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Mapping The Innovation Ecosystem In Indian States: A Sectoral And Institutional Perspective Based On GII Framework

Research Scholar :- Suresh Sharma

Vardhaman Mahaveer Open University Kota

Guide Name- Dr. S.K. Kulshrestha

(Assistant Professor)

Abstract : - This study presents a detailed mapping of the innovation ecosystem across Indian states, employing the Global Innovation Index (GII) framework with an emphasis on sectoral performance and institutional structures. Using secondary data spanning 2015 to 2024, this paper analyzes regional disparities in innovation capability and output through a multidimensional lens. It draws data from GII Reports (WIPO, INSEAD, Cornell), NITI Aayog's India Innovation Index, State Economic Surveys, DPIIT Startup Rankings, and national R&D statistics.The GII framework classifies innovation into two broad categories: Innovation Inputs (Institutions, Human Capital & Research, Infrastructure, Market & Business Sophistication) and Innovation Outputs (Knowledge & Technology Outputs, Creative Outputs). Applying this to Indian states, the study reveals stark variations in innovation performance. For example, as per the India Innovation Index 2021, Karnataka ranked 1st, driven by high R&D investment (₹10,484 crore in 2020-21), a vibrant startup ecosystem (over 13,000 startups registered by 2023), and institutions like IISc, ISRO, and multiple incubators. Maharashtra and Tamil Nadu followed due to their strength in manufacturing innovation, academic-industry linkages, and strong IP filing performance. Maharashtra alone accounted for 11.4% of India's patent filings in 2022. In contrast, states like Bihar, Jharkhand, and Uttar Pradesh ranked among the lowest due to low GERD (Gross Expenditure on R&D), poor infrastructure, and weak institutional support. For instance, Bihar's GERD as a share of GSDP was below 0.03% in 2022 compared to Karnataka's 0.93%. Moreover, while Kerala ranks high in human capital (literacy rate over 96%, high HEI density), it lags in startup facilitation and tech transfer mechanisms, indicating institutional gaps despite sectoral readiness. The study categorizes innovation into four sectors—IT & Services, Manufacturing, Agriculture, and Green Technologies. Sectoral analysis shows that: Karnataka and Telangana dominate in IT innovation, supported by skilled talent and policy support. Tamil Nadu leads in manufacturing R&D and product innovation. Punjab and Haryana show strong growth in agricultural innovation, including precision farming and biotech. Gujarat and Rajasthan are emerging in renewable energy and green technologies, backed by solar and wind infrastructure and policy subsidies. Institutionally, states with active innovation councils, PPP-led incubators, and university-linked R&D centers outperformed those lacking coordination. For instance, Gujarat's iCreate and Tamil Nadu's Innovation Grand Challenge are institutional models worth replicating.

Keyword :- Sector-wise Innovation Trends in Indian States, Institutional Factors Influencing Innovation, Theoretical Framework, Integration of the Triple Helix Model, Methodology, Institutional Perspective, Policy Implications and Recommendations.

Introduction :- Innovation has emerged as a critical driver of economic growth, competitiveness, and social development in the 21st century. In a rapidly evolving global economy, countries and regions that successfully foster innovation ecosystems are better equipped to generate high-value jobs, enhance productivity, and achieve sustainable development. India, as one of the world's fastest-growing economies and a leader in the global digital landscape, has taken significant strides in strengthening its innovation capacity. However, there exists considerable regional disparity in innovation performance across Indian states, which necessitates a deeper analysis of sectoral priorities and institutional mechanisms. This paper aims to map the innovation ecosystem in Indian states through the analytical lens of the Global Innovation Index (GII) framework, focusing on the period from 2015 to 2024.The GII framework, jointly developed by WIPO, INSEAD, and Cornell University, provides a comprehensive structure to evaluate innovation through two main components: Innovation Inputs (Institutions, Human Capital & Research, Infrastructure, Market Sophistication, Business Sophistication) and Innovation Outputs (Knowledge & Technology Outputs, Creative Outputs). India has improved significantly in the global GII rankings—from 81st in 2015 to 40th in 2023—reflecting robust national-level progress. However, this upward trend masks significant state-level imbalances.

According to NITI Aayog's India Innovation Index 2021, Karnataka ranked 1st among Major States, driven by a high density of startups (over 13,000 startups as of 2023), premier R&D institutions like IISc and ISRO, and substantial private sector investment in innovation (over ₹10,000 crore in R&D expenditure). On the other hand, states like Bihar, Uttar Pradesh, and Jharkhand consistently rank at the bottom due to weak institutional frameworks, low R&D spending (GERD < 0.05% of GSDP), limited higher education reach, and underdeveloped digital infrastructure Sectoral innovation also varies considerably. IT and digital innovation clusters are concentrated in states like Karnataka, Telangana, and Maharashtra. Manufacturing-led innovation is dominant in Tamil Nadu and Gujarat, while agriculture-based innovations are more prominent in Punjab and Haryana due to the adoption of biotechnology, smart irrigation, and precision farming tools. Additionally, states like Rajasthan and Gujarat are emerging as hubs for green technology and renewable energy innovation, supported by state-sponsored solar missions and investment incentives Institutionally, performance depends on the strength of policy frameworks, university-industry linkages, public-private partnerships and innovation governance. States with active innovation councils (e.g., Gujarat, Tamil Nadu), startup missions, and dedicated R&D incentives tend to foster more vibrant ecosystems.

