Hindawi
Mathematical Problems in Engineering
Volume 2022, Article ID 3408342, 13 pages
https://doi.org/10.1155/2022/3408342

Research Article

Data-Driven Green Development Efficiency of Regional Sci-Tech Finance: A Case Study of the Yangtze River Delta

Yuan Wang,[1,2] Hongjun Liu ,[1] Shuling Zhou,[1] Fan Liu,[1] Yaliu Yang ,[1] Juan Zhu,[1] and Yi Xu[1,2]

[1]*Business School, Suzhou University, Suzhou 234000, China*
[2]*Center for International Education, Philippine Christian University, Manila 1004, Philippines*

Correspondence should be addressed to Hongjun Liu; sxylhj@ahszu.edu.cn

Received 13 June 2022; Revised 10 July 2022; Accepted 15 July 2022; Published 29 August 2022

Academic Editor: A. M. Bastos Pereira

Green development is an important connotation of high-quality development and is one of the goals of scientific and technological innovation. This study constructs a data-driven measurement model of the green development efficiency of regional sci-tech finance, measures the green development efficiency of sci-tech finance by using the super-slack-based measure model, and deeply analyses and evaluates the changes in green development efficiency of regional sci-tech finance by calculating Malmquist index. This study calculates the green development efficiency of sci-tech finance in the Yangtze River Delta. Results show that the green development efficiency of sci-tech finance in the Yangtze River Delta is on the rise as a whole and maintains an efficient state, but differences are observed between provinces and cities. This study provides theoretical and methodological support for the evaluation of the green development efficiency of regional sci-tech finance and serves as reference for policy makers and researchers of sci-tech finance.

1. Introduction

1.1. Background. Under the background of the increasing pressure on global resources and the deterioration of the ecological environment, the United Nations Conference on environment and development proposed the "concept of sustainable development." Then, major economies around the world vigorously implement the "Green Deal" to determine a new economic development model with the "green" relationship between long-term stable growth, resource consumption, and environmental protection. The European Commission issued the European Green agreement in December 2019, aiming to build a modern economic system in which economic growth is decoupled from resource consumption. In March 2020, the European Commission issued the action plan for the new circular economy. The core content is applying the concept of the circular economy throughout the product life cycle to reduce resource consumption. The US federal government headed by Obama adopted the "Green Deal" to promote the circular economy, encourage relevant technological innovation, and rely on science and technology to promote the coordinated development of the environment and economy. Since 2017, with the high-quality transformation of China's economic growth momentum from factor investment driven to innovation driven, China's economy has developed from high-speed to high-quality development. The implementation of green development strategy through technological innovation has become a key measure to achieve the goal of sustainable development [1]. Green development needs scientific and technological support in a wide range of fields, and innovation has become the leading force for countries to accelerate green transformation and improve resource efficiency. The adoption and dissemination of innovation by enterprises are the key pillar of the national resource efficiency strategy and the development of circular economy [2].

Scientific and technological innovation begins with technology, and success depends on capital. Sci-tech finance cooperates the two elements of scientific and technological innovation and modern finance, serves scientific and technological innovation through modern finance, and then promotes scientific and technological progress. Sci-tech finance promotes innovative development, combines with green development, and brings economic and environmental returns at the same time. Comprehensively and effectively improving the green development efficiency of sci-tech finance is an important means of sustainable economic development and is the guarantee of high-quality economic development.

1.2. Literature Review. Green development is a green concept and connotation. It is a mode of economic growth and social development aimed at efficiency, harmony, and sustainability. Its essence is the coordination and unity of economy, population, resources, and environment [3]. Therefore, measuring the efficiency level of green development and exploring the influencing factors of green development have become the focus of scholars. Green development efficiency is the key index to measure green development. It can comprehensively evaluate the resource utilisation efficiency and resource and environmental consumption in economic development. Scholars mainly measure the efficiency of green development through data envelopment analysis (DEA) model [4], slack-based measure (SBM) model [5], super-SBM model [6], and SBM-DEA model [7]. However, the traditional DEA model ignores relaxation variables and cannot sort and distinguish the efficiency values of effective decision-making units at the same frontier. The super-SBM model and undesirable SBM model are widely used because they can effectively solve these limitations [8]. Scholars have explored the effects on green development from the aspects of environmental regulation [9], scientific and technological innovation, research and development (R&D) investment [10], industrial structure [11], urbanisation and marketisation [12], energy [13], foreign investment [14], financial development [15], manufacturing [16], and machine processes [17].

Green development needs the support of technological innovation. Yin et al. pointed out that technological innovation plays important strategic roles in green growth [18]. Zhang and Liu believed that advancing ahead in both technical conversion and scientific innovation efficiency should be the best path of green development [19]. Feng et al. proposed that financial development is an important driving force for promoting green technology innovation [20]. Fang and Shao [21] and Wang [22] reached the same conclusion in their research. Ye et al. research showed that the positive effect of the finance on green development by supporting green technology innovation is significant in eastern China [6]. However, Wang and Wang pointed out that insufficient investment in scientific and technological innovation is an important bottleneck factor limiting green development [23].

Sci-tech finance is the key to solve the investment in scientific and technological innovation. Sci-tech finance can optimise the allocation of resources, promote more capital flow to science and technology innovation enterprises or R&D institutions, and provide financial guarantee for green innovation [24], so as to alleviate their financing constraints [25] and improve the efficiency of green innovation by shortening the innovation cycle, dispersing or reducing innovation risks [26]. Large financing capacity can promote the formation of capital, make capital large-scale, and then promote the improvement of regional green innovation efficiency. As two systems [27], the combination effect of sci-tech finance affects the level of scientific and technological innovation [28]. Chen et al. studied the integration efficiency of sci-tech finance in Heilongjiang Province and found that financial structure and scientific and technological innovation affect and restrict each other, and a win-win relationship is observed between scientific and technological innovation and financial capital [29]. Research on the efficiency of sci-tech finance has become the focus to further promote the high-quality integration of financial industry and science and technology industry. Scholars mainly establish different evaluation index systems to measure the efficiency of sci-tech finance through DEA model [30, 31] and cat-o-c and cat-o-v models [32]. Li and Wen estimated the allocation efficiency of scientific and technological financial resources in 27 provinces and regions in China and considered that the overall allocation efficiency does not reach the effective state of resource allocation [33]. Qi et al. measured the allocation efficiency of scientific and technological financial resources in Hubei Province and found that the problem of low allocation efficiency of scientific and technological financial resources in Hubei Province is the low value of pure technical efficiency and small effect on scale efficiency [34]. Empirical research shows that the efficiency level of sci-tech finance is affected by the government and its policies, venture capital companies [35], human capital [36], infrastructure environment, education funds [37], the proportion of direct financing, and the incubation capacity of science and technology business incubators [38]. Da Fonseca, RS pointed out that the governments continue to play a critical and determining role in science, technology, and innovation financing whether through financial incentives, fiscal incentives, or a mix of both.

