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Study on Evaluation of the Interconnected Development of the Yangtze River Delta National Innovation Demonstration Zone

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Abstract: Based on the impression that the integrated regional development of the Yangtze River Delta has been levelled up as China's national strategy, it is a necessity to realize the high-quality interconnected development of the Yangtze River Delta National Innovation Demonstration Zone. Specifically, it involves the building of evaluation indexes for the interconnected development level of the demonstration zone from such dimensions as industry, economy, policy, space and ecology, determination of weights of various indexes based on the aggregation method for the expert judgment matrix, and design of an evaluation model for the interconnected development level. On this basis, the interconnected development level between different demonstration zones and the contributions of different indexes to the interconnected development level are studied by conducting empirical study on the evaluation of the interconnected development level of demonstration zones.

Keywords: Interconnected development; Evaluation; Demonstration zone; The Yangtze River Delta

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1. Introduction

The high-quality interconnected development of the Yangtze River Delta National Innovation Demonstration Zone is supported by the realistic foundation, but also faces a variety of practical challenges, such as administrative barriers, gaps in systems and mechanisms, and differences in development levels. Till now, there are relatively numerous studies on the evaluation of regional innovation capability, but relatively fewer studies on the evaluation of regional interconnected development levels. As the evaluation of the high-quality interconnected development level of a national innovation demonstration zone is relatively subjective, and conventional evaluation methods are realized on a qualitative basis, the quantitative evaluation instead of the qualitative evaluation can more accurately and visually describe the high-quality interconnected development capabilities of innovation demonstration zones.

The study mainly covers two aspects: building an index system and defining the evaluation methods. As for the former, the prevailing view is that the systematic analysis paradigm of "factor - structure – function" can become an effective support for the evaluation of the innovation capabilities of national innovation demonstration zones [1]. With respect to the selection of a national innovation demonstration

zone, 8 secondary indexes and 48 tertiary indexes have been built in the reference [2], covering four dimensions of carrier support, innovation, accumulation and radiation, and outward expansion and specific to regional development. The reference [3] has proposed a multi-dimension and multi-level regional interconnected development evaluation system, which is composed of 1 primary index, 8 secondary indexes, 24 tertiary indexes, and 58 quaternary indexes. For the evaluation of regional innovation capability and potential, the reference [4] has proposed 7 categories of moderate indexes and 23 items of minor indexes based on four major aspects: innovation industry elements, R&D infrastructure, innovation policy environment, and innovation supporting conditions. While for the latter aspect, building innovation indexes allows for a better reflection of the overall strength of the object [5]. With national innovation demonstration zones as the evaluation objects, the reference [6] proposes the "Vertical and Horizontal Scatter Degree Method," and the weight coefficients are determined based on the amount of information provided by the index data. The reference [7] gives a systematically analysis of the standardization of raw data and comprehensive evaluation calculations specific to evaluation of the capital supply and demand capacity of a national innovation demonstration zone.

Considering the particular nature of evaluating the interconnected development level of the national innovation demonstration zone, and the fact that expert judgments are mostly probabilistic judgments, this paper, based on fuzzy evaluation ideas and methods, determines the evaluation index system primarily from a quantitative perspective. The first step is to build an evaluation index system for the interconnected development level. Then, the information on expert evaluation is collected and an expert evaluation matrix is established. On this basis, an evaluation model for the interconnected development level is built, and corresponding empirical studies are carried out to verify the effectiveness of the evaluation results.

2. Building an index system for the evaluation of the high-quality interconnected development level of the Yangtze River Delta National Innovation Demonstration Zone

High quality and synergy are two key considerations in evaluating the high-quality interconnected development level of the Yangtze River Delta National Innovation Demonstration Zone. Synergy in the high-quality interconnected development of the Yangtze River Delta National Innovation Demonstration Zone can be specifically embodied in industry specialization, economic development, ecological governance, infrastructure and other aspects [8]. Specifically, Synergy in industry specialization is mainly manifested in the degree of synergy between advanced manufacturing and high-end service sectors. Synergy in economic development is embodied in the degree of synergy between financial resources and financial institutions. Synergy in ecological governance is mainly reflected in the degree of interconnected prevention and control of regional ecosystem, while synergy in infrastructure is mainly represented by the degree of co-construction and sharing of infrastructure resources such as transportation and utilities. Synergies in these four dimensions mutually restrict and influence each other, and jointly promote the integrated and high-quality development of the Yangtze River Delta.

