

Evidence-based financing for Kerala's knowledge economy: Patent metrics for policy reform

Rajesh Many

Assistant Professor, School of Gandhian Thought and Development Studies, Mahatma Gandhi University, Kottayam. Founding Director, Centre for Technology and Human Development Studies, Mahatma Gandhi University, Kottayam.

Abstract

This article examines how evidence-based financing strategies can accelerate Kerala's transition to a knowledge-based economy through enhanced production of economically valuable knowledge. Drawing on analysis of 850 patents and comprehensive R&D budget data (2023-2026), we identify strategic opportunities to optimize Kerala's innovation system through targeted resource allocation aligned with demonstrated patent productivity. Despite Kerala's commendable commitment of 0.30% of GSDP to research—exceeding the interstate average of 0.24%—its current research investments show significant potential for improved alignment with patent generation capacity. Our analysis employs the International Patent Classification (IPC) framework to identify established strengths in medical technologies, analytical sciences, and emergent capabilities in digital domains and nanotechnology, providing a foundation for precision investment targeting. We propose a methodological framework for knowledge financing that leverages Kerala's existing institutional structures while enhancing knowledge flows between individual inventors, research institutions, universities, and industry. The framework emphasizes three core strategies: sectoral resource optimization, IPC-focused investment approaches, and institutional reforms that enable self-regulation in knowledge production according to global standards. By implementing these

evidence-driven policy reforms, Kerala can effectively convert its outstanding human capital advantages and vibrant grassroots innovation culture into economically valuable unique knowledge, moving beyond reinvention toward frontier innovation. This approach offers valuable insights for regions globally that aim to leverage strong human development foundations for knowledge-driven economic transformation through responsible and strategically focused knowledge production.

Keywords: *Knowledge Economy, Evidence-based Financing, Patent Metrics, Innovation System, International Patent Classification, Research Investment, Knowledge Production, Regional Development, Policy Reform, Kerala*

JEL Classification: *O38, O34, O32, R58, H41, I23*

1. Introduction

Kerala presents a compelling paradox in India's developmental landscape. The state has consistently achieved exceptional social indicators, with near-universal literacy, high life expectancy, and positive health outcomes that rival developed nations (Parayil, 1996). These achievements have positioned Kerala as a model of human development within the developing world context. However, this social progress has not translated proportionally into economic prosperity, with persistent challenges including limited industrial growth, high unemployment among educated youth, and significant outmigration of skilled workers (Zachariah and Irudaya Rajan, 2012; Thomas, 2005).

As Kerala confronts these economic challenges, policymakers have increasingly emphasized the transition to a knowledge-based economy as a strategic imperative. This emphasis is evident in recent policy documents, including the state's explicit commitment in the 2021-22 Budget to position Kerala as a knowledge economy hub (Government of Kerala, 2021). The introduction of a separate budget document for Research and Development (R&D) expenditure—unprecedented among Indian states—further demonstrates this commitment. Between 2023-26, Kerala has projected an increase in R&D budgetary allocation from ₹348,244.27 lakhs to ₹403,935.99 lakhs, representing a 16% growth and constituting approximately 2.13% of total state allocations by 2025-26 (Government of Kerala, 2025).

Despite these substantial investments, empirical evidence suggests a significant gap in translating research expenditure into economically valuable knowledge outputs, particularly as measured by patent applications. Analysis of data from the Department of Science and Technology (2023) and Reserve Bank of India (2021) reveals that Kerala generates only 0.14 patent applications per crore of research expenditure, ranking 13th among 14 major Indian states despite allocating 0.30% of its Gross State Domestic Product (GSDP) to research—higher than the interstate average of 0.24%. This efficiency gap is particularly striking when compared to states like Telangana and Maharashtra, which achieve patent application rates of 1.77 and 0.94 per crore respectively, despite lower proportional R&D investments.

This discrepancy raises fundamental questions about the effectiveness of Kerala's innovation ecosystem and financial allocation strategies. The state has established a comprehensive institutional framework for knowledge production, encompassing research institutions under the Kerala State Council for Science, Technology and Environment (KSCSTE), state universities, specialized R&D centres, and innovation enablers like Kerala Development and Strategic Innovation Council (K-DISC) and Kerala Startup Mission (KSUM). However, the limited conversion of these institutional capabilities into patentable innovations suggests systemic inefficiencies in the research-to-commercialization pipeline.

The central research question this study addresses is: How can Kerala improve its research financing strategies to enhance economically valuable knowledge production, as measured by patent metrics, while leveraging its existing innovation system? This question has both theoretical and practical significance. Theoretically, it interrogates the relationship between public R&D investment and innovation outputs within a regional context characterized by strong human development but limited industrial base. Practically, it addresses an urgent policy concern for Kerala—how to optimize limited fiscal resources to accelerate the transition to a knowledge economy.

The specific objectives of this study are to:

1. Analyse the current structure and performance of Kerala's innovation system through the lens of patent productivity
2. Identify patterns and gaps in knowledge production across different technological domains using International Patent Classification (IPC) metrics

3. Develop an evidence-based framework for targeted R&D financing based on patent efficiency metrics
4. Formulate policy recommendations to enhance the conversion of research investments into economically valuable knowledge outputs

This paper contributes to the literature on regional innovation systems and knowledge-based economic development by providing empirical evidence on the relationship between R&D financing patterns and patent outcomes in the context of a developing region with strong social indicators. It also offers practical insights for policymakers seeking to optimize innovation investments in resource-constrained environments.

The analysis draws on multiple data sources, including detailed R&D budget allocations from the Government of Kerala (2023-2025), patent application (granted) data from the Indian Patent Advanced Search System (inPASS), and institutional mapping of Kerala's innovation ecosystem. This multi-faceted approach enables a comprehensive assessment of both the inputs (financial and institutional) and outputs (patents) of Kerala's knowledge production system, providing a foundation for evidence-based policy reform.

2. Literature review

The transition to knowledge-based economies represents a fundamental shift in economic organization, where knowledge becomes the primary driver of value creation and competitive advantage. This section examines the theoretical foundations of knowledge economies, the role of patents as indicators of economically valuable knowledge, frameworks for measuring regional innovation efficiency, and the relationship between R&D financing and patent outcomes.

2.1 Theoretical foundations of knowledge-based economies

The concept of knowledge-based economies has evolved from earlier theoretical frameworks on post-industrial society (Bell, 1999) and information economies (Machlup, 1973) to more comprehensive models emphasizing knowledge as the central factor of production (Drucker, 1993; OECD, 1996). Knowledge, unlike traditional factors such as land, labour, and capital, exhibits non-rivalry and potential non-excludability, leading to distinctive economic

properties including increasing returns to scale and positive externalities (Romer, 1990; Stiglitz, 1999).

Lundvall and Johnson (1994) categorized economically relevant knowledge into four types: know-what (factual knowledge), know-why (scientific principles), know-how (skills and capabilities), and know-who (social connections). Of these, know-why and know-how are particularly critical for innovation and technological advancement. Powell and Snellman (2004, p. 199) defined the knowledge economy as "production and services based on knowledge-intensive activities that contribute to an accelerated pace of technological and scientific advance as well as equally rapid obsolescence."

The endogenous growth theory, pioneered by Romer (1986, 1990) and expanded by Lucas (1988) and others, explicitly incorporates knowledge accumulation as the engine of economic growth. In this framework, investments in research, education, and innovation generate knowledge spillovers that enhance overall productivity. Significantly, this theory suggests that appropriate public policies, including R&D investments, can influence long-term growth rates by affecting the rate of knowledge production (Aghion and Howitt, 1992).

For regions like Kerala, the knowledge economy paradigm offers potential pathways to overcome traditional development constraints. Cooke (2001) and Asheim and Gertler (2005) emphasize the importance of regional innovation systems in knowledge-based development, highlighting how localized learning processes and institutional frameworks shape innovation capabilities. Lundvall (1992) and Nelson (1993) further elaborate on how national and regional innovation systems coordinate knowledge flows between universities, industry, and government—the "triple helix" described by Etzkowitz and Leydesdorff (2000).

2.2 Patents as indicators of economically valuable knowledge

Patents represent a critical indicator of economically valuable knowledge by conferring temporary monopoly rights in exchange for public disclosure of inventions that meet criteria of novelty, non-obviousness, and utility (Scotchmer, 2006). While patents capture only a subset of knowledge production—specifically, codified, technical knowledge with commercial applications—they provide a standardized, internationally comparable metric for innovation output (Griliches, 1990; Hall et al., 2001).

