Spatial-temporal Differentiation and Convergence of Technological Innovation Efficiency in China's Equipment Manufacturing Industry

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Abstract

Technological innovation is the core driving force driving China's equipment manufacturing industry to achieve high-quality development. This paper takes China's equipment manufacturing industry as the research object, based on dividing the technological innovation process into two stages of technological research and development and economic transformation, using the super-efficient DEA-SBM model to measure the technological innovation efficiency of China's equipment manufacturing industry from 2011 to 2020, and analyzing in-depth the evolution law of technological innovation efficiency of China's equipment manufacturing industry. The study concludes that the technological innovation efficiency of China's equipment manufacturing industry is relatively low, with a large space for improvement, showing a spatial distribution pattern of "high in the east and low in the west". Based on the conclusions of the study, specific measures to enhance the technological innovation efficiency of China's equipment manufacturing industry and promote the synergistic development of inter-regional technological innovation efficiency are proposed from the aspects of promoting the synergistic enhancement of technological research and development efficiency and economic transformation efficiency and promoting the synergistic development of inter-regional technological innovation efficiency. Firstly, to build a unified technology innovation factor market, to promote the free flow of technology innovation factors between regions, and to promote the optimal allocation of technology, talents and other innovation resources, in order to narrow the differences in the innovation efficiency of the regional equipment manufacturing industry; secondly, to establish a coordinated docking mechanism for inter-regional technological innovation activities in conjunction with the advantages of the region, to accelerate the transfer of technology by means of policy inclination, to stimulate the advantageous regions to provide technical support to other regions or to carry out.

Keywords: China, equipment manufacturing industry, technological innovation efficiency, super-efficiency DEA-SBM model

Introduction

Due to the weak ability of independent innovation, the key core technology is subject to developed countries, so the development of China's equipment manufacturing industry has long been locked in the global value chain of the middle and low-end link. "Big but not strong" has become a plague on China's equipment manufacturing industry to achieve high-quality development of the "old problem". Since the 18th CPC National Congress, the Chinese government has attached great importance to scientific and technological innovation and placed it in the core position of the overall situation of national development. In this context, for the Chinese equipment manufacturing industry development process facing the "old problems", how to promote China's equipment manufacturing industry through technological innovation to achieve high-quality development has gradually become an important topic for scholars to study. Based on this, this paper takes technological innovation as the research entry point, takes China's equipment manufacturing industry as the research object, reveals the technological innovation "black box" based on in-depth, uses the super-efficient DEA-SBM model to measure the technological innovation efficiency of China's equipment manufacturing industry, explores the evolution law of technological innovation efficiency of China's equipment manufacturing industry, and puts forward the proposal of improving the technological innovation efficiency of China's equipment manufacturing industry. And then put forward the specific measures to improve the technological innovation efficiency of China's equipment manufacturing industry and promote the synergistic development of inter-regional technological innovation efficiency.

The marginal contributions of this paper are: firstly, technological innovation is a complex process involving all aspects of the life cycle of new products, and this paper divides the technological innovation process into the stage of technological research and development and the stage of economic transformation, to reveal the "black box" of technological innovation in China's equipment manufacturing industry; secondly, it is to measure the technological innovation efficiency of China's equipment manufacturing industry by using the DEA-SBM model of super-efficiency, which can effectively and efficiently measure the technological innovation efficiency of China's equipment manufacturing industry. Secondly, the super-efficient DEA-SBM model is used to measure the technological innovation efficiency of China's equipment manufacturing industry, which effectively avoids the problems that the traditional DEA model can not sort the decision-making units efficiently and ignores the non-radial relaxation.