Objectives of the Study

This study is guided by four primary objectives:

1. To map the structure and performance of innovation ecosystems across Indian states.

2. To analyze sector-wise (e.g., agriculture, manufacturing, services) innovation trends.

3. To study the institutional factors (e.g., government, universities, industries) influencing innovation.

4. To identify regional disparities and policy gaps across Indian states.

Each of these objectives is discussed in depth below, with supporting data from 2015–2024.

Innovation ecosystems refer to the network of institutions, individuals, enterprises, and policies that enable the creation, diffusion and application of knowledge and technology. In India, this ecosystem varies widely across states due to differences in economic structure, political will, educational infrastructure and R&D capacity.

Top Performers: Karnataka has consistently ranked 1st in India Innovation Index (2020, 2021) due to its strong ecosystem—over 13,000 startups, R&D spending > 0.93% of GSDP, institutions like IISc, and robust ICT infrastructure. Tamil Nadu and Maharashtra perform strongly due to industrial R&D, tech parks, and higher education density.

Low Performers: Bihar, Uttar Pradesh, Chhattisgarh exhibit low innovation scores, due to poor R&D spending (less than 0.05% of GSDP), lack of industry-academia linkages, and inadequate digital infrastructure.

Sector-wise Innovation Trends in Indian States

Innovation is not uniform across sectors. Each state tends to specialize in different domains based on historical, geographic, and economic advantages.

a. Agricultural Innovation - States like Punjab, Haryana, Maharashtra, and Andhra Pradesh have shown significant innovation in agri-tech, including smart irrigation, drone-based monitoring, and bio-fertilizer research.

- Punjab adopted precision farming methods and biotech crops. PAU (Punjab Agricultural University) contributes to over 200+ agri patents since 2017.
- Maharashtra's e-NAM market digitalization and Rythu Bandhu Scheme in Telangana (though primarily a financial aid program) have spurred agri-digital startups.

b. Manufacturing Innovation - Tamil Nadu, Gujarat, and Maharashtra lead in manufacturing innovation. Tamil Nadu's share in industrial GVA is over 11% of India's total, with innovation in automotive, electronics, and textiles. Gujarat's GIDC and iCreate innovation hubs have incubated over 1500+ MSMEs using IoT and automation.

c. Service Sector and Digital Innovation -

- Karnataka (especially Bengaluru), Telangana, and Kerala have excelled in service-based innovation, particularly IT, fintech, and edtech.
- Karnataka's IT exports crossed ₹2 lakh crore in 2023, largely driven by innovation in AI, cloud computing, and cybersecurity.
- Kerala's Startup Mission (KSUM) has created over 4,000 startups focused on e-health, education, and digital media.

d. Green and Renewable Energy Innovation

- Rajasthan and Gujarat are emerging as leaders in solar energy innovation, with Rajasthan's installed solar capacity exceeding 16 GW in 2023.
- Rajasthan's RajSolarTech and Gujarat's Gujarat Solar Park integrate advanced R&D in photovoltaic efficiency and smart grid management.

Institutional Factors Influencing Innovation

Institutional factors are critical to understanding how innovation is enabled, supported, or restricted in each state. These include government policies, higher education institutions, industry participation, and public-private partnerships (PPP).

a. Role of State Governments

- Tamil Nadu's Innovation Policy 2023 offers seed funding, industry mentoring, and state-funded innovation challenges.
- Karnataka's Elevate 100 and K-tech policies prioritize high-potential startups and R&D subsidies.

b. Higher Education and Research Institutions

States with premier institutions such as IISc (Karnataka), IIT-Madras (Tamil Nadu), IIT-Bombay (Maharashtra), and NIPER (Punjab) exhibit high research output and innovation.

According to the 2023 NIRF Rankings, Karnataka and Tamil Nadu had over 15 institutions in the top 100, boosting knowledge generation and transfer.

c. Industry Participation

- Maharashtra and Gujarat lead in private sector innovation, supported by large-scale industrial clusters, SEZs, and manufacturing corridors.
- Maharashtra's industrial R&D expenditure was ₹11,207 crore in 2022–23, the highest among states.

d. Public-Private Partnerships and Incubators

Kerala Startup Mission, T-Hub (Telangana), and Gujarat's iCreate are model PPPs.

These incubators provide capital, mentoring, testing labs, and policy linkages.

Identifying Regional Disparities and Policy Gaps

Despite India's improvement in global innovation rankings, the distribution of innovation capacity remains heavily skewed.

Regional Patterns: - South and Western India (Karnataka, Maharashtra, Gujarat, Tamil Nadu) dominate in innovation readiness and performance.

Eastern and North-Central states (Jharkhand, Bihar, UP, MP) lag due to weak institutional setups, inadequate R&D, and low per capita income.

Innovation Index Rank Disparities (India Innovation Index 2021):

State Rank (2021)	GERD as %	GSDP Startups registered
Karnataka	1	0.93% - 13,000+
Maharashtra	2	0.88% -12,500+
Tamil Nadu	4	0.80% - 8,700+
Bihar	22	<0.05% <500
Uttar Pradesh	20	0.06% ~2,000

Rank	Major States	Score
1	Karnataka	42.5
2	Maharashtra	38.03
3	Tamil Nadu	37.91
4	Telangana	33.23
5	Kerala	30.58
6	Haryana	25.81
7	Andhra Pradesh	24.19
8	Gujarat	23.63
9	Uttar Pradesh	22.85
10	Punjab	22.54

Policy Gaps Identified:

Lack of localized innovation policies: Many states follow national schemes without tailoring to local industrial or demographic strengths.

Weak data systems: Absence of real-time innovation data and metrics at the district and municipal levels.

Poor academia-industry collaboration: Particularly in low-performing states, innovation remains confined to academic outputs without industry uptake.