The use of patent metrics has a substantial foundation in the economics of innovation literature. Jaffe and Trajtenberg (2002) demonstrate how patent data enable analysis of knowledge flows and spillovers between regions and sectors. Pavitt (1985) established the use of patents to classify technological trajectories and sectoral patterns of innovation. More recently, Lanjouw and Schankerman (2004) developed patent quality indicators that enhance the utility of patent counts as innovation measures.

For developing regions, patents offer particularly valuable insights into technological catch-up processes. Kim (1997) documented South Korea's transition from imitation to innovation through patent analysis, while Hu and Mathews (2005) used patent data to track China's technological trajectory. Furman and Hayes (2004) identify how "innovative capacity" reflected in patenting activity distinguishes innovation leaders from followers among developing economies.

The International Patent Classification (IPC) system provides a standardized taxonomy for categorizing patents according to technological domains. Studies by Schmoch (2008) and WIPO (2017) demonstrate how IPC analysis can reveal specialization patterns and identify emerging technological strengths. For regions like Kerala, IPC analysis offers a lens to assess alignment between research investments and economically valuable knowledge outputs (Abraham and Moitra, 2001).

However, the literature also acknowledges limitations of patents as innovation metrics. Not all innovations are patentable or patented, with sectoral variations in patent propensity (Cohen et al., 2000). Additionally, patent quality varies substantially, and raw counts may obscure important qualitative differences (Harhoff et al., 2003). These limitations necessitate complementary analyses when evaluating regional innovation systems.

2.3 Measuring innovation efficiency in regional economies

The concept of innovation efficiency—how effectively inputs such as R&D investments are converted into innovation outputs—has gained prominence in regional science and innovation studies. Furman et al. (2002) introduced the "national innovative capacity" framework, focusing on how structural, institutional, and policy factors influence the productivity of innovation investments. This framework has been adapted to regional

contexts by authors such as Fritsch and Slavtchev (2008), who examine how regional characteristics shape innovation efficiency.

Methodologically, several approaches have emerged to measure innovation efficiency. Data Envelopment Analysis (DEA) has been employed by Guan and Chen (2012) to benchmark regional innovation systems using multiple inputs (R&D expenditure, human capital) and outputs (patents, publications). Stochastic frontier analysis offers an alternative approach, allowing estimation of innovation production functions while accounting for inefficiency (Fu and Yang, 2009).

For developing regions, comparative efficiency analyses provide valuable policy insights. Mathews and Hu (2007) analysed innovation systems across East Asian economies, identifying how institutional configurations explain performance variations in technological catch-up processes. Similarly, Mani (2009) examined knowledge-intensive entrepreneurship across Indian states, highlighting how regional innovation governance affects technological development outcomes.

Recent literature has also emphasized the importance of analysing efficiency at different stages of the innovation process—from research to development to commercialization. Wang and Huang (2007) distinguish between technical efficiency (optimal use of R&D inputs) and commercial efficiency (conversion of innovations into economic value), noting that regions may excel in one dimension while underperforming in another. Their analysis of national innovation systems demonstrates that effective knowledge production requires both technical capability and commercialization mechanisms.

2.4 R&D financing and patent outcomes: Evidence and challenges

The relationship between R&D financing and patent outcomes has been extensively studied, with mixed findings regarding linearity, time lags, and contextual factors. Hall et al. (1986) established that R&D expenditures generally correlate with patent production, though with significant sectoral variations. Subsequent research has identified important moderating factors, including institutional quality (Varsakelis, 2006), absorptive capacity (Cohen and Levinthal, 1990), and industry structure (Cincera, 2006).

For public R&D investments specifically, David et al. (2000) review evidence on whether government funding complements or substitutes private R&D, finding heterogeneous effects across contexts. Guellec and Van Pottelsberghe de la Potterie (2003) demonstrate that public R&D can stimulate business R&D under appropriate institutional conditions. These findings suggest that the effectiveness of public research financing depends critically on policy design and implementation.

In developing economies, distinctive challenges affect the R&D-patent relationship. Intarakumnerd et al. (2002) highlight how weak linkages between universities, research institutions, and industry reduce the commercial impact of public research in Thailand. Similarly, Sutz (2000) identifies structural disconnections in Latin American innovation systems that limit knowledge translation. These challenges echo concerns raised by Kurian (1999) about Kerala's industrial ecosystem, where limited absorption capacity may constrain the economic impact of research.

Strategic approaches to R&D financing have emerged as critical for maximizing innovation returns. Foray et al., (2012) and Rusu (2013) advocate "smart specialization" strategies that target investments toward domains where regions possess comparative advantages. Similarly, Mazzucato (2013) argues for "mission-oriented" research funding that directs resources toward specific societal challenges. These approaches suggest alternatives to undifferentiated research subsidies.

For Kerala specifically, limited research exists on the relationship between its R&D investments and patent outcomes. Joseph and Harilal (2001) examine Kerala's industrial innovation capacity but without direct analysis of patent efficiency. More work by Mani (2004, 2013) on India's regional innovation systems provides comparative context, while not focusing specifically on Kerala's budgetary R&D allocation effects.

2.5 Research gap and theoretical framework

This review reveals several research gaps this study addresses. First, while substantial literature exists on innovation systems in developed economies, fewer studies examine knowledge translation challenges in regions with strong human development but limited industrial bases. Second, patent efficiency analysis has rarely been applied to state-level innovation systems in India, particularly with attention to budgetary allocations. Third, the use of IPC classifications to guide public R&D financing represents a novel approach within regional innovation policy.

Drawing on the reviewed literature, this study employs a theoretical framework that integrates elements of regional innovation systems theory (Cooke, 2001), efficiency analysis approaches (Furman et al., 2002), and strategic R&D allocation models (Foray et al., 2012 and Rusu, 2013). This framework posits that optimal knowledge production requires not only adequate financial inputs but also appropriate institutional arrangements, strategic prioritization based on regional capabilities, and policies that facilitate knowledge flows between research producers and users.

This study contributes to the literature by providing empirical evidence on how public R&D investments translate into patent outcomes within Kerala's specific institutional context, offering insights for both theoretical understanding of regional innovation dynamics and practical policy development for knowledge-based economic transformation.

3. Kerala's innovation ecosystem: Current status

3.1 Kerala's socioeconomic context and human development achievements

Kerala represents a unique developmental case within India, characterized by what has been termed the "Kerala model" of development—high social indicators despite moderate economic growth (Franke and Chasin, 1994; Parayil, 1996). The state has consistently outperformed other Indian states on human development metrics, with scholars widely recognizing it as a leader in literacy, healthcare, and social welfare indicators. As Jeffrey (1992) and Ramachandran (1996) have documented, these achievements stem from historical factors including progressive social movements, early investments in public education, and redistributive policies.

Despite these social development successes, Kerala faces persistent economic challenges. Researchers including Thomas (2005) and Kannan (2005) have noted the state's constrained economic growth and limited industrialization compared to other Indian states. Kumar and Yesudian (2007) highlight Kerala's paradoxical combination of advanced social indicators alongside employment challenges, particularly for educated youth. This creates what Zachariah and Irudaya Rajan (2012) describe as a significant "brain drain" phenomenon, with substantial emigration of skilled workers.

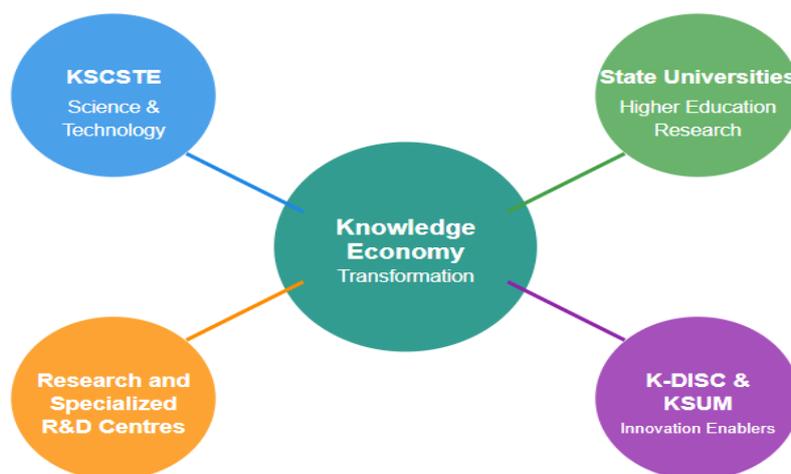
A distinctive feature of Kerala's economy has been its reliance on remittances from emigrant workers, primarily to Gulf countries. As documented by Rajan and Zachariah (2019), these remittances contribute substantially to the state's economy, creating what Osella and Osella (2000) characterize as a unique economic structure with high consumption but limited productive investment. While this model has supported high living standards, it has resulted in vulnerabilities including susceptibility to external economic shocks and fiscal constraints (Kannan, 2005).

