Measurement of Regional Science and Technology Innovation (STI) Capability and Construction of Multi-center Inclusive Development Network

Haiyun Sun*
Department of Public Administration, Party School of the CPC Shandong Provincial Committee (Shandong Academy of Governance), Jinan, Shandong, China
**Corresponding Author.*

Abstract: In the ever-evolving landscape of global competitiveness, the study of regional Science, Technology, and Innovation (STI) capabilities has emerged as a crucial tool for understanding and enhancing the dynamism and resilience of economies. The methodology of this study is anchored in a mixed-methods approach, combining quantitative and qualitative analyses to offer a holistic view of regional STI capabilities. The study employs a range of indicators, including R&D expenditure, STEM education metrics, innovation outputs, and economic contributions of high-tech industries. These indicators are normalized and aggregated into a composite index, providing a measurable framework to assess and compare STI capacities across regions. The value of building a multi-center STI network based on regional capabilities is a cornerstone of this study. Such networks harness the diverse strengths of various innovation centers, facilitating knowledge transfer, resource sharing, and joint problem-solving. This study represents a significant step towards understanding and enhancing regional STI capabilities. Through its comprehensive approach, it not only contributes to academic discourse but also offers practical guidance for stakeholders in crafting strategies that leverage innovation for regional development and global competitiveness.

Keywords: Regional STI; Measurement System; Polycentric Network; Inclusive Development

1. Introduction

Innovation stands as the cornerstone of economic proliferation. Regions excelling in Science, Technology, and Innovation (STI) catalyze their economic landscape, drawing investment, spawning employment opportunities, and nurturing novel industries. STI, in its regional embodiment, involves the cultivation and application of scientific and technological advancements within a defined geographic sphere. This domain has captured widespread attention for its profound influence on regional economic vitality, competitive edge, and societal well-being.

Governments, recognizing the strategic value of robust regional STI frameworks, are increasingly aligning their policies to transform these regions into hubs of technological leadership, thereby elevating their stature on the global stage. Innovations stemming from regional STI endeavors, particularly in sectors like healthcare, education, and environmental conservation, are pivotal in enhancing life quality both within their origin locales and globally. Crucially, regional STI initiatives play an instrumental role in forging sustainable technologies and practices, aligning with global environmental aspirations, such as those encapsulated in the United Nations Sustainable Development Goals (SDGs). The global resonance of regional R&D efforts is exemplified in milestones like COVID-19 vaccine development, underscoring the far-reaching implications of localized scientific and technological advancements. A region's competitiveness, as well as the business that takes place within it, is shaped by the region's characteristics, which include economic activity, institutional quality, infrastructure, and clustering [1].

The latest research in regional STI, as of 2023, highlights several key trends and areas of focus. According to the OECD Science, Technology and Innovation Outlook 2023, there is a strong emphasis on enabling transitions in times of disruption, particularly in sociotechnical systems such as energy, agrifood, and mobility. The report underscores the need for these systems to rapidly transform to become more sustainable and resilient. This necessitates a greater ambition and urgency in science, technology, and innovation (STI) policies by governments. Such policies should aim to enable transformative innovation, challenge existing fossil-based systems, and create opportunities for low-carbon technologies. However, rising geopolitical tensions and strategic competition in key emerging technologies may complicate international cooperation in these areas. The study of regional STI is crucial for understanding and harnessing the potential of technological and innovative advancements for economic, social, and environmental betterment. It underscores the interconnectedness of regional and global development and highlights the need for cooperative and coordinated efforts in fostering STI globally.

The structure of this article unfolds in an intricate and systematic manner: Part 2 meticulously compiles and categorizes a rich tapestry of pertinent literature. Part 3 elucidates the research methodology, ingeniously constructing a comprehensive indicator system to gauge the prowess of regional science and technology innovation. Part 4 delves into the analytical realm, dissecting the quantitative data with precision. Finally, Part 5 introduces the innovative concept of a multi-centre science and technology innovation network, coupling it with pragmatic recommendations derived from the study's findings.