1.3. Study Limitations. On the basis of the analysis of the above research results, domestic and foreign scholars have made great progress in the research of sci-tech finance and green innovation efficiency. However, some limitations are still observed as follows: (1) Sci-tech finance investment improves the production efficiency of enterprises, forms industrialised economic achievements, and plays a positive role in reducing energy consumption and pollution emission in the production process and improving the ecological environment. Therefore, the evaluation index of sci-tech financial efficiency must be further improved, so as to objectively evaluate the efficiency of sci-tech finance. (2) The traditional DEA model ignores the relaxation variable, cannot sort and distinguish the efficiency value of the same frontier effective decision-making unit, and ignores the key variable of undesirable output, leading to the distortion of the efficiency measurement results of sci-tech finance, and cannot reflect the green innovation effect of sci-tech finance. Therefore, a data-driven efficiency evaluation model with undesirable output must be built. (3) Correctly evaluating the efficiency level of regional sci-tech finance, showing the effect of sci-tech finance in promoting green economic development, revealing the influencing factors of green development of sci-tech finance, and providing targeted opinions are of great practical importance for improving the use efficiency of sci-tech financial resources and realising green economic development.

1.4. Theoretical Value and Practical Importance. This study establishes a new evaluation model of the green development efficiency of regional sci-tech finance and takes the Yangtze River Delta (YRD) as an example. This research has theoretical and practical importance. Theoretical significance includes measuring the green development efficiency of sci-tech finance from the perspective of data-driven and further improving the theoretical research content of sci-tech finance. The efficiency index system of sci-tech finance established in this study includes economic output and knowledge output and considers the output of ecological environment. A more comprehensive index system is helpful to measure the efficiency of sci-tech finance more objectively. The data-driven evaluation method is helpful to reveal the influencing factors of the efficiency of sci-tech finance more scientifically and accurately. It expands the research scope of sci-tech finance. Practical significance includes analysing the main factors affecting the green development efficiency of sci-tech finance and providing a feasible path for the green transformation and upgrading of science and technology enterprises through data-driven evaluation. These processes can provide policy suggestions for national policy makers to optimise the external environment of sci-tech finance and realise the coordinated development of economy and ecology under the green development background of regional economy. They also provide direction for financial institutions to further optimise the allocation of sci-tech financial resources, reform financial services, and provide research reference for relevant researchers.

1.5. Overview. The framework of this study to achieve the above research objectives is as follows: the first part is the introduction. The second part is the method, which mainly includes data-driven data collection, data model, data analysis, and application. The third part is the case analysis. Taking the YRD as an example, this study calculates the green development efficiency of sci-tech finance in three provinces and one city in the YRD and decomposes the total factor productivity (TFP). The fourth part is the conclusion.

2. Methods

This part introduces the data-driven green development efficiency measurement of regional sci-tech finance, including method process, data collection, data model, data analysis, and application.

2.1. Method and Process. As the initiative of scientific and technological innovation, sci-tech finance is the key factor to accelerate the green development of economy. Measuring the green development efficiency of sci-tech finance is of great importance to regional sustainable development. How to effectively and objectively measure the efficiency of green development is the focus of evaluating the effectiveness of the allocation of sci-tech financial resources. This study uses the super-SBM model and Malmquist index to investigate the current situation of the green development efficiency of regional sci-tech finance and proposes policy suggestions to improve the green development efficiency of sci-tech finance and implement the concept of green development as shown in Figure1.

2.2. Evaluation Index. The selection of input and output indicators determines the scientificity and accuracy of efficiency evaluation to measure the green development efficiency of sci-tech finance. Following the principle of representativeness and availability, this study draws lessons from Li (2019) and Zhao (2020) by focusing on the input and output of sci-tech finance. Twelve important indicators with high interpretation of input and output are selected to establish the evaluation system of the green development efficiency of sci-tech finance. The details are shown in Table 1.

In accordance with the factors, the investment resources of sci-tech finance can be divided into three aspects: policy input, personnel input, and capital input. This study selects personnel input and capital input as the primary indicators of sci-tech finance input because the policy input is difficult to quantify. The input indexes of sci-tech finance are based on the views of Zhao et al. [39, 40], R&D personnel equivalent to full-time equivalent are selected for personnel input, and R&D internal expenditure, financial sci-tech expenditure, and financial market support are selected for capital input. Financial market capital support includes bank credit, venture capital, science and technology insurance, and other capital market capital sources. The financial market supports scientific and technological innovation through scientific and technological loans of financial institutions, securities markets, venture capital, scientific and technological insurance, and others. The support of the financial market in science and technology innovation is mainly the science and technology loans of financial institutions. Therefore, this study selects the proportion of regional loans in deposits to reflect the support of funds in the financial market for science and technology innovation.

Sci-tech finance aims to promote scientific and technological development, promote the transfer and transformation of scientific and technological achievements, and accelerate the formation of industrialisation. Therefore, the direct output of sci-tech finance includes economic benefits and intellectual property rights. According to Qi et al. [34, 41], the economic output indicators are the turnover of technology market, the sales revenue of new high-tech products, and the operating revenue of high-tech industry. The three indicators are the direct expression of the

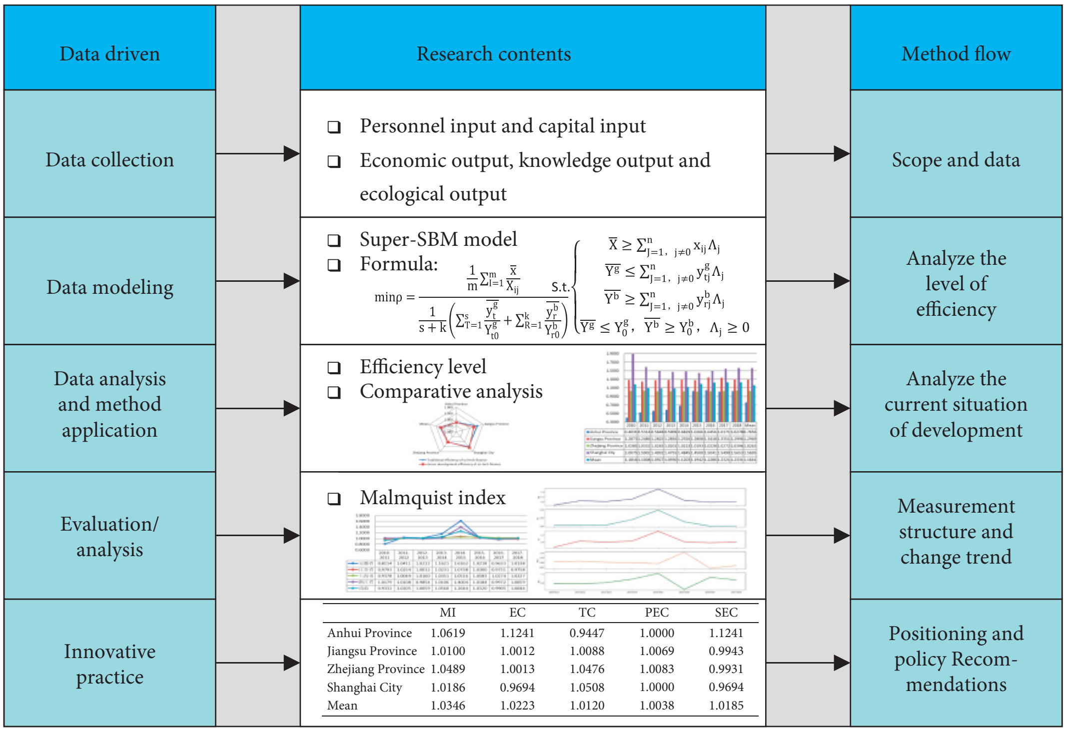


FIGURE 1: Method flow.

TABLE 1: Input-output indicators of the green development efficiency of regional sci-tech finance.