There are some researches on the index system for the regional collaboration and regional innovation capability, and some other researches on the selection index system and the innovation capability index system for national innovation demonstration zones [2-4,9]. Therefore, this paper builds the evaluation index system for the interconnected development level of the Yangtze River Delta National Innovation Demonstration Zone from five dimensions: industrial relevance B1, economic relevance B2, policy relevance B3, spatial relevance B4, and ecological relevance B5 in combination with researches in relevant works. The evaluation of the interconnected development level presents more obvious fuzziness, so only the primary and secondary indexes are built in the index system. The evaluation index system for the interconnected development level of an innovation demonstration zone is as shown in **Table 1**.

Table 1. Evaluation index system for the high-quality interconnected development level of the Yangtze River Delta National Innovation Demonstration Zone

Primary Index	Secondary Index	Description
Industrial relevance B1	Industry alliance B11	The number of inter-regional business cooperation-competition organizations
	Industrial chain relationship B12	The number of trans-regional industrial chains and the enterprises covered
Economic relevance B2	Market factor correlation B21	Trans-regional flow of labor, capital, and means of production between regions
	Economic growth correlation B22	Inter-regional per capita GDP growth rates and their correlation
Policy relevance B3	Coordinating agency B31	Inter-regional coordinating organizations and coordinating mechanisms of governmental authorities
	System building B32	System co-construction and system correlation between regions
	Public service platforms B33	Building of inter-regional public service platforms
Spatial relevance B4	Location correlation B41	Spatial distance and accessibility of central cities in different regions
	Infrastructure B42	Co-construction and sharing of infrastructure such as water, electricity, communications and other utilities in different regions
	Urban system B43	Similarity and relevance of the urban systems of different regions
Ecological relevance B5	Joint ecological governance B51	Relevance in environmental protection and pollution control by enterprises in different regions
	Regional cultural relevance B52	Similarity of cultural traditions of different regions

3. Design of evaluation methods

3.1. Calculation of index weights

The calculation of index weights in this section mainly involves using the classic "1-9 scale" method to construct an expert judgment matrix, and aggregating multiple expert matrices to form an integrated judgment matrix. Then, such specific operations as normalization are performed on the integrated judgment matrix for calculating the index weights.

The first step is to construct an expert matrix. Relying on expert surveys, the research team selects 5 experts to judge the significance of secondary indexes shown in Table 1, and an integrated judgment matrix M* is built as shown below:

$$M^{*}=\begin{bmatrix} 1 & 0.14 & 3.10 & 0.17 & 0.39 & 0.37 & 0.15 & 3.25 & 0.31 & 4.37 & 0.30 & 5.93 \\ 7.16 & 1 & 6.79 & 4.13 & 4.13 & 4.28 & 3.18 & 7.97 & 4.96 & 8.79 & 5.55 & 8.19 \\ 0.50 & 0.15 & 1 & 0.13 & 0.32 & 0.27 & 0.20 & 0.32 & 0.20 & 2.93 & 0.13 & 3.95 \\ 5.79 & 0.24 & 7.97 & 1 & 6.76 & 5.38 & 2.35 & 7.56 & 4.00 & 8.39 & 6.19 & 8.79 \\ 2.55 & 0.24 & 3.10 & 0.15 & 1 & 0.36 & 0.24 & 2.77 & 0.21 & 3.90 & 0.23 & 6.72 \\ 2.70 & 0.23 & 3.68 & 0.19 & 2.76 & 1 & 0.23 & 3.57 & 0.31 & 6.52 & 0.34 & 8.36 \\ 6.76 & 0.31 & 5.12 & 0.43 & 4.18 & 4.32 & 1 & 4.32 & 2.77 & 6.79 & 3.95 & 8.59 \\ 0.31 & 0.13 & 3.10 & 0.13 & 0.36 & 0.28 & 0.23 & 1 & 0.21 & 2.55 & 0.21 & 4.28 \\ 3.18 & 0.20 & 5.00 & 0.25 & 4.74 & 3.18 & 0.36 & 4.78 & 1 & 7.53 & 3.10 & 7.58 \\ 0.23 & 0.11 & 0.34 & 0.12 & 0.26 & 0.15 & 0.15 & 0.39 & 0.13 & 1 & 0.13 & 3.10 \\ 3.37 & 0.18 & 7.71 & 0.16 & 4.28 & 3.10 & 0.25 & 4.78 & 0.32 & 7.97 & 1 & 6.76 \\ 0.17 & 0.12 & 0.25 & 0.11 & 0.71 & 0.12 & 0.12 & 0.23 & 0.13 & 0.32 & 0.15 & 1 \end{bmatrix}$$

M* is an integrated judgment matrix based on the expert judgment matrix and aggregated using the multiplicative aggregation method. Through such specific operations as continued multiplication, extracting, and normalization of the element values of each row in the matrix M*, the corresponding quantized weights are calculated as follows:

$$w = (0.037,0.250,0.022,0.199,0.044,0.062,0.144,0.027,0.106,0.015,0.083,0.012) \quad (1)$$

However, the expert judgment matrix is significantly subjective and has certain biases. Therefore, it is necessary to verify the consistency of the expert judgment matrix to check whether the obtained W values meet the consistency requirement.