Funding bottlenecks: Limited access to venture capital or state innovation funds for early-stage entrepreneurs outside metros.

Recommendations for Policy and Institutional Strengthening

To address disparities and build robust innovation ecosystems across India, the following policy directions are recommended:

1. Localized Innovation Missions: Similar to Gujarat's iCreate or Kerala Startup Mission, every state should establish innovation bodies aligned to regional priorities.

2. District Innovation Indices: Develop innovation indices at the district level to track performance and gaps.

3. Innovation-linked Incentives: Encourage industries and universities to collaborate by offering tax breaks, land grants, and R&D-linked performance bonuses.

4. Capacity Building Programs: Upskill local government, university staff, and industry stakeholders in innovation management, IP, and technology transfer.

5. Decentralized R&D Funding: Create state-level innovation funds with flexible eligibility to support local entrepreneurs, MSMEs, and grassroots innovators.

6. Monitoring and Evaluation Systems: Institutionalize metrics to regularly evaluate the impact of innovation policies on economic growth, employment, and sustainability.

This study offers a comprehensive mapping of the innovation ecosystem across Indian states using the GII framework. It highlights how sectoral strengths (e.g., IT in Karnataka, manufacturing in Tamil Nadu, agriculture in Punjab) and institutional maturity (e.g., strong innovation councils, PPP incubators, R&D hubs) contribute to innovation outcomes. However, glaring disparities persist between innovation-rich and innovation-deficient states, underlining the urgent need for region-specific strategies and institutional reforms.

The findings reinforce that a "one-size-fits-all" approach cannot deliver balanced innovation growth across India. Instead, a strategic combination of sectoral focus, institutional strengthening, and policy innovation is essential to build inclusive, resilient, and sustainable innovation ecosystems aligned with India's long-term development goals.

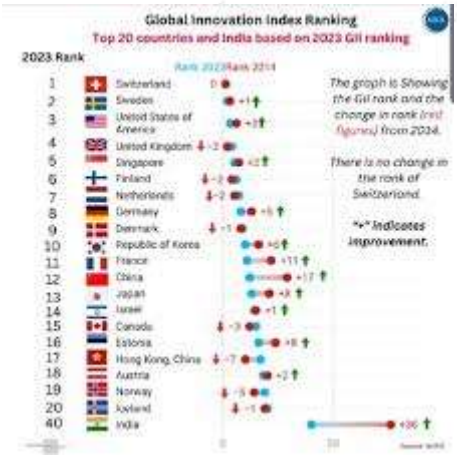
Theoretical Framework

Innovation ecosystems are complex, multi-layered systems involving numerous actors—governments, universities, industries, civil society—interacting through institutions, markets, and knowledge flows. Mapping these ecosystems requires a multidimensional framework that captures structural capabilities, knowledge generation, and the dynamic interactions among key players.

This study adopts a blended Global Innovation Index (GII) framework combined with the Triple Helix Model and an input-output approach to assess the performance of Indian states. The period of analysis spans 2015 to 2024, drawing on data from GII Reports, NITI Aayog's India Innovation Index, DPIIT Startup Rankings, State Economic Surveys, and R&D databases.

1. Global Innovation Index (GII) Framework

The GII framework divides innovation into seven core pillars, categorized under two broad components: Innovation Inputs and Innovation Outputs. These pillars form the backbone of the theoretical model used in this study.



A. Innovation Input Pillars

1. Institutions - Institutions include the political, regulatory, and business environment that shape the incentives and efficiency of innovation processes.

States with stable governance, transparent regulatory frameworks, and proactive policies (e.g., Karnataka, Tamil Nadu, Gujarat) show high innovation outcomes.

Karnataka, through the Karnataka Startup Policy 2022, created clear startup policies, innovation cells, and eased compliance procedures. In contrast, states like Bihar and Jharkhand, with limited institutional reforms, face challenges in policy execution and governance, leading to innovation stagnation.

2. Human Capital and Research

This pillar evaluates the role of education systems, research institutions, and investment in R&D.

Karnataka, Tamil Nadu, and Maharashtra dominate this pillar with top universities like IISc, IIT-Madras, and IIT-Bombay.

Karnataka's gross enrollment ratio in higher education exceeded 34% in 2023, and R&D spending reached over ₹10,484 crore in 2022–23.

States like Uttar Pradesh and Rajasthan lag with lower R&D funding and weak research infrastructure.

3. Infrastructure

Infrastructure includes ICT access, energy, transport, and ecological sustainability.

Telangana, Kerala, and Delhi have high internet penetration (>80%), mobile connectivity, and incubation infrastructure.

Gujarat's GIDC industrial parks and smart cities projects significantly support innovation infrastructure.

In eastern India, lack of digital infrastructure is a key constraint to ecosystem maturity.

4. Market Sophistication

This refers to the availability of credit, investment environment, and market size for new products and innovations.

Maharashtra, as India's financial hub, provides high venture capital activity and credit penetration.

In 2022, Maharashtra recorded ₹2,300 crore in startup funding, with Bengaluru and Mumbai among the top innovation hubs in South Asia.

States like Assam, Odisha, and Jharkhand suffer from limited venture capital exposure, reducing innovation commercialization.

5. Business Sophistication

This assesses firm-level innovation, knowledge absorption, and value-chain participation.

Tamil Nadu's electronics and automobile clusters, and Gujarat's chemicals and pharma industries, demonstrate high business R&D and innovation linkages.

Tamil Nadu's industrial exports exceeded ₹3.7 lakh crore in 2023, partly driven by tech-enhanced manufacturing and process innovation.