	Primary index	Secondary index	Tertiary index
Input in sci-tech finance	Input index	Personnel input	Full-time equivalent of R&D personnel ($x1$)
		Capital input	R&D internal expenditure ($x2$)
			Financial sci-tech expenditure ($x3$)
			Financial market support ($x4$)
Output in sci-tech finance	Expected output index	Economic output	Technology market turnover ($y1$)
			Sales revenue of high-tech new products ($y2$)
			Operating income of high-tech industry ($y3$)
		Knowledge output	Number of invention patents authorised ($y4$)
			The main retrieval tools include scientific and technological papers ($y5$)
	Undesirable output index	Ecological output	Waste water ($y6$)
			Waste gas ($y7$)
			Waste residue ($y8$)

transformation of scientific research achievements into money and reflect the economic benefits of sci-tech finance to a certain extent. The main retrieval tools for knowledge output include scientific papers and invention patent authorisation as secondary indicators. Sci-tech financial input is bound to be accompanied by undesirable output, such as effectively reducing energy consumption and pollution emissions in the production process. This study selects waste water, waste gas, and waste residue as the undesirable output index.

On the basis of the reliability and availability of data, this study collects and arranges the panel data of sci-tech finance input and output in Anhui Province, Zhejiang Province, Jiangsu Province, and Shanghai from 2010 to 2018. All data are derived from China Statistical Yearbook [42] and the statistical yearbook of three provinces and one city in the YRD [43–46]. The data of 2016 and 2018 are obtained through the arithmetic average method due to the lack of the operating income data of high-tech industry in 2017.

2.3. Data Modelling

2.3.1. Super-SBM Model with Undesirable Output. DEA is a nonparametric efficiency analysis method proposed by famous American operational research scientists Charnes, Cooper, and Rhodes. It can be used to evaluate the relative efficiency of multiple decision-making units (DMUs) with multiple inputs and outputs. DEA can decompose the original complex system into submodules, so as to explore the low efficiency of submodules. Combined with the insufficient output, the key crux of the low efficiency of the total system can be found. However, the traditional DEA model ignores the relaxation variables, radial deviation, and the influence of external environment, thereby making the measured efficiency deviate from the actual efficiency. Tone put the relaxation variable into the objective function and proposed a nonradial SBM model with undesirable output based on the relaxation variable [47]. However, the traditional SBM model cannot distinguish and sort multiple equally effective units. Thus, Tone proposed the super-SBM model [48] in 2002 to solve this problem. Compared with other DEA models, super-SBM model has obvious advantages. Firstly, super-SBM model solves the problem of nonzero relaxation of input or output that cannot be solved by the traditional DEA model and considers the relaxation variable as much as possible when calculating efficiency. Secondly, the super-SBM model allows the efficiency value to be greater than or equal to 1. When there are multiple effective DUMs, they can be sorted. Therefore, the super-SBM model can achieve the complete evaluation and sorting of DUMs. Referring to this method, this study selects the super-SBM model to measure the green development efficiency of regional sci-tech finance.

The basic principle is as follows: suppose that n DMUs are found, and m inputs, s expected outputs, and k undesirable outputs are obtained for each DMU. Assuming that the input, expected output, and undesirable output vectors of each DMU are expressed as $x \in R^m$, $y^g \in R^s$, and $y^b \in R^k$, respectively, the matrix can be defined as follows:

$$\begin{bmatrix} X = (x_1, \ldots, x_n) \in R^{m\times n} \\ Y^g = (y_1^g, \ldots, y_n^g) \in R^{s\times n} \\ Y^b = (y_1^b, \ldots, y_n^b) \in R^{k\times n} \end{bmatrix}. \tag{1}$$

Suppose $x > 0$, $y^g > 0$, and $y^b > 0$; the production possibility set is defined as follows: $p = \{(x\ ,\ y^g\ ,\ y^b) | x \geq X\lambda, y^g \leq Y^g\lambda, y^b \geq Y^b\lambda, \lambda \geq 0\}$.

The super-SBM model with undesirable output can be obtained as follows:

$$\min \rho = \frac{1/m \sum_{I=1}^{m} \left(\overline{x}/X_{ij}\right)}{1/s + k\left(\sum_{T=1}^{s}\left(\overline{y_t^g}/Y_{t0}^g\right) + \sum_{R=1}^{k}\left(\overline{y_r^b}/Y_{r0}^b\right)\right),} \tag{2}$$

$$s.t. \begin{cases} \overline{X} \geq \sum\limits_{j=1\ ,\ j\neq 0}^{n} x_{ij}\lambda_j \\ \overline{Y^g} \leq \sum\limits_{j=1, j\neq 0}^{n} y_{tj}^g\lambda_j \\ \overline{Y^b} \leq \sum\limits_{j=1, j\neq 0}^{n} y_{rj}^b\lambda_j \\ \overline{Y^g} \leq Y_0^g, \overline{Y^b} \geq Y_0^b, \lambda_j \geq 0, \\ i = 1, 2, \ldots, m; j = 1, 2, \ldots, n; t = 1, 2, \ldots, s; r = 1, 2, \ldots, k. \end{cases} \tag{3}$$

ρ is the calculated green development efficiency value of sci-tech finance. When $0 < \rho < 1$, the green development efficiency of regional sci-tech finance is in an invalid state. When $\rho \geq 1$, the green development efficiency of regional sci-tech finance is in an effective state, and the greater the ρ value, the greater the green development efficiency of sci-tech finance, and the higher the green development level of sci-tech finance.

2.3.2. Malmquist Index. The green development efficiency of sci-tech finance calculated by the super-SBM model is a static description, and Malmquist model can dynamically analyse the changes in the green development of sci-tech finance. Therefore, this study selects Malmquist index model to supplement and improve the analysis of the efficiency of sci-tech finance.

Malmquist productivity index was proposed by Malmquist, a Swedish scholar. Subsequently, some scholars applied it to measure productivity change. The construction of Malmquist index is based on the distance function. The change in technical efficiency is analysed from a dynamic point of view through the comparison of distance functions. Therefore, the Malmquist productivity index from period t to period $t+1$ is as follows:

$$\begin{aligned} MI &= M_i\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = \left(M^t \times M^{t+1}\right)^{1/2} \\ &= \left(\frac{D_i^t\left(x^{t+1}, y^{t+1}\right)}{D_i^t\left(x^t, y^t\right)} \times \frac{D_i^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_i^{t+1}\left(x^t, y^t\right)}\right)^{1/2}. \end{aligned} \tag{4}$$

MI reflects the changes in total factor productivity in the green development of sci-tech finance. $MI > 1$ indicates that the green development efficiency of sci-tech finance is improved. $MI < 1$ indicates that the green development efficiency of sci-tech finance decreases. $MI = 1$ indicates that the green development efficiency of sci-tech finance remains unchanged.

The use of Malmquist index to analyse the green development efficiency of regional sci-tech finance can also decompose the total factor productivity, so as to further observe whether the investment decision of sci-tech finance is correct or not and explore the reasons for the differences in resource allocation efficiency. Total factor productivity (TFP) is decomposed into technical progress change index (TC) and technical efficiency change index (EC), and EC is further decomposed into the product of pure technical efficiency index (PEC) and scale efficiency index (SEC).

$$\text{Total Factor Productivity (TFP)} = \text{Technical Efficiency (EC)} \times \text{Technical Progress (TC)}, \tag{5}$$

$$\text{Technical Efficiency (EC)} = \text{Pure Technical Efficiency (PEC)} \times \text{Scale Efficiency (SEC)}. \tag{6}$$

EC is used to measure the efficiency change in a DMU. $EC > 1$ indicates that the efficiency of DMU is improved, whereas $EC < 1$ indicates that the efficiency of DMU is reduced. TC is used to measure the technical change in a DMU from t period to $t + 1$ period.

