A Study on Regional Innovation Quality Evaluation Based on the TOPSIS Model

Lin Wang[1*], Fangting Tao[2]

{20190115@wbu.edu.cn[1], wbuherry@163.com[2]}

Wuhan Business University, Wuhan 430056, China

Abstract: Innovation development holds a central position among the five key principles of innovation, coordination, green, openness, and sharing. The integrated development of the Yangtze River Delta region has ascended to a national strategic level. The development in the Yangtze River Delta region focuses on "high quality" and "integration" as two key aspects, paving the way for a new economic development frontier. This study evaluates the comprehensive level of high-quality innovation in 41 cities in the Yangtze River Delta region based on panel data from 2010 to 2020. Using MATLAB software and the Entropy Weight method, the results indicate significant spatial disparities in the development of the Yangtze River Delta region, particularly showing a weakening trend from the center to the periphery. Under the support of Yangtze River Delta integration policies, the four research dimensions of technological innovation, economic innovation, social innovation, and ecological innovation tend to develop synergistically over time. Recommendations are made in terms of leveraging the strengths of the Yangtze River Delta, promoting talent mobility, fostering ecological innovation, and encouraging open innovation.

Keywords: Regional development, innovation quality, development level.

1 Introduction and Literature Review

1.1 Research Background

Constructing the strategic goal of building an innovative nation, China is transitioning from a phase of high-speed development to one of high-quality development. This "new normal" emphasizes the issues of imbalance and inadequacy in the development process. The driving factors for development have shifted from traditional inputs to efficiency and, subsequently, innovation. High-quality innovation is leading the way toward high-quality development. Economic and social development should focus on promoting high-quality development. The main theme is to deepen supply-side structural reform, prioritize quality and efficiency, and genuinely transform the development approach. This transformation encompasses changes in quality, efficiency, and driving forces. The Yangtze River Delta region is expected to take the lead in forming a new development pattern, becoming a highland of reform and development. It adheres to the five principles of innovation, coordination, green, openness, and sharing, aiming to build a resource-efficient, culturally diverse, industrially sustainable, and environmentally friendly society.

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1.2 Literature Review

As economic development continues to advance, there is a growing discussion, both domestically and internationally, about high-quality development. International research focuses on the high-quality development of modern supply chain foundations, exploring potential, improving efficiency, and enhancing quality. Scholars like Tingting Li and Dan Lv[1], Xu Ayuan, Sun Yangsheng, and Hu Yonghuan[2] propose new development concepts for establishing modern intelligent supply chains. Xuejiao Li and Shuoyi Peng[3] examine the fundamental essence of high-quality innovative development in the new era from the perspectives of theory, institutions, technology, and cultural innovation. Many of the studies mentioned above are at the national level, focusing on high-quality development. Researchers in the field of regional studies, such as Weng Yijing, Zhou Xiangxiang, and Chen Sijing[4], Yao Shujie, Zhang Fan[5], and Zeng Gang, Hu Senlin[6], tend to concentrate on the Yangtze Economic Belt and eastern regions, primarily examining the differential mechanisms of regional high-quality development and regional development patterns. Factors affecting the development of the Yangtze River Delta are also analyzed in a more targeted manner, for instance, Du Limin, Wang Ruqi, and Xiao Zhaohua[7] focus on ecological innovation, while Zhang Hongyuan, Mao Zejian, and Zhu Guojun[8] concentrate on the central cities in the Yangtze River Delta. From the current research literature, it is evident that there is a lack of research on the cities within the Yangtze River Delta region as a whole. Given this context, the study conducts an evaluation and analysis of the high-quality development levels of 41 cities in the Yangtze River Delta region from four dimensions: technological innovation, economic innovation, social innovation, and ecological innovation. Subsequent assessments provide an overview of the development in different dimensions within the Yangtze River Delta, under the overarching theme of high-quality development.

2 Analysis of Regional Innovation Quality Development Index

2.1 Research Methodology and Data Sources

High-quality innovation and development of the industrial structure exhibit diversity and multi-dimensional characteristics. The driving factors have shifted from traditional input-driven to efficiency-driven and then to innovation-driven. Utilizing the diversity of data information on high-quality industrial development, the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) can be effectively applied. The Entropy Weight method combines the advantages of Entropy Weight method and is more objective as it can determine the weights based on the dispersion of indicators and measure the intensity and conflict between indicators. It is more objective relative to other methods[9]. By analyzing the data related to high-quality industrial innovation development from 2010 to 2020, it evaluates and ranks the innovation output and quality of existing provinces and industries over a specified period. This evaluation calculates the relative proximity to the ideal solution, enabling the assessment and analysis of the level of high-quality development in the industrial structure during the designated time period.