B. Innovation Output Pillars

6. Knowledge and Technology Outputs

This includes patents, trademarks, high-tech exports, and knowledge diffusion.

Maharashtra and Karnataka together contributed over 24% of India's patents filed in 2023 (Maharashtra: ~13,500; Karnataka: ~10,800).

Karnataka's high-tech exports (mainly IT services) crossed ₹2 lakh crore, contributing to both national and state GDP.

7. Creative Outputs

This captures creative goods and services, intangible assets, and online creativity. Kerala and Tamil Nadu lead in cultural and digital creativity due to their film industries, e-literature, and educational platforms.

Delhi NCR, home to multiple media tech startups and online content platforms, ranks high in digital design and multimedia exports.

2. Integration of the Triple Helix Model

The Triple Helix Model (Etzkowitz & Leydesdorff, 2000) conceptualizes innovation as a dynamic interaction between Universities, Industries, and Governments. This interaction creates hybrid institutions such as incubators, science parks, and innovation councils.

University–Industry Linkages:

IIT-Madras Research Park supports over 70 corporate R&D units, including TCS, Titan, and Saint-Gobain. Gujarat's iCreate promotes joint product development between students and MSMEs.

Government–University Collaboration: - Kerala Startup Mission (KSUM) provides direct government support to university-based innovations. Karnataka's K-Tech innovation hubs are co-managed by public universities and the IT department.

Government–Industry Cooperation:

Tamil Nadu Innovation Initiative (TANII) promotes PPP models where industries co-invest in state-run innovation schemes. Telangana's T-Hub is a prime example where government and industry collaborate on funding, mentoring, and scaling startups.

States that integrate these three actors in structured policy and operational mechanisms demonstrate greater innovation output and resilience.

3. Innovation Input–Output Approach

To assess the efficiency of innovation ecosystems, this study uses the input–output model, a standard technique in innovation studies.

Innovation Inputs:

Policy infrastructure (laws, incentives), Financial resources (public R&D, private investment), Human capital (education, researchers), Physical infrastructure (labs, IT parks).

Innovation Outputs:

Patents, copyrights, trademarks, Publications and citations, Startups and unicorns, High-tech exports and new product launches

State-Level Efficiency Comparison (2023): -

State	Input Rank	Output Rank	Efficiency	(Output/Input)
Karnataka	1	1	High	(1.00)
Maharashtra	2	3	Moderate	(0.85)
Tamil Nadu	4	2	High	(1.12)
Bihar	19	22	Low	(0.53)
Gujarat	5	4	High	(0.95)

Insight: - Tamil Nadu demonstrates high efficiency, translating relatively fewer resources into greater innovation outputs. Bihar shows a large gap between input and output, indicating structural and institutional inefficiencies.

Summary of Theoretical Insights

- GII Pillar Triple Helix Dimension Example State(s) Data-Driven Insight
- Institutions Government Karnataka, Tamil Nadu Strong policies and ease of doing innovation
- Human Capital Universities Maharashtra, Kerala High GER, research quality
- Infrastructure All three Telangana, Gujarat ICT readiness and startup zones
- Market Sophistication Industry Maharashtra Access to VC, startup financing
- Business Sophistication Industry–University Gujarat, TN Strong manufacturing R&D and MSME linkages
- Knowledge & Tech Output Universities + Industry Karnataka, Maharashtra Patent filings, publications, exports
- Creative Output Universities + Industry Kerala, Delhi Media, education, and cultural content startups

The integration of the GII pillars with the Triple Helix model and the input-output approach offers a robust framework to assess and compare the innovation ecosystems of Indian states. The framework captures not only structural inputs like infrastructure and human capital but also the dynamic institutional interactions and actual innovation outcomes. States like Karnataka, Tamil Nadu, and Maharashtra benefit from high synergy among government, academia, and industry, supported by robust policies and infrastructure. Meanwhile, states like Bihar and UP lag due to weak institutional support and inefficient conversion of inputs to outputs.

The theoretical framework thus supports the overarching goal of the study: to evaluate innovation disparities, identify institutional gaps, and recommend policy interventions tailored to state-specific strengths and weaknesses.

Data Sources (2015–2024):

A Foundation for Mapping Innovation Ecosystems Accurate and comprehensive data are the backbone of any empirical study, especially when evaluating complex and multi-dimensional themes such as innovation. The present research employs a diverse array of reliable secondary data sources spanning the period from 2015 to 2024. These datasets help assess the structural composition, performance, and regional disparities of innovation

ecosystems across Indian states from both sectoral and industrialisation perspectives, using the Global Innovation Index (GII) framework.

1. Global Innovation Index (GII) Reports - The GII is the primary conceptual and analytical framework used in this study. It provides internationally comparable data across 132 economies, measuring innovation performance using a composite index of 7 pillars, including institutions, infrastructure, human capital, market sophistication, business sophistication, and innovation outputs.

- Institutions score (political stability, regulatory quality)
- Education and R&D investment
- ICT access and infrastructure
- Business environment and market conditions
- Patent applications, knowledge diffusion
- High-tech and creative goods exports

Relevance to Indian States: - Though the GII is country-level, its framework has been adapted to assess state-level innovation performance. States like Karnataka, Maharashtra, and Tamil Nadu exhibit strong scores when disaggregated through national datasets aligned with GII indicators.

2. India Innovation Index (III) - The India Innovation Index is a localized application of the GII framework at the state and union territory level. It serves as the central tool for ranking Indian states based on innovation inputs and outputs.

