Spatial Dynamics of Innovation Capabilities across Indian States and Union Territories: Evidence from a Fuzzy Set Qualitative Analysis

Dr. Sindhu. K [1], Dr. Siby. K.M [2], Dr. R. Santhosh [3], and Dr. N. Karunakaran [3*]

[1] Associate Professor, Department of Economics, The Cochin College, Kochi-2, Kerala, India. E mail: sindhuk@thecochincollege.edu.in; https://orcid.org/0009-0006-8548-2134
[2] Assistant Professor, Postgraduate Department of Economics, St. Paul's College, Kalamassery, Kerala, India. E mail: siby@stpauls.ac.in; https://orcid.org/0000-0001-8699-4701
[3] Professor, Department of Economics, Government Law College, Thiruvanathapuram, 695037, Kerala, India. E mail: santhoshreco@gmail.com; https://orcid.org/0009-0002-5077-3549
[3] Principal, People Institute of Management Studies (PIMS), Munnad-Post, Chengala (Via), Kasaragod, 671541, Kerala, India, E mail: narankarun@gmail.com; https://orcid.org/0000-0002-7213-2841*

KEYWORDS
National Innovation System; GII; India Innovation Index; NITI Ayog; Innovation enablers; fsQCA.

ABSTRACT
To evaluate the innovation ecosystem of various States and Union Territories (UTs) and to improve the existing innovation outcome, the National Institution for Transforming India (NITI Ayog) has constructed the India Innovation Index (III) in line with the Global Innovation Index (GII) methodology. This paper studied the relationship among various innovation enablers (INEN) and innovation performance (INPER) of Indian States and UTs, based on data from the India Innovation Index (III) 2021. A fuzzy set qualitative comparative analysis (fsQCA) on the innovation index dataset is applied in the study to investigate the causal relations between INEN and INPER. Three sub-samples namely Major States, City States and UTs and North East and Hill States are used for comparing performance across different categories. The analysis shows that for the Major States, Knowledge Workers (KN_WORKERS) acts as a core condition along with Human Capital (HC) Business Environment (BE) and Safety and Legal Environment (S_L_ENVT) on INPER. For City States and UTs, HC and BE are the core factors on high INPER whereas for North East and Hill States, Investment (INVST) comes first as the major INEN along with all other enablers as peripheral conditions. This concludes that existence of any one of these conditions alone is not necessary enough to predict high INPER across all three sample sets. Additionally, there are considerable differences in the configurations of INEN sufficient enough to forecast high INPER across the three categories of States and UTs. It recommends policy making taking into consideration the influence of different region-specific configurations of INEN on INPER.

1. Introduction

The significance of the innovation capability in building the growth trajectory of nations has been increasingly recognized in recent years. The positive link between innovation and economic growth has been demonstrated in several studies (Furman, Porter & Stern, 2002). It is also established that innovation activities do not occur in a vacuum and are closely related to the National Innovation System (NIS) (Lundvall, 2007). The interrelationships embedded in various elements of the innovation system also are delineated according to their role as inputs, outputs, moderators or as a measure of productivity (Nasierowski and Arcelus, 1999). The multidimensional nature of different dimensions of innovation systems is identified and established in later studies (Fagerberg & Srholec, 2008). Evaluation of the complex innovation systems necessitated the inclusion of different qualitative inputs that may determine the innovation outcomes of a country. Such a measure of innovation systems can help countries focus on specific inputs that enable high INPER (Metcalfe & Ramlogan, 2008). Global Innovation Index (GII), created incorporating various INPER indicators and enabler indicators, provided the theoretical framework for evaluating the national innovation systems (Cornell University, INSEAD, & WIPO, 2020). Several empirical studies conducted on the GII in the NIS framework proved that high INPER can be achieved by a country through different combinations of enabling factors (Mahroun & Al Saleh, 2013, Crespo & Crespo, 2016). It is also demonstrated that countries with different economic levels have diverse combinations of enablers that support high performance in innovation and related activities (Watkin et al, 2015).

