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Research Article

Research on Innovation Performance in Heterogeneous Region: Evidence from Yangtze Economic Belt in China

Lin Zou[1] **and Yi-wen Zhu**[2,3]

[1]*Institute of Management, Shanghai University of Engineering Science, Shanghai 201620, China*
[2]*Center for Modern Chinese City Studies, East China Normal University, Shanghai 200062, China*
[3]*Institute of Urban Development, East China Normal University, Shanghai 200062, China*

Correspondence should be addressed to Yi-wen Zhu; zhuyiwen19@163.com

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Innovation has become the main impetus for regional development. Effective utilization of innovation resources is crucial in promoting sustainable innovation. From the theoretical aspect, there still exists uncertainty of how to effectively evaluate innovation performance. From the empirical aspect, we still doubt whether regions of higher economic level or high innovation quantity really show positive regional innovation performance, especially in heterogeneous regions. This paper uses DEA-Malmquist index to measure regional innovation performance of the Yangtze River Economic Belt in China. Regions of similar performance levels are grouped by ward clustering, analysis regional innovation performance characteristics, and problem-solving paths of regions in different development stages. The empirical research proves that overall performance of Yangtze River Economic Belt is not high. The economic core area has realized increase of innovation volume through large amount of material input and resource consumption, instead of realizing full utilization of innovative resources; how to improve the utilization rate of existing technical resources has been neglected. Different regions with similar innovation performance show different characteristics and innovation problems, including resource mismatch, input redundancy, or insufficient output. There are also some differences in the way the region's specific innovation performance is improved.

1. Introduction

With the development of economy, knowledge has replaced capital and became the resource with great strategic value. Innovation has become the main impetus of economic development [1, 2]. Knowledge production, allocation, and uses had become basic factor for economic growth [3, 4]. Romer had pointed out that R&D research aimed at pursing economic profits can realize knowledge accumulation and promote long-term economic growth [5]. That means, in the era of knowledge and learning economy, R&D ability of region is the key factor for regional economic development. Promoting development of Yangtze River Economic Belt is national strategy that affects the development of China. The Yangtze River Economic Belt has achieved remarkable development in recent years, and internal heterogeneity is obvious. The interregional economic and innovation levels are quite different. How to realize interregional coordinated development and sustainable development of innovation resources is a strategic problem that needs to be solved urgently in China.

Innovation performance includes ability of firms to put new products into market [6] or refer to technological innovation ability [7]. Relation between innovation performance and economic development has become a consensus; this paper, based on knowledge production function, selected metropolis of Yangtze Economic Belt and analyzed overall level, spatial distribution, and various tendencies of the innovation performance. The following problems are expected to be solved. (1) What is the overall level and trend of regional R&D performance in Yangtze River Economic Belt? Which cities are nodes with high R&D performance? (2) What are the main problems of R&D performance in Yangtze River Economic Belt? (3) The Yangtze River Economic Belt is divided into groups of similar levels according to R&D performance. What are their problems and the main directions for solving these problems?

This paper is organized as follows: the next section is critical review of regional innovation and innovation performance; the third section is description of data and methodology of our research; the fourth section describes economic and innovation feature of Yangtze River Economic Belt; regional performance analysis and problem of each region are presented in the fifth section. In the last part, we offer some concluding remarks.

2. Literature Review

Regional innovation performance has been investigated in the literature [8–10]. Existing researches have systematically discussed the issue of what regional innovation performance means and how it should be measured [11–14]. Nelson had pointed out that innovations do not "fall from heaven" [15]; they need creative actors and wide range of resources; the absolute count of innovations generated by regional organizations within certain time period can be used as an indicator of regions' innovative success [16]. From the economic standpoint, it is more interesting to evaluate innovation success in light of the invested resources [13, 17]. From this perspective, regions achieving competitive advantage by increasing investment of R&D resources has become a consensus.

Inventions and innovation are not evenly distributed in space but tend to be clustered in certain locations [18, 19]. That is because of regional differences in availability and quality of local inputs, as well as geographically bounded knowledge spillovers [20]. So when talking about regional innovation performance, we should not merely focus on one side of R&D input or output quantity, as there will be great R&D resource difference among regions and also for the same region of different development stages. What matters is that we should set innovative output and input factors into relation on regional level, as it implies that both are known and can be meaningfully measured in the context of regions [21]. That means we should use R&D performance logic in evaluating innovation performance.