These structural challenges have prompted Kerala's policymakers to prioritize knowledge-based development strategies. Recent policy documents and development plans from the Kerala government have increasingly emphasized innovation and knowledge economy as strategic priorities for sustainable economic growth. This policy orientation acknowledges both Kerala's strong foundation in human development and the need to create sustainable economic opportunities locally to retain skilled talent.

3.2 Structure of Kerala's innovation system: Institutional mapping

Kerala has established a comprehensive institutional framework for knowledge production and innovation, organized into four interconnected pillars that collectively constitute its innovation ecosystem. This four-pillar structure encompasses scientific research institutions, higher education, specialized R&D centres, and innovation enablers.

Figure 1: The four-pillar framework of Kerala’s knowledge production and innovation ecosystem



3.2.1 KSCSTE (science & technology)

The Kerala State Council for Science, Technology and Environment (KSCSTE) serves as the cornerstone of the state's scientific research infrastructure. Established in 2002 as an autonomous body, KSCSTE coordinates and promotes scientific research through specialized research institutes focusing on areas of strategic importance to Kerala. Key institutions under KSCSTE include the Jawaharlal Nehru Tropical Botanic Garden and Research Institute (JNTBGRI), Kerala Forest Research Institute (KFRI), Centre for Water Resources Development and Management (CWRDM), National Transportation Planning and Research Centre (NATPAC), and Institute of Advanced Virology (IAV).

These institutions conduct fundamental and applied research addressing Kerala's environmental, developmental, and health challenges. Their outputs align primarily with IPC categories related to plant sciences (A01H, A61K), environmental technologies (E03B, G01W), and biotechnology (C12N), reflecting Kerala's natural resource advantages and sustainability priorities (KSCSTE Annual Report, 2022). The detailed institutional profiles and their associated IPC categories are presented in Appendix Table 3.1.

3.2.2 State Universities (higher education research)

Kerala's university system forms the second pillar of the innovation ecosystem, providing both specialized research capabilities and the human capital necessary for a knowledge

economy. The state has 14 universities spanning diverse disciplines, with notable research-focused institutions including University of Kerala, University of Calicut, Cochin University of Science and Technology (CUSAT), Kerala Agricultural University (KAU), Kerala University of Digital Sciences, Innovation and Technology (KUDSIT), Kerala University of Health and Allied Sciences (KUHAS), and Mahatma Gandhi University (MGU).

These universities generate knowledge across multiple IPC domains, including agricultural technologies (A01B-G), digital computing (G06F, G06N), biotechnology (C12N), and medical sciences (A61B, A61K). The universities also play a crucial role in talent development, creating the skilled workforce required for knowledge-intensive industries (Higher Education Department, Government of Kerala, 2021). Appendix Table 3.2 provides a detailed mapping of universities to their primary research domains and associated IPC categories.

3.2.3 Research and specialized R&D centres

Complementing the broader research capabilities of universities, Kerala has established specialized R&D centres focusing on specific technological domains and applied research. These institutions bridge the gap between fundamental research and commercial applications. Examples include the Centre for Engineering Research and Development (CERD), International Centre for Free and Open Source Software (ICFOSS), State Board of Medical Research, India Innovation Centre for Graphene (IICG), and Biological Production Complex for animal vaccines.

The specialized knowledge outputs from these institutions align with IPC categories for digital technologies (G06F, H04L), advanced materials (B82Y, C01B), medical innovations (A61B, A61K), and engineering solutions (G01N, E04B). The focused nature of these institutions accelerates technology development in priority sectors. A comprehensive list of these specialized R&D centres with their technical domains and IPC classifications is provided in Appendix Table 3.3.

3.2.4 K-DISC & KSUM (innovation enablers)

The fourth pillar comprises institutional mechanisms that facilitate the translation of knowledge into economic value. Kerala Development and Strategic Innovation Council (K-

DISC) and Kerala Startup Mission (KSUM) serve as catalysts for innovation-driven entrepreneurship. Established in 2021, K-DISC provides strategic direction for innovation policy, while KSUM functions as the nodal agency of the State Government for promoting entrepreneurship in the state.

KSUM's mandate encompasses a comprehensive entrepreneurship support framework including expert mentoring, funding support, infrastructure facilities, networking opportunities, and related mechanisms to empower entrepreneurs. With over 40,000 entrepreneurs and more than 5,000 startups, Kerala has established a significant entrepreneurial ecosystem within the state (Government of Kerala, 2025). Despite this entrepreneurial activity, patent data indicates that these startup ventures have not proportionally translated into intellectual property development.

The structural configuration of Kerala's innovation system exhibits distinctive characteristics that differentiate it from alternative innovation ecosystems in India. The system demonstrates notable public sector predominance, contrasting with regions such as Bangalore or Hyderabad where private enterprise plays a more substantial role in research and innovation activities. Furthermore, the state's innovation infrastructure displays pronounced specialization aligned with Kerala's ecological and social characteristics, particularly in biomedical, environmental, and agricultural domains.

While the institutional framework theoretically encompasses the complete innovation value chain from fundamental research through commercialization, evidence suggests suboptimal knowledge transfer between system components. The innovation system architecture appears designed to facilitate knowledge flows from basic research conducted by KSCSTE and universities, through applied development at specialized centres, to eventual commercialization facilitated by KSUM. However, empirical patent analysis indicates that these components frequently operate with limited integration, creating knowledge translation inefficiencies between research generation and commercial application. This structural discontinuity represents a significant consideration for enhancing system effectiveness in knowledge-based economic development.

3.3 R&D Budgetary provisions and financing patterns

Kerala has pioneered a distinctive approach to R&D financing among Indian states, introducing a separate budget document for research and development in 2023-24. This methodological innovation enables detailed tracking of research investments across sectors and institutions. Analysis of budget data from 2023-24 to 2025-26 reveals several notable patterns.

Table 1: Kerala's R&D budget allocation trends (2023-2025)

Year	Plan R&D (Rs. lakhs)	Non-Plan R&D (Rs. lakhs)	Total R&D (Rs. lakhs)	Growth Rate	R&D % of Total Budget
2023-24	150,102.60	198,141.60	348,244.27	-	2.08%
2024-25	152,117.40	215,734.40	367,851.79	5.63%	2.09%
2025-26	172,389.00	231,547.00	403,935.99	9.81%	2.13%

Source: State Finance Department, Government of Kerala (2023-2025)

Kerala's total R&D allocation has shown consistent growth, increasing from Rs.348,244.27 lakhs in 2023-24 to a projected Rs.403,935.99 lakhs in 2025-26, representing a 16.0% increase over the three-year period. This growth outpaces the overall budget expansion of 12.9% during the same period, indicating prioritization of research investments (Government of Kerala, 2025).

The state allocates approximately 2.13% of its total budget to R&D activities by 2025-26, significantly higher than most Indian states. This allocation is divided between Plan expenditure (focused on new initiatives and capital investments) and Non-Plan expenditure (covering recurring operational costs). Non-Plan R&D allocations consistently exceed Plan allocations (Rs.231, 547.00 lakhs vs. Rs.172, 389.00 lakhs in 2025-26), suggesting significant resources are directed toward maintaining existing research infrastructure rather than new initiatives.

Analysis of sectoral allocations reveals distinctive prioritization patterns with Education R&D receiving the largest share (44.81% in 2025-26), followed by Medical Health, Family Welfare and Sanitation (25.13%), Agricultural Research (14.03%), and Industrial Research (9.16%). This sectoral distribution reveals a potential misalignment between R&D investments and domains most conducive to patent generation. Industrial, environmental, and

infrastructure research—sectors with high patenting potential—receive collectively only 11.72% of R&D allocations, while education and healthcare dominate financing. The detailed sectoral breakdown of R&D allocations is presented in Appendix Table 3.4.

While examining institutional R&D funding patterns, notable observations emerge regarding performance variation across different components of Kerala's innovation system. Central Government Institutions operating in Kerala demonstrate relatively higher patent efficiency, accounting for 34.24% of Kerala's patents.

The KSCSTE institutions, while conducting valuable fundamental research in domains aligned with Kerala's natural advantages, face opportunities to strengthen their intellectual property development strategies. These institutions possess significant research capabilities in areas such as biodiversity, environmental sciences, and transportation, but their patent outputs could be enhanced through more targeted research prioritization and patent-oriented project selection mechanisms.