Research Objective

1. To study using a super-efficient DEA-SBM model to measure the technological innovation efficiency of China's equipment manufacturing industry from 2011 to 2020, in-depth analysis of the evolutionary characteristics of the technological innovation efficiency of China's equipment manufacturing industry

Literature Review

Since the Chinese government put forward the concept of "equipment manufacturing industry" in 1998, scholars have carried out a large number of research on issues related to the equipment manufacturing industry. After systematic sorting, the main research literature on the technical innovation efficiency of China's equipment manufacturing industry includes: Jingyu, L. et al. (2007). measured the technical efficiency of China's equipment manufacturing industry by using the model proposed by Battese, G & Coelli, T. (1992), and based on which, they comparatively analyzed the spatial differences in the technical efficiency of China's equipment manufacturing industry. Wang, Z. B., & Sun, C. (2007) quantitatively measured and ranked the technological innovation efficiency of seven sub-industries in China's equipment manufacturing industry by using the multi-indicator input-output analysis and factor weighting method. Zhang, M. Q., & Zhang, T. Y. (2013). measured the technical innovation efficiency of the equipment manufacturing industry in Shaanxi Province from 2001 to 2010 by using the DEA method. Pang, H. M. (2014). also used the DEA method to measure the technical efficiency of the equipment manufacturing industry and special equipment manufacturing industry in 27 provincial-level administrative regions in China in 2011 and analyzed the spatial distribution of the special equipment manufacturing industry by using different comparisons. Xia, H. L., et al. (2016) used the SFA method to measure the technological innovation efficiency of the equipment manufacturing industry in Suzhou and analyzed the influencing factors and their effects. Shimei, L. et al. (2018) used the DEA-Malmquist method to measure the innovation efficiency of China's high-end equipment manufacturing industry. Tong, J. X., et al.(2019). took the Chinese equipment manufacturing industry in 18 provincial-level administrative regions in five regions, including the Pearl River Delta, the Bohai Rim, and the Yangtze River Delta, as the research object, and used the three-stage DEA method to comprehensively analyze the spatial layout, dynamic development, and influencing factors of the technical efficiency of the equipment manufacturing industry in 2011-2015. Chao K. (2020) measured the technological innovation efficiency of China's equipment manufacturing industry and its seven sub-industries from 2010 to 2017 using the SFA method based on the output distance function. Xiaowen, T. et al. (2021) measured and analyzed the technological innovation capacity of seven subsectors of high-end equipment manufacturing based on the 2011-2018 data of China's high-end equipment manufacturing industry, combined with the "VHSD-EM" comprehensive dynamic evaluation model. Chengdong, W. et al. (2021) measured the independent technological innovation efficiency of China's high-end equipment manufacturing industry using the DEA-Malmquist index method. Zhao, Q., & Zhao, L. X. et al. (2022) used the SFA method to measure the technological innovation efficiency of eight subsectors of the equipment manufacturing industry in Liaoning Province from 2013 to 2018. (Bai, J. H., et al. (2009).

Research Methodology

Technological Innovation Process

Technological innovation is a complex process, and early research usually analyses technological innovation as a whole and does not study the internal structure and operation mechanism of the technological innovation system. In order to solve the problem of the "black box" of technological innovation, scholars divide technological innovation activities into different stages and research each stage. Freeman, C. (1991) believes that technological innovation activities include the whole process of designing, processing producing marketing, and commercialization of new products. The specific performance is: through the technology research and development activities will be R & D innovation resources into R & D innovation results, and then R & D innovation results and other non-R & D innovation resources into the production, manufacturing process, and ultimately produce new products to meet market demand.

The equipment manufacturing industry as the manufacturing industry "spine", represents the technical level of the manufacturing industry, to promote the equipment manufacturing industry's technological innovation, China's manufacturing industry gets rid of the low end of the value chain to lock an important path. In order to meet the market demand, China's equipment manufacturing industry must carry out continuous technological innovation. Combined with the connotation of technological innovation, this paper argues that the process of technological innovation in the equipment manufacturing industry is specific: new product technology research and development → new product manufacturing → new product sales. Based on this, this paper divides the technological innovation process of the equipment manufacturing industry into two stages: technology research and development (first stage) and economic transformation (second stage). Among them, the technology research and development stage reflects the R & D talent and R & D capital and other R & D inputs into patents and other R & D outputs of the process. The economic transformation stage reflects the technology R & D stage of R & D outputs based on continued investment in personnel, capital, and other non-R & D resources, and ultimately transformed into a new product of the economic output process. Specifically as shown in Figure 1.