The R&D performance means ability of a country or region that can transform various input resources (capital or personnel) to multioutput in R&D activities, which can be regarded as relation between R&D input and output [22]. As it has been indicated by Broekel [16] and Fritsch and Slavtchev [23], innovation performance may be impacted by a wide range of regional factors such as urbanization economies, knowledge spillover, the presence of universities, and regional cooperation intensity [24]. That is to say, the location difference relates to "quality" or "performance" of the region, leading to different levels of innovative output even if the inputs are identical in quantitative as well as in qualitative terms.

In recent research, some of the empirical approaches are focusing on relation between innovation input and output resources [25–27]. The economic unit appears to be inefficient if it cannot generate maximum feasible output from given inputs. As we have mentioned before, regional economy and resources difference may lead to imbalance of innovation (it does not mean it has higher innovation performance); what is more important is that it should also have the abilities to maximize transformation of input resources to output.

So from the regional innovation performance aspect, what we are thinking about is not only whether regions of higher economic or higher resources input quantity will have higher abilities in knowledge transfer, but also when the overall innovation performance improves and whether the technology level and technology performance improve at the same time, which will then move us one step further to making clear what (technology improvement or tech-resource fully utilization) really matters for regional innovation improvement under different circumstance. We attempt to make a preliminary regulation summary of innovation performance in different economic stages, trying to find out its main route in improving regional innovation performance.

3. Methodology

3.1. Research Method

3.1.1. Data Envelopment Analysis. This method was established by Charnes and Cooper in 1978; it is widely used in evaluating R&D performance for countries or regions. This paper is based on existing research method of performance evaluation Constant Returns to Scale (CRS) (CRS is based on situation of Constant Returns to Scale, $\theta_m = 1$ indicates R&D resources are all applied on production, and the output has reached optimal level combined with resources input; when $\theta_m < 1$, the R&D resources ineffectiveness; if $\theta_m$is closer to 1, indicates that R&D resources of the city are more efficient. DEA (M is the city number of our research; K means this system is divided into K kinds of indicator; L is the output index, we assume $x_{mk}\,(x_{mk} > 0)$ represents the kth kind of input resource of the mth city. $y_{ml}\,(y_{ml} > 0)$ represents the lth kind of output of the mth city. For these M cities $m\,(m = 1, 2, \ldots, M)$, $\theta\,(0 < \theta \leq 1)$ represents the overall efficiency index) and added $\sum_{m=1}^{M} \lambda_m = 1$ into formula, making the Variable Returns to Scale (VRS) model. Through the VRS model, we can divide the overall performance as product of θ_{TE} (technical performance), $0 < \theta_{\mathrm{TE}} \leq 1$, $\theta_{\mathrm{TE}} \geq \theta_m$ and θ_{SE} (scale performance), $0 < \theta_{\mathrm{SE}} \leq 1$, $\theta_{\mathrm{SE}} \geq \theta_m$. The same thing is when θ_{TE} and θ_{SE} approach 1, both technical performance and scale performance of R&D input and output going higher. When $\theta_{\mathrm{TE}} = 1$ or $\theta_{\mathrm{SE}} = 1$, this means either technical performance or scale performance has reached optimal level.

$$\begin{cases} \min\left(\theta - \varepsilon\left(\sum_{k=1}^{K} s^{-} + \sum_{l=1}^{L} s^{+}\right)\right), \\ \text{s.t.} \sum_{m=1}^{M} x_{mk}\lambda_m + s^{-} = \theta x_k^m, \quad k = 1, 2, \ldots, K, \\ \sum_{m=1}^{M} x_{ml}\lambda_m + s^{+} = y_l^m, \quad l = 1, 2, \ldots, L, \\ \lambda_m \geq 0, \quad m = 1, 2, \ldots, M. \end{cases} \tag{1}$$

3.1.2. Malmquist-DEA Index. Malmquist index was initially proposed by Malmquist in 1953 as a consumption index. Researches as Caves in 1982 applied it to productivity various analysis. It is used in measuring improvement of total factor productivity, various performances, and technology improvement ((x_{t+1}, y_{t+1}) and (x_t, y_t) distinctively represent the input and output of the years $t+1$ and t. d_0^t and d_0^{t+1} indicate the distance functions of the years t and $t+1$).

$$M_0 = \left[\frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)} \cdot \frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)}\right]^{(1/2)}. \tag{2}$$

Under circumstance of constant scale returns, the index can be divided into overall performance change index (EC) and technical change index (TC); the divided process is as follows. Under the circumstance of Variable Scale Returns, EC can be one step further divided into pure technology performance (PTF) and scale performance (SE).

$$M_0(y_{t+1}, x_{t+1}, y_t x_t) = \frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)}\left[\frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_{t+1}, y_{t+1})} \cdot \frac{d_0^t(x_t, y_t)}{d_0^{t+1}(x_t, y_t)}\right]^{(1/2)} = \mathrm{EC} \cdot \mathrm{TC}. \tag{3}$$