2.4. Data Analysis and Application. This research is based on the measurement of the green development efficiency of regional sci-tech finance driven by data. The specific data analysis and application are as follows:

Firstly, we construct the input-output index of the green development of regional sci-tech finance, calculate the green development efficiency of regional sci-tech finance by using the super-SBM model, and analyse its change trend.

Secondly, we use the super-SBM model to calculate the efficiency of regional sci-tech finance (excluding undesirable output) and compare it with the green development efficiency of regional sci-tech finance.

Thirdly, we use the Malmquist index to analyse the dynamic changes in green total factor productivity of regional sci-tech finance and identify the main factors affecting the improvement of green development efficiency of regional sci-tech finance in accordance with the decomposition of the green total factor productivity of regional sci-tech finance.

Finally, we propose policy suggestions to improve the green development efficiency of regional sci-tech finance in accordance with the above analysis.

The steps are shown in Figure 2.

3. Case Study

This study takes the YRD as an example, collects and sorts out the data in accordance with the input-output indicators of the green development of regional sci-tech finance, and measures and evaluates the green development efficiency of sci-tech finance in the YRD by using the super-SBM model and Malmquist index to prove the effectiveness of the proposed method.

3.1. Case Study Background. The YRD includes Shanghai, Jiangsu Province, Zhejiang Province, and Anhui Province. The YRD is one of the regions with the most active economic development, the highest degree of openness, and the strongest innovation ability in China. It is also a major strategic growth pole of China's economic development. In 2020, the gross domestic product (GDP) of the YRD ranked fifth in the world. In 2021, the GDP of the YRD reached 27.6 trillion Yuan, accounting for 24% of China's total economy. The high-speed economic growth and high-quality development of the YRD promote the construction of China's modern economic system and help the YRD become the growth pole of the global economy, which is of great importance to the high-quality development of the world economy.

Under the integrated development strategy of the YRD, scientific and technological innovation, as one of the driving forces of economic development, is extremely important. Strengthening the integration of regional innovation in the YRD and building a science and technology innovation community in the YRD have a strong demand for sci-tech finance. However, the development of the YRD is restricted by resources and environment, so the green development of sci-tech finance in the YRD has high research value.

3.2. Results

3.2.1. Measurement of Sci-Tech Financial Efficiency in the YRD. This study uses Maxdea Ultra 7.0 software to calculate the green development efficiency of sci-tech finance in the YRD from 2010 to 2018 without considering the output lag. In the follow-up research, this study chooses to measure the green development efficiency of regional sci-tech finance under the condition of constant return to scale. Some of the results are shown below.

In accordance with the green development efficiency value, the green development level can be defined, and the green development efficiency level can be analysed vertically. Green development efficiency value greater than or equal to 1 indicates extremely high efficiency. Green development efficiency value greater than 0.6 indicates high efficiency. Green development efficiency value less than 0.6 indicates

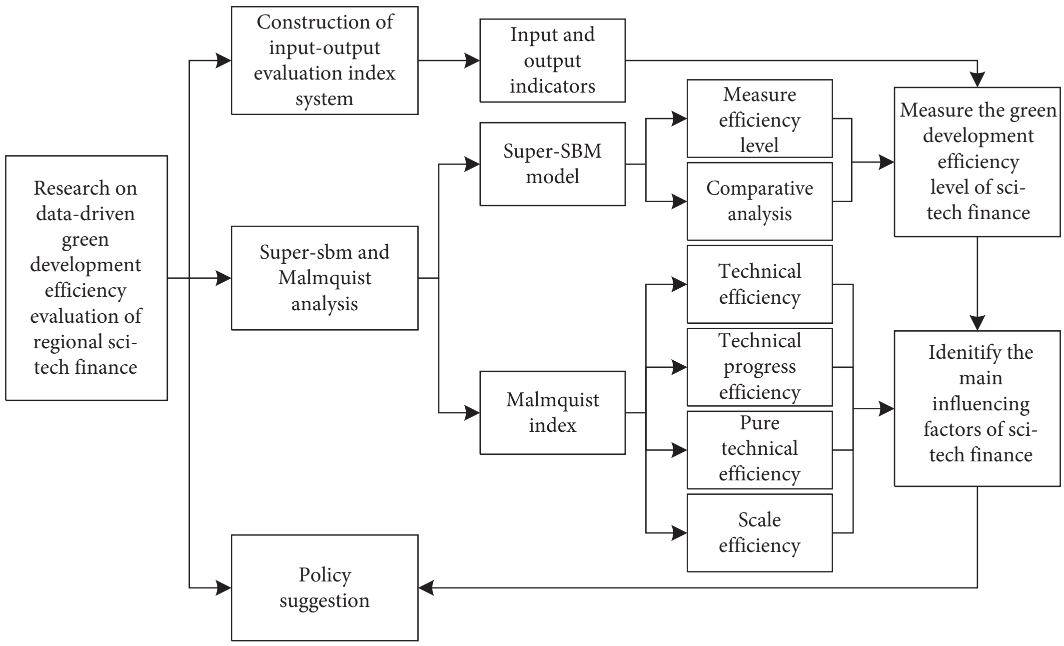


Figure 2: Data analysis and application.

low efficiency. As shown in Figure 3, from 2010 to 2018, the average green development efficiency of sci-tech finance in three provinces and one city in the YRD reached high efficiency. The green development efficiency of sci-tech finance in Zhejiang, Jiangsu, and Shanghai fluctuated and is greater than 1. The efficiency value of the green development of sci-tech finance in Anhui Province is in a rapid rising stage from 2010 to 2016, whereas it is in a volatile rise from 2016 to 2018. On the whole, the overall green development level of sci-tech finance in Anhui Province improved significantly.

In comparison, Anhui Province has the highest degree of improvement in the green development efficiency of sci-tech finance, from 0.4031 in 2010 to 1.0278 in 2018, an increase of 0.6247. Jiangsu Province and Zhejiang Province are relatively stable and have been in a state of high efficiency. Shanghai showed a slow downward trend in the green development efficiency of sci-tech finance, which decreased by 0.5575 from 2.0075 in 2010 to 1.45 in 2015 and reached the lowest level in 2015. This finding indicated that although the utilisation efficiency of sci-tech financial resources remained efficient, the utilisation capacity of resources decreased. From 2015 to 2018, the green development efficiency value of sci-tech finance in Shanghai increased slightly but did not reach the previous level.

On the whole, significant differences are observed in the green development efficiency of sci-tech finance among the three provinces and one city in the YRD. Shanghai has the highest green development efficiency of sci-tech finance, followed by Jiangsu Province, Zhejiang Province, and Anhui Province. As the largest economic centre in China, Shanghai has a high level of economic development. Its industries are mainly modern manufacturing and high-tech industries. Therefore, the green development efficiency of sci-tech finance is extremely high. The investment in sci-tech finance in Jiangsu Province ranks first in the YRD. However, the ability of scientific and technological innovation is weaker than that in Shanghai because the secondary industry is the leading industry in Jiangsu Province. Anhui Province is relatively late in development than Jiangsu and Zhejiang, and its scientific and technological innovation ability is weak, resulting in the low efficiency of the green development of sci-tech finance. However, in recent years, the economy of Anhui Province has developed rapidly, resulting in the rapid improvement of the green development efficiency of sci-tech finance.