2. Literature Review

The literature on regional STI is diverse, covering economic, social, and policy aspects of innovation at the regional level. It provides valuable insights into how regions can leverage STI for economic growth and social development, and how policies and ecosystems can be designed to foster innovation and address contemporary challenges.

A significant portion of the literature focuses on the concept of regional innovation systems [2], open innovation system [3], the hierarchical regional innovation system [4], and challenge-oriented regional innovation systems [5]. This includes how regions foster innovation through interactions between universities, industry, government, and other actors [6].With growing concerns about climate change and sustainability [7-8], there is an increasing focus on how regions can foster green and sustainable technologies through STI initiatives, technological advancements and future trends [9].

Many studies examine the role of STI in regional economic development, including how innovation drives economic growth [10]. The relationship between the regional STI system and the high-quality development of the economy is characterized by a coordinated evolution [11], endowment, stock and agglomeration of STI talents [12-14], job creation [15], attracting investment [16], improving the well-being of society at large [17], measurement and the causes identification of Regional disparity [18], and competitiveness in global markets [19].

Literature often discusses the impact of government policies on regional STI development [20]. This encompasses funding for research, tax incentives for innovation [21], and policies as political strategies [22] that encourage technology transfer and commercialization [23]. The dynamics of regional clusters is also a topic of interest, which analyzes how these clusters develop and contribute to regional and national economies [24], and the industry agglomeration effect shows obvious regional heterogeneity [25].

The literature on regional STI underscores its critical role in shaping the economic and social fabric of regions. The research field is dynamic, with ongoing debates and evolving perspectives, particularly concerning policy implications, sustainability, and the balance between local needs and global trends. Understanding and fostering regional STI remains a key priority for policymakers, researchers, and practitioners alike.

3. Measurement Methodology and Indicator System

3.1 Measurement Methodology and Indicator System

The study adopts the method of projection pursuit model based on Accelerated Genetic Algorithm (AGA-PP). The method achieves the purpose of researching and analyzing high-dimensional data by projecting the high-dimensional data onto a low-dimensional subspace and finding a projection that reflects the structure or characteristics of the original high-dimensional data. It has the advantages of robustness, anti-interference and high accuracy. Genetic algorithms are a class of evolutionary algorithms used in computational science for solving optimization and search problems by mimicking the process of natural selection. The combined model can more accurately track the changes and development trends of the regional STI index.

3.1.1 Data normalization

In this paper, MATLAB 2018b is used to normalize the data. Then the projection pursuit method based on accelerated genetic algorithm is used to find the optimal projection projection direction. If applied to regional STI, such a model could potentially be used for optimizing and predicting trends in innovation and technological development across different regions. This could include analyzing the impact of various factors on STI indices or optimizing resource allocation for innovation. To compare and combine these indicators, which may have different units and scales, the research normalize them firstly:

Min-Max Normalization: (X-Xmin) / (Xmax-Xmin), where X is the original value.

Z-score Normalization: (X-μ) /σ, where μ is the mean and σ is the standard deviation.

3.1.2 Constructing the objective function

Assuming that vector a = (a1, a2, ··· , an) is the projection direction, the projection value Z (i) of the i th sample is

$$Z(i) = \sum_{j-1}^{n} a_j * X*(i, j), i = 1,2,3,...,m. \quad (1)$$

Define the objective function as Q (a), S (a) as the inter-class distance, and D (a) as the intra-class intra-class density. Then we have

$$Q(a) = S(a) * D(a), D(a) = \sum_{i=1}^{m} \sum_{j=1}^{m} [R - r(i, j)]u[R - r(i, j)], \quad (2)$$

$$r(i, j) = Z(i) - Z(j), u(t) = \begin{cases} 1, t \geq 0 \\ 0, t \leq 0 \end{cases}, S(a) = \sqrt{\frac{\sum_{i=1}^{n}[Z(i) - E(Z)]2}{n}} \quad (3)$$

where E(Z) is the expected value of the projection, R is the window width parameter for estimating the local scatter density, here set to 1/10 of S(a), and r(i,j) is the value of the inter-sample interval.