When the index exceeds 1, productivity tends to increase; otherwise, it means productivity is decreasing; if technical change index exceeds 1, this indicates improvement of existing technology; whereas in technology retrogression if technical performance exceeds 1, this indicates technology performance improved; otherwise, technology performance worsened. Also if scale performance exceeds 1, this indicates the time "$t+1$" is more close to constant scale returns, or gradually approaches fitted scale compared to time "t"; otherwise it is getting farther to fitted scale. Malmquist-DEA index not only comprehensively evaluates performance of knowledge innovation but also analyzes performance evolution among various regions. Based on this aspect, this paper combined two methods together in measuring metropolis performance circumstance of Yangtze Economic Belt.

3.2. Data and Index Construction. From the data aspect, the measure for innovation output is generally based on number of patents, which included some limitations [23]. As patents are granted for invention, invention is not necessarily transformed into an innovation, a new product, or production technology, and there are other ways besides patenting to appropriate the returns of successful R&D activities [28]. Crepon used a number of patents and sales of new products in manifested innovation [29]; researchers think that R&D only represented parts of innovation output, while number of papers published in the science journal and number of new products developed are all variables of R&D output. Hagedoorn used number of patents, patent citation, and number of new products in reflecting the performance of enterprises [30], while Belderbos et al. used labor productivity rate and innovation products in measuring innovation performance [31]. So based on the traditional index selection, this paper uses patent, publications, and high-tech industry output rate as output index.

Focus on relationship between R&D input and output is called knowledge production function, and a consensus has been reached on the input indicators which mainly contain R&D personnel and R&D expenditure. As a proxy for input to the innovation process in the private sector, R&D employees were classified as working in R&D if they have tertiary degree in engineering or in the natural science [32]. Based on these facts, this paper chose full-time equivalent of R&D employees and R&D expenditure as input index (Table 1).

Considering the availability and comprehensiveness of existing data, the cross-sectional data analysis from 2000 to 2018 takes into account the time lag between input and output in R&D activities, and the maximum time lag for R&D resource input to output is 1 year. Therefore, the output indicators are selected from the data of t years, and the input indicators are selected from the data of t – 1 years.

4. Economic and Innovation Feature of the Case Region

4.1. Economic Heterogeneity. Yangtze River Economic Belt includes 11 provinces and cities: Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, Hunan, Chongqing, Sichuan, Yunnan, and Guizhou. Yangtze River Economic Belt accounts for 21% and 43% of China's land area and population; it is representative region of innovation in China. By comparing R&D proportion of Yangtze River Economic Belt and China, proportion of R&D expenditure in Yangtze River Economic Belt accounts for 46% of China, and R&D personnel accounts for 45%.

Moreover, there is huge economic heterogeneity among these regions; GDP per capita of Shanghai has reached 12.7 million yuan in 2018, while GDP per capita is only 3.9 million yuan in Sichuan province (middle region) and 3.4 million yuan in Yunnan province (western region). Based on regional economic heterogeneity, this research divided

Table 1: The evaluation index of input and output performance of R&D resources.

Type	First grade indicator	Second grade indicator
Input indicator	R&D input	R&D expenditure per unit of GDP R&D personnel of full-time equivalent (ten thousand/year)
Output indicator	Patent output Innovation output	Number of patents per thousand Number of scientific papers per thousand High-tech product output rate

Yangtze River Economic Belt into three regions: Region 1 (according to "Yangtze River Delta Regional Planning (2010)," there are one direct-controlled municipality and two provinces, Shanghai, Jiangsu, and Zhejiang, and 16 core cities within this region) is Yangtze River Delta; this region accounts for only 2% and 12% of the country's area and population (Table 2). But it accounts for 1/5 of the country's GDP and nearly half (42%) of the country's international trade volume. This region is one of the earliest open-up regions in China; it has policy advantages from the government. So Region1 is relatively small region, has start advantages and higher economic development level, and owns more enterprise headquarters and FDI. This region sets Shanghai as economic leader, which makes it grow faster than others.

Region 2 (Region 2 contains four provinces: Anhui, Jiangxi, Hubei, and Hunan) is located in midland China, which accounts for 7% and 17% of the country's area and population. Region 2 acts as a bridge between east and west China; manufacturing accounts for more than half (51%) of the region's GDP. Region 3 (Region 3, western metropolis area, contains three provinces and one direct-controlled municipality: Chongqing, Sichuan, Yunnan, and Guizhou) is economic periphery region in the west of China. It accounts for 12% of the country's area but only 14% of the whole population. It has large land area (12%) but low population density; population outflow is serious and GDP only accounts for 9% of China. According to Chenery, industrialization can be divided into six stages; cities in Region 1 have already stepped into post-industrialization stages, but cities in Region 2 or Region 3 are still in initial industrialization stage.