3.2.2. Comparative Analysis. To deeply understand the green development efficiency level of regional sci-tech finance, this study performs a comparative analysis between the green development efficiency of sci-tech finance considering ecological output and the traditional sci-tech finance efficiency without considering undesirable output, as shown in the figure below.

From Figure 4, we can see that in general, the green development efficiency of sci-tech finance considering environmental pollution in Anhui Province, Jiangsu Province, and Zhejiang Province is lower than that without environmental pollution. This shows that the emission of environmental pollutants, such as "three wastes," is one of the reasons affecting the efficiency level of regional sci-tech finance. This condition indicates that distortion occurs in the evaluation of sci-tech finance efficiency without considering environmental pollution. By contrast, significant differences are observed in the effects of environmental factors on the efficiency of sci-tech finance in three provinces and one city in the YRD. Jiangsu Province is the most affected, followed by Zhejiang Province and Anhui Province, and Shanghai is unaffected. The main reason is that the tertiary industry in

Shanghai accounts for about 80% of the industrial structure, and the industry is also dominated by modern manufacturing and high-tech industries. Shanghai has a high technology transformation effect and is relatively leading in promoting environmental improvement through technological innovation. The secondary industry is the leading industry in Jiangsu Province, and its environmental protection ability is weaker than that of Shanghai. Therefore, the efficiency of sci-tech finance is obviously affected by environmental factors.

3.2.3. Dynamic Evolution of the Green Development Efficiency of Sci-Tech Finance in the YRD. This study uses the panel data of three provinces and one city from 2010 to 2018 and applies the Malmquist index model to further explore the change in the green development efficiency of sci-tech finance over time. These processes are performed to more comprehensively analyse the development trend of sci-tech finance in the YRD. The Malmquist index and its decomposition value of three provinces and one city in the YRD are calculated on Maxdea Ultra 7.0 software. The calculation results are as follows.

As shown in Figure 5, on the whole, the average value of MI in the YRD fluctuates around 1, indicating that the overall efficiency of the green development of sci-tech finance in the YRD is unstable. Specifically, from 2010 to 2015, the green development efficiency of sci-tech finance in the YRD was in an upward trend, peaked in 2015, decreased, and exhibited an inflection point in 2017. The technical efficiency of sci-tech finance in the YRD during the study period is greater than 1, and the technical progress index is less than 1 in 2011, 2013, and 2017 by further decomposing MI. This finding shows that the convergence between the progress of technical efficiency and the change in MI is higher.

As shown in Figure 6, from the perspective of three provinces and one city, from 2010 to 2018, the dynamic efficiency of science and technology finance in Anhui Province improved the fastest, with an average increase of 6.19%, followed by Zhejiang Province, with an average growth rate of 4.89%, and Jiangsu Province and Shanghai have an average growth rate of less than 2%. This finding shows that Jiangsu Province and Shanghai have been growing slowly due to the high efficiency of the green development of sci-tech finance and the less room for progress than Anhui Province and Zhejiang Province. Anhui Province and Zhejiang Province have lagged behind Jiangsu Province and Shanghai in economy and technology. In recent years, the national YRD regional strategy has greatly improved their economic development level, industrial structure, and resource allocation. Therefore, the green development efficiency of sci-tech finance has been improved rapidly.

The further decomposition of the index of three provinces and one city shows that the reasons for the rapid growth of the green development efficiency of sci-tech finance in Anhui Province and Zhejiang Province are different. The driving force for the rapid growth of the green development efficiency of sci-tech finance in Anhui Province is the technical efficiency (EC = 1.1241), contributing a growth rate of 12.41%, and the driving force of Zhejiang Province is the technical progress (TC = 1.0476), contributing a growth rate of 4.76% compared with the technical efficiency (EC = 1.0013).

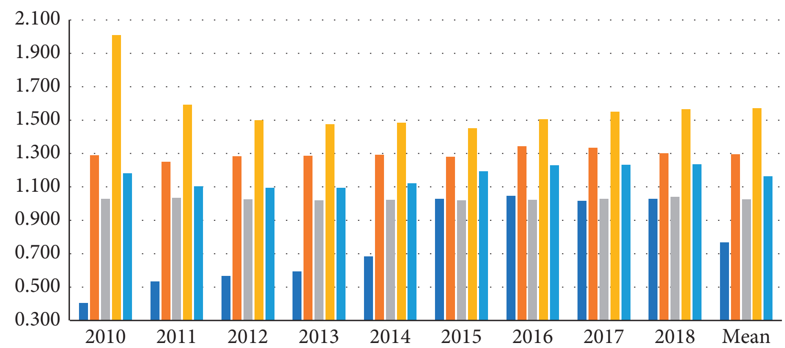
To sum up, this study uses the super-SBM model with undesirable output and Malmquist index to explore the characteristics of the green development efficiency of sci-tech finance in three provinces and one city in the YRD from 2010 to 2018 from the two dimensions of time series dynamic evolution and influencing factors and draws the following conclusions: (1) The green development efficiency of sci-tech finance in the YRD shows an upward trend as a whole, but the efficiency of sci-tech finance in three provinces and one city is different. Shanghai, Jiangsu Province, and Zhejiang Province have maintained high efficiency, whereas Anhui Province has developed rapidly from low efficiency to high efficiency. (2) The emission of environmental pollutants is one of the reasons affecting the efficiency of regional sci-tech finance. (3) On the whole, except for 2010–2011 and 2016–2017, the Malmquist index is greater than 1. The changes in technological progress and technological and financial efficiency are the same, but the speed of the technological progress of three provinces and one city is different. Anhui Province has made rapid progress and gradually narrowed the efficiency gap in sci-tech finance with other provinces and cities.

3.3. Policy Suggestions. On the basis of the above research conclusions, the policy suggestions to optimise the efficiency of financial resource allocation and further improve the green development efficiency of sci-tech finance in the YRD are proposed as follows.

3.3.1. Further Improve Scientific and Technological Innovation. In accordance with Table 2, the average green development efficiency of sci-tech finance in Shanghai is 1.5695, and the average green development efficiency of sci-tech finance in Anhui Province is 0.7656. The main reason for such a large difference is that Shanghai's scientific and technological innovation ability exceeds that of Anhui Province and is in the centre of the YRD. Therefore, we must improve the ability of regional science and technology innovation to improve the green development efficiency of regional sci-tech finance. On the one hand, scientific and technological innovation promotes the adjustment of industrial structure, so as to promote the development of high-tech industries, especially low-carbon industries, and help further control the emission of pollutants. On the other hand, technological progress brings sustainable and rapid economic development, which helps to promote the efficiency of sci-tech finance. The government should support enterprises to further improve scientific and technological innovation and technology and abandon or upgrade enterprises with high pollution and high investment whilst increasing the support of scientific and technological innovation investment. The investment of sci-tech finance must focus on the rational allocation of energy and the

Table 2: Average Malmquist index and its decomposition in three provinces and one city.