3.1.3 Solving the objective function with accelerated genetic algorithm

The accelerated genetic algorithm solution formula commonly used in academia is:

$$\max Q(a) = S(a) * D(a), s.t. \sum_{j}^{n} a2(j) = 1 \quad (4)$$

3.2 Indicator System

3.2.1 Regional science and technology innovation index system

Measuring regional STI capacity involves a multifaceted approach, considering various indicators across different dimensions. While there isn't a single formula that universally applies, a composite index can be created by combining several relevant metrics. There are more studies on regional science and technology innovation index system in the established literature, among which the representative results are Global Innovation Index (GII), Knowledge Competitiveness Index (WCI), Silicon Valley Index, etc.

The research results of Chinese scholars on the level of regional STI are equally rich, and can be broadly categorized according to the number of indicators. The first category is to measure regional S&T innovation capacity with a few representative indicators, such as the number of patent applications [26], the number of patents authorized and the total output value of high-tech industries [27], the number of patents applied and authorized and the income from the sale of new products [28]. The second category is to establish an indicator system consisting of multiple indicators to comprehensively evaluate the regional level of science and technology innovation [29]. Synthesizing the above findings in the literature, the influencing factors related to regional STI are summarized as shown in Table 1. These indicators cover almost all aspects of politics, economy, society and ecology.

Table 1. The Influencing Factors Related to Regional STI

Indicators	Sub-indicators
Research and	1. R&D Expenditure: Total and per capita spending on research and development as a

Development (R&D)Metrics	percentage of GDP.
	2. R&D Personnel: Number of researchers and scientists per capita or as a percentage of total employment.
Education and Human Capital	1. STEM Education: Enrollment and graduation rates in science, technology, engineering, and mathematics (STEM) fields at higher education institutions.
	2. Workforce Qualifications: Proportion of the workforce with advanced degrees or qualifications in relevant fields.
	3. Continuous Learning and Training: Availability and participation rates in ongoing education and skill development programs related to STI.
Innovation Outputs	1. Patents and Intellectual Property: Number of patents filed, trademarks registered, and other intellectual property indicators.
	2. Research Publications: Quantity and quality (e.g., citation rates) of scientific and technical publications.
	3. Technological Products and Innovations: Development and commercialization of new technologies, products, and services.
Infrastructure	1. Technological Infrastructure: Availability and quality of technological infrastructure, including broadband connectivity, technological parks, and innovation hubs.
	2. Institutional Infrastructure: Presence and performance of research institutions, universities, and think tanks.
Economic Indicators	1. High-Tech Industry Contribution: The economic output or value-added by high-tech industries as a percentage of the regional GDP.
	2. Startups and Entrepreneurial Activity: Number, growth, and success rate of startups, particularly in high-tech sectors.
Policy and Regulatory Environment	1. Government Support and Policies: Effectiveness of government policies, funding, and support programs for STI.
	2. Business and Innovation-Friendly Environment: Measures of the ease of doing business, including regulatory hurdles, tax policies, and legal protections for innovation.
Collaboration and Networks	1. Collaborative Projects: Extent and impact of collaborative projects between academia, industry, and government.
	2. International Cooperation: Involvement in international STI projects and partnerships.
Social and Environmental Impact	1. Societal Impact of STI: How STI contributions address social challenges, improve quality of life, and contribute to societal goals.
	2. Sustainability and Green Innovation: Efforts and achievements in sustainable development and environmentally friendly innovations.

These measures, when combined and analyzed, provide a comprehensive overview of a region's STI capacity. They not only reflect the current state but also help identify areas for improvement and investment to foster a robust and dynamic STI ecosystem.

3.2.2 Specific measurement indicators

Measuring the regional level of STI capacity involves assessing various indicators that collectively provide insights into the region's ability to generate, adopt, and utilize scientific and technological advancements. A model to measure regional STI capacity can be designed by incorporating several key dimensions: Combining the specific characteristics of regional STI capacity listed in Table 1 and the related innovation index system, this research screens out 12 indicators from the three aspects of STI inputs, STI outputs and science and technology innovation environment, which are used to construct a comprehensive evaluation index system of regional science and technology innovation level, as shown in Table 2.