From interregional economic relation aspect, density of economic linkages among regions in Yangtze River Economic Belt is still at a low level. The density of Region 1 is the highest, with Shanghai, Suzhou, and Nanjing as economic center of Region 1 and playing the role of economic radiation to Region 2 and Region 3; Wuhan, Nanchang, and Changsha are the economic center of Region 2, which have close economic linkages with Region 1, playing the role of connecting east and west regions; most cities in Region 3 have weaker links with other regions, but Chongqing has strong economic ties with Region 2 through Yichang.

4.2. Spatial Distinction of Innovation. Innovation output is considered to be an important indicator reflecting the level of regional innovation; level of R&D investment in Yangtze River Economic Belt accounts for important proportion in China. Innovation output shows spatial distinction. Specifically, trend-surface analysis of innovation output from northeast to southwest direction of Yangtze River Economic Belt changes from high to low and shows "core-periphery" feature. Spatial correlation analysis of innovation output shows that Moran's I index of the Yangtze River Economic Belt is all positive, and spatial dependence characteristics of innovation output are becoming obvious. According to LISA local autocorrelation analysis, high-value output agglomeration of Yangtze River Economic Belt is not significant; no city is located in High-High area; Shanghai, Suzhou, Ningbo, Hangzhou, Wuhan, Changsha, and Chongqing cities show higher value characteristics than surrounding cities. The Low-Low cluster is prominently located in Lijiang, Linyi, Baoshan, and Lishui in Region 3. High-value cluster of innovative output continues to expand northward in Region1, while level of innovation output between Region 1 and Region 2 tends to be similar, but the level of agglomeration is relatively low (Figure 1). Otherwise, from interregional innovation connection aspect, centrality of innovative network was enhanced, network density decreased due to expansion of network scale, and the core of network structure is significant; network core-peripheral structure is increasingly significant.

Due to huge regional economic heterogeneity, differences in innovation volume among regions are inevitable. Therefore, when analyzing areas with large spans and significant internal differences, we should not only focus on the absolute amount of innovation volume but also ignore problem of whether knowledge or R&D resources are reasonably configured. Therefore, this paper proposes problems of innovation in heterogeneous regions of China through innovation performance analysis. On the whole, the economic development level, innovation level, and resource elements of different regions of the Yangtze River Economic Belt must be quite different. Therefore, the cooperation network between regions not only enhances the connectivity of innovation resources, but also realizes the rational allocation of innovation resources.

5. Spatial Analysis of Innovation Performance in Yangtze River Economic Belt

5.1. Regional Overall Innovation Performance. Through the performance calculation of R&D investment and output factors, the overall innovation performance level of the Yangtze River Economic Belt is low. The comprehensive innovation performance of the Yangtze River Economic Belt rose from 0.237 to 0.408 during 2000 to 2018. The average level of innovation performance in Yangtze River Economic Belt is still less than 50% of optimal performance in the last 18 years. From 2000 to 2018, the overall innovation

Table 2: Context of the research regions.

Region/Nation (%)	Region 1	Region 2	Region 3
Area	2%	7%	12%
Population	12%	17%	14%
GDP	20%	13%	9%
Export-import volume	42%	3%	2%
R&D expenditure/GDP	2.4%	1.2%	0.9%
Sector/overall GDP (%)	Region 1	Region 2	Region 3
Sector one (agriculture)	5%	13%	13%
Sector two (manufacturing)	49%	51%	49%
Sector three (service)	46%	36%	38%
Total no. of regions	Region 1	Region 2	Region 3
Area (square km)	211,300	710,000	1,132,000
Population (thousand)	157,090	228,100	190,690
GDP (billion USD)	1561	1028	708
Export-import volume (million USD)	362706.98	22640.09	18326.67
Total no. of nations	Overall	Cooperate	Cooperate/overall
Patenting	2,799,829	22,699	1%
Publication	26,248	3,749	14%