	MI	EC	TC	PEC	SEC
Anhui Province	1.0619	1.1241	0.9447	1.0000	1.1241
Jiangsu Province	1.0100	1.0012	1.0088	1.0069	0.9943
Zhejiang Province	1.0489	1.0013	1.0476	1.0083	0.9931
Shanghai City	1.0186	0.9694	1.0508	1.0000	0.9694
Mean	1.0346	1.0223	1.0120	1.0038	1.0185



	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean
Anhui Province	0.4031	0.5314	0.5648	0.5909	0.6829	1.0266	1.0456	1.0171	1.0278	0.7656
Jiangsu Province	1.2873	1.2486	1.2825	1.2856	1.2926	1.2808	1.3418	1.3351	1.2996	1.2949
Zhejiang Province	1.0285	1.0332	1.0245	1.0201	1.0213	1.0193	1.0228	1.0272	1.0396	1.0263
Shanghai City	2.0075	1.5902	1.4992	1.4755	1.4845	1.4500	1.5041	1.5490	1.5653	1.5695
Mean	1.1816	1.1008	1.0927	1.0930	1.1203	1.1942	1.2286	1.2321	1.2331	1.1641

Figure 3: Efficiency value of the green development of sci-tech finance in the YRD, 2010–2018.

protection of ecological environment, so as to truly realise the high-quality development of economy.

3.3.2. Promote the Construction of a Regional Ecological Integrated Governance System. In accordance with Figure 7, undesirable outputs reduce the green development efficiency of regional sci-tech finance. Therefore, to improve the green development efficiency of regional sci-tech finance and achieve a win-win situation in regional economic development and ecological environment, we must improve the expected output and reduce the total amount of undesirable output. Ecological problems have the characteristics of diffusion and externality, and it is inevitable to promote the construction of a regional ecological integrated governance system. Based on firmly establishing the concept of green development, we should establish a unified and authoritative regional ecological supervision organization, formulate unified environmental testing standards and environmental law enforcement, and fully mobilize the enthusiasm of the public, social organizations, and enterprises to participate in ecological construction (see Figures 3–6).

3.3.3. Seek Common Ground Whilst Reserving Differences in Regional Management. From the above analysis, the reasons for promoting the efficiency growth of the green development of sci-tech finance in regional provinces and cities are different. The driving force for the rapid growth of the green development efficiency of sci-tech finance in Anhui Province depends on the technical efficiency (EC = 1.1241), the driving force of Zhejiang Province and Shanghai is the technological progress (TC is 1.0476 and 1.0508, respectively), and a small gap is observed between the technical efficiency and the contribution of technological progress in Jiangsu Province. Based on the different resource endowments and scientific and technological innovation capabilities of provinces and cities, we should emphasize the scientific and technological level and scientific and technological innovation capability and pay attention to the differentiation of regional sci-tech financial management at the current stage to achieve regional green development. For example, Anhui provincial government should focus on accelerating technological efficiency, whilst Zhejiang Province and Shanghai should focus on improving the level of technological progress.

3.4. Discussion and Management Enlightenment. Compared with the existing literature [34, 35], this study has the following advantages. Firstly, this study further improves the evaluation index of regional sci-tech financial efficiency. On the basis of the traditional sci-tech financial efficiency evaluation index, this study adds ecological output as undesirable output, which can more objectively evaluate the effects of regional sci-tech financial investment on scientific and technological innovation and ecological environment. Secondly, the super-SBM model and Malmquist index are used to measure the green development efficiency of regional sci-tech finance and analyse the level and timing changes in

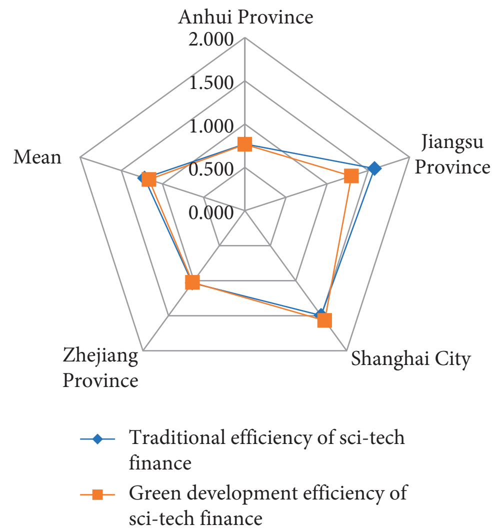
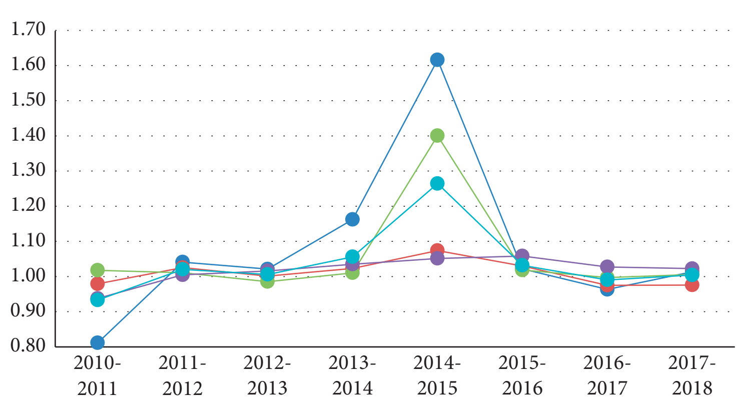


Figure 4: Comparative analysis of the efficiency of sci-tech finance in the YRD.

Figure 5: Malmquist index and its efficiency decomposition in the YRD, 2010–2018.



	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018
Anhui Province	0.811	1.041	1.021	1.162	1.616	1.022	0.963	1.014
Jiangsu Province	0.979	1.025	1.001	1.023	1.074	1.030	0.975	0.976
Zhejiang Province	1.018	1.011	0.985	1.011	1.400	1.018	0.997	1.006
Shanghai City	0.938	1.005	1.016	1.035	1.052	1.058	1.027	1.023
Mean	0.933	1.021	1.006	1.056	1.264	1.032	0.991	1.004

Figure 6: Malmquist index in three provinces and one city, 2010–2018.

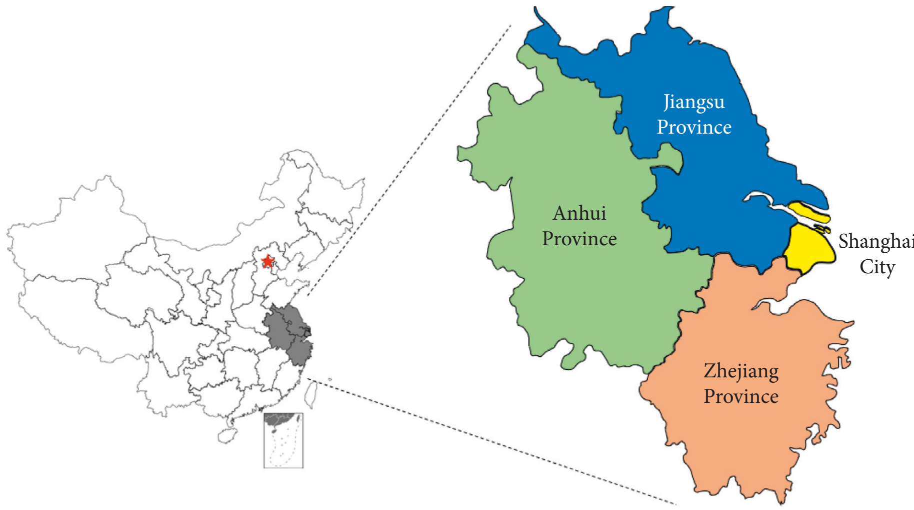


Figure 7: Yangtze river delta.

the green development efficiency of sci-tech finance. The evaluation of sci-tech finance efficiency is more objective and comprehensive, which is helpful to provide scientific decision-making basis. Finally, this study proposes some suggestions to improve science and technology innovation technology and improve the regional green development governance system to realise the sustainable development of economy and environment from the perspective of sci-tech finance, so as to make the decision more targeted.