Table 2.Regional STI Indicator System

Indicators	Sub-indicators	Tertiary indicators
Investment in STI	research funding （B1）	R&D input intensity（X1） R&D expenditure provision（X2）

（A1）	human capital （B2）	R&D personnel Full-time equivalent（X3） Years of schooling per labour force（X4）
STI outputs （A2）	Patent outputs （B3）	Number of patents granted（X5） Number of green patents granted（X6）
	Translation of innovations （B4）	Amount of technology market contracts（X7） Number of incubators（X8）
STI environment （A3）	Entrepreneurial environment （B5）	Number of incubators（X9） Number of incubated enterprises（X10）
	popularization of science （B6）	Number of science books published（X11） Number of participants in thematic activities on science popularization（X12）

The data of this study are obtained from China Statistical Yearbook, China Population and Employment Statistical Yearbook, China Science and Technology Statistical Yearbook, the statistical yearbooks of provinces and statistical bulletins in previous years. The work of measuring regional STI index mainly includes data collection and supplementation, raw data processing, weight selection and index measurement, etc. The data measurement before 2020 compares and analyses part of the results of the existing studies [30].

Although a few regions with special circumstances are not considered due to the lack of values for the variables of interest and the way the economic zones are divided. However, this study still divides the innovation regions into six according to the common way of dividing administrative regions, which are: North China, Northeast China, East China, Central and South China, Southwest China, and Northwest China. This approach offers a structured way to quantify regional STI capacity, providing valuable insights for policymakers, researchers, and stakeholders involved in regional development and innovation planning.

4. Data Analysis

4.1 Optimal Projection Direction

By normalizing the data, the optimal projection direction can be found according to the projection tracing method in the accelerated genetic algorithm, and the parameters are set as follows: the size of the population is 400, the crossover probability is 0.8, the mutation probability is 0.2, the number of optimization variables is 12, the number of random numbers required for the mutation direction is 10, the number of acceleration times is 7, and the limitation number of acceleration times is 2 after two generations of evolution. By running the program 2000 times, 2000 projection directions and 2000 objective function values are obtained, and the largest objective function value is obtained by descending order, and its corresponding projection direction is the optimal projection direction (as shown in Table 3), and with the optimal projection direction as the weight, the projected values of the regional scientific and technological innovation level of the 30 provinces in the period of 2013-2020 can be obtained (as shown in Table 4).

Table 3.Optimal Projection Direction

Norm	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
Optimal projection direction	0.213	0.398	0.276	0.102	0.409	0.420	0.259	0.364	0.184	0.238	0.196	0.193

4.2 General Characteristics

As can be seen from the data reflected in Table 4, the STI indices of 30 different provinces showed an increasing trend during the period 2013-2020. Some regions have slightly adjusted, but the overall trend remains upward. Among them, Beijing, as a region with a unique political and economic status, has the strongest overall STI capacity, as can be seen from the initial data in 2013, far exceeding the other 29 provinces. STI Growth of Guangdong and Jiangsu is much stronger. By 2020, the ratio of the level of coordinated regional development between Beijing (2.78), which has the highest level of regional STI, and Qinghai (0.06), which has the lowest level of regional STI, is about 46.33. From the perspective of a single provincial division, the gap in the level of science, technology and innovation between regions is gradually widening. This is because Beijing, Guangdong and other provinces, as regional centers, have the unique advantage of attracting a large amount of high-quality resources from neighbouring provinces, widening the development gap with other provinces. Among them, Shandong can barely keep up with the development of Beijing and Guangdong, while Hebei, Tianjin and Fujian are lagging behind due to the siphoning off of high-quality resources, and the gap between Hainan and other eastern provinces in terms of science, technology and innovation is getting wider and wider due to its low level of economic development.