Specialized R&D Centres represent an area of potential growth in patent productivity. These centres possess domain-specific technical expertise but currently demonstrate varied performance in converting their specialized knowledge into patentable innovations. The centres' position as intermediaries between basic research and application makes them particularly valuable for enhancing the innovation pipeline, suggesting opportunities for policy interventions to strengthen their patent orientation.

The innovation enablers (K-DISC and KSUM) have successfully fostered entrepreneurial activity but show room for improvement in facilitating patent development among supported startups. While KSUM has created a dynamic startup ecosystem, the entrepreneurial ventures tend to focus on service models and incremental innovations rather than developing novel patentable technologies. This suggests a need for initiatives that specifically encourage IP-focused innovation within the startup community.

4. Empirical analysis and findings

4.1 Methodology for patent landscape analysis

This study employs a mixed-methods approach to analyse Kerala's patent landscape and R&D investment patterns, combining quantitative analysis of patent data with qualitative

assessment of institutional structures and financing frameworks. The investigation focuses on identifying knowledge production patterns, technological specializations, and structural characteristics of Kerala's innovation system to inform evidence-based policy recommendations.

The primary data sources include the Indian Patent Advanced Search System (inPASS) for patent information, Kerala's R&D budget documents (2023-2026) for expenditure data, and complementary institutional information from annual reports and policy documents. The analysis focuses on granted patents rather than applications to ensure examination of validated innovations, with a dataset of 850 patents where the first applicant is from Kerala.

For patent data extraction, a systematic methodology was employed. The Indian Patent Advanced Search System (inPASS) was queried using the keyword "Kerala" in the Applicant Address field, which initially yielded 3,860 patent submissions as of March 25, 2025. From these submissions, only granted patents were selected, resulting in 1,000 patents. Further refinement of the dataset included exclusion of approximately 50 patents showing group patent status where Kerala-based entities collaborated with institutions from other regions, due to data discrepancies in the collaborative information. Patents lacking IPC classification information were also removed. Following this data cleaning process, the final sample consisted of 850 patents with first applicants from Kerala.

Each patent record was manually classified by applicant type after carefully examining the applicant's name, address, and institutional affiliation. The field of invention and IPC classifications were extracted directly from the inPASS system, which already contained this information for each patent record, enabling multi-dimensional analysis of technological domains and institutional patterns.

Budget data was extracted from Kerala's official R&D budget documents for the fiscal years 2023-24 through 2025-26, with sectoral and institutional allocations systematically coded to enable comparison with patent output patterns. This approach allowed for analysis of investment-patent relationships across different sectors and institutional categories.

The methodology acknowledges certain limitations, including the cumulative nature of patent data representing innovations granted over multiple years rather than annual outputs, the imperfect nature of patents as innovation indicators (particularly for domains where patenting

is less common), and challenges in precisely allocating R&D expenditures to specific institutions. Despite these constraints, the approach enables robust identification of structural patterns in Kerala's knowledge production landscape.

4.2 Comparative context of Kerala's research investment and patent production

To provide context for Kerala's knowledge production patterns, a comparative analysis of research investment and patent application data across Indian states reveals important insights. While this comparative data represents a specific time period (2020-21) rather than cumulative granted patents, it offers a valuable reference point for understanding Kerala's position within the broader national innovation landscape.

According to data from the Department of Science and Technology (2023) and Reserve Bank of India (2021), Kerala allocates a higher percentage of GSDP to research (0.30%) than the interstate average (0.24%). However, this substantial investment generated only 0.14 patent applications per crore of expenditure in 2020-21—significantly below the average of 0.63 and ranking 13th among 14 major states examined. This positioning contrasts markedly with states like Telangana and Maharashtra, which despite lower proportional R&D investments (0.10% of GSDP each), achieved patent application rates of 1.77 and 0.94 per crore respectively during the same period.

Table 2: Research-to-Patent Conversion Efficiency Across Indian States (2020-21)

State	Research as % of GSDP	Research Expenditure (Rs. Crore)	Patent Applications	Patent Applications per Rs.1 Crore Spent	Efficiency Rank
Telangana	0.10%	938.30	1,662	1.77	1
Punjab	0.20%	1,160.20	1,650	1.42	2
Rajasthan	0.00%	342.70	449	1.31	3
Maharashtra	0.10%	4,476.90	4,214	0.94	4
Tamil Nadu	0.20%	4,504.70	3,945	0.88	5
Karnataka	0.20%	3,824.70	2,784	0.73	6
Andhra Pradesh	0.20%	2,187.00	709	0.32	7
Haryana	0.30%	2,617.10	765	0.29	8
Uttar Pradesh	0.40%	8,028.30	2,317	0.29	9
Madhya Pradesh	0.20%	1,503.50	398	0.26	10
Gujarat	0.20%	3,706.00	921	0.25	11
West Bengal	0.20%	2,342.40	505	0.22	12
Kerala	0.30%	2,954.30	426	0.14	13
Bihar	0.50%	3,139.70	62	0.02	14
Average	0.24%	2,863.64	1,737.57	0.63	-

Source: DST (2023) and RBI (2021)

This comparative context suggests that structural factors beyond simply funding levels may significantly influence patent production. States with stronger industrial bases and manufacturing sectors (Maharashtra, Tamil Nadu) demonstrate higher patent application rates than Kerala, suggesting that the presence of industrial R&D and commercialization pathways may enhance knowledge production. Similarly, institutional configuration appears significant, as high-performing states feature greater private sector participation in research and stronger industry-academia linkages than Kerala.

This contextual analysis provides a backdrop for examining Kerala's patent landscape in greater depth, with attention to the specific patterns and characteristics that may inform targeted policy interventions.

4.4 Knowledge production patterns in Kerala: IPC analysis

Analysis of International Patent Classification (IPC) data provides granular insights into Kerala's knowledge production strengths, specialization patterns, and potential misalignments between research investments and patenting outcomes. Kerala's patents demonstrate concentration in specific technological domains, with notable strengths in medical technologies, mechanical engineering, chemical compositions, and increasingly in digital technologies.

Table 3: Distribution of Kerala patents by IPC section

IPC Section	Description	Patents (%)*	Top Subsection
A: Human Necessities	Medical, agricultural, food, personal items	96.94%	A61K (21.65%)
G: Physics	Measuring, computing, control, signalling	54.24%	G01N (10.12%)
C: Chemistry; Metallurgy	Organic, inorganic compounds, metallurgy	47.65%	C12N (4.35%)
B: Performing Operations; Transporting	Mechanical engineering, transport	47.53%	B82Y (5.18%)
H: Electricity	Electric elements, generation, communication	33.41%	H04L (6.35%)
F: Mechanical Engineering	Engines, pumps, mechanical elements	22.71%	F16K (2.94%)
E: Fixed Constructions	Building, mining, water supply	15.76%	E04B (3.41%)
D: Textiles; Paper	Textiles, flexible materials, paper	5.65%	D01F (1.41%)

*Percentages sum to more than 100% as patents can be classified under multiple sections.

Source: Analysis based on in PASS data (2025)

The technological distribution exhibits several notable patterns. The most prominent feature is the overwhelming representation of medical technologies, with A61K (preparations for medical purposes) appearing in 21.65% of patents and A61B (diagnostics, surgery) in 14.47%. G01N (investigating materials by determining properties) appears in 10.12% of patents, indicating capability in analytical sciences. Digital technologies show significant representation with G06F (electric digital data processing) at 8.35% and H04L (transmission of digital information) at 6.35%. A detailed breakdown of the top IPC subsections is provided in Appendix Table 4.1.

Cross-analysing IPC classifications with applicant types reveals distinctive specialization patterns across different components of Kerala's innovation ecosystem. Central Government Institutions demonstrate concentrated strength in A61K (18.21%), G01N (17.87%), and A61B (17.53%). Individual Inventors show particular focus on A61K (22.55%), A61B (11.76%), and H04L (8.50%), with distinctive activity in kitchen equipment (A47J: 7.19%) and horticulture (A01G: 6.54%). Private Companies specialize in G06F (22.35%) and A61K (21.18%), while State Government Universities demonstrate pronounced specialization in A61K (38.71%). Private Universities show distinctive capabilities in energy technologies (H01M: 21.28%). The complete distribution of IPC subsections by applicant type is presented in Appendix Table 4.2, and the distribution of patents by field of invention (as per inPASS system) is available in Appendix Table 4.3.

This differentiated pattern suggests that Kerala's innovation system features complementary specializations across institutional types, with potential for greater synergy through enhanced knowledge flows. However, the distribution reveals limited overlap between academic research strengths and private sector innovation domains, suggesting challenges in the commercialization pipeline.