On the basis of the above research and conclusions, we obtain the following management enlightenment.

(1) Under the background of green economic development, regional differences require a set of scientific and reasonable measurement and evaluation index system of regional scientific, technological, and financial efficiency. It is conducive to grasp the situation of sci-tech finance promoting scientific and technological innovation and to understand the effects of scientific and technological financial resource investment on the ecological environment.

(2) The measurement and evaluation of the green development efficiency of regional sci-tech finance must start from the dynamic and static aspects, so as to better grasp and understand the current situation and development trend of regional sci-tech finance and provide a scientific basis for the formulation of sci-tech finance policies in the future.

(3) In the context of big data, we can diagnose and find problems through the establishment of models for data analysis, thereby helping to drive the scientificity of decision-making. Therefore, research of regional sci-tech finance should fully utilise big data and analyse the innovation effect and ecological effect of sci-tech finance more scientifically through data driving.

4. Conclusion

Sci-tech finance is the key driving force to promote the high-quality integrated development of regional economy and an important factor to realise the sustainable development of economy and environment. Therefore, the efficiency of sci-tech finance and the efficiency of financial capital allocation must be further improved, and the deep integration of finance and science and technology industry must be promoted. This study proposes a data-driven measurement and evaluation method of the green development efficiency of regional sci-tech finance, which is calculated by the super-SBM model, is analysed by Malmquist index, and provides targeted suggestions.

The main innovations of this study are as follows: (1) this study constructs the measurement index of the green development efficiency of regional sci-tech finance. The input index of the index system consists of four input indexes: R&D personnel converted into full-time equivalent, internal expenditure of R&D funds, government science and technology expenditure, and financial market fund support, which cover the main sources of sci-tech finance. The output index consists of direct output and undesirable output, where the direct output consists of economic benefits and intellectual property rights, and the three waste indexes are selected for the undesirable output. The input-output evaluation index system of the green development efficiency of sci-tech finance is more comprehensive, and the evaluation of the efficiency of sci-tech finance is more reliable. (2) This study constructs a data-driven evaluation of the green development efficiency of regional sci-tech finance. The evaluation process is more objective, and the evaluation results are more credible. (3) The time series measurement and influencing factor analysis of the green development efficiency of regional sci-tech finance can comprehensively analyse the changes in the green development efficiency of regional sci-tech finance, so as to provide a scientific decision-making basis for the formulation of sci-tech finance policies.

However, this study has some deficiencies: the selection of indicators of the green development efficiency of sci-tech finance needs to be further improved. The effects of sci-tech financial input on the ecological environment depend on the existence of undesirable output and environmental input factors, such as energy consumption and water resource consumption.

The evaluation of the green development efficiency of regional sci-tech finance is a complex study. In the future research, we will more comprehensively evaluate the dynamic changes in the green development efficiency of sci-tech finance from the perspective of time sequence and space, further improve the input-output index system of sci-tech finance, and build a complete sci-tech finance system, so as to explore the path for promoting the deep integration of finance and scientific and technological innovation from a more diversified perspective to promote high-quality integrated development of regional economy.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

This research was funded by the following projects: Excellent Youth Fund Project of Suzhou University (2013xqrw010); Key Scientific Research Project of Suzhou University (2019yzd13); Research Project of Humanities and Social Sciences of Anhui Provincial Department of Education in 2020 (sk2020a0531); Research Project of Humanities and Social Sciences of Anhui Provincial Department of Education in 2019 (sk2019a0527); Research Project of Humanities and Social Sciences of Anhui Provincial Department of Education in 2021 (sk2021a0092); Support Program for Outstanding Young Talents in Colleges and Universities of Anhui Provincial Department of Education in 2021 (gxyqZD2021039); Innovation Team of Suzhou University (2018kytd02); and Research Platform Project of Suzhou University (2019yfk20).

References

[1] H. Y. Huang, F. R. Wang, M. L. Song, T. Balezentis, and D. Streimikiene, "Green innovations for sustainable development of China: Analysis based on the nested spatial panel models," *Technology in Society*, vol. 65, Article ID 101593, 2021.

[2] G. Cainelli, A. D'Amato, and M. Mazzanti, "Resource efficient eco-innovations for a circular economy: Evidence from EU firms," *Research Policy*, vol. 49, no. 1, Article ID 103827, 2020.

[3] N. P. Jiang and R. K. Xiang, "Some problems of green economic development in China," *Contemp Econ Res*, vol. 2, no. 2, pp. 50–54, 2013.

[4] F. Chao, W. Miao, C. L. Guan, and B. H. Jian, "Green development performance and its influencing factors: A global perspective," *Journal of Cleaner Production*, vol. 144, pp. 323–333, 2017.

[5] F. D. Qiu, Y. Chen, J. T. Tan, J. B. Liu, Z. Y. Zheng, and X. L. Zhang, "Spatial-temporal Heterogeneity of green development efficiency and its influencing factors in growing Metropolitan Area: A case study for the Xuzhou Metropolitan Area," *Chinese Geographical Science*, vol. 30, no. 2, pp. 352–365, 2020.

[6] T. F. Ye, X. L. Xiang, X. Y. Ge, and K. L. Yang, "Research on green finance and green development based eco-efficiency and spatial Econometric Analysis," *Sustainability*, vol. 14, no. 5, p. 2825, 2022.

[7] H. Li, F. He, and G. J. Deng, "How does environmental regulation promote technological innovation and green development? New Evidence from China," *Polish Journal of Environmental Studies*, vol. 29, no. 1, pp. 689–702, 2019.

[8] G. Li, Y. Zhou, F. Liu, and T. Wang, "Regional differences of manufacturing green development efficiency considering undesirable outputs in the Yangtze River economic belt based on super-SBM and WSR system methodology," *Frontiers in Environmental Science*, vol. 8, Article ID 631911, 2021.

[9] R. Wang, "The influence of environmental regulation on the efficiency of China's regional green economy based on the GMM model," *Polish Journal of Environmental Studies*, vol. 29, no. 3, pp. 2395–2402, 2020.

[10] S. T. Kim, G. L. Cho, S. D. Lee, and B. Lim, "An Analysis on the economic performance of industrial R&D investments to Achieve green growth strategy," *Journal of Korean Economy Studies*, vol. 29, no. 2, pp. 5–50, 2011.

[11] G. F. Liang, D. J. Yu, and L. F. Ke, "An empirical study on dynamic evolution of industrial structure and green economic growth—based on data from China's Underdeveloped Areas," *Sustainability*, vol. 13, no. 15, p. 8154, 2021.

[12] M. L. Zhang and B. Z. Li, "How to design regional characteristics to improve green economic efficiency: a fuzzy-set qualitative comparative analysis approach," *Environmental Science and Pollution Research*, vol. 4, pp. 6125–6139, 2022.

[13] V. Tawiah, A. Zakari, and F. F. Adedoyin, "Determinants of green growth in developed and developing countries," *Environmental Science and Pollution Research*, vol. 29, pp. 39227–39242, 2021.

[14] D. S. Yu, X. P. Li, J. J. Yu, and H. Li, "The impact of the spatial agglomeration of foreign direct investment on green total factor productivity of Chinese cities," *Journal of Environmental Management*, vol. 290, no. 290, Article ID 112666, 2021.