Table 4. Regional STI Index (2013-2020)

Region	Provinces	2013	2014	2015	2016	2017	2018	2019	2020	Average value	Growth rate (%)
North China(R1)	Beijing	1.50	1.66	1.98	2.06	2.21	2.34	2.66	2.78	2.15	9.26
	Tianjin	0.43	0.45	0.48	0.49	0.45	0.46	0.50	0.49	0.47	1.97
	Hebei	0.20	0.20	0.24	0.29	0.34	0.38	0.42	0.45	0.31	12.74
	Shanxi	0.15	0.14	0.15	0.16	0.17	0.18	0.19	0.19	0.16	3.96
	Neimenggu	0.09	0.09	0.11	0.14	0.12	0.12	0.13	0.14	0.12	6.31
Northeast China (R2)	Liaoning	0.32	0.32	0.34	0.38	0.42	0.43	0.45	0.48	0.39	5.99
	Jilin	0.13	0.13	0.14	0.18	0.21	0.19	0.23	0.24	0.18	9.03
	Heilongjiang	0.16	0.16	0.21	0.22	0.24	0.24	0.26	0.28	0.22	8.18
Eastern China(R3)	Shanghai	0.72	0.75	0.83	0.93	0.96	1.01	1.15	1.18	0.94	7.34
	Jiangsu	1.15	1.16	1.43	1.59	1.75	1.86	1.98	2.16	1.64	9.44
	Zhejiang	0.59	0.63	0.78	0.99	1.00	1.16	1.32	1.42	0.99	13.47
	Anhui	0.28	0.30	0.40	0.48	0.52	0.59	0.62	0.70	0.49	14.29
	Fujian	0.24	0.25	0.30	0.34	0.40	0.45	0.48	0.52	0.37	11.64
	Jiangxi	0.12	0.13	0.14	0.17	0.21	0.24	0.28	0.29	0.20	13.46
	Shandong	0.62	0.69	0.82	0.93	1.01	1.09	1.07	1.23	0.93	10.27
Central and Southern China(R4)	Henan	0.25	0.27	0.31	0.39	0.42	0.46	0.48	0.54	0.39	11.86
	Hubei	0.37	0.43	0.49	0.52	0.63	0.70	0.85	0.87	0.61	13.10
	Hunan	0.26	0.26	0.30	0.35	0.43	0.45	0.52	0.55	0.39	11.33
	Guangdong	0.92	0.96	1.18	1.41	1.64	2.00	2.20	2.38	1.59	14.48
	Guangxi	0.10	0.12	0.15	0.17	0.18	0.19	0.20	0.22	0.17	12.54
	Hainan	0.05	0.05	0.05	0.06	0.06	0.07	0.07	0.07	0.06	5.89
Southwest China(R5)	Chongqing	0.17	0.18	0.22	0.25	0.29	0.33	0.36	0.39	0.27	12.09
	Sichuan	0.31	0.34	0.40	0.46	0.52	0.57	0.62	0.68	0.49	11.78
	Guizhou	0.05	0.05	0.06	0.08	0.09	0.11	0.13	0.13	0.09	16.25
	Yunnan	0.09	0.09	0.11	0.12	0.15	0.16	0.17	0.19	0.13	11.32
Northwest China(R6)	Shaanxi	0.38	0.42	0.43	0.46	0.55	0.58	0.70	0.70	0.53	9.24
	Gansu	0.10	0.10	0.12	0.14	0.16	0.15	0.16	0.18	0.14	9.47
	Qinghai	0.04	0.04	0.03	0.04	0.05	0.05	0.06	0.06	0.05	6.78
	Ningxia	0.04	0.05	0.07	0.08	0.09	0.09	0.12	0.12	0.08	15.96
	Xinjiang	0.07	0.07	0.09	0.10	0.10	0.10	0.11	0.12	0.09	8.47

The 30 provinces and cities are divided into 6 regions that are independent of each other according to administrative divisions, and the mean and growth rate in Table 4 are weighted to obtain a mean value respectively. The general descriptive analysis of the datasets can be seen in Table 5, and there is not much variability in the growth rates and means of the six regions.