The analysis of multiple IPC classifications reveals substantial cross-domain knowledge integration, with 58.12% of Kerala's patents including multiple IPC classifications. The specific patterns of cross-domain integration are detailed in Appendix Table 4.4, highlighting the most frequent combinations. The most prominent pattern involves combinations of medical technology classifications with digital technologies, reflecting the growing integration of computational approaches in healthcare. Patents combining nanotechnology with medical preparations represent a second significant pattern, indicating interdisciplinary research at the interface of nanoscience and biomedicine. This cross-domain integration

represents a positive aspect of Kerala's innovation landscape, indicating capacity for interdisciplinary research despite challenges in overall patent production rates.

4.5 Research investment allocation and patent production patterns

Comparing the distribution of R&D investments across sectors with the pattern of patent outputs reveals significant misalignments that may contribute to Kerala's patent production challenges. Analysis of sectoral allocation of R&D funding against the distribution of patents by field of invention highlights several critical gaps.

Table 4: Comparison of R&D investment and patent output by sector

Sector	Share of R&D Budget (2025-26)	Share of Patents*	Investment-Patent Ratio**
Education	44.81%	7.29%	6.15
Medical & Health	25.13%	10.00%	2.51
Agriculture	14.03%	1.65%	8.50
Industrial	9.16%	24.00%	0.38
Infrastructure	2.16%	2.59%	0.83
Environmental	0.40%	0.94%	0.43

*Patent share based on primary field of invention classification

**Ratio of budget share to patent share; values above 1 indicate lower patent productivity

Source: Analysis based on budget data (Government of Kerala, 2023-2025) and inPASS data (2025)

Several striking patterns emerge from this comparison. Despite receiving 44.81% of R&D allocations, education-related institutions generate only 7.29% of Kerala's patents, yielding an investment-patent ratio of 6.15—the second-highest among major sectors. Agricultural research receives 14.03% of funding but generates only 1.65% of patents, resulting in the highest investment-patent ratio (8.50).

In contrast, industrial research demonstrates the highest patent productivity, generating 24.00% of patents while receiving just 9.16% of R&D allocations (ratio: 0.38). The environmental sector, though small in both budget share (0.40%) and patent share (0.94%), shows relatively high productivity (ratio: 0.43), suggesting potential for strategic expansion given Kerala's natural advantages and sustainability challenges.

This analysis reveals that Kerala's current R&D allocation pattern may not be optimally aligned with patent generation potential across sectors. The concentration of resources in

sectors with lower patent productivity may contribute to the overall challenges observed in the state's research-to-patent conversion.

4.6 Summary of key findings

The empirical analysis reveals several critical insights about Kerala's innovation ecosystem and knowledge production patterns. Despite substantial R&D investments and comprehensive institutional infrastructure, Kerala's patent landscape shows distinctive structural characteristics that influence its knowledge production capacity.

A significant misalignment exists between sectoral R&D allocations and patent production patterns, with education and agriculture receiving disproportionately high funding relative to their patent outputs, while industrial research demonstrates higher productivity. This sectoral imbalance suggests opportunities for strategic reallocation to enhance overall knowledge production.

Patent production varies substantially across institutional types, with individual inventors and Central Government Institutions dominating the landscape, while State Universities show modest contributions despite substantial funding. These variations indicate potential for institutional learning and adaptation of successful practices across the innovation system.

Kerala shows distinct technological strengths in medical technologies (A61K, A61B), analytical sciences (G01N), and emerging capabilities in digital technologies (G06F, H04L) and nanotechnology (B82Y), with complementary specializations across different institutional categories. This technological profile offers a foundation for building distinctive competencies in targeted domains.

Individual inventors represent the largest single category of patent applicants (36.00%), indicating a vibrant grassroots innovation culture that exists somewhat independently of formal institutional frameworks. Better integration of these individual innovators with the formal innovation system could enhance overall knowledge production.

These findings point to both structural challenges in Kerala's innovation ecosystem and potential opportunities for enhancing patent productivity through evidence-based financing strategies, institutional reforms, and targeted initiatives to strengthen knowledge flows among the various components of the innovation system.

5. Policy framework for enhancing patent production

5.1 Evidence-based financing strategies

Kerala's substantial R&D investments demonstrate commitment to knowledge production, but patent landscape analysis indicates need for strategic resource reallocation. The significant misalignment between sectoral R&D allocations and patent outputs necessitates investment recalibration. Industrial research allocation should increase from the current 9.16% to approximately 15-20% of total R&D budget, given its superior productivity (24% of patents from less than 10% of funding). Environmental research merits increased allocation from 0.40% to approximately 2-3%, given its relatively high productivity and alignment with Kerala's ecological advantages.

Education and agricultural sectors require structural reforms in incentive systems and institutional practices alongside funding. As Intarakumnerd et al. (2002) observe in Thailand's innovation system analysis, sectoral rebalancing alone is insufficient without addressing underlying institutional challenges in research translation.

Kerala should implement performance-based allocation mechanisms rewarding patent productivity and commercialization outcomes. A patent performance premium model would allocate institutional funding based on patent metrics, creating direct incentives while maintaining core research. Matching grants for industry-academia partnerships would leverage state investments to attract private sector engagement, while staged funding would establish milestones-based support for research commercialization.

5.2 IPC-focused investment approach

Analysis of Kerala's patent landscape through International Patent Classification (IPC) reveals distinct technological strengths and opportunities that should guide targeted investments.

Kerala should prioritize three technological domain categories: established strength domains (medical technologies, analytical sciences, mechanical engineering); emergent opportunity domains showing promising capabilities (digital technologies, nanotechnology, energy conversion); and strategic gap domains with limited current activity but high future relevance (agricultural biotechnology, sustainable construction, advanced materials).

This domain-based approach provides greater precision than traditional sectoral allocations, aligning with Foray et al.'s (2012) "smart specialization" strategy emphasizing comparative advantages while developing new capabilities in adjacent domains.

The high prevalence (58.12%) of patents with multiple IPC classifications highlights interdisciplinary research importance. Convergence research programs should fund cross-domain projects at the intersection of Kerala's strength areas, while problem-centered innovation platforms should establish frameworks focused on major societal challenges, integrating knowledge from multiple technological domains.

5.3 Institutional reform for innovation efficiency

State Government Universities, despite substantial R&D funding, contribute only 7.29% of Kerala's patents—indicating systemic barriers to knowledge translation. University IP policy harmonization, technology transfer office strengthening, and patent-linked academic incentives would address the current incentive structure prioritizing publication over patenting.

Central Government Institutions demonstrate higher patent productivity (34.24% of patents), suggesting practices for system-wide adoption. Institutional specialization enhancement and cross-institutional coordination mechanisms would improve research productivity based on established effectiveness principles (Nelson, 1993; OECD, 2010).

Individual inventors, representing 36.00% of patent holders, operate largely outside formal institutional frameworks. Inventor-institution fellowship programs, regional innovation hubs, and patent agent networks would integrate this valuable innovation resource while preserving its distinctive creativity.

5.4 Reforming innovation governance: K-DISC and KSUM

Critical analysis of Kerala's innovation enablers reveals misalignment between intended functions and operational focus. K-DISC, established to provide strategic innovation direction, has focused disproportionately on peripheral activities rather than core knowledge economy facilitation. The Kerala Knowledge Economy Mission (KKEM) under K-DISC duplicates conventional skill development initiatives already undertaken by educational

institutions, reflecting conceptual misalignment with contemporary understanding of knowledge economies, which emphasizes novel knowledge generation and application.

KSUM has successfully nurtured startup quantity, but the overall low level of private industry patents in Kerala (10% of total) indicates limited development of technology-intensive ventures generating intellectual property. This orientation fails to leverage Kerala's research base for economic transformation through high-value knowledge enterprises.

These institutions require fundamental restructuring to prioritize knowledge translation. K-DISC should focus on strategic coordination across innovation pillars, with explicit metrics for knowledge flow enhancement and IP generation. The Kerala Knowledge Economy Mission should be reoriented toward analysing knowledge production patterns, identifying strategic investment domains, and designing targeted interventions that enhance economically valuable knowledge creation.

KSUM requires strategic reorientation toward technology-intensive entrepreneurship with specific IP development objectives, including specialized incubation tracks for research commercialization and technology transfer partnerships with research institutions. Performance metrics should emphasize quality indicators including technologies licensed and research-based ventures established.

5.5 Implementation framework

Implementation requires appropriate governance structure through a Kerala Innovation Council as an apex body coordinating innovation policy across departments and institutions, with direct oversight of R&D resource allocation. A phased implementation strategy would progress from institutional reforms through financing strategy implementation to establishing long-term governance models, with regular performance evaluation using standardized innovation metrics.