To test the consistency of the judgment matrix, it is necessary to introduce a consistency index CI.

$$CI = \frac{\lambda_{max}-n}{n-1} \quad (2)$$

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} \quad (3)$$

λ_{max} is the maximum eigenvalue of the judgment matrix, with Meanwhile, the corresponding average random consistency index RI is introduced. **Table 2** shows the average random consistency indexes obtained from 1000 samples of the judgment matrixes of orders 1-12.

Table 2. Values of the consistency index RI

The order of matrix	Value of RI
1	0
2	0
3	0.52
4	0.89
5	1.12
6	1.26
7	1.36
8	1.41
9	1.46
10	1.49
11	1.52
12	1.54

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} = 13.111 \quad (4)$$

$$CI = \frac{\lambda_{max} - n}{n-1} = 0.101 \quad (5)$$

$$CR = \frac{CI}{RI} = \frac{0.101}{1.54} = 0.065 \quad (6)$$

$$CR < 0.1 \quad (7)$$

Therefore, the judgment matrix and the weights obtained are accepted.
Accordingly, the calculated weight of each primary index is:

$$W = \sum_{i=1}^{5} w_{ij} = (0.287, 0.221, 0.250, 0.148, 0.095) \quad (8)$$

3.2. Building of the evaluation model

Due to the significant fuzziness in the evaluation indexes for the high-quality interconnected development level of the Yangtze River Delta National Innovation Demonstration Zone, in the building of the evaluation model, the expert group evaluations are built in stages. The basic concept is as follows: Firstly, the evaluation indexes for the interconnected development level between two demonstration zones are scored based on the expert evaluations; secondly, an evaluation model for the interconnected development level between the two demonstration zones is built to quantify the interconnected development level.

Parameter description:

b_{ij}: quantized expert evaluation value of the evaluation index for the interconnected development level B_{ij};
w'_{ij}: weight of the evaluation index for the interconnected development level B_{ij};
w'_i: weight of the evaluation index for the interconnected development level B_i, with $w'_i = \sum_{j=1} w'_{ij}$
S: interconnected development level between the two demonstration zones, where S_i is the interconnected development level in terms of the index B_i.

On this basis, the evaluation model for the high-quality interconnected development level of the Yangtze River Delta National Innovation Demonstration Zone is built:

$$S = \sum_{i=1}^{5} b_i \times w_i' = \sum_{i=1} \sum_{j=1} b_{ij} \times w_{ij}' \quad (9)$$

It shall be noted that the quantification of the interconnected development between the two demonstration zones is essentially lack of direct application significance. Therefore, combining with the comparative analysis of the evaluation indexes for the interconnected development capability of the demonstration zones makes it possible to have a more comprehensive understanding of the advantages and disadvantages of the interconnected development in the demonstration zones.

4. Demonstration of interconnected development evaluation results

4.1. Data collection

The evaluation of the high-quality interconnected development in the Hefei-Wuhu-Bengbu National Innovation Demonstration Zone and the Hangzhou National Innovation Demonstration Zone is taken as an example. Evaluation information from multiple experts is collected to build an evaluation matrix, and the empirical study on the evaluation of the high-quality interconnected development level of the Yangtze River Delta National Innovation Demonstration Zone is conducted on this basis.

The expert evaluation matrix is set as $A = \begin{bmatrix} a_{11} & & \\ & a_{ii} & \\ & & a_{mn} \end{bmatrix}$, where $A_i = \{a_{i1}, a_{i2} \dots \dots a_{in}\}$ represents the evaluation information from the i-th expert.

With reference to the "1-9 scale" method, the evaluation indexes for the high-quality interconnected

development level of the Yangtze River Delta National Innovation Demonstration Zone are quantized and scored. The rules are as follows:

Table 3. Quantified values of evaluation indexes for the high-quality interconnected development level of the Yangtze River Delta National Innovation Demonstration Zone

Grading of interconnected development level	Breakdown of interconnected development level	Quantitative value of interconnected development level
Low	Extremely	1
	Significant	2
	Average	3
Medium	Medium to low	4
	Medium	5
	Medium to high	6
High	Average	7
	Significant	8
	Extremely	9

With reference to the evaluation scoring rules in **Table 3**, the evaluation data of 5 evaluation experts from A_1 to A_5 is collected, and the evaluation values of the interconnected development level in terms of the 12 secondary indexes are represented by b_1 to b_{12}, respectively, resulting the evaluation data as shown in **Table 4**.