Though there are cross-country studies on GII in the NIS framework, there are only a few studies that examined regional differences in performances in innovation within national economies. India developed its innovation index in the NIS framework in 2019, but research is almost lacking in this area (Shine Shaji, Mahendra Varman P and Karunakaran N, 2024). The present study fills this gap and sheds light on the complex causal relations between INEN and INPER depicted in the India Innovation Index (III). Using the data on the India Innovation Index (III) 2021, the study looks at the various combinations of INEN that support high INPER in States and UTs. FsQCA methodology is applied on the innovation index dataset to investigate the causal relations between INEN and INPER. Three sub-samples namely Major States, City States & UTs and North East & Hill States are used for comparing performance across different categories (table 3)

2. Objectives

The main objectives are: (i) to identify the enablers of innovation or their different configurations that is necessary to achieve high innovation performance in States and UTs of the country, (ii) to determine if various configurations of innovation enablers are adequate to forecast high innovation performance, and (iii) to determine how different configuration of innovation enablers leading to high innovation performance differ among the three subsamples of States/UTs.

3. Method

3.1. National Innovation System (NIS): This has arisen from the understanding that innovation results from a combination of institutional structures, supportive activities, BEs, and infrastructure. The major function of NIS is to foster innovation and augment economic growth within countries. It initiates collaborative efforts among governments, businesses, universities, and other stakeholders. NIS is defined as a network of organizations that both individually and jointly contribute to the creation and adoption of cutting-edge technologies, as well as establish and carry out policies that have an impact on the innovation process. This system encompasses

interconnected institutions aimed at creating, storing, and transferring knowledge, skills, and artefacts that define new technologies (Metcalfe, 1995). The NIS approach emphasizes the importance of investing in HC and research through tertiary education and scientific institutes (Lundvall, 1992). Education, recognized as fundamental to a nation's progress, is seen as pivotal in nurturing creativity and contributing to overall national growth by generating new knowledge. Additional components of the NIS framework include organizations, intangible asset efficiency, technology, training, education, and public policy. Consequently, measuring INPER should consider the intricate relationships among various innovation inputs, recognizing that different combinations of these inputs may yield similar innovation outcomes across different countries (Mahroum & Al-Saleh, 2013).

3.2. Global Innovation Index (GII): Several indices have been developed to evaluate the effectiveness of efforts for strengthening the innovation system, the most popular being the GII which measures multifaceted dimensions of the innovation ecosystem in countries. Innovation Output is explained as the product of various innovative activities within the economy, whereas Innovation Input measures the aspects of the national economy that facilitate innovation. (Cornell University, INSEAD, & WIPO, 2020)

3.3. India Innovation Index (III): Innovation is acknowledged as the most fundamental factor in the present development paradigm of India. With a large research capacity and talent pool, the country has vast potential to improve its INPER. Enhancing the innovation capabilities and performance has been at the center of policy reforms in the country in recent years. To assess the performance of various States and UTs in innovation and to improve the existing innovation outcomes, NITI Ayog with the Institute for Competitiveness as the knowledge partner has constructed the India Innovation Index (III) in 2019, in line with the methodology of Global Innovation Index (GII).

Table 1: India Innovation Index (2021) Framework

Innovation input index	
Human Capital (HC)	School education Tertiary and Higher education
Investment (INVST)	Research and Development (R&D) Market sophistication
Knowledge Workers (KN_WORKERS)	Workforce
Business Environment (BE)	Trade, competition and market scale Credit Digital Infrastructure
Safety and Legal Environment (S_L_ENVT)	Security/safety environment Legal/regulatory environment
Innovation output index	
Knowledge Output (KO)	Knowledge creation Knowledge Impact Intangible assets

Knowledge Diffusion (KD)	Knowledge dissemination Creative goods and services

Source: India Innovation Index Report, 2021

India Innovation Index provides a comprehensive framework for examining the nation's internal innovation ecosystem. It is also intended to analyze the regional performances taking into account the strengths and weaknesses. The III framework has seven pillars; enabler pillars measure the innovation inputs and performance pillars the innovation output. The Enabler pillar has five components viz. HC, INVST, KN_WORKERS, BE, and S_L_ENVT. The Performance pillar consists of two components i.e. Knowledge Output (KO) and Knowledge Diffusion (KD). Both pillars are made up of various indicators showing innovation inputs and performance. The indicators in the framework of III have changed during 2019-2021. III 2019 consisted of 23 enabler indicators and 10 performance indicators, III 2020 consisted of 25 enabler indicators and 11 performance indicators. The III 2021 consists of 50 enabler indicators and 16 performer indicators (India Innovation Index Report, 2021)

3.4. Data: This makes use of the data given in the India Innovation Index 2021. The sample in the analysis consists of all the States and UTs of the country, which are classified into three subcategories i.e. Major states, North East and Hill states, and City States and UTs. A comparative analysis to determine which INEN contributes to high INPER in each of the three categories of States and UTs was used. Only a single year i.e. 2021 is taken for the study as the framework of the index has been revised three times ever since it was constructed.