6. Discussion and implications

6.1 Critical evaluation of findings

Kerala's innovation system presents a paradox: substantial R&D investment coexists with patent production dominated by individual inventors and government institutions rather than

commercial entities. The education sector's high funding (44.81% of R&D budget) with limited patent contribution (7.29%) indicates misalignment between academic priorities and patentable innovation. Similarly, agricultural research shows low patent productivity despite significant investment.

Individual inventors (36.00% of patents) and Central Government Institutions (34.24%) dominate Kerala's patent landscape, contrasting with established innovation hubs where private enterprises lead. This structure reveals both strengths in grassroots innovation culture and weaknesses in private sector engagement (10.00% of patents) and university contribution (7.29%).

IPC analysis shows technological strengths in medical, analytical, and mechanical domains, with emerging capabilities in digital technologies and nanotechnology—a profile differing from leading regions with stronger representation in information technologies and advanced manufacturing.

6.2 Theoretical implications for knowledge economy development

The Kerala case challenges linear innovation models by demonstrating that R&D inputs do not automatically translate to innovation outputs without appropriate institutional contexts. It highlights institutional design importance in innovation systems, showing how structural factors significantly influence knowledge production patterns.

The dominance of public institutions and individual inventors suggests alternative innovation configurations for contexts with different institutional histories and industrial structures, questioning universal application of Western innovation models.

Kerala's case demonstrates that exceptional educational achievements do not automatically generate proportional innovation outputs without institutional frameworks channelling knowledge toward economic applications. This observation supports Acemoglu and Robinson's (2013) emphasis on inclusive economic institutions as innovation determinants.

The prominence of individual inventors highlights grassroots innovation importance in regional development, aligning with emerging perspectives on "inclusive innovation" recognizing diverse knowledge sources beyond formal institutions (Chataway et al., 2014).

6.3 Practical implications for policymakers

Policymakers should strategically rebalance research investments toward domains with demonstrated patent productivity, while implementing comprehensive reforms in academic innovation systems including technology transfer mechanisms and patent-linked incentives.

The vibrant grassroots innovation culture merits systematic support through mechanisms connecting individual inventors with institutional resources and market opportunities, while the limited private sector participation in patenting requires targeted incentives for corporate R&D and industry-academia engagement.

Strategic investment guidance should prioritize domains where Kerala demonstrates comparative advantage while developing capabilities in high-growth fields, coordinated through an overarching innovation council harmonizing research priorities and institutional policies.

6.4 Limitations and future research directions

Study limitations include dependence on patents as innovation indicators despite their capturing only a subset of valuable knowledge, focus on quantitative counts rather than qualitative assessment, limited historical analysis, and minimal examination of organizational practices explaining performance variations.

Future research directions include comparative case studies of high-performing institutions, sectoral innovation studies, analysis of commercialization pathways, and research on grassroots innovation dynamics.

7. Conclusion

Kerala presents a compelling case in transitioning to a knowledge-based economy despite strong human development foundations. The state has established a comprehensive innovation system with significant R&D investments, yet shows distinctive patent production patterns dominated by individual inventors and government institutions rather than private enterprises.

The empirical analysis reveals technological strengths in specific domains and significant challenges in institutional performance and sectoral allocation. Policy recommendations include evidence-based financing strategies, IPC-focused investment approaches, and institutional reforms including K-DISC and KSUM reorientation toward effective knowledge production facilitation rather than peripheral activities.

Kerala's knowledge economy transition requires fundamental reconfiguration of innovation governance, incentive structures, and institutional practices. By addressing these structural challenges while building on existing strengths in human capital and grassroots innovation, Kerala can enhance patent productivity and accelerate knowledge-based economic development.

References

- Abraham, B. P., & Moitra, S. D. (2001). Innovation assessment through patent analysis. *Technovation*, 21(4), 245-252.
- Acemoglu, D., & Robinson, J. A. (2013). *Why nations fail: The origins of power, prosperity, and poverty* (Main ed.). Profile Books.
- Aghion, P., & Howitt, P. (1992). A model of growth through creative destruction. *Econometrica*, 60(2), 323-351.
- Asheim, B. T., & Gertler, M. S. (2005). The geography of innovation: Regional innovation systems. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The Oxford handbook of innovation* (pp. 291-317). Oxford University Press.
- Bell, D. (1999). *The coming of post-industrial society: A venture in social forecasting*. Basic Books.
- Cattaneo, M. C. (2014). Mazzucato M.(2013), The entrepreneurial state. Debunking public vs. private sector myths. *Economia politica*, 31(1), 103-110.
- Chataway, J., Hanlin, R., & Kaplinsky, R. (2014). Inclusive innovation: An architecture for policy development. *Innovation and Development*, 4(1), 33-54.
- Chen, K., & Guan, J. (2012). Measuring the efficiency of China's regional innovation systems: Application of network data envelopment analysis (DEA). *Regional Studies*, 46(3), 355-377.
- Cincera, M. (2005). Firms' productivity growth and R&D spillovers: An analysis of alternative technological proximity measures. *Economics of Innovation and New Technology*, 14(8), 657-682.
- Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35(1), 128-152.
- Cohen, W. M., Nelson, R. R., & Walsh, J. P. (2000). Protecting their intellectual assets: Appropriability conditions and why U.S. manufacturing firms patent (or not). NBER Working Paper No. 7552.
- Cooke, P. (2001). Regional innovation systems, clusters, and the knowledge economy. *Industrial and Corporate Change*, 10(4), 945-974.

- David, P. A., Hall, B. H., & Toole, A. A. (2000). Is public R&D a complement or substitute for private R&D? A review of the econometric evidence. *Research Policy*, 29(4-5), 497-529.
- Department of Science and Technology (DST). (2023). Patent application data. Government of India.
- Drucker, P. F. (1993). *Post-capitalist society*. HarperBusiness.
- Edquist, C. (1997). *Systems of innovation: Technologies, institutions, and organizations*. Pinter.
- Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: From national systems and "Mode 2" to a triple helix of university–industry–government relations. *Research Policy*, 29(2), 109-123.
- Foray, D., David, P. A., & Hall, B. (2012). Smart specialization: The concept. In *Knowledge for Growth: Prospects for science, technology and innovation*. European Commission.
- Franke, R. W., & Chasin, B. H. (1994). *Kerala: Radical reform as development in an Indian state*. Food First Books.
- Fritsch, M., & Slavtchev, V. (2008). Determinants of the Efficiency of Regional Innovation Systems. *Regional Studies*, 45(7), 905–918.
- Fu, X., & Yang, Q. G. (2009). Exploring the cross-country gap in patenting: A stochastic frontier approach. *Research Policy*, 38(7), 1203-1213.
- Furman, J. L., & Hayes, R. (2004). Catching up or standing still? National innovative productivity among 'follower' countries, 1978–1999. *Research Policy*, 33(9), 1329-1354.
- Furman, J. L., Porter, M. E., & Stern, S. (2002). The determinants of national innovative capacity. *Research Policy*, 31(6), 899-933.
- Government of Kerala. (2021). *Budget 2021-22*. Finance Department, Government of Kerala.
- Government of Kerala. (2023). *Research & Development Budget 2023-26*. Finance Department, Government of Kerala.

- Griliches, Z. (1990). Patent statistics as economic indicators: A survey. *Journal of Economic Literature*, 28(4), 1661-1707.
- Guellec, D., & Van Pottelsberghe de la Potterie, B. (2003). The impact of public R&D expenditure on business R&D. *Economics of Innovation and New Technology*, 12(3), 225-243.
- Hall, B. H., Griliches, Z., & Hausman, J. A. (1986). Patents and R&D: Is there a lag? *International Economic Review*, 27(2), 265-283.
- Hall, B. H., Jaffe, A. B., & Trajtenberg, M. (2001). The NBER patent citation data file: Lessons, insights and methodological tools. NBER Working Paper No. 8498.
- Harhoff, D., Scherer, F. M., & Vopel, K. (2003). Citations, family size, opposition and the value of patent rights. *Research Policy*, 32(8), 1343-1363.
- Higher Education Department, Government of Kerala. (2021). *Annual Report 2020-21*.
- Hu, A. G., & Mathews, J. A. (2005). National innovative capacity in East Asia. *Research Policy*, 34(9), 1322-1349.
- Intarakumnerd, P., Chairatana, P. A., & Tangchitpiboon, T. (2002). National innovation system in less successful developing countries: The case of Thailand. *Research Policy*, 31(8-9), 1445-1457.
- Jaffe, A. B., & Trajtenberg, M. (2002). *Patents, citations, and innovations: A window on the knowledge economy*. MIT Press.
- Jeffrey, R. (1992). *Politics, women and well-being: How Kerala became "a model"*. Macmillan.
- Joseph, K. J. (2009). Sectoral innovation systems in developing countries: The case of ICT in India. In B. Å. Lundvall, K. J. Joseph, C. Chaminade, & J. Vang (Eds.), *Handbook of innovation systems and developing countries* (pp. 183-213). Edward Elgar.
- Joseph, K. J., & Harilal, K. N. (2001). Structure and growth of India's IT exports: Implications of an export-oriented growth strategy. *Economic and Political Weekly*, 36(34), 3263-3270.
- Kannan, K. P. (2005). Kerala's turnaround in growth: Role of social development, remittances and reform. *Economic and Political Weekly*, 40(6), 548-554.