Indicators Used: - Innovation Enablers: Human capital, investment, knowledge workers, business environment, safety and legal environment Innovation Performance: Knowledge output, knowledge diffusion

Notable Findings: -

- Karnataka ranked 1st in all three rounds (2019, 2020, 2021).
- Bihar, Jharkhand, Chhattisgarh ranked lowest due to weak R&D infrastructure and limited startup activity.
- The southern and western regions showed consistent outperformance in institutional and industrial innovation inputs.

3. State Economic Surveys

State Economic Surveys offer state-level financial, industrial, and social data, which are essential for understanding the sectoral composition of innovation (agriculture, manufacturing, services) and state investment trends.

Key Data Extracted:

- State GDP by sector (agriculture, industry, services)
- Government expenditure on education and technology
- Industrial growth rates and infrastructure development
- Skill development and employment statistics

Tamil Nadu's Survey (2023–24) reported a 16% growth in industrial GVA, aligning with innovation in automobile and electronics manufacturing. Karnataka's survey recorded over ₹10,000 crore R&D investment, highlighting its leadership in innovation financing.

4. Startup India Rankings

Startup India Rankings assess states based on their startup ecosystem development, infrastructure, policy support, seed funding, and ease of registration.

Indicators Used:- Number of recognized startups, State policy support (incubators, accelerators), Regulatory facilitation and funding access

Data Highlights: -

- Karnataka, Gujarat, and Maharashtra emerged as top performers across all editions.
- Gujarat supported over 5000 startups via iCreate and state innovation programs.
- Uttar Pradesh improved dramatically in 2022, reaching over 3200 DPIIT-registered startups, showing potential despite infrastructural gaps.

5. R&D Expenditure Data

This data is vital to measure innovation input, specifically investment in research and development across the central and state governments and private sectors.

Data Observations: - India's national GERD is 0.7% of GDP, while Karnataka's GERD crossed 0.93% of GSDP in 2022.

Maharashtra, Gujarat, and Tamil Nadu also reported higher industrial R&D expenditure.

States like Bihar, Assam, and Odisha spend less than 0.05% of GSDP, reflecting limited R&D commitment.

6. Patent and Publication Databases

These databases are crucial for capturing innovation output metrics, especially knowledge and technology generation.

Data Collected: - Annual patent applications (domestic + foreign filings), Scientific articles by state-based institutions, Citation impact and H-index, Utility models, trademarks, and copyrights.

- Karnataka filed over 10,800 patents in 2023, primarily in IT, biotech, and electronics.
- Maharashtra led in cumulative filings (~13,500) due to industrial R&D centers and universities.
- IIT Madras, IISc, and CSIR institutes were top contributors to publications and patent citations.
- Northern and Eastern states showed minimal activity in IP generation, indicating poor innovation commercialization.

Data Integration Approach

To ensure accurate analysis:- Data was normalized and compared per capita, where appropriate (e.g., startups per million people, patents per 10,000 researchers). Time-series trends (2015–2024) were developed to observe growth trajectories. States were clustered into high, moderate, and low innovation performers based on composite GII-style scores. Each data point was mapped to the GII pillars for sectoral (e.g., manufacturing, IT, agriculture) and institutional (government, academia, industry) analysis.

The combined use of multi-source longitudinal data (2015–2024) enables a comprehensive mapping of India's state-level innovation ecosystem. By drawing from authoritative sources like GII, NITI Aayog, DST, IPO India, and Scopus, the study ensures empirical reliability and conceptual alignment with global best practices. This framework allows for a nuanced evaluation of how institutional, financial, human, and infrastructural inputs translate into tangible innovation outcomes—across states, sectors, and time. This empirical backbone is critical for understanding regional disparities, tracking innovation growth, and recommending state-specific strategies for inclusive and sustainable innovation-led industrialisation in India.

Methodology

The methodology for mapping the innovation ecosystem in Indian states is grounded in a mixed-method comparative framework, combining quantitative analysis, sectoral mapping, institutional assessment, and optional

spatial techniques. The study covers the period 2015 to 2024, aligning innovation indicators with the Global Innovation Index (GII) framework and adapting them to the Indian federal context.

1. Comparative Analysis Using GII-Based Indicators

The primary approach involves a comparative analysis of Indian states across the seven GII pillars:

Institutions, Human Capital & Research, Infrastructure, Market Sophistication, Business Sophistication, Knowledge & Technology Outputs, Creative Outputs. State-level data are extracted from:- India Innovation Index (NITI Aayog), State Economic Surveys, DST R&D reports, Startup India portal.

Each indicator is normalized (e.g., per capita patents, GERD as % of GSDP) to ensure comparability across states with differing population sizes and economies.To benchmark performance, Indian states are grouped into high, medium, and low innovation performers, similar to U.S. state comparisons often done using the State Technology and Science Index (Milken Institute).

2. Sectoral Analysis

The study identifies how key sectors drive innovation in Indian states:

Agriculture and Agri-Tech,Manufacturing and Industrial R&D,Information Technology (IT),Startups and Digital Platforms.

Each sector is analyzed using indicators such as:- Sector-specific R&D spending, Output in terms of innovation (startups, patents, product launches), Policy interventions (e.g., agriculture innovation grants, IT parks).

3. Institutional Analysis

Institutions are key enablers in the innovation ecosystem. The study examines the roles of: Universities and technical institutes (e.g., IITs, NITs, state agriculture universities), Government policies and funding programs (e.g., Elevate 100, KSUM, iCreate), Incubators and accelerators (e.g., T-Hub, Atal Incubation Centers).

Metrics include:- Number of incubators per state, Startup success rate (3–5 year survival rate) ,R&D publication-output from universities, Government innovation budget allocation.