The regional level of STI shows a gradient decline in the distribution of eastern, central, northeastern and western regions. The STI capacity of East China, Central and South China, and Southwest China is growing faster. These regions have a low base level of STI, and lower absolute growth leads to larger relative growth. The regional STI level in the Northeast has increased slightly, and its gap has remained basically unchanged. This is due to the lack of impetus for industrial transformation, serious labour drain and lagging economic development in the

Northeast, which hindered the improvement of the STI level. Larger regions may behave differently in terms of the consistency of the average scores across regions compared to smaller regions, but it is possible to find in figure 1 that the overall variability is not as great as subjectively imagined, and does not show a huge development gap depending on the geographical location.

Table 5. General Descriptive Statistics

	N statistics	Min-value statistics	Max-value statistics	Mean statistics	SDS	kurtosis	
						statisticians	standard error
Average Value	6	0.18	0.79	0.4433	0.24842	-1.955	1.741
Growth Rate	6	6.85	12.86	10.0617	2.34904	-1.530	1.741
Available Cases(No.)	6						

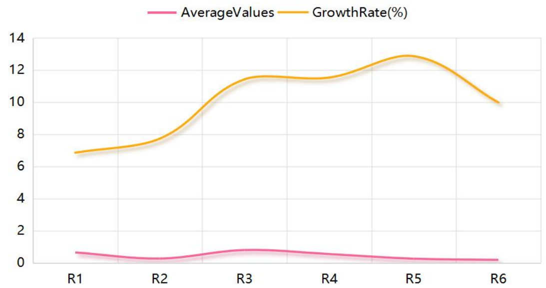

Figure 1. Mapping of Regional STI Trends

But, what is clear is that each of the three regions with better STI capabilities, East China, North China and Central and South China, has a centre or sub-centre belonging to the region, such as Beijing and Tianjin in North China and Guangdong in Central and South China. And some regions show a trend of coordinated multi-centres, such as Shanghai, Jiangsu and Zhejiang in East China. The three regions of Northwest China, Southwest China and Northeast China are the weakest in terms of STI capacity and do not have an obvious centre location.

Acknowledging the inherent limitations of this study is crucial. Primarily, its reliance on secondary data sources may impinge upon the precision and completeness of the data. Additionally, constraints in public access resulted in some datasets lacking the latest and most current information. To enrich the understanding of the innovation processes at more granular levels like counties and cities, future research should contemplate harnessing primary data through methodologies such as surveys or interviews, thereby providing a richer, more detailed perspective.

5. Conclusions

5.1 Usefulness and Scope of the Polycentric Framework

In the process of constructing a multi-centre STI network, it is necessary to exclude the limitations of geographical boundaries, start from networking, establish the underlying logic of sharing innovation resources and results transformation, and achieve the integrated and inclusive development of innovation. This framework would represent the diverse and interconnected nature of regional STI systems, highlighting how different centers of innovation within a region contribute to the overall STI capacity. This context calls for innovations in its technical and social aspects, which are inherently geographical processes, drawing of the socio-institutional texture of specific places, on the connections they establish to one another, and the multi-scalar logics in which they are embedded.

The STI network diagram elegantly captures the symmetrical and organized nature of the innovation network, highlighting the intricate web of connections among various entities. Figure 2 focuses on establishing both intra- and cross-regional STI linkages, aiming to create a unified resource and user tree, which includes potential innovation agents. This network encompasses diverse STI resources like human capital, policy frameworks, funding, financial platforms, intellectual property, and research infrastructure. The actors and users in this ecosystem range from leading enterprises, startups, multinational corporations, citizens, governments, to non-profits. Linkages within this network are forged through trust, transformation of achievements, intellectual property exchanges, and synchronous information flows. Utilizing cutting-edge technologies like AI and big data, the network transcends geographical boundaries, coalescing resources and

information into a cloud-based, interconnected system.
In this visualization:
Nodes represent different centers (regions) in the STI network, such as universities, research institutions, technology parks, major companies, startups, and policymakers.
Edges show the relationships and interactions between these centers. Edges are styled to represent different types of relationships and are uniformly colored for a cleaner understanding.