Table 2: Definition of Variables used in the model

Variables	Description
Outcome Variable: Innovation Index Score	Displays the innovation capacities and outcome at the sub-national level
Innovation Performance (INPR)	
HC	Accounts for the level and quality of education and research capability which translates into the innovation capacity of a region
BE	Captures factors that influence both the capacity of the government to foster innovation and private entrepreneurial activities.
INVST	Considers public and private funding which determines the financial strength of a region and the amount it spends on R&D.
KN_WORKERS	Indicates the employment of highly skilled professional by firms which strengthens their productivity, competitiveness, and innovation potential
S_L_ENVT	Measures the actions taken by governments to minimize the burden of regulation, preserve property rights, create and implement open and equitable processes, and regulate markets effectively.

Source: India Innovation Index Report, 2021

4. Results

4.1. Method and Calibration of the Outcome: This employs the fsQCA technique to analyze the data with the help of fsQCA 4.1 software. The fsQCA enables to conduct a comprehensive analysis of causality between a set of conditions and a specific outcome (Ragin, 2008). This analysis was pioneered by Ragin C.C. (2000) and used later by many researchers in social science studies. Crespo & Crespo (2016) have done an elaborate study on GII in the NIS framework in the fsQCA approach. To investigate the causal relationships between INEN and INPER, the current study empirically tests three propositions. The study also takes into account three sets of samples of States and UTs of India. The variables in the study include the INPER indicated by the Innovation Index score and five enablers of innovation such as HC, BE, INVST, KN_WORKERS and S_L_ENVT. Table 2 displays the definition of the performance and enabler variables used in the study. The model used in the three samples of the study is:

INPER = f (HC, BE, INVST, KN_WORKERS, S_L_ENVT)

The partition of Indian States into three categories was performed based on the status of the States such as the Major States, North Eastern and Hill States, and UTs and City States to compare the effects of IE individually and in a combined manner on the INPER of these categories of Indian States and UTs. Table 3 displays the categorization of Indian States.

Table 3: Categorization of States and UTs

Major States	Andhra Pradesh, Karnataka, Kerala, Telangana, Tamil Nadu, Bihar, Chhattisgarh, Gujarat, Haryana, Jharkhand, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Uttar Pradesh, West Bengal
City States & UTs	Andaman Nicobar Islands, Lakshadweep, Jammu & Kashmir, Chandigarh, Dadra and Nagar Haveli & Daman and Diu, Delhi, Goa, Puducherry, Ladakh
North East & Hill States	Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, Uttarakhand, Himachal Pradesh

Source: India Innovation Index Report, 2021

The first step in the fsQCA analysis is to calibrate the original data of outcome and causal conditions into three substantive thresholds (Ragin C. C., 2008): full membership (1.0), full non-membership (0.0) and the crossover point (0.5). Full membership and full non-membership are qualitative states that are not arbitrary (Ragin C. C., 2006). Following this method, in the present study, the primary dependent variable (innovation capacity and ecosystem outcome) is represented by the overall score of innovation index of the India Innovation Index (2021). The membership of a state in the set of states with high innovation capacity is coded as 0 if a State/UT shows an average or below-average INPER and 1 if a State/UT shows an above-average INPER. With respect to INPER, the crossover point for Major states is 14.02, for City States and UTs is 15.74 and for Hill and North East States is 14.41. The independent variables are assessed using the five innovation input conditions (HC INVST, KW, BE, S_L_ENVT) and calibrated using the same method.

Table 4: Calibration Criteria for outcome and enabler variables

Category	Calibration Criteria	INPER	HC	BE	INVST	KN_WORKERS	S_L_ENVT
Major States (n=17)	MAX	18.01	30.88	40.8	19.06	9.17	39.68
	MEAN	14.02	24.28	32.49	6.81	4.86	21.91
	MIN	10.97	13.29	22.8	2.37	0.78	10.97
UTs(n=9)	MAX	11.27	36.8	39.28	11.34	22.44	60.5
	MEAN	15.74	25.74	27.20	4.84	8.14	36.51
	MIN	5.91	12.06	11.27	0	0.16	25.14
North East & Hill States (n=10)	MAX	19.37	35.23	27.89	17.12	12.78	72.13
	MEAN	14.41	27.72	21.56	6.58	4.84	44.52
	MIN	11.00	24.44	17.00	1.32	0.53	23.04

Table 5: Intermediate Solutions for Major States, UTs and Hilly and North East States