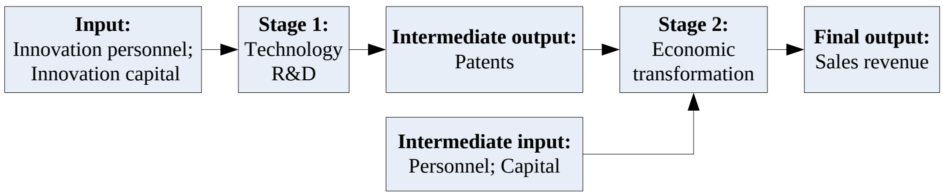


Figure 1 The two-stage process of technological innovation in the equipment manufacturing industry

Super-efficient DEA-SBM model

When measuring relative efficiency, traditional DEA models often have multiple decision units with an efficiency value of 1, thus failing to effectively rank the decision units. To solve this problem Andersen P， & Petersen N C. A(1993). proposed a super-efficient DEA model based on the traditional DEA model to further compare the efficiency values of effective decision units. Under the assumption of constant returns to scale, the super-efficient DEA model is specified as follows:

$$\min \theta$$
$$s.t. \quad \sum_{\substack{i=1 \\ i\neq k}}^{n} x_i \lambda_i \leq \theta x_{k0} \qquad (1)$$
$$\sum_{\substack{i=1 \\ i\neq k}}^{n} y_i \lambda_i \geq y_{k0}$$
$$\lambda_i \geq 0 \quad i = 1, 2, \cdots n$$

Under the assumption of variable returns to scale, the super-efficiency DEA model has the following:

$$\min \theta$$
$$s.t. \quad \sum_{\substack{i=1 \\ i\neq k}}^{n} x_i \lambda_i \leq \theta x_{k0} \qquad (2)$$
$$\sum_{\substack{i=1 \\ i\neq k}}^{n} y_i \lambda_i \geq y_{k0}$$
$$\sum_{\substack{i=1 \\ i\neq k}}^{n} \lambda_i = 1$$
$$\lambda_i \geq 0 \quad i = 1, 2, \cdots n$$

The basic idea of the super-efficient DEA model: is to evaluate the efficiency of a decision unit, it is first excluded. At the time of evaluation, in the case of an ineffective decision unit, its production frontier is unchanged, so its final efficiency value is the same as measured with the traditional DEA model. However, in the case of the efficient decision unit, the inputs are proportionally increased while its efficiency value remains unchanged, and the percentage increase in inputs is recorded as the super-efficiency evaluation value. Because its production frontier is shifted backward, the evaluated efficiency value is greater than the efficiency value measured using the traditional DEA model.

The radial model ignores non-radial relaxation in the efficiency measure. Tone K. (2001) constructed the SBM model from the perspective of relaxation variables, which measures the efficiency value of the decision unit from the non-radial perspective, and the results obtained eliminate both radial inefficiencies and non-radial inefficiencies, so that whether the decision unit is efficient or not can be judged directly based on the efficiency value without further reference to the results of relaxation variable measurement. Tone K. (2001) also used the SBM model to measure the efficiency value of the decision unit from the non-radial perspective. variable measurement results. The SBM model proposed by Tone K. (2002) based on the assumption of variable returns to scale is specified as follows:

$$\rho^* = \min \rho = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \frac{s_i^-}{x_{i0}}}{1 + \frac{1}{s}\sum_{r=1}^{s} \frac{s_r^+}{y_{r0}}}$$
$$s.t. \quad x_{i0} = \sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- \qquad (3)$$
$$y_{r0} = \sum_{j=1}^{n} \lambda_j x_{rj} - s_r^+$$
$$s^- \geq 0, s^+ \geq 0, \lambda \geq 0$$
$$\sum_{i=1}^{n} \lambda_i = 1$$