The data for the comprehensive evaluation of the high-quality innovation development level in the Yangtze River Delta is sourced from various official publications and platforms, including the *China Statistical Yearbook, China Science and Technology Statistical Yearbook, China*

Education Statistical Yearbook, China Ecological Statistical Yearbook, Shanghai Statistical Yearbook, the China Economic and Social Big Data Research Platform, and the Yangtze Economic Belt Big Data Platform. These sources collect data on 14 evaluation indicators for assessing high-quality innovation development in the Yangtze River Delta.

2.2 Evaluation Index System for Regional Innovation Level

2.2.1 Construction of the Index System

High-quality industrial development necessitates a transformation of the industrial development approach, leading to a more advanced industrial structure, rational industrial organization, and intelligent rationalization of industrial chains. Given the complexity of the evaluation system, this paper focuses on the principles of scientific rigor, comprehensiveness, and effectiveness in selecting indicators, exploring them from four aspects: technological innovation, economic innovation, social innovation, and ecological innovation(See Table 1).

Technological Innovation: Science and technology are considered the primary productive forces[10-12], and in the current landscape of international competition, the essence lies in the comparison of comprehensive national strength based on economic development and technological capabilities. Technological innovation capability has become an increasingly decisive factor in determining comprehensive national strength and plays an indispensable role in international and regional dynamics. This study examines technological innovation from four perspectives: R&D expenditure, the number of high-tech enterprises, full-time equivalent R&D personnel, and the number of patented applications and grants. R&D expenditure and full-time equivalent R&D personnel reflect the financial intensity and the number of researchers involved in high-quality technological development. The number of high-tech enterprises combines the fields of science and technology with corporate development, thereby enhancing the efficiency of technological development. The number of patented applications and grants reflects the output of technological research.

Economic Innovation: According to economic growth theories, innovation becomes a new driver of development when an economy reaches a certain stage[13]. In the 21st century, economic development is no longer reliant on resource consumption and abundant labor inputs. High-quality economic development necessitates achieving sustainable development in the era of information technology and global connectivity. The synergy between innovation chains and industrial chains can promote regional integrated development under the umbrella of innovation, creating an innovation community among regions[14] and ensuring sustained economic development. In the dimension of economic innovation, the study explores four aspects: sales revenue from new products of industrial enterprises above a certain scale, regional GDP, the Consumer Price Index (CPI), and exports. Sales revenue from new products of industrial enterprises above a certain scale reflects the income from the sale of new products in various provinces and cities of the Yangtze River Delta, which exceed the standardized scale set by the national standards. This stimulates the demand structure upgrade for new product development[15], driving effective supply of innovative products and contributing to economic development. Regional GDP and the Consumer Price Index (CPI) can reflect the economic development trends of the 41 cities in the Yangtze River Delta over a specific period. The Yangtze River Delta region is located in the central and lower reaches of the Yangtze River, serving as a pivotal hub for land and water transportation, and a gateway to the Asia-Pacific

region. Total exports are an important indicator reflecting the strength of open and innovative development in the Yangtze River Delta region under China's opening-up policies.

Social Innovation: With the rapid advancement of science and technology and the continuous progression into the digital age, social services are gradually transitioning into digital forms. Models of social development such as "Digital + Intelligence" and "Digital + Good Governance" have become new calling cards for cities[16]. Local government general budget expenditures serve as the fundamental guarantee for high-quality innovative development[17]. The total fixed asset investment in the entire society includes the total costs of fixed asset investment, including land acquisition fees and the purchase of old buildings, reflecting the scale and speed of investment in fixed assets and the comprehensive investment ratio[18]. The completeness of hospitals and public libraries on the surface reflects the adequacy of regional infrastructure[19].

Ecological Innovation: From the perspective of ecological innovation, during the "14th Five-Year Plan" period, the country has proposed the continuation of deepening reforms in ecological and environmental policies to promote the modernization of the ecological governance system and governance capabilities. The 18th Party Congress outlined the "Five-sphere Integrated Plan" and the "Four-pronged Comprehensive Strategy," promoting the construction of an upward and better ecological civilization, and fostering harmonious coexistence between humans and nature. Under the category of wastewater treatment, indicators for pollutants like COD and TP are moving towards benign development. The continued treatment of urban sewage plays a crucial role in the removal of pollutants and maintaining their stability. Water is an indispensable resource for human production and development, and water resources also play a significant role in the ecosystem, serving as an important indicator for measuring ecological development.