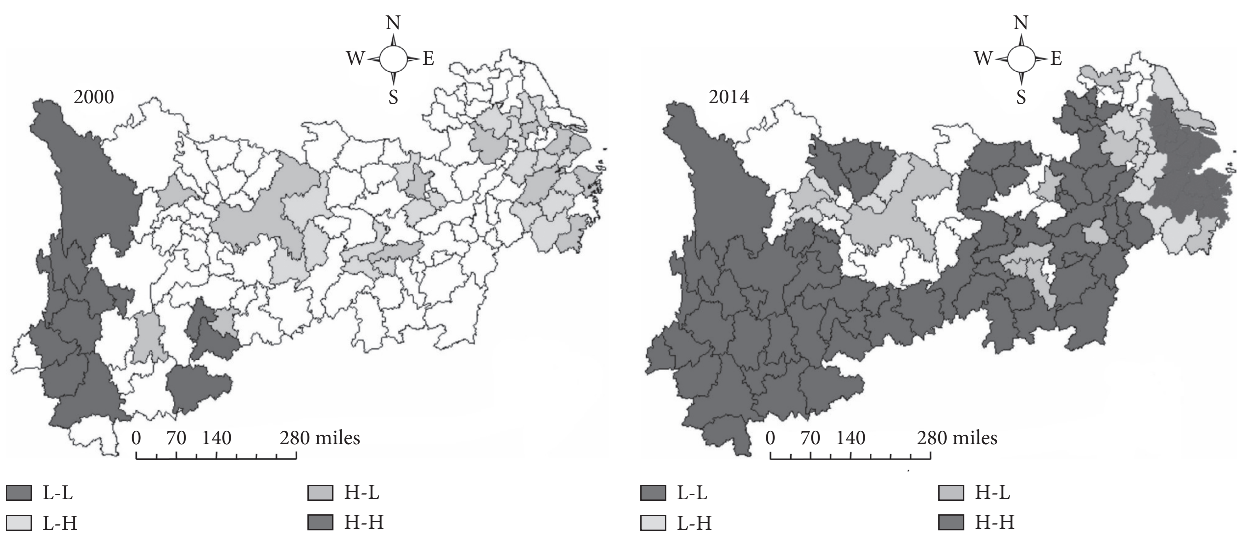

Figure 1: Spatial co-relation of innovation in Yangtze Economic Belt.

performance showed an upward trend, specifically, only 15 of the cities with a performance level of more than 50% in Yangtze River Economic Belt in 2000. Among them, Shanghai, Nanjing, Wenzhou, and Quzhou in Yangtze River Delta, Nanchang, Wuhan, Jiujiang, and Zhangjiajie in the middle regions, and Kunming and Tongren in west regions reached the optimal level. By 2018, the number of cities with an optimal performance level of over 50% increased to 33. Overall performance level is improving but slow; one of the important issues to be solved in Yangtze River Economic Belt to enhance regional innovation is how to effectively use innovative resources and improve innovation performance.

From the perspective of pure technical performance, 68% of the city's pure technical performance is gradually rising, and pure technical performance is higher than overall performance. From 2000 to 2018, pure technical performance rose from 0.411 to 0.553. In 2000, there were 15 cities with the highest technical performance in the Yangtze River Economic Belt; the number of cities with the best technical performance has increased to 20 cities by 2018. This phenomenon is not only found in central economic cities, but also distributed in peripheral cities in Region 2 and west Region 3. In 2000, 33 cities with pure technical performance of more than 50% accounted for 31.4% of the total number. Among them, 24 cities have a pure technical performance of over 70%. By 2018, there were 55 cities with a pure technical performance of more than 50%, accounting for 52.4% of the total number. Among them, the number of cities with pure technical performance of 70% or more increased to 37. For areas with large numbers of cities and huge development differences, from 2000 to 2018, the change in pure technical performance indicates that the overall technical level of the Yangtze River Economic Belt has improved.

From the perspective of scale performance, scale performance of the Yangtze River Economic Belt is normally higher than technology and overall performance of the same period. From 2000 to 2018, the scale performance decreased from 0.635 to 0.739. In 2000, the scale performance reached more than 50%, which accounts for 62% of the total. Among them, 53 have an optimal performance of more than 70%. By 2018, proportion of the optimal performance of more than 50% increased to 84.8%, of which 62 cities reached over 70% of the optimal performance. Therefore, the trend of the scale performance of Yangtze River Economic Belt is stable. How to realize resource integration and utilization is key to solving the problem of overall innovation performance and sustainable development.