where ρ^* is the optimal efficiency value of the SBM model. When $0 \leq \rho^* < 1$, it means that the decision unit is inefficient; when $\rho^* = 1$, i.e., $s^- = s^+ = 0$ means that the decision unit is efficient. When using the SBM to measure the efficiency of a decision unit, there may be multiple decision units that are all efficient. Like the traditional DEA model, the SBM model is unable to rank these valid decision units. For this reason, it is not possible to analyze and compare effective decision units in depth. To overcome this shortcoming, Tone K. (2002) proposed the super-efficient SBM model, the basic principle of which is to exclude evaluating decision units from the set of decision units. For the inefficient decision unit, the efficiency value will be the same as the SBM model because the frontier of its production will not change. Whereas, for the SBM efficient decision unit, since the production frontier surface will be recalculated and nudged, its efficiency value may be greater than 1. The angular-free super-efficient SBM model is specified as:

$$
\begin{aligned}
&\rho_{SE}^* = \min \rho_{SE} = \frac{\frac{1}{m}\sum_{i=1}^{m}\frac{\bar{x}_i}{x_{i0}}}{\frac{1}{s}\sum_{r=1}^{s}\frac{\bar{y}_r}{y_{r0}}} \\
&s.t. \quad \bar{x} \geq \sum_{j=1}^{n}\lambda_j x_j \\
&\quad \bar{y} \leq \sum_{j=1}^{n}\lambda_j x_j \\
&\quad \bar{x} \geq 0, \bar{y} \geq 0, \lambda \geq 0 \\
&\quad \sum_{i=1}^{n}\lambda_i = 1
\end{aligned}
\qquad (4)
$$

where $\bar{x}$ and $\bar{y}$ are the input vectors and output vectors in the subset $\bar{P}$ of new production possibilities excluding the decision unit (x_0, y_0), and ρ_{SE}^* is the efficiency value of the super-efficient SBM model.

Research Results

Technological Innovation Efficiency Measurement

1 Selection and Explanation of Input-Output Indicators

Selection and Explanation of Input-Output Indicators in Technology R&D Stage

(1) Selection and explanation of input indicators

At the technology R&D stage, innovation inputs are mainly in terms of both innovation personnel and innovation capital. Drawing on the existing literature, innovation personnel are expressed in terms of full-time equivalents of R&D personnel, and innovation capital is expressed in terms of R&D capital stock.

(2) Selection and description of output indicators

There is no uniform opinion on the measurement index of innovation output in the technology R&D stage, and scholars usually use the number of patent applications or the number of patent grants to express it. Considering that the number of patent applications can better reflect the technological R&D results of enterprises and is not easily affected by the lag period, this paper chooses the number of patent applications as the output indicator of the technology R&D stage. As invention patents can better reflect the innovation ability of enterprises' core technologies, this paper chooses the number of invention patent applications as the output variable of the technology R&D stage.

Selection and description of input-output indicators for the economic transformation stage

(1) Selection and explanation of input indicators

In the economic transformation stage, the output of the technology R&D stage is firstly taken as the input of this stage and then continues to input non-R&D resources, which mainly include two parts: non-R&D personnel and non-R&D funds. Drawing on relevant literature, non-R&D personnel inputs are expressed as the average number of employees. New product development costs reflect other costs invested in developing new products, broadening market channels, etc. Therefore, new product development costs are taken as non-R&D capital input and expressed by new product development expenditure.

(2) Selection and explanation of output indicators

According to the above index selection and description, the final construction of the equipment manufacturing industry technical innovation efficiency evaluation of the input-output indicator system is specific as shown in Table 1.

Table 1 Indicator System for Evaluating Technological Innovation Efficiency in China's Equipment Manufacturing Industry

Stage	Primary Indicator	Secondary Indicator	Tertiary Indicator	Measurement Method
Technology Development Phase	Innovation Input	Personnel	R&D Personnel	"Full-Time Equivalent R&D Personnel
		Funding	R&D Capital	R&D Capital Stock
	Innovation Output	Patents	Number of Patent Applications	Number of Invention Patent Applications
Economic Transformation Stage	Innovation Input	Patents	Number of Patent Applications	Number of Invention Patent Applications
		Personnel	Number of Employees	Average Number of Employees
		Funding	New Product Development Costs	New Product Development Expenditure
	Innovation Input	New	New Product Sales	New Product Sales Revenue

Products	Performance

Technological innovation efficiency measurement model

In this paper, the technological innovation process is divided into two stages technological research and development and economic transformation, therefore, the technological innovation efficiency should be able to reflect the overall situation of innovation efficiency in the two stages of technological research and development and economic transformation. Based on this, according to the knowledge of geometry, the technical innovation efficiency measurement model is constructed as follows:

$$tie = \sqrt{tre^2 + ete^2} \tag{5}$$

Where tie is the technical innovation efficiency, tre is the technology R&D efficiency, and ete is the economic transformation efficiency. Both technical R&D efficiency and economic transformation efficiency are measured by the super-efficient DEA-SBM model.