Table 1: Evaluation Index System for the Quantity and Quality of Innovation Achievements in Existing Provinces and Industries Over a Specified Time Period

Primary Indicators	Secondary Indicators	Indicator Explanations	Symbols	Units	Attributes
Technological Innovation	R&D Expenditure	Actual Expenditure on Funds for Technological Innovation Activities	a1	Billion (Yuan)	+
	Number of High-Tech Enterprises	Number of High-Tech Enterprises, reflecting the innovative leadership of an area.	a2	Number	+
	Full-Time Equivalent R&D Personnel	R&D Personnel Input in Research and Development Organizations	a3	Person-year	+
	Number of Patented Applications and Grants	Number of Scientific Papers Published by Research and Development Organizations	a4	item	+
Economic Innovation	Sales revenue from new products of large-scale industrial enterprises	It refers to the sales revenue from new products in the production and operation processes of large-scale industrial enterprises in the Yangtze River Delta.	b1	Billion (Yuan)	+
	Regional Gross Domestic Product (GDP)	It refers to the sum of value-added contributions from all industries in the Yangtze	b2	Hundred Million (Yuan)	+

		River Delta region.			
	Consumer Price Index (CPI) (Base Year = 100)	It is an indicator reflecting the price fluctuations of typical consumer goods and services purchased by households.	b3	—	—
	Exports	It refers to the total value of exports from the Yangtze River Delta region over a specified period.	b4	Ten Thousand (Yuan)	+
Social Innovation	Local Government General Budget Expenditure	It refers to the general budget expenditure of the individual provinces and cities in the Yangtze River Delta region.	c1	Ten Thousand (Yuan)	+
	Total Fixed Asset Investment in the Entire Society	It includes expenses such as land acquisition fees and the purchase of old buildings, which are distinct from fixed asset investment.	c2	Hundred Million (Yuan)	+
	Number of Hospitals	It refers to the total number of hospitals in the various provinces and cities in the Yangtze River Delta region over specific time periods.	c3	Item	+
	Number of Public Libraries	It refers to the total number of public libraries in the various provinces and cities of the Yangtze River Delta region over specific time periods.	d1	Item	+
Ecological Innovation	Urban Wastewater Treatment Rate (%)	Reflecting the urban wastewater treatment capacity in various provinces and cities.	e1	Billion cubic meters	+
	Total Water Resources	It refers to the water resource storage volume in various regions of the Yangtze River Delta at different time periods.	e2	Metre	+

2.3 Model Selection & Modeling

2.3.1 - Entropy Weight Method

The Criteria Importance Through Intercriteria Correlation (CIIC) method, proposed by Diakoulaki in 1995, is an objective weighting technique. It establishes objective indicator weights by measuring the comparative strength and conflict between indicators. Standard deviation is used to represent comparative strength, while the correlation coefficient indicates conflict. However, previous research by scholars has pointed out that the correlation coefficients of indicators may exhibit negative values, and the substantive conflict of indicators is independent of their sign. Additionally, the standard deviation does not account for dimensionless considerations. Therefore, this study employs an improved version, which eliminates the dimensionality influence by replacing the standard deviation with the standard deviation coefficient and neutralizes the sign effect by adding the absolute value to the correlation coefficient. Furthermore, it is important to note that the CIIC method, while effective

in evaluating the comparative strength and conflict between indicators using standard deviation and correlation coefficients, does not reflect the degree of dispersion among indicators. Hence, this paper combines the CIIC method with the Entropy Weight Method to capture indicator weights.

To begin, let's assume there are m evaluation samples and n evaluation indicators. The original value of the nth indicator for the mth evaluation sample is denoted as X_ij, where i = 1, 2, 3, …, m, and j = 1, 2, 3, …, n.

Dimensionless Processing:

$$x_{ij} = \frac{x_{ij} - x_{\min}}{x_{\max} - x_{\min}} \text{ (1)Positive Variants}$$

$$x_{ij} = \frac{x_{\max} - x_{ij}}{x_{\max} - x_{\min}} \text{ (2)Negative Variants}$$

For year i, after standardizing the indicators, x_{ij} is the minimum value of indicator j, and $x_{\max}$ is the maximum value of indicator j.

