ISSN: 2688-8645

Research on the Transformation Efficiency of S&T Achievements in China's Equipment Manufacturing Industry

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Abstract

In this paper, DEA-Malmquist model is used to calculate the transformation efficiency of S&T achievements in China's equipment manufacturing industry, and the causes of low transformation efficiency of S&T achievements are analyzed and studied. The results show that the low transformation efficiency of S&T achievements in equipment manufacturing industry from 2012 to 2018 is due to the relatively backward technical level of the industry; The key to improving the transformation efficiency of S&T achievements in equipment manufacturing industry is to improve the level of resource allocation and transformation technology.

Keywords

Transformation Efficiency of S&T Achievements; Equipment Manufacturing Industry; DEA-Malmquist Model.

1. Introduction

S&T achievements mainly refer to new technologies, new products, new processes, new materials, new devices and their systems. No matter what kind of S&T achievements, they must condense innovative and useful knowledge. Due to the intangibility of S&T achievements, the process of transforming them into actual economic and social benefits is complex and uncertain, which also makes it difficult to measure the effect of the transformation process of S&T achievements with a simple index (such as the transformation rate of S&T achievements).

Equipment manufacturing industry is characterized by technology intensive and knowledge intensive. It is the heart of industry and the lifeline of the national economy. Its development level provides an important guarantee for the upgrading of industrial structure and technological progress, and is the basis for improving the quality of China's economic development. At present, a new round of S&T revolution and industrial reform intersect with the transformation of China's economic development mode at the same time The Chinese government has promulgated "made in China 2025", a strategic action program for building a strong manufacturing country. As stated in the Interim Measures for the administration of the national S&T achievements transformation guidance fund, the contribution of S&T to the economy depends not only on the improvement of the level of technology used, but also on the improvement of the use and diffusion of existing technologies. Therefore, this paper will conduct an in-depth study on the transformation efficiency of S&T achievements in China's equipment manufacturing industry, trying to explore an effective path to improve it.

2. Research Status

S&T achievements are generally regarded as the effective results of people's S&T activities. The definition of it in the Interim Measures for the administration of the national S&T achievements transformation guidance fund (2011) focuses on the innovation of existing research and the creation of new things, mainly focusing on the materialization and usefulness of S&T achievements.

On the selection of evaluation indicators for the transformation efficiency of S&T achievements, Timothy R et al. (2007) [1] pointed out in their research on technology transfer in universities that the substantive transformation of S&T achievements is the result of application or commercial use. Artz et al. (2010) [2] pointed out that due to competition and operation reasons, the degree of resource investment in R&D activities has an important impact on the efficiency of S&T innovation of enterprises. Pikkemaat et al. (2019) [3] proposed the impact of management investment on the process of S&T activities. Considering that the early stage of the transformation of S&T achievements is a scientific research behavior, which is essentially an innovation activity, in the selection of input variables, the conditions for scientific research activities should be incorporated into the evaluation system. Feng Yao (2011) [4] pointed out the common practice of listing capital input and labor input as input vectors in the evaluation of the transformation efficiency of S&T achievements. Xiao Renqiao et al. (2012) [5] combined with the characteristics of innovative R&D activities in high-tech industries, selected R&D funds as capital input index, and R&D personnel full-time equivalent was used to express human input. Dong Jie and Huang Fujie (2012) [6] added economic benefits to the evaluation index system when studying the transformation of regional S&T achievements.

In terms of calculation, data envelopment analysis (DEA) and parametric stochastic frontier analysis (SFA) are two main methods. Siegel (1999) [7] and Chapple (2005) [8] respectively used the above two methods to calculate the transformation efficiency of S&T achievements of European and American universities, and achieved good calculation results. He bin and Fan Shuo (2013) [9] pointed out that hypothesis testing can be conducted on the estimation results and confidence intervals can be constructed in SFA calculation and analysis, but the method needs to clarify the mathematical expression of a priori production function or cost function. DEA method has no special requirements on the setting of a priori function, and the robustness of the analysis results is significant, but it is lack of hypothesis test and confidence interval construction. Therefore, at present, DEA method is mostly used by Chinese scholars. He Jingtong and Feng Yao (2011) [10] used the DEA- Malmquist model to calculate the transformation efficiency of S&T achievements in China's high-tech industry, and concluded that the transformation efficiency of S&T achievements in China's high-tech industry showed a downward trend from 1999 to 2008.

Based on previous studies, the index design emphasizes the commercial value or market value of the transformation of S&T achievements. Here, the transformation efficiency of S&T achievements in the equipment manufacturing industry is regarded as an important index to measure the production level of S&T products and the application ability of technological innovation in the industry. It measures the transformation efficiency of S&T achievements caused by R&D related resource input into market trading products and the production transformation efficiency that creates economic benefits. The research perspective is a breakthrough compared with previous studies.