Data Sources

There are a total of 31 provincial-level administrative regions in China, due to the serious lack of relevant data the Tibet region was excluded, for this reason, the research object of this paper is 30 provincial-level administrative regions in China. Since 2011, the statistical caliber of the equipment manufacturing industry has changed, and the statistical scope has been adjusted from legal person industrial enterprises with an annual main business income of 5 million yuan and above to legal person industrial enterprises with an annual main business income of 20 million yuan and above. To maintain the consistency of the statistical caliber, the data are selected from 2011-2020. The raw data in this paper are all from the 2012-2021 statistical yearbooks of 30 provincial-level administrative regions in China.

Analysis of Technological Innovation Efficiency

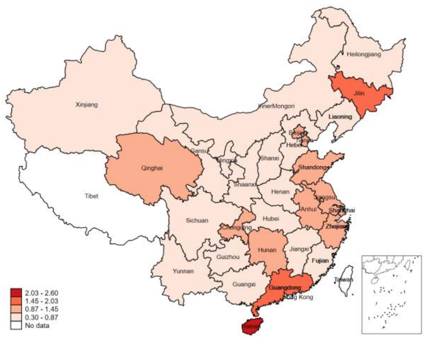
Based on the technical innovation efficiency measurement model constructed above, the technical innovation efficiency of the equipment manufacturing industry in 30 provincial-level administrative regions in China from 2011 to 2020 is shown in Table 2. Table 2 can be obtained, from the overall point of view, the equipment manufacturing industry technology innovation efficiency ranked in the top 3 provincial administrative regions were Guangdong, Qinghai, and Hainan. The bottom three provincial administrative regions in terms of average technological innovation efficiency of the equipment manufacturing industry are Heilongjiang, Shaanxi, and Yunnan.

From the perspective of time series, the technological innovation efficiency of the equipment manufacturing industry in 23 provincial-level administrative regions shows different degrees of increase in the examination period, among which, the top 3 provincial-level administrative regions in terms of increase are Qinghai, Xinjiang, and Jiangxi respectively. The bottom 3 provincial administrative regions in terms of technological innovation efficiency are Heilongjiang, Shaanxi, and Yunnan.

Table 2 Technological Innovation Efficiency of Equipment Manufacturing Industry in 30 Provincial-level Administrative Regions of China, 2011-2020