Indicator Comparison:

$$\begin{cases} \overline{x}_j = \dfrac{1}{n}\sum_{i=1}^{m} x_{ij} \\ \alpha_j = \sqrt{\dfrac{\sum_{i=1}^{m}(x_{ij} - \overline{x}_j)^2}{n-1}} \end{cases} \tag{3}$$

In this context, $\overline{x}_j$ represents the average value of the indicators, and α_j represents the standard deviation of indicator j. In the CIIC method, standard deviation is used to express the comparative strength of the research indicators. A larger standard deviation indicates greater variability in the indicator values, which in turn reflects more information and a stronger evaluation intensity for the indicators. Consequently, indicators with larger standard deviations are assigned greater weights.

Indicator Conflict:

$$s_j = \sum_{i=1}^{m}(1 - r_{ij}) \tag{4}$$

In this context, r_{ij} represents the correlation coefficient between i and j. In the CIIC method, correlation coefficients are used to express the conflict between the research indicators. A higher correlation coefficient indicates stronger interrelationship between the indicators, suggesting a greater amount of shared information and lower conflict. However, excessive redundancy can

weaken the evaluation strength of the indicators, leading to smaller weights.

According to the CIIC method, indicator information is calculated as follows:

$$\sigma_j = \frac{\alpha_j}{\overline{x}_j} \sum_{i=1}^{m} (1 - |r_{ij}|) \tag{5}$$

In this context, σ_j represents the information content of indicator j. A larger value of σ_j indicates a greater impact in the evaluation of that particular indicator, resulting in a higher weight. To eliminate the influence of units and the sign, the standard deviation is replaced by the standard deviation coefficient. Additionally, adding the absolute value to the correlation coefficient enhances the accuracy of the weight calculation.

The weight of the j-th indicator:

$$W_1 = \frac{\sigma_j}{\sum_{j=1}^{n} \sigma_j} \tag{6}$$

Based on the Entropy Weight Method, the calculation of the probability for research object i and indicator j is as follows:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{7}$$

From this, the calculation of the information entropy for indicator j is as follows:

$$c_j = -\frac{1}{\ln m} \sum_{i=1}^{m} \ln p_{ij} \tag{8}$$

Weight of indicator j

$$W_2 = \frac{1 - c_j}{\sum_{j=1}^{n} (1 - c_j)} \tag{9}$$

Based on the improved CIIC-Entropy Weight Method, the calculation of the weights is as follows:

$$W_j = \Upsilon W_1 + (1 - \Upsilon) W_2 \tag{10}$$

In this paper, it is assumed that the improved CIIC method and the Entropy Weight Method have equal importance, with γ being set to 0.5.

2.3.2 TOPSIS

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is used to rank research objects by calculating their proximity to the ideal solution. By combining TOPSIS with the improved CIIC-Entropy Weight Method, it becomes possible to effectively reflect the correlations and importance among variables and address issues related to inverse ranking, ultimately enhancing the accuracy of the evaluation.

To calculate the weighted matrix, where $Z_{ij} = x_{ij} \cdot W_j$

$$Z = \begin{pmatrix} Z_{11} & \cdots & Z_{1n} \\ \vdots & \ddots & \vdots \\ Z_{m1} & \cdots & Z_{mn} \end{pmatrix} \tag{11}$$

To determine the positive ideal solution (PIS) and negative ideal solution (NIS) in the context of the TOPSIS method (J_1 as the set of positive criteria and J_2 as the set of negative criteria):

$$Z^+ = (Z_1^+, Z_2^+, \cdots, Z_n^+) = \{\max Z_{ij} | j \in J_1, \min Z_{ij} | j \in J_2\}$$

$$Z^- = (Z_1^-, Z_2^-, \cdots, Z_n^-) = \{\min Z_{ij} | j \in J_1, \max Z_{ij} | j \in J_2\}$$

To calculate the distance of each evaluation object to the Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS) in the context of the TOPSIS method

$$L_i^+ = \sqrt{\sum_{j=1}^{n} (Z_{ij} - Z_j^+)^2} \tag{12}$$

$$L_i^- = \sqrt{\sum_{j=1}^{n} (Z_{ij} - Z_j^-)^2} \tag{13}$$

To calculate the proximity (closeness) of the i-th evaluation object to the obtained Ideal Solution (IS), you can use the following formula:

$$\varphi_i = \frac{L_i^-}{L_i^+ - L_i^-} (0 \leqslant \varphi_i \leqslant 1) \tag{14}$$