5.2. Regional Total Factor Productivity Change. In this chapter, we use Malmquist-DEA model to calculate the Malmquist index of R&D resources of Yangtze River Economic Belt from 2000 to 2018 (Figure 2). From data analysis, R&D Resources Comprehensive Performance Change Index (0.911) and Pure Technical Performance Change Index (0.889) are less than 1, while Technology Progress Change Index (4.683), the Scale Performance Change Index (1.025), and the Total Factor Productivity Change Index (4.267) are all greater than 1. The total factor productivity index of the Yangtze River Economic Belt from 2000 to 2018 was 5.263, which indicates that productivity has increased during this period. The technical change index is 4.683, indicating that the overall regional technology level is gradually improving. Since the technical performance is less than 1 (0.889), although the technical level is improving overall, the technical performance of the region is gradually decreasing. It shows that the performance change of Yangtze River Economic Belt is mainly due to the innovation and progress of technology, but the existing technology is not necessarily fully utilized. The scale performance is 1.025, indicating that regional innovation is gradually changing to the optimal scale and gradually approaching fixed-scale compensation these years.

Moreover, from trend of productivity and technology changes in Yangtze River Economic Belt from 2000 to 2018, regional production performance has increased and the overall technical level has been greatly improved, but technical performance has decreased. The gap between the improvement of technology level and the decline of technical performance has gradually widened, indicating that the existing technologies in the economic region have not been fully utilized. Changes of innovation performance mainly depend on the improvement of the overall technical level in the process of technological development. From the perspective of innovation scale, the Yangtze River Economic Belt has been adjusted and its scale has gradually become rationalized. At the same time, various regions within Yangtze River Economic Belt are at different stages of development. So the innovation performance is also affected by factors such as regional innovation investment, economic level, technical level, institutional conditions, and social and cultural conditions. Therefore, it is necessary to carry out cluster analysis on areas with similar performance levels and to specifically analyze the specific characteristics and constraints in different groups.

5.3. Regional Grouping and Problems of Yangtze River Economic Belt. In this chapter, through cluster analysis of regions with similar levels of innovation performance, we try to find out the problems faced by regions with different performance levels in Yangtze River Economic Belt and propose effective ways and directions for solving problems.

With ward cluster analysis of innovation performance of Yangtze River Economic Belt in 2018, cities can be divided into 4 major groups; the innovation performance of the four groups was, respectively, 0.809, 0.499, 0.308, and 0.122 (Table 3). The number of cities in Group 1 is the lowest among the four groups (22%), but the overall level of innovation performance is the highest. Comprehensive performance, pure technical performance, and scale performance all achieve more than 60% of optimal performance. Cities of Group 2 have a combined performance of 0.499, a pure technical performance of 0.656, and a scale performance of 0.766. The other two groups have a large number of cities but the performance level is relatively low; the overall performance of Group 3 is 0.308, the pure technical performance is 0.479, and the scale performance is 0.730. Group 3 is higher than Group 4 (comprehensive performance is 0.122, pure technical performance is 0.245, and scale performance is 0.629). Overall, the two groups have less input redundancy. Compared with Group 1 and Group 2, problems of these two groups are insufficient innovation output; 77.6% of cities in Group 3 and Group 4 have insufficient output. Group 4 is particularly significant (93.3%), and the problem of insufficient output is mainly reflected in applied knowledge and insufficient high-tech output.

From our specific analysis, in Group 1, cities like Shanghai, Hangzhou, and Nanjing and other cities in the eastern part of the economic belt have achieved the best performance. The absolute values of economic development level and innovation input and output of other cities in Group 1 are much higher than cities in other groups. From the performance analysis, most of the R&D resource inputs and outputs in these cities are not problematic; the main reason for the low performance is the incompatibility of R&D resources and inputs and outputs. The DEA calculation results show that R&D resources of the Yangtze River Delta in Group 1 are diminishing returns to scale. Therefore, comprehensive performance can be improved by reducing the R&D resources invested.

87.5% of cities in Group 2 have input redundancy; particularly, cities such as Wenzhou, Yangzhou, Zhenjiang, Lianyungang, and Huzhou in Region1; Xiangtan, Huaihua, and Yingtan in Region 2; and Meishan and other cities in Region 3 have problems of redundant R&D personnel and funding. Therefore, the main way to achieve best performance of Group 2 is to encourage development of basic scientific research and at the same time appropriately adjust the input of R&D funds. As cities in Group 2 are often declining in scale, they cannot always expand the scale of resources when strengthening basic innovation research. Cities in Group 2 can achieve regional optimal development by enhancing the rational allocation of resources across regions or interregional cooperation among universities.