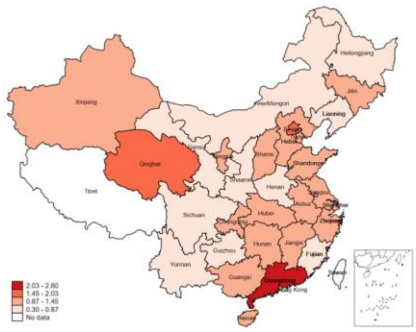
Provinces	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Average Value	rankings
Beijing	1.347	1.644	1.280	1.233	0.982	0.880	0.952	1.016	1.387	1.481	1.220	8
Tianjin	0.987	1.097	1.221	1.135	0.976	0.888	0.942	0.979	1.130	1.137	1.049	11
Hebei	0.446	0.563	0.807	0.802	0.741	0.700	0.798	0.980	0.943	0.983	0.776	20
Shanxi	0.391	0.413	0.620	0.550	0.572	0.626	0.651	0.871	0.886	0.905	0.649	25
Neimenggu	0.394	0.443	0.632	0.526	0.553	0.509	0.715	0.857	0.837	0.793	0.626	26
Liaoning	0.563	0.625	0.799	0.784	0.704	0.676	0.683	0.922	0.849	0.802	0.741	23
Jilin	1.518	1.698	0.61	1.305	1.419	1.424	1.579	1.178	1.339	1.119	1.319	5
Heilongjiang	0.325	0.339	0.488	0.442	0.413	0.409	0.486	0.638	0.800	0.834	0.517	30
Shanghai	1.278	1.040	1.077	1.020	0.793	0.823	0.960	0.953	1.035	1.044	1.002	13
Jiangsu	1.422	1.537	1.436	1.479	1.407	1.332	1.200	1.080	1.025	1.328	1.325	4
Zhejiang	1.004	0.994	1.300	1.360	1.446	1.460	1.353	1.498	1.508	1.228	1.315	7
Anhui	0.952	1.033	1.193	1.373	1.572	1.619	1.447	1.462	1.149	1.358	1.316	6
Fujian	0.572	0.584	0.668	0.626	0.548	0.534	0.556	0.623	0.666	0.641	0.602	27
Jiangxi	0.426	0.515	0.865	0.736	0.688	0.693	0.713	0.915	1.121	1.117	0.779	19
Shandong	1.164	1.182	0.940	0.843	0.718	0.699	0.808	0.802	0.814	0.897	0.887	15
Henan	0.447	0.457	1.072	0.806	0.779	0.681	0.732	1.048	0.759	0.817	0.760	21
Hubei	0.600	0.701	0.815	0.831	0.754	0.743	0.859	0.952	1.003	0.997	0.826	16
Hunan	0.928	1.124	1.092	1.127	1.123	1.126	1.134	1.099	0.968	0.922	1.064	10
Guangdong	1.951	1.742	1.578	1.527	1.441	1.758	2.255	2.311	2.550	2.317	1.943	1
Guangxi	0.572	0.611	0.991	0.870	0.868	1.150	0.920	0.979	0.908	1.011	0.888	14
Hainan	2.392	1.736	1.703	1.827	1.403	1.570	1.557	1.266	1.736	1.323	1.651	3
Chongqing	1.152	0.819	1.127	1.121	1.029	0.923	1.009	0.859	0.928	1.127	1.009	12
Sichuan	0.633	0.625	0.816	0.858	0.772	0.691	0.754	0.715	0.802	0.797	0.746	22
Guizhou	0.725	0.813	1.065	0.910	0.769	0.693	0.747	0.733	0.804	0.749	0.801	18
Yunnan	0.574	0.603	0.723	0.652	0.536	0.525	0.482	0.58	0.596	0.677	0.595	28
Shaanxi	0.471	0.408	0.558	0.493	0.416	0.412	0.494	0.619	0.741	0.675	0.529	29
Gansu	0.613	0.695	1.070	0.923	0.790	0.435	0.559	0.615	0.867	0.801	0.737	24
Qinghai	1.008	1.551	1.584	1.755	2.574	1.887	1.509	2.288	1.838	1.933	1.793	2
Ningxia	0.750	1.180	1.358	0.980	1.090	0.892	1.222	1.288	1.263	1.205	1.123	9
Xinjiang	0.450	0.491	0.788	0.951	0.818	0.639	0.695	0.827	1.263	1.273	0.820	17
Average Value	0.869	0.909	1.009	0.995	0.956	0.913	0.959	1.032	1.084	1.076	-	-

To further analyze the regional distribution of the technological innovation efficiency of China's equipment manufacturing industry, the technological innovation efficiency of China's equipment manufacturing industry in 30 provincial-level administrative regions will be divided into four groups according to the equidistant spacing, with different colors representing different groups, and the darker the color indicates the higher the technological innovation efficiency. The first group is the darkest group, which represents the group with the highest technological innovation efficiency. The fourth group is the lightest color group, which represents the group with the lowest technological innovation efficiency. The regional distribution of technological innovation efficiency of the equipment manufacturing industry in 30 provincial-level administrative regions of China is shown in Figure 1. It can be obtained from Figure 1: Firstly, from 2011 to 2020, the technological innovation efficiency of China's equipment manufacturing industry has gained a relatively large increase, but it presents a stage-by-stage characteristic. Specifically, from 2011 to 2015, China's equipment manufacturing industry technology innovation efficiency did not substantially improve, but from 2015 to 2020 the emergence a more substantial increase; Second, with a higher technological innovation efficiency of the region is still less, most of the regions of technological innovation efficiency are still low. Sichuan, Guizhou, Fujian, Shaanxi, Heilongjiang, and other 10 regions of technological innovation efficiency in 2011-2020 are in the fourth group; Third, the spatial correlation of technological innovation efficiency of China's equipment manufacturing industry is not high, the spatial spillover of the regions with higher technological innovation efficiency is not obvious, as shown in the first group and the second group of regions in 2011-2020 show frequent changes in the characteristics.