2.4 Estimation Results and Empirical Analysis

2.4.1 Comprehensive Analysis of High-Quality Development in the Yangtze River Delta Region

The Yangtze River Delta region integration strategy has been formally established, marking the beginning of a new era in its development. With the approval of the "Comprehensive Plan for the Ecological and Green Integrated Development Demonstration Zone in the Yangtze River Delta" and the introduction of the "Outline of Development Planning for the Yangtze River Delta Region," the Yangtze River Delta has become a focal point for nationwide reform. Fueled by high-level government planning and its own pursuit of high-quality development, the Yangtze River Delta is undergoing a transformation in terms of quality, efficiency, and dynamism, heralding a period of remarkable change. Table 2 below presents the scores for the 41 cities in the Yangtze River Delta region from 2010 to 2020:

Table 2: Scores for High-Quality Innovative Development in 41 Cities in the Yangtze River Delta Region

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	score
Shanghai	0.042	0.0546	0.0547	0.0474	0.046	0.0419	0.0364	0.0502	0.0516	0.0424	0.04672
Nanjing	0.0279	0.0371	0.0352	0.0338	0.0308	0.0311	0.028	0.0315	0.0307	0.0286	0.03147
Wuxi	0.0323	0.0351	0.0331	0.0281	0.0297	0.0303	0.0281	0.0312	0.0293	0.0284	0.03056
Changzhou	0.0223	0.0264	0.0267	0.025	0.0232	0.0263	0.0258	0.0255	0.023	0.0233	0.02475
Suzhou	0.0353	0.0439	0.0447	0.0337	0.0386	0.036	0.0308	0.0357	0.0354	0.0315	0.03656
Nantong	0.0238	0.0271	0.0274	0.0248	0.0239	0.0271	0.0254	0.0248	0.0209	0.0231	0.02483
Yancheng	0.021	0.0213	0.0226	0.0228	0.0193	0.0245	0.0227	0.0196	0.0173	0.0218	0.02129
Yangzhou	0.0217	0.0248	0.0239	0.0235	0.0207	0.0251	0.0234	0.0206	0.0166	0.0215	0.02218
Zhenjiang	0.0212	0.0196	0.02	0.0214	0.0182	0.0224	0.023	0.0197	0.0144	0.0221	0.0202
Taizhou	0.0205	0.0191	0.018	0.0222	0.0164	0.0231	0.0237	0.0213	0.0155	0.0214	0.02012
Xuzhou	0.0209	0.0224	0.0226	0.0239	0.0216	0.0247	0.0239	0.0221	0.0198	0.0239	0.02258
Lianyungang	0.0208	0.02	0.0208	0.0215	0.0156	0.0213	0.0206	0.0155	0.0126	0.0202	0.01889
Huai’an	0.0196	0.0147	0.0179	0.021	0.0184	0.0233	0.0226	0.0199	0.0158	0.0206	0.01938
Su’qian	0.0211	0.0218	0.0226	0.0224	0.0215	0.0241	0.0237	0.0216	0.0179	0.0228	0.02195
Hangzhou	0.0346	0.0406	0.0423	0.0319	0.0456	0.0395	0.0351	0.047	0.0398	0.0357	0.03921
Ningbo	0.0288	0.033	0.0336	0.0284	0.0305	0.033	0.0281	0.0409	0.041	0.0381	0.03354
Wenzhou	0.027	0.0201	0.0271	0.0256	0.0261	0.026	0.0265	0.0299	0.0298	0.028	0.02661
Shaoxing	0.0217	0.0206	0.026	0.0233	0.0196	0.025	0.024	0.0254	0.0228	0.0246	0.0233
Huzhou	0.0212	0.0204	0.0211	0.0225	0.0188	0.0237	0.0233	0.0236	0.0205	0.0234	0.02185
Jiaxing	0.0221	0.0214	0.0222	0.0109	0.0187	0.0105	0.0202	0.0169	0.0166	0.0239	0.01834
Jinhua	0.0215	0.02	0.0245	0.0235	0.0217	0.0245	0.0241	0.0259	0.0229	0.0256	0.02342
Quzhou	0.0214	0.0127	0.0219	0.0223	0.019	0.0234	0.024	0.0243	0.0201	0.0233	0.02124
Zhoushan	0.019	0.0177	0.0163	0.0211	0.0131	0.0208	0.023	0.0206	0.015	0.0205	0.01871
Taizhou	0.0239	0.0224	0.0234	0.0239	0.0216	0.0248	0.0231	0.0238	0.0227	0.0255	0.02351
Li’shui	0.0265	0.0198	0.0275	0.0253	0.0248	0.025	0.0252	0.0286	0.0243	0.0263	0.02533
Hefei	0.0256	0.0296	0.0276	0.0269	0.0317	0.0281	0.0265	0.0303	0.0324	0.0261	0.02848
Wuhu	0.0239	0.0211	0.0186	0.0236	0.0229	0.0219	0.0339	0.0196	0.0289	0.0253	0.02397
Ma’anshan	0.0224	0.0197	0.0187	0.0235	0.026	0.0225	0.0233	0.0221	0.0277	0.0235	0.02294
Tongling	0.0289	0.0458	0.0301	0.0289	0.02	0.0209	0.0191	0.0115	0.0225	0.0227	0.02504