Category	Conditions	Raw Coverage	Consistency	Solution Coverage	Solution Consistency
Major States (n=17)	HC*BE*KNW_WORKERS	0.702842	0.89769	0.75323	0.896923
	HC*~INVST*KNW_WORKERS*S_L_ENVT	0.450904	0.97486		
UTs(n=9)	HC*~INVST*~KN_WORKERS*~S_L_ENVT*BE	0.378049	0.095122	0.792683	0.887978
	HC*INVST*KN_WORKERS*~S_L_ENVT*BE	0.47561	0.146341		
	HC*INVST*~KN_WORKERS*S_L_ENVT*BE	0.321951	0.107317		
	HC*~INVST*KN_WORKERS*S_L_ENVT*BE	0.312195	0.0804878		
North East & Hill States (n=10)	~HC*~BE*INVST*S_L_ENVT	0.419214	0.21179	0.790393	0.880779
	HC*BE*KN_WORKERS*~S_L_ENVT	0.384279	0.218341		
	HC*~BE*~INVST*~KN_WORKERS*S_L_ENVT	0.353712	0.148472		

Table 6: Configurations for Innovation Performance for Major States, Union Territories and Hilly & North East States of India

	Major States		Union Territories				Hilly North Eastern States		
CONFIGURATION	Path one	Path Two	Path one	Path Two	Path Three	Path Four	Path one	Path Two	Path Three
HC									
BE									
INVST									
KN_WORKERS									
S_L_ENVT									
Consistency	0.897	0.974	0.856	0.937	0.963	0.955	0.979	0.871	0.857
Raw Coverage	0.702	0.450	0.378	0.475	0.321	0.312	0.419	0.384	0.353
Overall Solution Consistency	0.896923		0.792683				0.880779		
Overall Solution Coverage	0.75323		0.887978				0.790393		

 Core Condition Peripheral Condition Absence of condition

5. Discussion

Tables 5 and 6 comprise significant configurations of INEN that lead to high INPER in three categories of Indian states.

5.1. Results for Major States of India: The intermediate solutions for major states of India put forth two paths with significant overall solution consistency of 0.89 and an overall solution coverage of 0.75. Both paths have Knowledge Workers as the necessary condition for INPER in major states of India. The first configuration with Knowledge Workers as necessary condition along with HC and BE as peripheral conditions has a commendable consistency of 0.89 and raw coverage of 0.72. The second configuration with KN_Workers as the core condition and presence of two peripheral enablers such as HC and S_L_ENVT in the absence of INVST has a consistency of 0.97 but the explanatory power of such a combination is low since coverage is

0.45, though it is within the recommended rage.

5.2. Results for City States and UTs of India: The intermediate solutions for UTs of India showcased four combinations of INEN which led to high INPER. In contrast to the Major States of India, all four paths signify HC and BE as core conditions for INPER in UTs. It is finds that to obtain high INPER, this group offers more multifaceted solutions. The overall solution consistency (0.79) and overall solution coverage (0.88) are significantly above threshold levels. Though all four paths have consistency well above the threshold level of 0.8, the second path with HC and BE as core enablers and INVST and KN_WORKERS as peripheral enablers in the absence of S_L_ENVT condition has the highest raw coverage of 0.475 signifying 47 per cent explanatory power of the configuration in INPER outcome.

5.3. Results for North East and the Hill States of India: The intermediate solutions produce three paths with INVST as the core enabler in path one. The overall solution consistency (0.88) and overall solution coverage (0.79) are above the threshold levels. The first configuration with INVST enabler as core condition and S_L_ENVT as peripheral condition even in the absence of HC and BE has high consistency (0.97) implying that 97 percent of North East and Hilly States with strong INVST and S_L_ENVT achieve high INPER even in the absence of sufficient HC and BE. The raw coverage of the first path (0.41) demonstrates the comparatively good explanatory power of configuration for the outcome variable INPER. The second path shows the presence of HC, BE and KW as peripheral conditions in the absence of S_L_ENVT can produce high INPER in North East and Hill States of India with a consistency of 0.87 and a raw coverage of 0.38. The third path with HC and S_L_ENVT as peripheral conditions in the absence of BE, INVST and Knowledge Workers has a consistency of 0.85 and raw coverage of 0.35.