a. year 2011

b. year 2015



c. year 2020

Figure 2 Evolution of technological innovation efficiency in the equipment manufacturing industry in 30 provincial-level administrative regions of China

China's 30 provincial-level administrative regions are divided into three major zones, namely, the eastern zone, the central zone, and the western zone, to further examine the regional differences and evolution of technological innovation efficiency in the equipment manufacturing industry. The eastern belt has the highest technological innovation efficiency in the equipment manufacturing industry, with an average value of 1.137 during the examination period, and the western belt has the lowest technological innovation efficiency in the equipment manufacturing industry, with an average value of 0.879. During the examination period, the technological innovation efficiency of the equipment manufacturing industry in the three major belts has been improved to different degrees, but the magnitude of the improvement varies, with the smallest magnitude of the improvement in the equipment manufacturing industry in the eastern belt and the largest magnitude of the improvement in the technological innovation efficiency of the equipment manufacturing industry in the central belt. There are differences in the magnitude of improvement, among which, the improvement of technical innovation efficiency of the equipment manufacturing industry in the eastern belt is the smallest, and that in the central belt is the largest.

Table 3 Technological Innovation Efficiency of China's Equipment Manufacturing Industry in Three Major Zones, 2011-2020

Region	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	average value
Eastern Region	1.193	1.159	1.164	1.149	1.014	1.029	1.097	1.130	1.240	1.198	1.137
Central Region	0.698	0.785	0.844	0.896	0.915	0.915	0.950	1.020	1.003	1.009	0.904
Western Region	0.667	0.749	0.974	0.913	0.929	0.796	0.828	0.942	0.986	1.004	0.879
Nationalwide	0.869	0.909	1.009	0.995	0.956	0.913	0.959	1.032	1.084	1.076	-

Discussion

This paper takes China's equipment manufacturing industry as the research object, on the basis of using a super-efficient DEA-SBM model to measure the technological innovation efficiency of China's equipment manufacturing industry from 2011 to 2020, in-depth analysis of the evolutionary characteristics of the technological innovation efficiency of China's equipment manufacturing industry, and the study obtains the specific conclusions as follows:

Firstly, China's equipment manufacturing industry technology innovation efficiency is low, and technology research and development link efficiency is not high, which is the main reason leading to China's equipment manufacturing industry technology innovation efficiency is low;

Secondly, China's equipment manufacturing industry technology innovation efficiency has a large space for improvement. There are 6 provincial administrative regions equipment manufacturing industry technology innovation efficiency presents two stages are high characteristics, namely, technology research and development efficiency and economic transformation efficiency are higher than the average value. There are 11 provincial administrative regions with equipment manufacturing industry technology innovation efficiency shows "high and low" characteristics, there are 13 provincial administrative regions with equipment manufacturing industry technology innovation efficiency that shows "double low" characteristics;

Thirdly, the technological innovation efficiency of China's equipment manufacturing industry shows a spatial distribution pattern of "high in the east and low in the west", and the spatial spillover of technological innovation efficiency is not obvious.

Recommendation

Based on the above research conclusions, to enhance the technological innovation efficiency of China's equipment manufacturing industry and promote the balanced regional development of technological innovation efficiency in the equipment manufacturing industry, to promote China's equipment manufacturing industry to achieve high-quality development, the following countermeasure recommendations are put forward.