Chizhou	0.0133	0.0206	0.013	0.0203	0.0164	0.0219	0.0199	0.0176	0.0133	0.0097	0.0166
Anqing	0.0237	0.0193	0.0192	0.024	0.0244	0.0242	0.0238	0.0167	0.0247	0.0206	0.02206
Xuancheng	0.0253	0.0192	0.0096	0.0218	0.0252	0.0227	0.0209	0.0206	0.0251	0.0238	0.02142
Chuzhou	0.0235	0.0226	0.0287	0.0233	0.0249	0.0227	0.0221	0.0223	0.0275	0.0201	0.02377
Bengbu	0.0226	0.0284	0.024	0.0242	0.0276	0.0236	0.0236	0.0241	0.0256	0.0256	0.02493
Huaibei	0.0252	0.0242	0.0211	0.0235	0.0261	0.0223	0.0233	0.022	0.0252	0.026	0.02389
Huainan	0.0228	0.0253	0.0211	0.0234	0.0261	0.022	0.021	0.0179	0.0293	0.0221	0.0231
Suzhou	0.0219	0.0077	0.0185	0.0237	0.0265	0.0233	0.0216	0.0229	0.0263	0.0217	0.02141
Fuyang	0.0297	0.0171	0.0142	0.0224	0.0225	0.0202	0.0205	0.0186	0.0224	0.0185	0.02061
Haozhou	0.0246	0.0243	0.0205	0.0234	0.0255	0.0226	0.0203	0.0194	0.0223	0.0209	0.02238
Liuan	0.0241	0.0147	0.0147	0.0232	0.0248	0.024	0.0235	0.0237	0.0286	0.0263	0.02276
Huangshan	0.0242	0.0235	0.0243	0.0236	0.0259	0.0321	0.0221	0.0242	0.0215	0.0207	0.02333

It is evident from Table 2 that the ranking of the 41 cities in the Yangtze River Delta, from highest to lowest, is as follows: Shanghai, Hangzhou, Suzhou, Ningbo, Nanjing, Wuxi, Hefei, Wenzhou, Lishui, Tongling, Bengbu, Nantong, Changzhou, Wuhu, Huaibei, Chuzhou, Taizhou, Jinhua, Huangshan, Shaoxing, Huainan, Ma'anshan, Lu'an, Xuzhou, Huzhou, Yangzhou, Anqing, Suqian, Huzhou, Xuancheng, Suzhou, Yancheng, Quzhou, Fuyang, Zhenjiang, Taizhou, Huaian, Lianyungang, Zhoushan, Jiaxing, and Chizhou. Among these cities, Shanghai, Hangzhou, Suzhou, Ningbo, Nanjing, and Wuxi have relatively high scores, reflecting their higher level of high-quality development. They exhibit significant innovative strengths in four areas: technological innovation, economic innovation, social innovation, and ecological innovation. On the other hand, cities like Wenzhou, Lishui, and Tongling have lower overall scores.