6. Conclusion

This made use of fsQCA to assess the impact of INEN in different combinations and individually on the INPER of Major States, City States & UTs and North East and Hill States of India and found significant differences in their impact on INPER. It examined whether any of the INEN is a prerequisite for the innovation outcome and whether they can predict high INPER for three sets of samples. For the Major States of India, KN_Workers is identified as the core condition of high INPER. For City States and UTs, HC and BE are the core factors on high INPER whereas for North East and Hill States, INVST comes first as the major innovation enabler along with all other enablers as peripheral conditions. Based on this, the study shows that high INPER in three sets of the sample can be predicted without requiring any one of the INEN as a necessary condition. It is found that The Major states have two paths with different configurations, City States and UTs offer four different paths and North East and Hill States have three paths with different combinations of enablers predicting high INPER. Hence it may be concluded that the same INPER may also be predicted using different combinations of INEN. There are also significant differences in the configurations of INEN that are sufficient to predict high INPER across different categories of States and UTs in the country. This has demonstrated that the innovation performances in different categories of State/UTs follow different paradigms. It is also found that to obtain high INPER, the City States and UTs offer more multifaceted solutions. North East and the Hill States seem to require more investment for innovation and economic development compared to the other two samples. These findings are important for policymaking as they reveal the need for multifaceted policies at the regional level to influence different region-specific configurations of INEN thereby enhancing INPER.

References

[1] Andrew Watkins, Theo Papaioannou, Julius Mugwagwa, Dinar Kale (2015): National innovation systems and the intermediary role of industry associations in building institutional capacities for innovation in developing countries: A critical review of the literature, Research Policy, 44 (8), 1407-1418
[2] Cornell, U, INSEAD & WIPO (2015): The Global Innovation Index 2015: Effective innovation policies for development, Fontainebleau, Ithaca and Geneva
[3] Fernandes Crespo, Nuno& Crespo, Cátia. (2016). Global Innovation Index: Moving beyond the absolute ranking with a fuzzy-set analysis, GIKA Conference, Global Innovation and Knowledge Academy, Valencia, Spain.
[4] Furman, Jeffrey & Porter, Michael & Stern, Scott. (2002). The Determinants of National Innovative Capacity. Research Policy. 31. 899-933. 10.1016/S0048-7333(01)00152-4.
[5] Jan Fagerberg and Martin Srholec (2008): National innovation systems, capabilities and economic development, Research Policy, Volume 37, Issue 9, October 2008, Pages 1417-1435
[6] Lundvall, Bengt-Åke. (2007). National Innovation Systems—Analytical Concept and Development Tool. Industry & Innovation. 14. 95-119. 10.1080/13662710601130863.
[7] Mahroum, Sami &Alsaleh, Yasser. (2013). Towards a functional framework for measuring national innovation efficacy. Technovation. 33. 320–332. 10.1016/j.technovation.2013.03.013.
[8] Metcalfe Stan, (1995): The economic foundations of technology policy/equilibrium and evolutionary perspectives, Handbook of the economics of innovation and technological change. - Oxford [u.a.]: Blackwell, ISBN 0-631-17773-6. - 1995, p. 409-512
[9] Metcalfe, Stan &Ramlogan, Ronnie. (2008). Innovation Systems and the Competitive Process in Developing Countries. The Quarterly Review of Economics and Finance. 48. 433-446. 10.1016/j.qref.2006.12.021.
[10] Nasierowski, Wojciech&Arcelus, F. (2012). What is Innovativeness: Literature Review. Foundations of Management. 4. 10.2478/fman-2013-0004.
[11] NITI Ayog and Institute for Competitiveness (2021): India Innovation Index (2021)
[12] Ragin C. Charles (2000): Fuzzy-set Social Science, Chicago University Press, Chicago
[13] Ragin C. Charles (2006): Set Relations in Social Research: Evaluating Their Consistency and Coverage, Political Analysis 14 (3), 291-310
[14] Ragin, C. Charles. (2008). Redesigning Social Inquiry: Fuzzy Sets and Beyond. Bibliovault OAI Repository, the University of Chicago Press. 10.7208/chicago/9780226702797.001.0001.
[15] Shine Shaji, Mahendra Varman P and Karunakaran N (2024), "Macroeconomic determinants of inflation in Asian inflation targeting nations: An empirical panel data analysis", MSW Management, 34(2): 90-108. https://mswmanagementj.com/index.php/home/article/view/213
[16] Watkins, Andrew &Papaioannou, Theo &Mugwagwa, Julius & Kale, Dinar. (2015). National innovation systems and the intermediary role of industry associations in building institutional capacities for innovation in developing countries: A critical review of the literature. Research Policy. 44. 10.1016/j.respol.2015.05.004.