(1) Promote the synergistic improvement of technology R&D efficiency and economic transformation efficiency

Specific measures to enhance the efficiency of technology research and development are: first, encourage equipment manufacturing enterprises to increase R & D capital investment, improve enterprise technology research and development management and incentive system. Change the thinking of the top management of the enterprise, from the traditional focus on technology introduction, to independent innovation, to build the enterprise's own technical barriers. At the same time, with the help of a new generation of information technology, strengthen the management of technology R & D process, reduce the cost of communication and coordination of technology R & D process. Specialized introduction of technology R & D incentive system to stimulate the enthusiasm of technology research and development personnel engaged in R & D. Secondly, increase government policy support. The equipment manufacturing industry is the representative of advanced manufacturing technology in a country or region and is the key to building a manufacturing power in China. Under the top-level design of innovation-driven equipment manufacturing industry to achieve high-quality development, due to the equipment manufacturing industry technology research and development has the characteristics of large capital investment, long research and development cycle, uncertainty, and so on, which makes the equipment manufacturing industry enterprises have little willingness to carry out independent innovation. For this reason, the government should increase the support for the equipment manufacturing industry to carry out technological research and development, through technological research and development incentives, financial subsidies, and tax incentives to support the equipment manufacturing industry enterprises to engage in technological research and development activities.

Specific measures to enhance the efficiency of economic transformation are as follows: First, strengthening the protection of intellectual property rights. Good intellectual property protection can, on the one hand, help stimulate the enthusiasm of equipment manufacturing enterprises to carry out technological innovation, and, on the other hand, provide institutional safeguards for the smooth implementation of technology transactions. To this end, the relevant Chinese government departments should focus on the main problems of intellectual property protection in the technology market, and carry out special studies to accelerate the legislative process of intellectual property protection; secondly, increase the construction of the technology market, and form a unified standard for the construction of the technology market. The technology transaction market provides a trading platform for technology transactions. However, China's current technology transaction market still exists in the overall layout is still unbalanced and relatively dispersed, the system lacks systematization and other problems. To this end, firstly, the layout of the technology trading market should be improved through policy leadership, a national interconnected technology trading market should be established, and the national technology trading market industry standards should be gradually unified by unifying the trading rules, trading objects, trading processes, trading services, and so on. Secondly, innovate the management of the technology transaction market, promote the smooth flow of technology transactions, and realize the double harvest of economic and social benefits. Targeted management will be carried out for the whole process of technology transactions, such as access to the main parties and objects of technology transactions, transaction auctions, and transformation of achievements; the integration and development of science and technology finance and intellectual property rights, which are closely related to the technology transaction market; and the matching conditions of the technology transaction market such as the institutional mechanism, policies and regulations, and the entrepreneurial environment, etc. will be comprehensively assessed and implemented. Finally, the service guarantee should be strengthened to achieve the standardization, orderliness, and prosperous development of the technology transaction market. Technology transaction services, including technology transaction venue services, technology transaction brokerage services, technology transaction consulting services, and other service matters, require professional talents to complete, which requires cultivating and giving full play to the role of professional technology intermediary talents, such as technology managers, technology brokers, appraisers, consultants, and other professional technology intermediaries.

(2) Promote the synergistic development of inter-regional technological innovation efficiency.

Firstly, to build a unified technology innovation factor market, to promote the free flow of technology innovation factors between regions, and to promote the optimal allocation of technology, talents and other innovation resources, in order to narrow the differences in the innovation efficiency of the regional equipment manufacturing industry; secondly, to establish a coordinated docking mechanism for inter-regional technological innovation activities in conjunction with the advantages of the region, to accelerate the transfer of technology by means of policy inclination, to stimulate the advantageous regions to provide technical support to other regions or to carry out The third is to establish a nationwide mechanism for coordinated distribution of innovation resources, dredge up the channels of radiation from regions with high innovation efficiency to regions with low innovation efficiency, use the demonstration effect of regions with high innovation efficiency, and form benign interaction between the growth of technological innovation efficiency in different regions, so as to improve the convergence of the overall technological innovation efficiency of China's and its various regions' equipment manufacturing industries. Speed. Accelerate the convergence of technological innovation efficiency of the equipment manufacturing industry through differentiated policies, and promote the overall improvement of innovation efficiency of the equipment manufacturing industry in various regions.

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