The distribution of scores for cities in the Yangtze River Delta can be depicted as follows:

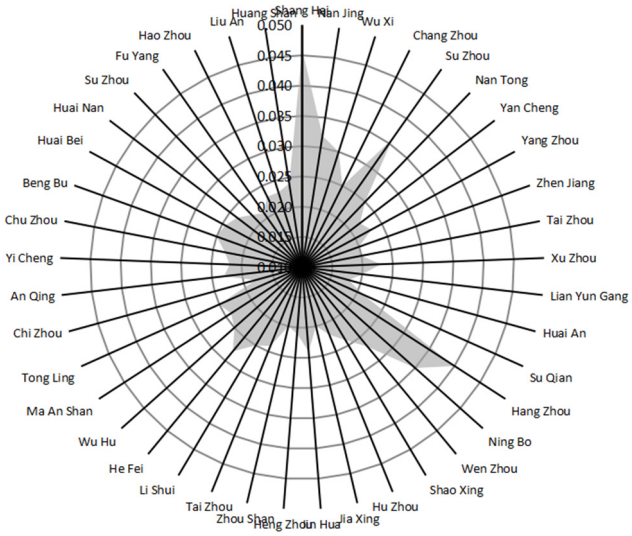

Figure 1: Distribution of High-Quality Development Scores for Cities in the Yangtze River Delta

Simultaneously, from the distribution graph of high-quality innovation in various cities depicted in Figure 1, it is evident that there are spatial differences in high-quality development in the Yangtze River Delta. Cities with higher scores, such as Shanghai, Hangzhou, Suzhou, Ningbo, and Nanjing, are mostly located in the eastern part of the Yangtze River Delta and are predominantly central cities. Conversely, cities with relatively lower scores, like Chizhou and Fuyang, are mostly situated in the western part of the Yangtze River Delta. Overall, a development trend from east to west and from central to peripheral, with varying degrees of strength, is observed. As a result, Shanghai consistently maintains the highest level of development among the three provinces and one municipality in the Yangtze River Delta, while cities in Zhejiang Province rank relatively high, indicating a higher level of high-quality innovative development. Anhui Province, except for cities like Hefei and Tongling, has relatively lower scores for most cities, reflecting significant spatial development differences within the Yangtze River Delta region.

2.4.2 Subsection Investigation of High-Quality Development in the Yangtze River Delta Region

From Figure 2, it can be observed that the Yangtze River Delta region exhibits differences in four aspects: technological innovation, economic innovation, social innovation, and ecological innovation. Ecological innovation was at a disadvantage during the period from 2010 to 2013, with overall low levels of innovation in the ecological domain. The primary focus was on technological and economic development, with traditional resource consumption as the main driving factor. However, during the period from 2015 to 2020, there was a gradual shift in the structure of innovation, transitioning from a focus on technological and economic innovation to a predominant emphasis on ecological and social innovation. Graph 2 reveals that the gap between these four areas of innovation and development is gradually narrowing, signifying more pronounced momentum toward coordinated development in all aspects in the Yangtze River Delta region.

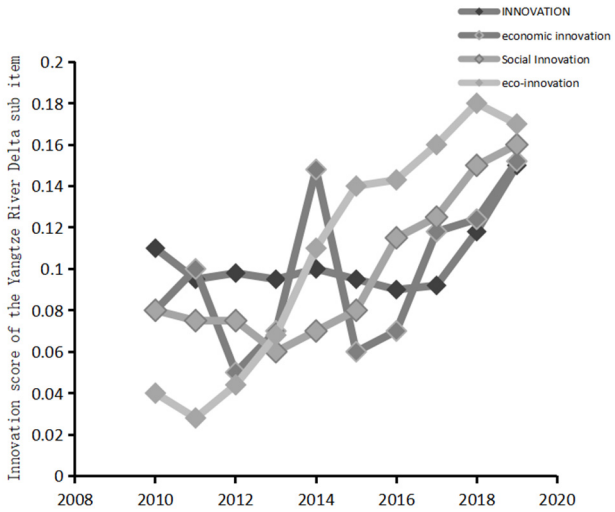

Figure 2: Subscores for the Evaluation of the Yangtze River Delta Region

3 Research Conclusions and Policy Recommendations

3.1 Research Conclusions

Firstly, in 2020, the Yangtze River Delta region, under the integration of strategies, maintained stability while seeking progress, continuously achieving a transition from old to new driving forces, and optimizing its economic structure. The overall state of high-quality economic development was positive. As a developed region in the east with a focus on technological innovation, the Yangtze River Delta demonstrated high technological capabilities and a concentration of professional technical talents. This facilitated high-quality innovative development in the region. As evident in Figure 2, levels of technological innovation, economic innovation, social innovation, and ecological innovation in the Yangtze River Delta exhibited an upward trend from 2010 to 2020. The region moved towards high-quality development under the influence of national policy support and its own breakthroughs.