4. Quantitative Methods

To evaluate relationships between innovation inputs and outputs, the following statistical techniques are applied:

a. Correlation Analysis: - To test relationships between:- GERD and patents, Number of startups and employment, Literacy rates and innovation output.

b. Regression Analysis:- To quantify the influence of factors like:- Infrastructure quality on startup density, R&D spending on high-tech exports.

c. Cluster Analysis:- To classify Indian states into innovation clusters (high, medium, low performers), similar to U.S. models (e.g., Massachusetts vs Mississippi in innovation rankings). K-means clustering is used on variables such as patent filings, GDP share of R&D, startup growth, etc.

5. GIS-Based Mapping (Optional Layer)

For advanced spatial visualization, Geographic Information Systems (GIS) tools (e.g., QGIS, ArcGIS) are used to:- Visualize innovation hotspots across Indian states, Map sectoral innovation zones (e.g., solar innovation in Rajasthan, IT in Bengaluru), Identify “innovation deserts” with low activity.

This allows policymakers to visually assess regional disparities and prioritize interventions.

Sectoral Perspective: Mapping Sector-Specific Contributions and Challenges Different sectors contribute uniquely to India's innovation landscape. This section discusses leading sectors in key states and highlights their global context by comparing with similar innovation patterns in U.S. states.

1. IT and Digital Startups: Karnataka and Telangana

- Karnataka, led by Bengaluru, is India's Silicon Valley, housing over 13,000 startups, and contributing to over ₹2 lakh crore in IT exports in 2023.
- Telangana hosts T-Hub, one of India's largest startup incubators, and has focused on AI, IoT, and blockchain startups.

Karnataka's GERD: 0.93% of GSDP

Highest per capita patents in IT sector

300+ incubators/accelerators in Bengaluru

U.S. Parallel:- California (Silicon Valley) plays a similar role in the U.S., contributing over 25% of U.S. venture capital funding, with thousands of tech unicorns and globally dominant IT exports. Both regions demonstrate strong university-industry linkages, high digital literacy, and government-backed innovation infrastructure.

2. Agri-Tech Innovation: Punjab and Haryana -

Punjab and Haryana lead in precision agriculture, drip irrigation, and biotechnology in crops. Institutions like PAU and Haryana Agriculture University have developed over 500+ improved seed varieties and digital apps for farmers.

Key Metrics:

Punjab's agri R&D budget: ₹850 crore (2022–23)

Use of drones and remote sensing in soil and crop monitoring

100+ agri-startups supported by state policies

U.S. Parallel:- Iowa and Nebraska in the U.S. lead in agri-biotech and smart farming, leveraging satellite-based yield prediction, automated tractors, and AI for soil analytics. The U.S. also promotes public-private agri-research through universities like Iowa State and USDA labs.

Challenges in India:

Small landholdings, Low farmer tech adoption,Lack of startup scalability in rural markets.

3. Pharmaceutical and Biotech Innovation: Gujarat and Maharashtra

India Context:- Gujarat is India's pharma capital, contributing 33% of India's drug manufacturing and 28% of exports.

Maharashtra has strong life sciences innovation, with hubs like Pune and Mumbai focused on vaccine R&D, clinical trials, and medical devices.

U.S. Parallel:- Massachusetts, particularly Boston-Cambridge, leads U.S. biotech with companies like Moderna and Biogen, and dense university networks (Harvard, MIT). It contributes billions in NIH-funded biomedical research annually.

Challenges in India:- High dependency on China for Active Pharmaceutical Ingredients (APIs),Regulatory hurdles and IP protection issues,Limited public R&D in next-gen pharma (e.g., gene therapy).

4. Sector-Specific Challenges and Innovation Gaps

While India shows high innovation potential, significant sectoral gaps exist:-

Sector Challenges Innovation Gaps, Agriculture Poor funding, tech adoption barriers Limited agri-startup success in rural markets, IT & Startups Urban-rural digital divide Underrepresentation from tier-2, tier-3 cities, Pharma/Biotech Regulatory delays, IP concerns Weak linkages between universities and industry, Manufacturing Low automation, outdated tech Few state policies focus on Industry 4.0.

The methodology and sectoral analysis of India's innovation ecosystem provide a multidimensional understanding of state-level capabilities and challenges. By leveraging GII-based indicators, comparative statistical techniques, and sector-specific insights, this study creates a robust framework for innovation mapping. Further, using U.S. state examples (California, Iowa, Massachusetts) adds global benchmarking and highlights the potential for India's regional ecosystems to evolve into globally competitive hubs through policy innovation, institutional strengthening, and sector-specific support.

Institutional Perspective

The strength of an innovation ecosystem largely depends on the synergy between academic institutions, research organizations, government policy frameworks, and private sector involvement. In India, the Global Innovation Index (GII) framework—particularly through the "Institutions," "Human Capital & Research," and "Business Sophistication" pillars—helps in understanding how institutional mechanisms influence state-wise innovation performance.

A. Academic Institutions: IITs, NITs, and Central Universities

India has built a solid base of higher education institutions. There are: - 23 IITs, 31 NITs, and 54 central universities spread across different states.These institutions serve as major contributors to R&D publications, technology transfers, and startup incubation.

- IIT Madras has consistently ranked high on innovation parameters and hosts India's first Institute of Eminence Research Park.
- IIT Delhi launched FITT (Foundation for Innovation and Technology Transfer), which has helped over 200 startups since 2017.

However, a large number of state universities and Tier 2/3 colleges are underfunded and lack research output, especially in states like Bihar and Chhattisgarh.