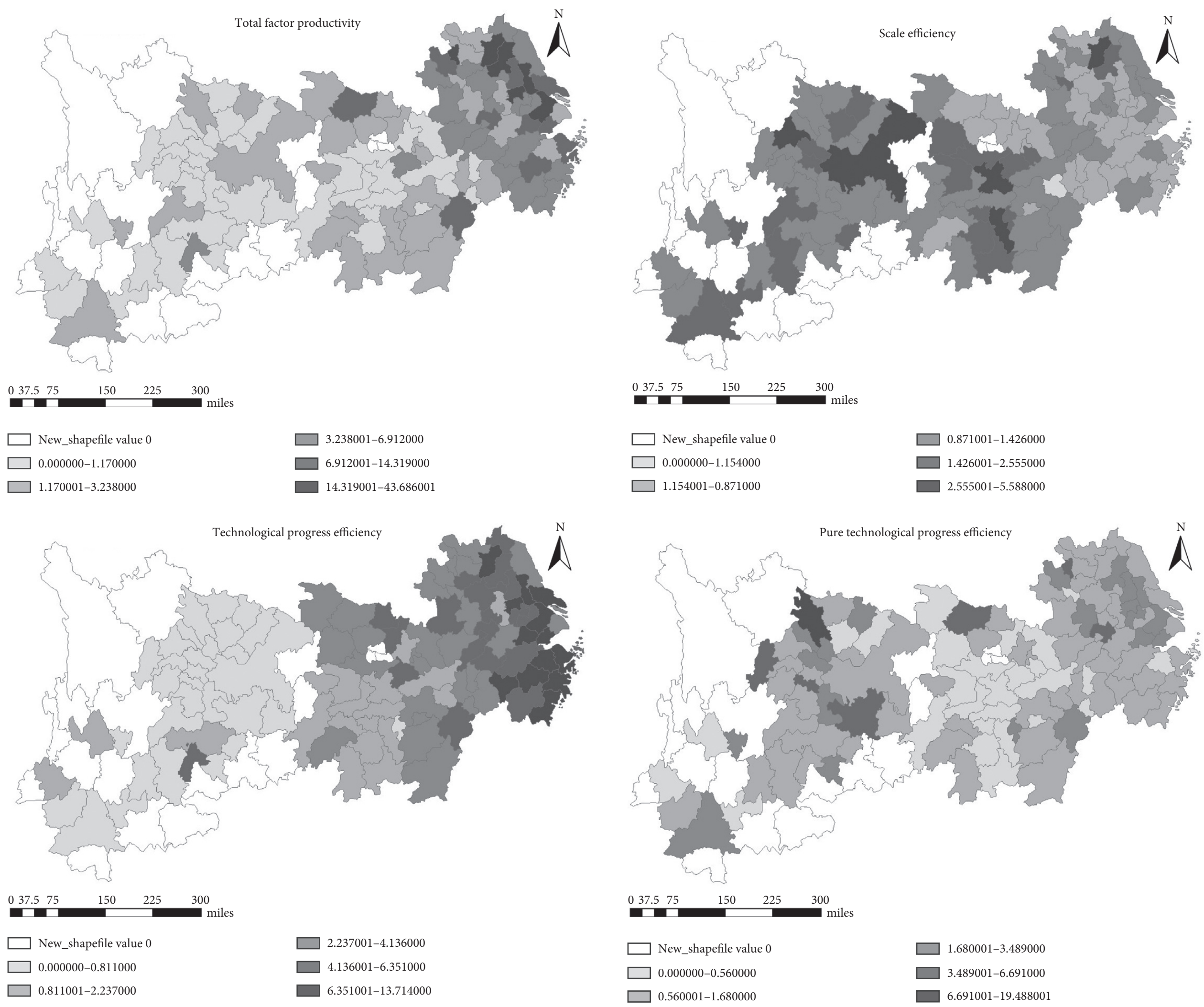

Figure 2: The Malmquist index analysis of Yangtze Economic Belt until 2018.

Table 3: Innovation performance of groups in Yangtze Economic Belt.

Group	City no.	%	Total performance	Technology performance	Scale performance
Group 1	23	22	0.809	0.940	0.864
Group 2	24	23	0.499	0.656	0.766
Group 3	28	27	0.308	0.479	0.730
Group 4	30	29	0.122	0.245	0.629

In Group 3, 60.7% of cities have insufficient high-tech and application knowledge output. The high-tech output value and application knowledge output in Group 4, respectively, accounted for 60% and 36.6%. By comparison, cities in Group 3 are mostly diminishing returns to scale; only few cities can continue to increase output by increasing the size of resources, while 37% of the cities in Group 4 show increase in returns to scale; therefore, although the cities in Group 4 have the lowest innovation performance, they can achieve performance optimization by continuing to expand the scale of resource input.