Secondly, based on Table 2, it is apparent that the Yangtze River Delta region currently maintains a relatively high overall level of development and possesses a high level of innovation. However, there is an issue of regional imbalances in high-quality development in the Yangtze River Delta. The development distribution can be generally summarized as from strong to weak, with an intermediate-peripheral and east-west geographical pattern. This pattern has a negative impact to some extent on the construction of collaborative development in the Yangtze River Delta. The "core-periphery" economic development layout has resulted in relatively weak economic development in peripheral regions, while core regions exhibit strong economic development. This has led to development disparities from strong to weak.

Thirdly, the gap between technological innovation, economic innovation, social innovation, and ecological innovation in the Yangtze River Delta has gradually narrowed, indicating a clear trend towards "integrated innovative development." Simultaneously, the level of ecological innovation, as seen in Figure 2, experienced the highest growth rate from 2010 to 2020. The Yangtze River Delta is gradually moving away from traditional economic development relying on resource consumption. It is now integrating ecological protection and ecological development to create a new scenario of sustainable ecological and economic development.

3.2 Policy Recommendations

Firstly, cities should lead with their own advantageous resources and use government policies as auxiliary support to implement a "one core, multiple centers" development model. As the integration of the Yangtze River Delta region advances and the economy develops rapidly, cities in the Yangtze River Delta have accumulated unique advantages in terms of innovation dynamics and capabilities. They have established a multi-center innovation network, with Shanghai as the leading core city, and cities like Suzhou, Hangzhou, Nanjing, and Hefei as sub-centers. This network exhibits a concentric distribution pattern with innovative cities at the center, external innovative cities as the second circle, and regional innovative cities at the outermost circle. Therefore, each city should set development goals, pathways, directions, and measures based on their local resource advantages and actual development foundation. They should harmonize theory with practice, integrate the overall and the local, plan strategically while optimizing functional division. Leveraging Shanghai's leading role, they should enhance service functions around the "Five Centers" construction, connect the innovation chain with the

industrial chain, combine universities, government, and enterprises, and optimize the allocation of regional resources.

Secondly, strengthen the collaborative innovation linkage among cities in the Yangtze River Delta, promoting the optimization of human resource allocation. First, enhance cooperation in human resources, stimulate talent mobility between cities, optimize human resource allocation through joint job fairs, sharing of talent resources, and other methods, and improve the utilization rate of talent. Adjust social welfare reasonably, strengthen cooperation with high schools, research institutes, and research centers in the Yangtze River Delta, accelerate talent recruitment, and cultivate high-level talents. Second, promote the integration of the industrial chain, with each city promoting the development of the industrial chain based on their advantages, avoiding overlapping efforts. Finally, in terms of technological collaborative innovation, improve the concentration of high-tech development, adopting an intensive development mode. Fully leverage the role of the comprehensive national science center and national laboratories, integrate effective resources for technological innovation, and create national science and technology bases.

Thirdly, the Yangtze River Delta region should incorporate ecological benefits and human development into the system of innovative development goals. With rapid economic development and urbanization, the nation is increasingly emphasizing green and sustainable development. Green and sustainable development is guiding urban construction and action. It should play its role as a driving force to accelerate the transformation from old to new driving forces, promote ecological technological innovation, and unlock corresponding economic benefits. Differentiated ecological construction should be carried out in the region, combining scientific theory with specific practice to drive overall ecological development with local ecological development.

Fourthly, harness the regional advantages of the Yangtze River Delta, adhere to open development, construct internal and external development chains, and create a dual-cycle pattern of domestic and international circulation. Leverage the effectiveness of the Belt and Road Initiative, seize opportunities, and integrate the innovation clusters of the Yangtze River Delta into the construction of the Belt and Road Initiative's industrial chain. Build an international development hub. Simultaneously, strengthen technological invention and application, optimize the import and export industrial structure, build international standard quality brands, shape a good image, attract high-quality international brands for cooperation. The government should encourage foreign investment appropriately, facilitate the entry of foreign companies, and implement fiscal and monetary policies that promote the flow of domestic and foreign capital, such as adjusting import and export tariffs and exchange rates, making full use of international resources, opening international markets, and optimizing resource allocation. Relying on cities like Shanghai, Hangzhou, Nanjing, and Hefei, attract multinational companies to enter and actively welcome international organizations to settle in the cities.

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