- Kim, L. (1997). *Imitation to innovation: The dynamics of Korea's technological learning*. Harvard Business School Press.
- KSCSTE Annual Report. (2022). Kerala State Council for Science, Technology and Environment, Government of Kerala.
- KSUM Annual Report. (2022). Kerala Startup Mission, Government of Kerala.
- Kurian, N. J. (1999). State Government Finances: A Survey of Recent Trends. *Economic and Political Weekly*, 34(19), 1115–1125.
- Lanjouw, J. O., & Schankerman, M. (2004). Patent quality and research productivity: Measuring innovation with multiple indicators. *The Economic Journal*, 114(495), 441-465.
- Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, 22(1), 3-42.
- Lundvall, B. Å. (1992). *National systems of innovation: Towards a theory of innovation and interactive learning*. Pinter.
- Lundvall, B. Å., & Johnson, B. (1994). The learning economy. *Journal of Industry Studies*, 1(2), 23-42.
- Machlup, F. (1973). *The production and distribution of knowledge in the United States* (Paperback ed.). Princeton University Press. (Original work published 1962)
- Mani, S. (2004). Institutional support for investment in domestic technologies: An analysis of the role of government in India. *Technological Forecasting and Social Change*, 71(8), 855-863.
- Mani, S. (2009). The growth of knowledge-intensive entrepreneurship in India, 1991–2007. *Research Policy*, 38(2), 358-370.
- Mani, S. (2013). Evolution of the sectoral system of innovation of India's aeronautical industry. *International Journal of Technology and Globalisation*, 7(1-2), 92-117.
- Mathews, J. A., & Hu, M. C. (2007). Enhancing the role of universities in building national innovative capacity in Asia: The case of Taiwan. *World Development*, 35(6), 1005-1020.
- Mazzucato, M. (2013). *The entrepreneurial state: Debunking public vs. private sector myths*. Anthem Press.

- Nelson, R. R. (1993). *National innovation systems: A comparative analysis*. Oxford University Press.
- OECD. (1996). *The knowledge-based economy*. Organisation for Economic Co-operation and Development.
- OECD. (2010). *The OECD innovation strategy: Getting a head start on tomorrow*. Organisation for Economic Co-operation and Development.
- Osella, F., & Osella, C. (2000). *Social mobility in Kerala: Modernity and identity in conflict*. Pluto Press.
- Parayil, G. (1996). The 'Kerala model' of development: development and sustainability in the Third World. *Third World Quarterly*, 17(5), 941-958.
- Pavitt, K. (1985). Patent statistics as indicators of innovative activities: Possibilities and problems. *Scientometrics*, 7(1-2), 77-99.
- Powell, W. W., & Snellman, K. (2004). The knowledge economy. *Annual Review of Sociology*, 30, 199-220.
- Rajan, S. I., & Zachariah, K. C. (2019). Emigration and remittances: New evidences from the Kerala Migration Survey 2018. Working Paper 483, Centre for Development Studies, Thiruvananthapuram.
- Ramachandran, V. K. (1997). On Kerala's development achievements. In J. Drèze & A. Sen (Eds.), *Indian development: Selected regional perspectives* (pp. 205-356). Oxford University Press.
- Reserve Bank of India (RBI). (2021). Research and development expenditure of states and UTs. Reserve Bank of India.
- Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of political economy*, 94(5), 1002-1037.
- Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, 98(5, Part 2), S71-S102
- Rusu, M. (2013). Smart specialization: A possible solution to the new global challenges. *Procedia Economics and Finance*, 6, 128-136.
- Schmoch, U. (2008). Concept of a technology classification for country comparisons. Final Report to the World Intellectual Property Organisation.

- Scotchmer, S. (2006). *Innovation and incentives*. The MIT Press.
- Stiglitz, J. E. (1999). Knowledge as a global public good. In I. Kaul, I. Grunberg, & M. A. Stern (Eds.), *Global public goods: International cooperation in the 21st century* (pp. 308-325). Oxford University Press.
- Sutz, J. (2000). The university–industry–government relations in Latin America. *Research policy*, 29(2), 279-290.
- Thomas, J. J. (2005). Kerala's industrial backwardness: a case of path dependence in industrialization?. *World Development*, 33(5), 763-783.
- Varsakelis, N. C. (2006). Education, political institutions and innovative activity: A cross-country empirical investigation. *Research Policy*, 35(7), 1083-1090.
- Wang, E. C., & Huang, W. (2007). Relative efficiency of R&D activities: A cross-country study accounting for environmental factors in the DEA approach. *Research Policy*, 36(2), 260-273.
- WIPO. (2017). *World intellectual property report 2017: Intangible capital in global value chains*. World Intellectual Property Organization.
- Zachariah, K. C., & Irudaya Rajan, S. (2012). Inflexion in Kerala's Gulf connection: Report on Kerala Migration Survey 2011 (Working Paper No. 450). Centre for Development Studies.

Appendix Tables

Appendix Table 3.1: Key KSCSTE research institutions and focus areas

Institution	Primary Research Focus	Main IPC Categories
Jawaharlal Nehru Tropical Botanic Garden and Research Institute (JNTBGRI)	Medicinal plant research, biodiversity conservation, biotechnology	A01H, A61K, C12N
Kerala Forest Research Institute (KFRI)	Forest ecology, biodiversity, sustainable forestry	A01G, A01N, G01N
Centre for Water Resources Development and Management (CWRDM)	Water resource management, hydrology, watershed development	E03B, G01W, E02B
National Transportation Planning and Research Centre (NATPAC)	Transport engineering, traffic management, infrastructure planning	G08G, E01C, B60P
Kerala School of Mathematics	Mathematical modeling, theoretical mathematics, computational methods	G06F, G06N
Malabar Botanical Garden and Institute for Plant Sciences	Plant taxonomy, conservation biology, botanical research	A01H, A01G, C12N
Srinivasa Ramanujan Institute for Basic Sciences	Basic research in physics, chemistry, mathematics	G01, B01J, C01B
Institute of Climate Change Studies	Climate modeling, environmental impact assessment, sustainability	G01W, Y02A, Y02E
Institute of Advanced Virology	Viral diagnostics, vaccine development, epidemiology	C12N, A61K, G01N
Regional Cancer Centre, Thiruvananthapuram	Cancer research, diagnostics, treatment protocols	A61B, A61K, G01N

Appendix Table 3.2: Major state universities and research domains

University	Research Specialization	Primary IPC Categories
University of Kerala	Interdisciplinary research, biotechnology, physics	G06Q, G01N, C07
University of Calicut	Social sciences, natural sciences, materials research	G06Q, C01, G01
Cochin University of Science and Technology (CUSAT)	Material science, ocean sciences, photonics	G01N, B01J, G02B
Kerala Agricultural University (KAU)	Agricultural technology, crop improvement, farming systems	A01B, A01C, A01G
Kerala University of Digital Sciences, Innovation and Technology (KUDSIT)	Digital technologies, AI, information systems	G06F, G06N, H04L
Kerala University of Health and Allied Sciences (KUHAS)	Medical research, healthcare technologies, biomedical engineering	A61B, A61K, A61N
Kerala University of Fisheries and Ocean Studies (KUFOS)	Aquaculture, marine biotechnology, fisheries management	A01K, C12N, A01G
Mahatma Gandhi University (MGU)	Environmental sciences, biochemistry, nanoscience	B82Y, C01B, G01N
Sree Sankaracharya University of Sanskrit	Sanskrit studies, ancient texts, cultural heritage	G10L, G06F
Kannur University	Regional studies, social sciences, natural sciences	G06Q, G01N
Malayalam University	Language studies, literature, cultural research	G10L, G06F
Kerala Veterinary and Animal Sciences University	Animal health, veterinary medicine, animal biotechnology	A61D, A23K, A01K