Combining the spatial differentiation of the four groups, 85% of the cities in Groups 1 and 2 are located in Yangtze River Delta and middle Yangtze River regions, which are in post-industrial or late industrialization development stage; 87.9% of the cities in Groups 3 and 4 are in the western regions of Yangtze River Economic Belt, which are in industrialization or early industrialization development stage; 57.1% of the cities in Group 3 are located in the middle region of Yangtze River Economic Belt, and 63.3% of the cities in Group 4 are located in the western region of Yangtze River Economic Belt. Existing researches have confirmed that there is correlation between economic development and regional innovation. Our research further confirms these points through our empirical analysis. Further, in the same economic development stage, regions with similar performance levels have different ways to achieve the best performance.

6. Conclusion and Discussion

This paper constructs an evaluation index system to measure regional innovation performance; the index system includes R&D expenditure per unit of GDP, R&D personnel of full-time equivalent, number of patents per thousand, number of scientific papers per thousand, and high-tech product output rate. Malmquist-DEA index is used to measure innovation performance of heterogeneous regions in the Yangtze River Economic Belt.

Cities of Yangtze River Economic Belt have strong heterogeneity; from the perspective of economic development, the eastern Region 1 is core economic development region which developed in post-industrialization stage. Most cities in Region 2 and Region 3 are economic periphery cities; these cities are still in middle industrialization and early industrialization stage. The main conclusions and recommendations from the analysis of our research include the following:

(1) The intraregional differences of cities in Yangtze River Economic Belt are significant; the overall level of regional innovation performance is low. The economic core region increased volume of innovation through large amount of material input and resource consumption. How to improve the optimal allocation and coordination of interregional resources to improve performance of innovation resources has become the primary problem to be solved in such regions.

(2) In the case of low economic development level region, regional technical level has improved; on the contrary, the regional production performance has not increased but is gradually decreasing. The trend of technical level and technical performance is reversed, and improvement of comprehensive performance level is achieved through a large amount of resources invested in technological innovation. Therefore, how to improve the utilization of existing technology resources is worth further consideration.

(3) Regions with similar performance levels in Yangtze River Economic Belt can be divided into 4 groups. Specifically, the overall level of regional innovation performance in the post-industrial development stage is higher; the reason for the low performance is problem of mismatch among R&D resource scale, input, and output. Such cities need to adjust their scales to achieve performance optimization. Regions with relatively low economic development levels need reasonable regional resource optimization and allocation.

The view that there is a positive correlation between the level of regional economic development and regional innovation output has been proposed by some innovation-related research. However, this paper emphasizes that it does not mean that regions with higher economic development level or higher innovation input or output will have better innovation performance, especially for heterogeneous regions in different economic stages. Specifically, this paper attempts to summarize the general regulation of innovation performance in heterogeneous regions of China, especially in regions or cities in different economic development stages. Through the analysis, this paper tries to find out the main problems existing in regional innovation performance of China and put forward relative solutions for heterogeneous region, which may have certain significance in promoting the research of regional differential innovation.

This paper proposes that cities in the post-industrial economic development stage in China have better innovation ability, and these cities rarely have problem of insufficient innovation input and output. The main problem that affects innovation performance is the mismatch between innovation scale and innovation input-output. Therefore, it is a better choice for such cities to achieve the optimal performance not to blindly pursue the scale effect, but to appropriately reduce the innovation scale. Cities in middle stage of industrialization have the main problems of redundant resource input or reduced return on scale. Therefore, it is not the best way to only focus on increasing the scale of innovation output by increasing input. Better suggestion is to improve the utilization of exising resources or establish interregional organization alliance to improve the regional innovation performance. The innovation performance of cities in primary stage of industrialization is relatively low. The main characteristic of these cities is that the innovation output is obviously insufficient, especially in the field of basic scientific research and high-tech research.

From the perspective of how to effectively solve the problem of heterogeneous regional innovation performance, this paper suggests that cities with higher economic development level achieve the goal of improving innovation performance by improving the utilization of existing resources or building efficient cross-regional alliances. The marginal cities with relatively underdeveloped economy show the characteristics of increasing returns to scale. Therefore, it is necessary to expand the scale of R&D resources to improve innovation performance, or to improve the regional commercialization ability through R&D of new products.

In this paper, panel data is selected to analyze the innovation performance of China's heterogeneous regions. DEA method is an important scientific method to solve the problem of heterogeneous regional innovation performance, but its limitation is that it cannot effectively analyze the causes of performance differences or regional low performance. In the follow-up research, the main factors affecting the innovation performance of heterogeneous regions and their influencing mechanism will be further discussed.

Data Availability

The R&D expenditure, R&D personnel of full-time equivalent data and patent, and scientific papers data supporting this innovation performance analysis of this study have not been made available. Because these data belong to thirdparty rights, the authors can only use these data for academic research but have no right to publish the data source.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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