Table 4. Expert evaluation data of the interconnected development level

	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}	b_{11}	b_{12}
A_1	6	7	4	6	4	4	1	8	2	2	3	6
A_2	7	6	5	7	3	3	2	7	2	2	2	6
A_3	5	6	6	7	4	3	3	7	3	2	2	7
A_4	7	5	7	6	5	3	2	6	3	3	4	5
A_5	6	5	7	8	3	3	2	7	2	3	5	7

4.2. Empirical analysis

From the evaluation model for the interconnected development level, we can obtain the following:

$$S = \sum_{i=1}^{5} b_i \times w_i^{'} = \sum_{i=1} \sum_{j=1} b_{ij} \times w_{ij}^{'} = (4.59,4.53,4.78,4.46,4.76) \quad (10)$$

where $S_i$represents the quantitative evaluation value for the i-th expert.

The Q_k is used to represent the coordination level evaluation of the k-th index among the 12 indexes for the level evaluation, and the following can be obtained through the additive aggregation method:

$$Q_k = (6.2, 5.8, 5.8, 6.8, 3.8, 3.2, 2, 7, 2.4, 2.4, 3.2, 6.2) \quad (11)$$

Combined with the quantitative value of the integrated interconnected development level in terms of each index, the expert evaluation data shows that the two indexes “Economic Growth Correlation B22” and “Location Correlation B41” present a relatively high coordination level, while the index “Public Service Platforms B33” shows a lowest level.

The T_k is used to represent the contribution of the coordination level evaluation of the k-th index among the 12 indexes for the level evaluation to the evaluation value of the overall regional coordination

level. $b_k$and $w_k$represent the expert evaluation value and index weight of the k-th index among the 12 indexes, respectively.

$$T_k = b_k \times w_k \quad (12)$$

Then, the contribution of each expert's evaluation of the coordination level corresponding to each index to the regional coordination level can be obtained, as shown in **Table 5**.

Table 5. Regional coordination level contributions corresponding to indexes

	A_1	A_2	A_3	A_4	A_5
T_1	0.22	0.26	0.19	0.26	0.22
T_2	1.75	1.5	1.5	1.25	1.25
T_3	0.09	0.11	0.13	0.15	0.15
T_4	1.19	1.39	1.39	1.19	1.59
T_5	0.17	0.13	0.17	0.22	0.13
T_6	0.25	0.19	0.19	0.19	0.19
T_7	0.14	0.29	0.43	0.29	0.29
T_8	0.21	0.19	0.19	0.16	0.19
T_9	0.21	0.21	0.32	0.32	0.21
T_{10}	0.03	0.03	0.03	0.05	0.05
T_{11}	0.25	0.17	0.17	0.33	0.41
T_{12}	0.07	0.07	0.08	0.06	0.08

Through calculating the arithmetic average, the average of the overall coordination level contribution of each index is obtained:

$$T = (0.23, 1.45, 0.13, 1.35, 0.17, 0.20, 0.29, 0.19, 0.25, 0.04, 0.26, 0.07) \quad (13)$$

From the quantification of the overall coordination level contribution of each index, it can be seen that the indexes "Industrial Chain Relationship B12" and "Economic Growth Correlation B22" contribute relatively high to the overall interconnected development of the region, and indexes "Urban System B43" and "Regional Cultural Relevance B52" have relatively low contributions to the overall interconnected development of the region.

5. Conclusion

The evaluation of the interconnected development level of the Yangtze River Delta National Innovation Demonstration Zone is not only an intuitive reflection of the interconnected development in the Zone, but also a detailed and quantitative reflection of the coordination levels of specific indexes. Starting from the building of the index system, this paper summarizes, sorts out and selects relevant evaluation indexes, and builds the evaluation index system for the high-quality interconnected development level of the Yangtze River Delta National Innovation Demonstration Zone. On the basis of the building of the index system, expert opinion information is collected for building the judgment matrix and determining the weights of the indexes, and then the evaluation model for the interconnected development level is built. The empirical study on the evaluation result of the interconnected development level is carried out combined with specific expert evaluation information. With the evaluation of the interconnected development level, it can not only directly reflect the overall coordination in the Yangtze River Delta National Innovation Demonstration Zone, but also show the interconnected development level of each index and their contributions to the overall interconnected development level, providing recommendations for the high-quality interconnected development of the Yangtze River Delta National Innovation Demonstration Zone.

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Disclosure statement

The authors declare no conflict of interest.

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