Appendix Table 3.3: Specialized R&D centres and their focus areas

R&D Centre	Technical Domain	Primary IPC Categories
Centre for Engineering Research and Development (CERD)	Engineering solutions, material testing, structural analysis	G01N, E04B,B01D
Transportation Engineering Research Centre (TERC)	Transport infrastructure, traffic management, road safety	E01C, G08G,B60P
Product Design & Development Centre	Industrial design, product innovation, ergonomics	B29C, B44C,G06F
Rural Technology Development Centre	Appropriate technologies, rural innovations, small-scale solutions	A01D, F24S, F03D
Centre for Bamboo Technology	Bamboo applications, sustainable materials, construction techniques	B27K, E04C,C08L
Robotics & AI nodal Centre	Robotics, automation, artificial intelligence applications	G05B, G06N, B25J
Centre of Excellence in Systems, Energy & Environment	Energy efficiency, environmental technologies, systems engineering	F03G, Y02E,Y02B
Centre for High Performance Computing	Computational modeling, data analytics, parallel computing	G06F, G06N
International Centre for Free and Open Source Software (ICFOSS)	Open source software, digital solutions, IT frameworks	G06F, H04L,G06Q
India Innovation Centre for Graphene (IICG)	Graphene applications, advanced materials, nanotechnology	B82Y, C01B,H01L
Biological Production Complex	Vaccines, biological products, veterinary pharmaceuticals	A61K, C12N, A61D
Kerala Livestock Development Board	Animal breeding, genetic improvement, livestock management	A01K, C12N, A23K
State Board of Medical Research	Clinical research, medical diagnostics, public health	A61B, A61K, G01N
International Research Institute of Ayurveda (IRIA)	Ayurvedic medicine, herbal formulations, traditional knowledge	A61K, A61P, A61B
Interdisciplinary Research Centres at Govt. Engineering Colleges	Cross-disciplinary engineering solutions, applied research	G06F, H01L, B01J

Appendix Table 3.4: Sectorial distribution of Kerala's R&D budget (2023-2026)

Sector	2023-24 (₹ lakhs)	2024-25 (₹ lakhs)	2025-26 (₹ lakhs)	Growth (2023-26)	Share (2025-26)
Education R&D	161,168.43	170,640.35	181,020.47	12.32%	44.81%
Medical Health, Family Welfare and Sanitation	80,212.18	87,104.55	101,498.96	26.54%	25.13%
Agricultural Research	51,011.25	54,095.94	56,692.10	11.14%	14.03%
Industrial Research	27,615.00	34,443.35	37,020.70	34.06%	9.16%
Infrastructure Research	5,606.98	6,456.37	8,736.89	55.82%	2.16%
Others	14,622.74	7,138.92	9,955.94	-31.91%	2.46%
Social Security and Welfare	3,294.00	3,583.86	3,030.37	-8.00%	0.75%
Welfare of SC/ST	871.37	984.17	2,294.46	163.31%	0.57%
Environmental Research	1,943.13	1,431.64	1,629.07	-16.16%	0.40%
Housing and Urban Development	1,169.41	1,282.00	1,260.57	7.80%	0.31%
Fiscal Research	668.67	624.52	707.20	5.76%	0.18%
Labour Research	61.11	66.12	89.26	46.07%	0.02%
Total	348,244.27	367,851.79	403,935.99	16.00%	100.00%

Appendix Table 4.1: Top 10 IPC Subsections in Kerala Patents

IPC Subsection	Description	Count	Percentage
A61K	Preparations for medical, dental, or toilet purposes	184	21.65%
A61B	Diagnosis; Surgery; Identification	123	14.47%
G01N	Investigating materials by determining properties	86	10.12%
A61F	Prostheses; Orthopedic, nursing devices	75	8.82%
G06F	Electric digital data processing	71	8.35%
A61L	Sterilizing materials; Bandages; Surgical articles	63	7.41%
H04L	Transmission of digital information	54	6.35%
H01L	Semiconductor devices; Electric solid state devices	48	5.65%
B82Y	Applications of nanostructures	44	5.18%
H01M	Conversion of chemical energy into electrical energy	42	4.94%

Appendix Table 4.2: IPC Subsection Distribution by Applicant Type**4.2.1: Central Government Institution (Total: 291 patents)**

IPC Subsection	Description	Count	Percentage
A61K	Preparations for medical, dental, or toilet purposes	53	18.21%
G01N	Investigating materials by determining their properties	52	17.87%
A61B	Diagnosis; Surgery; Identification	51	17.53%
A61F	Prostheses; Orthopedic, nursing devices	49	16.84%
A61L	Sterilizing materials; Bandages; Surgical articles	39	13.40%

4.2.2: Individual (Total: 306 patents)

IPC Subsection	Description	Count	Percentage
A61K	Preparations for medical, dental, or toilet purposes	69	22.55%
A61B	Diagnosis; Surgery; Identification	36	11.76%
H04L	Transmission of digital information	26	8.50%
A47J	Kitchen equipment; Coffee mills; Apparatus for beverages	22	7.19%
G06F	Electric digital data processing	22	7.19%
A01G	Horticulture; Cultivation of vegetables, flowers, etc.	20	6.54%

4.2.3: Private Company (Total: 85 patents)

IPC Subsection	Description	Count	Percentage
G06F	Electric digital data processing	19	22.35%
A61K	Preparations for medical, dental, or toilet purposes	18	21.18%
A61B	Diagnosis; Surgery; Identification	12	14.12%
H04L	Transmission of digital information	10	11.76%
B01J	Chemical or physical processes	10	11.76%
G06Q	Data processing systems for administrative purposes	8	9.41%
G06T	Image data processing or generation	8	9.41%

4.2.4: State Government University (Total: 62 patents)

IPC Subsection	Description	Count	Percentage
A61K	Preparations for medical, dental, or toilet purposes	24	38.71%
C08L	Compositions of macromolecular compounds	9	14.52%
G01N	Investigating materials by determining properties	9	14.52%
B82Y	Specific uses of nanostructures	8	12.90%
C08K	Use of inorganic or non-macromolecular organic substances as compounding ingredients	8	12.90%

4.2.5: Private University (Total: 47 patents)

IPC Subsection	Description	Count	Percentage
H01M	Processes for direct conversion of chemical energy into electrical energy	10	21.28%
A61B	Diagnosis; Surgery; Identification	10	21.28%
G06F	Electric digital data processing	10	21.28%
A61K	Preparations for medical, dental, or toilet purposes	9	19.15%
A61L	Methods for sterilizing materials; Bandages; Surgical articles	8	17.02%
H04L	Transmission of digital information	7	14.89%

Appendix Table 4.3: Distribution of Field of Invention in Kerala Patents

Field of Invention	Count	Percentage	Primary Applicant Type
Mechanical Engineering	204	24.00%	Individual (56.4%)
Chemical	128	15.06%	Central Government Institution (42.2%)
Bio-Medical Engineering	85	10.00%	Central Government Institution (55.3%)
Electrical	59	6.94%	Central Government Institution (42.4%)
Physics	49	5.76%	Central Government Institution (42.9%)
Electronics	44	5.18%	Central Government Institution (43.2%)
Communication	44	5.18%	Central Government Institution (27.3%)
Computer Science	38	4.47%	Private Company (26.3%)
Biotechnology	35	4.12%	Central Government Institution (37.1%)
Polymer Technology	29	3.41%	Central Government Institution (55.2%)
Other Fields	135	15.88%	Various
Total	850	100.00%	-

Appendix Table 4.4: Cross-Domain integration patterns in Kerala patents

Primary-Secondary IPC Combination	Count	Percentage of Multi-classified Patents	Primary Applicant Type
A61K - A61B (Medical Preparations - Diagnostics)	68	13.73%	Central Government Institution
A61K - A61P (Medical Preparations - Therapeutic Activity)	42	8.48%	State Government University
G06F - G06Q (Digital Processing - Business Methods)	26	5.25%	Private Company
A61B - G06F (Medical Diagnostics - Digital Processing)	24	4.85%	Private University
B82Y - A61K (Nanotechnology - Medical Preparations)	23	4.65%	State Government University
G01N - C12Q (Analytical Testing - Measuring Enzymes)	19	3.84%	Central Government Institution
C02F - H01M (Water Treatment - Energy Conversion)	14	2.83%	Private University
Other Combinations	279	56.37%	Various
Total Multi-classified Patents	495	100.00%	-

Note: 495 patents (58.12% of total) have multiple IPC classifications