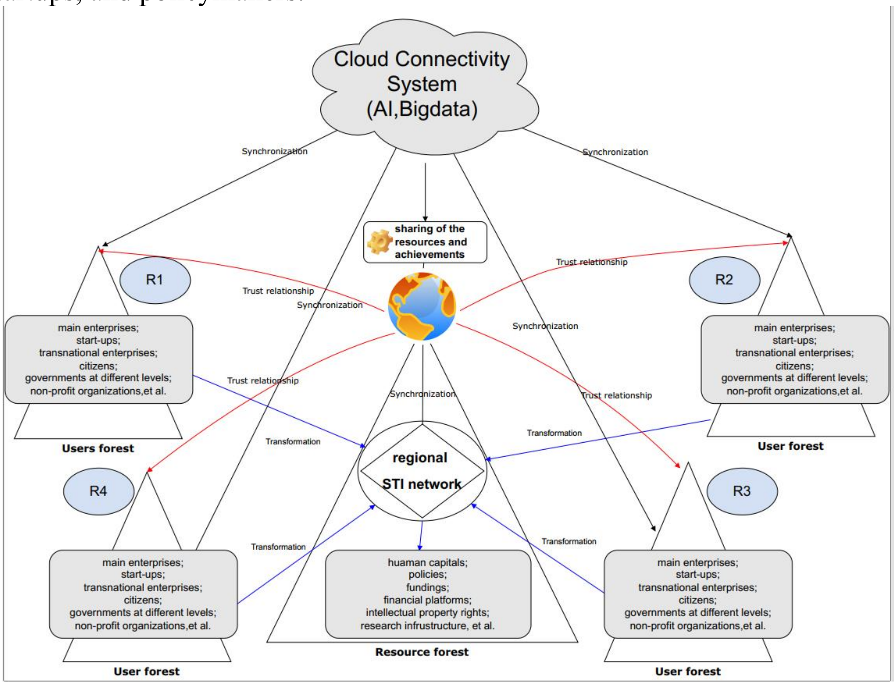

Figure 2. The Polycentric Spectrum of STI Networks

This harmonious and aesthetically pleasing depiction masterfully encapsulates the complex tapestry of interactions within the STI network. It illuminates the significant role each entity plays, interweaving their contributions into the rich mosaic of the STI ecosystem. This visual representation serves not only as a guide but also as a testament to the multifaceted nature of science and technology innovation.

5.2 Policy Suggestion

From the results of the research, China's regional economic development is unbalanced, and there are significant differences in the scientific and technological innovation capacity of each region.The leading trend is obvious in the eastern region, while the central, western and northeastern regions are all relatively low, and there are common problems such as weak support for the innovation system, low conversion rate of innovative results, and unsound incentive mechanisms for scientific research institutions and their staff. Innovation factors play a very important role in the successful practice of widespread innovation. The innovation process requires the participation and collaboration of agents in the system. Through participation and collaboration, knowledge, information, and know-how are transmitted easily and rapidly, encouraging the adoption of innovations that improve economic, social, and environmental well-being.
Establishing a polycentric STI network paradigm involves creating a cohesive and collaborative ecosystem of various innovation hubs. This requires strategic planning, investment, and policy support from all kinds of actors. From the perspective of policy makers, the establishment of such a multi-centre science, technology and innovation network requires a precise layout in the following aspects:
5.2.1 Facilitate collaboration and networking
Policymakers are encouraged to forge collaborative platforms, fostering spaces where institutions, businesses, and governmental bodies can synergize on STI projects. Concurrently, governmental actors should champion cross-sector partnerships, particularly those aligning with the Triple Helix model of innovation - a collaboration

between academia, industry, and government. It's vital for policymakers to transcend traditional geographical constraints in power dynamics to foster inclusive development. In the context of a globalized, integrated market environment, the concept of regional innovation gains prominence, with the network's boundaries extending globally, reflecting an expansive, interconnected innovation landscape.

Foster International and Inter-regional Cooperation: Promote collaborations beyond national borders to leverage global knowledge and resources. Promoting international and inter-regional cooperation, promoting cooperation in science, technology and innovation that transcends national boundaries, and making full use of global knowledge and resources have become an inevitable trend towards the future.

