improvements of skills within the organizations

Table A.2. Multivariate Probit regression: all inventive firms

	(1) FINOBS	(2) KNOBS	(3) NETOBS	(4) DEMOBS	(5) REGOBS	(6) OTHER
Size	-0.096*	-0.147***	-0.053	-0.047	-0.029	-0.101**
	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)
MNE	-0.083	-0.416**	-0.550***	-0.393**	-0.046	0.155
	(0.14)	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)
R&D intra-mural	-0.152	-0.017	0.288*	0.180	0.174	-0.304*
	(0.14)	(0.13)	(0.12)	(0.13)	(0.12)	(0.12)
R&D extra-mural	-0.044	-0.142	0.055	-0.209	-0.174	-0.197
	(0.14)	(0.13)	(0.12)	(0.13)	(0.12)	(0.13)
Cooperation	0.213	0.283*	-0.461***	-0.120	-0.038	0.300*
	(0.14)	(0.13)	(0.12)	(0.13)	(0.11)	(0.12)
Training	0.009	-0.072	0.061	0.277*	0.059	0.080
	(0.12)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)
Constant	1.545***	1.533***	0.560***	0.949***	-0.131	0.181
	(0.19)	(0.18)	(0.15)	(0.16)	(0.15)	(0.16)
Observations	720	720	720	720	720	720

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table (A.3). Descriptive statistics and variables included on the instrumental variable regression.								
Variable	**Name in regression**	**Mean**	**Std. Dev.**	**Coef. Var.**	**Variance**	**Max.**	**Min.**	**Operationalization**
Technological innovation	tech inno	0.15	0.35	2.41	0.13	1.00	0.00	Binary variable accounting for the presence of product or process innovation strategies
R&D intensity	R&D_inten	8.42	2.21	0.26	4.88	13.76	-0.62	The ratio of R&D expenditures to firms' sales
Informal methods of intellectual property	IMIP	0.08	0.26	3.50	0.07	1.00	0.00	Binary variables for the use of instruments of intellectual property
Size	Size	4.14	1.45	0.35	2.10	8.98	0.00	Total labor employed by the firms
Cooperation with other firms	COF	0.10	0.29	3.08	0.09	1.00	0.00	Binary variable for the occurrence of cooperative projects with other private firms.
Cooperation with other research institutions	CREO	0.06	0.23	4.08	0.05	1.00	0.00	Binary variable for the presence of cooperation agreements with research institutions
Obstacles Synergies #1	OBS1	-3.54	5.05	-1.43	25.54	9.52	-9.42	LPCA scores embodying interdependences across financial, network, demand and knowledge barriers

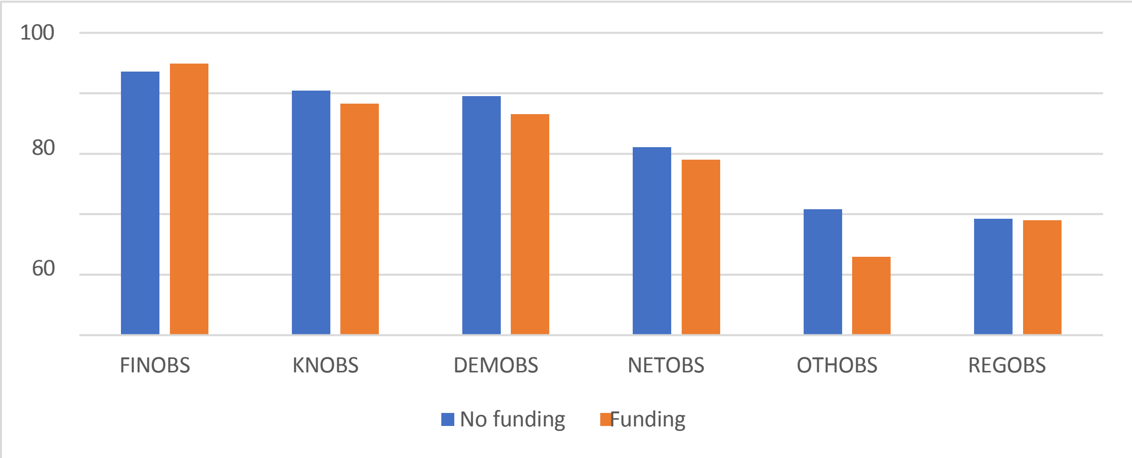
Obstacles Synergies #2	OBS2	2.87	4.04	1.41	16.36	8.00	-7.84	LPCA scores embodying interdependences regulatory and other barriers related to internal resistance to innovation

Table A.4. Number of inventive firms per type of funding and size (2013-2018).				
Type of firm	**Small**	**Medium**	**Large**	**Total**
No funding	648	1,852	1,100	3,600
Funding	185	154	71	410
Total	833	2,006	1,171	4,010

Table A.5. R&D intensity per type of firm (2013-2018).							
Type of firm	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**All years**
No funding	8.24	8.32	8.47	8.61	8.75	8.85	8.53
Funding	8.28	8.37	7.64	7.05	8.05	8.05	7.96
All firms	8.25	8.33	8.32	8.36	8.66	8.74	8.44

Table A.6 Number of inventive firms per type of funding and per innovation strategy being pursued (2013-2018)					
Type of firm	**Product inno.**	**Process inno.**	**Product and process**	**Other inno. strategy**	**Total**
No funding	284	754	546	2,016	3,600
Funding	86	98	116	110	410
All firms	370	852	662	2,126	4,010

Figure A.1 Percentage of firms facing different obstacles to innovate.



A.7 Intensity of innovation obstacles.

Following Zahler et al. (2023), our instrument to account for the endogeneity of innovation obstacles can be built as follows:

$$IV^{k}_{s,r,t} \equiv \sum_{j\epsilon k} \left[\sum_{i\epsilon \Xi_{s,r,t}} \frac{intensity^{kj}_{i,s,r,t}}{n(\Xi_{s,r,t})} \right] / n(k)$$

Where $intensity^{k}_{s,r,t}$ indicates the severity through which constraint $\boldsymbol{j}$ affects innovation activity at firm $\boldsymbol{i}$ operating at sector $\boldsymbol{s}$ which is located within region $\boldsymbol{r}$ at time $\boldsymbol{t}$. **j** constitutes each of the binary responses on innovation obstacles as reported by our sample of inventive firms, while **k** represents our proposed grouping of obstacles synergies (obs1 and obs2). The intensity levels described by this instrument range from 0 (being the lowest) to 1 (being the highest). ($\Xi_{s,r,t}$) comprises the group of inventive firms established in sector s in region $\boldsymbol{r}$ at time $\boldsymbol{t}$ (the cardinality of $\Xi_{s,r,t}$) and $n(k)$ introduces the number of questions categorized at group of obstacles synergies.

Notes

1 Tests for the exogeneity and strength of our preferred instruments are included at the bottom panel of table (4). For every specification, the Wald exogeneity test rejects the null of no endogeneity, while the Cragg-Donald F-test accepts the alternative that the instruments are not weak.