[15] T. H. Li and G. K. Liao, "The Heterogeneous impact of financial development on green total factor productivity," *Frontiers in Energy Research*, vol. 8, 2020.

[16] S. Jia, Q. H. Yuan, J. X. Lv, Y. Liu, D. W. Ren, and Z. W. Zhang, "Therblig-embedded value stream mapping method for lean energy machining," *Energy*, vol. 138, pp. 1081–1098, 2017.

[17] S. Jia, W. Cai, C. H. Liu et al., "Energy modeling and visualization analysis method of drilling processes in the manufacturing industry," *Energy*, vol. 228, no. 228, Article ID 120567, 2021.

[18] K. D. Yin, R. C. Zhang, X. Jin, and L. Yu, "Research and optimization of the Coupling and coordination of environmental regulation, technological innovation, and green development," *Sustainability*, vol. 14, no. 1, p. 501, 2022.

[19] J. X. Zhang and R. C. Liu, "Evolution of urban green innovation efficiency under environmental regulations: A case study of Xi'an," *Chinese Journal of Urban and Environmental Studies*, vol. 08, no. 03, Article ID 2050015, 2020.

[20] S. L. Feng, R. Zhang, and G. X. Li, "Environmental decentralization, digital finance and green technology innovation," *Structural Change and Economic Dynamics*, vol. 61, pp. 70–83, 2022.

[21] Y. Fang and Z. Q. Shao, "Whether green finance can effectively moderate the green technology innovation effect of Heterogeneous environmental regulation," *International Journal of Environmental Research and Public Health*, vol. 19, no. 6, p. 3646, 2022.

[22] X. Y. Wang, "Research on the impact mechanism of green finance on the green innovation performance of China's manufacturing industry," *Managerial and Decision Economics*, vol. 2, no. 2, 2022.

[23] Y. Wang and X. M. Wang, "Analysis on green development level and restricting factors of Lanzhou-Xining urban Agglomeration development Zone," *Areal Research and Development*, vol. 40, no. 4, pp. 32–38, 2021.

[24] M. X. Zhang, S. J. Wei, and X. Y. Zhu, "Science and technology finance: from concept to theoretical system," *China Soft Science*, vol. 4, pp. 31–42, 2018.

[25] C. H. Yu, X. Q. Wu, D. Y. Zhang, S. Chen, and J. S. Zhao, "Demand for green finance: Resolving financing constraints on green innovation in China," *Energy Policy*, vol. 2021, Article ID 112255, 2021.

[26] K. X. Meng and Q. H. Yan, "Green finance and investment structure optimization of eterprise eco-innovation," *Studies in Science of Science*, vol. 35, no. 12, pp. 1886–1895, 2017.

[27] M. K. Shi and L. Y. Yu, "Cooperative efficiency measurement of China's provincial science financial system based on network data envelopment analysis and its time-spatial differences," *Journal of Shanghai University. Natural Science Edition*, vol. 26, no. 6, pp. 1015–1025, 2020.

[28] L. Y. Ma and X. M. Li, "Does science and technology finance policies promote regional innovation? Quasi - natural Experiment based on the Pilot policy of combining science and technology with finance," *China Soft Science*, vol. 12, pp. 30–42, 2019.

[29] T. T. Chen, S. L. Zhang, and F. N. Zhang, "An empirical study on the integration efficiency of science and technology finance in Heilongjiang Province Based on Projection Pursuit Model," in *Proceedings of the International Conference on Robots & Intelligent System (ICRIS)*, pp. 644–649, IEEE, Sanya, China, November 2020.

[30] P. Adamovsky and V. Gonda, "Differences in efficiency of national innovation systems of Slovakia and selected EU countries," *Politicka Ekonomie*, vol. 67, no. 2, pp. 181–197, 2019.

[31] J. F. Zhao, X. Deng, L. Shen, C. R. Huang, and C. J. Chen, "Performance evaluation of Guangdong province technology finance based on DEA model," *Application of Intelligent Systems in Multi-modal Information Analytics*, vol. 1233, pp. 96–104, 2020.

[32] M. A. Karadayi and Y. Ekinci, "Evaluating R&D performance of EU countries using categorical DEA," *Technology Analysis & Strategic Management*, vol. 31, no. 2, pp. 227–238, 2019.

[33] J. X. Li and X. N. Wen, "Research on the relationship between the Allocation efficiency and influencing factors of China's science and technology finance," *China Soft Science*, no. 1, pp. 164–174, 2019.

[34] B. Q. Qi, Z. C. Chen, and H. Ao, "Comparative study on the Allocation efficiency of science and technology financial resources in Hubei province," in *Proceedings of the 4th International Conference on Management Engineering, Software Engineering and Service Sciences*, pp. 140–146, ICMSS, January 2020.

[35] R. S. Da Fonseca and A. P. Veloso, "The Practice and future of financing science, technology, and innovation," *Foresight and STI Governance*, vol. 12, no. 2, pp. 6–22, 2018.

[36] C. C. Zhang, "Factors influencing the Allocation of regional sci-tech financial resources based on the multiple Regression model," *Mathematical Problems in Engineering*, pp. 1–9, 2021.

[37] W. Han, P. Wang, Y. Jiang, and H. Han, "Nonlinear influence of financial technology on regional innovation capability: based on the Threshold effect Analysis of human capital," *Sustainability*, vol. 14, no. 2, p. 1007, 2022.

[38] Y. N. Chen, X. Li, and W. Li, "Analysis on Determinants and Spatiotemporal Heterogeneity of science and technology innovation efficiency at Chinese provincial level," *China Soft Science*, no. 4, pp. 137–149, 2021.

[39] D. Zhao, H. Ao, and M. Y. Yu, "Research on the Allocation efficiency of sci-tech finance in Hubei province," *International Conference on E-Business, Information Management and Computer*, no. 9, pp. 140–144, 2020.

[40] X. W. Wang, M. L. Xie, and Y. Q. Tian, "Calculation of technology finance efficiency and influencing factor Analysis in digital economy Era," *Science and Technology Management Research*, no. 2, pp. 61–69, 2022.

[41] L. Shen and W. X. Fan, "The spatial Spillover effect of Port development on economic openness: research based on two-Regime spatial Durbin model," *Management Review*, vol. 33, no. 1, pp. 44–53+67, 2021.

[42] National Bureau of Statistics, "National Bureau of Statistics," 2022, http://www.stats.gov.cn/tjsj/ndsj.

[43] Anhui Provincial Bureau of Statistics, "Anhui provincial Bureau of Statistics," 2022, http://tjj.ah.gov.cn/ssah/qwfbjd/tjnj/index.html.

[44] Jiangsu Provincial Bureau of Statistics, "Jiangsu provincial Bureau of Statistics," 2022, http://tj.jiangsu.gov.cn/col/col83749/index.html.

[45] Zhejiang Provincial Bureau of Statistics, "Zhejiang provincial Bureau of Statistics," 2022, http://tjj.zj.gov.cn/col/col1525563/index.html.

[46] Shanghai Bureau of Statistics, "Shanghai Bureau of Statistics," 2022, https://tjj.sh.gov.cn/tjnj/index.html.

[47] K. Tone, "A slacks-based measure of efficiency in data envelopment analysis," *European Journal of Operational Research*, vol. 3, pp. 498–509, 2001.

[48] K. Tone, "A slacks-based measure of super-efficiency in data envelopment analysis," *European Journal of Operational Research*, vol. 143, no. 1, pp. 32–41, 2002.