5.2.2 Streamline regulatory frameworks

Harmonize Regulations: Align and simplify regulatory frameworks across regions to facilitate the seamless exchange of knowledge, talent, and resources. Harmonized regulations can accelerate innovation by creating a more conducive environment for sharing ideas, research, and technology. By aligning and simplifying regulatory frameworks across different regions, institutions aim to reduce the barriers that hinder collaboration. This includes making it easier for researchers, professionals, and organizations to work together across borders. Simplified regulatory processes can reduce the administrative burden on regional STI. In a globalized economy, regions that can effectively harmonize their regulations may become more competitive as they can attract global talent and investments more easily.

Intellectual Property (IP) Management: Establish clear and fair IP policies that protect innovators while encouraging open innovation and collaboration. Strong IPR protection encourages innovation by ensuring that inventors and creators can reap the benefits of their work. This is particularly important in fields like technology and pharmaceuticals, where research and development costs are high. Effective IPR protection is key to enabling technology transfer between entities and regions. When innovators are assured that their intellectual property will be respected and protected, they are more likely to share their technology, contributing to the diffusion of innovation across different regions. Governments should promote knowledge transfer and mobility of researchers and professionals. Implementing policies that facilitate the mobility of talent across different centers in the network will bring more creativity of development and encourage knowledge transfer initiatives.

5.2.3 Invest in infrastructure and technology research

Develop Innovation Infrastructure: Governments can increase their allocation of funds specifically for research infrastructure, and invest in physical infrastructure like technology parks, incubators, and research labs that can serve as nodes in the STI network. Engaging in partnerships between the public sector and private enterprises (PPPs) can be an effective way to pool resources and expertise. Strengthening international cooperation is another useful and effective method. Collaborating with international institutions and governments can not only bring in additional funding but also share the costs and benefits of large-scale research infrastructure. This is particularly relevant for high-cost, high-impact projects like particle accelerators, space observatories, and large-scale environmental monitoring networks.

Enhance Digital Connectivity: Ensure robust digital infrastructure to facilitate virtual collaboration and access to digital resources. In other words, Ensuring widespread access to high-speed internet and advanced digital tools is foundational. This includes investments in broadband, 5G networks, cloud computing, and data centers. Creating and supporting open data platforms where researchers can share data and findings is essential. It is necessary that establishing universal data standards and protocols to ensure compatibility and ease of sharing between different systems and institutions.

5.2.4 Financial incentives and policy tools

Provide Targeted Funding: Allocate grants and funds specifically for projects that promote inter-centre collaboration. Financial incentives, awards, and recognition can be used to encourage researchers and institutions to collaborate digitally. Direct financial support in the form of grants and subsidies can be provided to researchers and organizations undertaking innovative projects. Creating or facilitating access to venture capital and seed funding can help start-ups and small businesses develop and commercialize new technologies.

Offer Tax Incentives: Implement tax incentives for businesses and institutions that engage in collaborative STI activities within the network. Governments can offer tax incentives to businesses that invest in R&D. These may include tax credits or deductions for R&D expenditures, which can significantly reduce the cost of innovation for companies.

Regulatory Sandboxes: The governments should create support mechanisms for start-ups and small and medium enterprises (SMEs) to engage with and benefit from the network. Implementing regulatory sandboxes allows businesses to test and develop new technologies in a controlled environment with relaxed regulatory requirements. Ensuring that STI policies are aligned across different government departments and levels can create a more coherent and supportive environment for innovation.

Regional STI emerges as an inexorable wave in the global scientific and technological landscape, transcending traditional geographical confines. This shift from a centralized to a polycentric model in China's STI landscape is particularly evident. The formation of such a multi-centre network necessitates a holistic infusion and synergy of policies, funds, platforms, and intellectual property across varied dimensions. Essential to this endeavor is fostering public awareness and educational initiatives, nurturing a societal ethos that champions and nurtures innovation. Ultimately, regional STI should aim to bolster global competitiveness, driving societal progress and enhancing the collective well-being.

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Data Availability

The data that support the findings of this study are openly available in public resources.

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