B. Research Organizations: ISRO, CSIR, ICMR, ICAR

National laboratories under CSIR (Council of Scientific and Industrial Research), ISRO, ICMR, and ICAR are major contributors to technological progress. CSIR has 37 labs across India and contributes nearly 10% of India's patents annually. ISRO has facilitated the growth of space-tech startups in Karnataka and Kerala through its open data and satellite programs. However, the lack of collaboration between these elite labs and local industries/universities remains a concern, particularly in states without a research infrastructure base.

C. Government Innovation Policies

Several flagship programs launched by the Government of India have significantly influenced innovation ecosystems:-

- Startup India (2016): Enabled over 115,000 DPIIT-recognized startups as of 2024.
- Make in India (2014): Aimed at increasing manufacturing's share in GDP.
- Atal Innovation Mission (AIM): Over 10,000 Atal Tinkering Labs (ATLs) in schools and 100+ Atal Incubation Centers (AICs).

- Digital India, Smart Cities Mission, National Education Policy (NEP) 2020 have also contributed indirectly by strengthening digital infrastructure and research orientation.

According to NITI Aayog's India Innovation Index (2021 and 2023):

States with policy convergence and coordination among ministries and state bodies perform better in innovation (e.g., Karnataka, Maharashtra). Lagging states often lack state-level innovation councils and have weak program implementation.

D. Role of the Private Sector and Venture Capital

India ranks among the top 3 startup ecosystems globally with over 110 unicorns as of 2024. Private incubators, such as T-Hub (Telangana), C-CAMP (Bengaluru), and iCreate (Gujarat), have emerged as major innovation engines. Venture Capital (VC) inflows crossed $36 billion in 2021 but remain concentrated in Delhi, Mumbai, and Bengaluru, leaving hinterland regions underfunded. Private participation in PPP R&D is increasing but still lags compared to countries like the USA or Germany. Only about 40% of GERD (Gross Expenditure on R&D) in India is from the private sector, compared to over 70% in OECD countries.

2. Regional Comparison and Innovation Disparity

The India Innovation Index published by NITI Aayog (2019, 2021, and 2023) provides comprehensive data on state-wise innovation performance. Based on the latest 2023 rankings and GII-aligned methodology, the regional comparison can be classified into:

A. High-Performing States - These states score well on innovation input-output indicators, infrastructure, education, digital penetration, and startup success:

State Rank (III 2023) Highlights

- Karnataka 1 Highest in patents, startups, R&D spend
- Maharashtra 2 Strong industrial base, pharma, biotech
- Delhi (UT) 3 Leading in VC inflow, academic research

Karnataka scored 25.4 on innovation index, driven by strong public-private partnerships, especially in Bengaluru. Maharashtra has excellent higher education density and industrial clustering, particularly in Pune and Mumbai.

B. Emerging Performers - State Rank (III 2023) Strengths

- Tamil Nadu 4 Industrial R&D, AICTE/UGC-supported innovation
- Telangana 5 T-Hub, proactive startup policies
- Gujarat 6 Manufacturing innovation, iCreate incubation

These states are showing improvement due to targeted state policies, ease of doing business, and structured industrial R&D programs.

C. Lagging States

State Rank (III 2023) Constraints

- Bihar 28 Weak R&D, poor university research
- Jharkhand 27 Low investment, brain drain
- NE States 24–29 Lack of infrastructure and VC interest

These regions lag due to poor digital and physical infrastructure, weak educational institutions, and limited innovation funding.

Root Causes of Regional Disparities: -

Infrastructure Deficit: Most lagging states lack innovation corridors, R&D labs, and broadband connectivity.

Funding Access: Startups in Tier 2 and Tier 3 cities face severe capital constraints.

Governance and Bureaucracy: Delays in approvals, corruption, and lack of coordination hurt innovation.

Educational Quality: Limited innovation-oriented pedagogy and lack of faculty training outside elite institutions.

3. Barriers to Innovation in India

Despite growing recognition and policy support, multiple systemic barriers continue to stifle India's innovation potential:

A. Bureaucratic Hurdles and Regulatory Issues :- Complex compliance, licensing issues, and time-consuming approvals discourage startups and R&D efforts. India ranks 63rd in Ease of Doing Business (World Bank 2020)—improved but still behind many emerging economies.High-tech sectors like biotech face excessive regulations, reducing their agility.

B. Limited Access to Finance :- Venture capital funding is urban-centric, mostly focused on Delhi, Mumbai, Bengaluru. NITI Aayog (2023) noted that over 60% of Indian states receive less than 5% of national innovation investment. Credit support through banks remains weak for early-stage startups in rural areas and non-tech sectors.

C. Lack of Industry–Academia Collaboration in Smaller States :- While IITs and NITs collaborate with industries, most state universities do not.Less than 10% of Indian startups emerge from academic incubation, compared to 30–40% in the U.S. and South Korea. Faculty are rarely incentivized to commercialize research.

D. Poor Infrastructure in Some Regions :- Broadband, transport, and digital infrastructure are major roadblocks in Eastern and Northeastern India. Weak last-mile connectivity hinders adoption of innovation in agriculture, education, and logistics sectors.

Mapping innovation in India reveals a complex but evolving institutional and regional landscape. Academic and research institutions, proactive policy support, and private sector engagement are driving growth in certain states, while systemic barriers and regional inequality hinder balanced national progress. NITI Aayog's India Innovation Index remains a vital tool for tracking state performance and guiding policy reform. Going forward, a more decentralized and inclusive approach, strengthening PPP models, improving research-industry linkages, and expanding financial access will be critical to unlock India's full innovation potential.

Policy Implications and Recommendations

The mapping of India's innovation ecosystem through a factorial and institutional lens using the Global Innovation Index (GII) framework reveals significant disparities across states, driven by uneven institutional strength, sectoral focus, and policy implementation. To bridge these gaps and foster a more balanced and inclusive innovation landscape, the following policy recommendations are proposed:

1. Increased R&D Funding

A major finding from the comparative state analysis is the underinvestment in research and development (R&D), especially by state governments. While India spends only 0.7% of its GDP on R&D—compared to over 2% in countries like China and South Korea—the spending is heavily concentrated in a few sectors and regions.

Policy Recommendation:- States must allocate dedicated R&D budgets, particularly for universities, incubators, and sector-specific labs. Introduction of State Innovation Grants to support local technological advancement, especially in backward districts.

2. Strengthening Institutional Capacity

Strong institutions are critical for effective innovation ecosystems. States with better governance, policy alignment, and inter-agency coordination (like Karnataka and Gujarat) outperform others.

Policy Recommendation: - Establish or strengthen State Innovation Councils and Science and Technology Missions for coordinated policy execution. Regular training and capacity-building for officials handling startup, MSME, and R&D programs to enhance institutional responsiveness.

3. Sectoral Strategies for MSMEs, Agriculture, and Green Tech

Innovation in India has been highly urban and tech-sector centric, sidelining sectors like agriculture and traditional MSMEs. A factorial approach reveals the urgent need for tailored innovation strategies.

Policy Recommendation: - Create sectoral innovation roadmaps with clear targets for MSMEs, agri-tech, and sustainable energy. Encourage technology transfer hubs, common facility centers, and cluster innovation programs at the district level. For instance, agri-tech startups in Punjab and Haryana can be scaled with better integration of AI, drone technology, and soil analytics—backed by Krishi Vigyan Kendras and ICAR labs.

4. Skilling and Innovation Education

Human capital is a critical pillar under GII. The innovation gap in India is also a skills gap. Many youth, particularly in rural and lagging states, lack exposure to digital and entrepreneurial skills.

Policy Recommendation:- Embed design thinking, coding, and entrepreneurship modules in school and college curricula, aligned with the NEP 2020. Expand reach of Atal Tinkering Labs and create innovation fellowships for university students in science, tech, and business.

5. Promoting Start-up Culture and Digital Entrepreneurship

To democratize innovation, state governments must foster inclusive startup ecosystems beyond metro cities.

Policy Recommendation: - Expand startup policy frameworks at the state level, ensuring ease of registration, tax incentives, and market access. Strengthen digital infrastructure, provide seed funding, and incentivize private venture capital in Tier 2/3 cities. States like Telangana and Kerala have shown success with initiatives like T-Hub and K-Startup Mission, which can be replicated nationwide.

A robust innovation ecosystem requires a multi-pronged policy approach. By investing in R&D, building institutional capacity, focusing on sector-specific strategies, developing human capital, and promoting inclusive startup ecosystems, Indian states can unlock their innovation potential. These interventions must be context-specific, evidence-based, and aligned with the broader goals of economic growth, digital transformation, and sustainable development.

Conclusion :- This study, titled "Mapping the Innovation Ecosystem in Indian States: A Factorial and Institutional Perspective Based on the GII Framework", presents a comprehensive assessment of the structure, performance, and disparities within India's regional innovation ecosystems from 2015 to 2024. Leveraging the Global Innovation Index (GII) pillars and data from NITI Aayog's India Innovation Index, DPIIT, DST, and other national agencies, the study highlights the complex interplay between institutions, sectoral dynamics, and innovation outcomes across Indian states. The innovation landscape in India is marked by regional asymmetry, with states like Karnataka, Maharashtra, and Delhi emerging as consistent leaders due to their strong digital infrastructure, higher education institutions (IITs, IISc), active startup ecosystems, and sustained public-private R&D collaboration. These states exhibit superior performance across GII pillars—particularly in human capital, market sophistication, and knowledge outputs. On the contrary, states like Bihar, Jharkhand, and several Northeastern states lag due to institutional weaknesses, poor infrastructure, minimal innovation investment, and limited academia-industry linkage.

From a sectoral perspective, Karnataka and Telangana lead in IT and digital startups; Punjab and Haryana exhibit strengths in agri-tech; Gujarat and Maharashtra dominate in pharma and biotech innovation. However, many states still face sector-specific innovation gaps, particularly in MSMEs, traditional industries, and agriculture, which are often excluded from mainstream innovation strategies. Institutionally, the study underlines the pivotal role played by academic institutions, research organizations (e.g., ISRO, CSIR), and government schemes (Startup India, Make in India) in shaping regional innovation capabilities. Yet, institutional coordination and the depth of University–Industry–Government collaboration, conceptualized through the Triple Helix Model, remain uneven. The study also identifies several persistent barriers to innovation—including bureaucratic inefficiencies, inadequate venture capital access in smaller states, weak digital infrastructure, and underdeveloped innovation policies at the state level. In light of these insights, the study proposes targeted policy recommendations: increased state-level R&D funding, stronger institutional governance, sector-specific innovation support (particularly for agriculture, green tech, and MSMEs), expansion of innovation education and skilling programs, and inclusive promotion of digital and startup culture across rural and semi-urban areas. Additionally, it recommends replicating successful models such as Telangana's T-Hub and Kerala's K-Startup Mission in other states.

In conclusion, India's journey toward becoming a global innovation hub depends not only on national policies but significantly on state-level innovation capacity. An ecosystem-oriented, sector-sensitive, and institutionally empowered innovation policy is essential to bridging regional disparities, harnessing local potential, and realizing inclusive and sustainable innovation-led development across India.

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