3. Research Methods and Indicators

3.1. Malmquist Index

The basis of Malmquist index is to determine the distance function, which is defined under the conditions of input variables and output variables. This paper takes the input oriented DEA-Malmquist index model as the efficiency measurement model, and the output distance function of the model is:

$$D_0\left(x, y\right) = \inf\left\{\delta : \left(x, y \middle| \delta\right) \in p\left(x\right)\right\} \tag{1}$$

In equation (1), x and y represent input vector and output vector respectively, and $p(x)$ represents all possible production sets, δ Indicates the efficiency index of directional output. At this time, when the output vector y falls outside the production set $p(x)$, it means that the output distance function D_0 is greater than 1; If the output vector y falls inside the production set $p(x)$, it means that the output distance function D_0 is less than 1 at this time; If the output vector y falls on the boundary of the production set $p(x)$, it means that the output distance function D_0 is equal to 1, the boundary of production set $p(x)$ is the production frontier of all production possibility sets.

Based on the input-output situation in $t-1$ period, the mathematical expression of output oriented Malmquist index is as follows:

$$M_0^{t-1}\left(X_t,Y_t,X_{t-1},Y_{t-1}\right)=\frac{D_0^{t-1}\left(X_t,Y_t\right)}{D_0^{t-1}\left(X_{t-1},Y_{t-1}\right)} \tag{2}$$

Caves pointed out that by geometric averaging of equation (2), the difference of index calculation results caused by different period selection can be avoided:

$$M_0\left(x_t,y_t,x_{t-1},y_{t-1}\right)=\left[\frac{D_0^{t-1}\left(x_t,y_t\right)}{D_0^{t-1}\left(x_{t-1},y_{t-1}\right)}\times\frac{D_0^{t}\left(x_t,y_t\right)}{D_0^{t}\left(x_t,y_t\right)}\right]^{1/2} \tag{3}$$

When the return to scale of production remains unchanged, Malmquist index can be further decomposed, namely TECHCH and EFFCH. TECHCH is the change of production frontier from the previous phase to the next phase, which represents the change direction and degree of technical level. EFFCH is the distance from the previous period to the next period of the decision-making unit, which expresses the resource allocation efficiency of the production set.

$$\begin{aligned}M_0\left(x_t,y_t,x_{t-1},y_{t-1}\right)&=\frac{D_0^{t}\left(x_t,y_t\right)}{D_0^{t-1}\left(x_{t-1},y_{t-1}\right)}\times\left[\frac{D_0^{t-1}\left(x_t,y_t\right)}{D_0^{t}\left(x_t,y_t\right)}\times\frac{D_0^{t}\left(x_{t-1},y_{t-1}\right)}{D_0^{t}\left(x_{t-1},y_{t-1}\right)}\right]^{1/2}\\&=EFFCH\times TECHCH\end{aligned} \tag{4}$$

Now, Malmquist index can be expressed as:

$$M_0\left(x_t,y_t,x_{t-1},y_{t-1}\right)=TECHCH\times EFFCH=TECHCH\times PECH\times SECH \tag{5}$$

In which， PECH represents pure technical efficiency and SECH represents scale efficiency.

According to the definition of Malmquist index, when $M_0>1$, it represents the improvement of production efficiency compared with the previous period; When $M_0<1$, it means that the production efficiency is lower than that of the previous period. When $M_0=1$, it means that the production efficiency remains unchanged compared with that of the previous period.

Usually, Malmquist index is calculated by DEA-BCC model or DEA-CCR model, and Malmquist index in any time period is calculated by calculating four distance functions. For the input-output vector set of period $t\left(X_t,Y_t\right)$, $D_0^{t-1}(X_{t-1},Y_{t-1})$, $D_0^{t}(X_t,Y_t)$, $D_0^{t}(X_{t-1},Y_{t-1})$, $D_0^{t}(X_t,Y_t)$ need to be calculated. The mathematical expression of solving this function by DEA model is as follows:

$$\begin{cases} [D_0^{t-1}(X_{t-1}, Y_{t-1})]^{-1} = \max_{\theta\lambda} \theta \\ st. -\theta y_{i,t-1} + Y_{t-1}\lambda \geq 0 \\ x_{i,t-1} - X_{t-1}\lambda \geq 0 \\ \lambda \geq 0 \end{cases} \tag{6}$$

$$\begin{cases} [D_0^{t}(X_{t}, Y_{t})]^{-1} = \max_{\theta\lambda} \theta \\ st. -\theta y_{i,t} + Y_{t}\lambda \geq 0 \\ x_{i,t} - X_{t}\lambda \geq 0 \\ \lambda \geq 0 \end{cases} \tag{7}$$

$$\begin{cases} [D_0^{t}(x_{t-1}, y_{t-1})]^{-1} = \max_{\theta\lambda} \theta \\ st. -\theta y_{i,t-1} + Y_{t}\lambda \geq 0 \\ x_{i,t-1} - X_{t}\lambda \geq 0 \\ \lambda \geq 0 \end{cases} \tag{8}$$

$$\begin{cases} [D_0^{t-1}(X_{t}, Y_{t})]^{-1} = \max_{\theta\lambda} \theta \\ st. -\theta y_{i,t-1} + Y_{t-1}\lambda \geq 0 \\ x_{i,t} - X_{t}\lambda \geq 0 \\ \lambda \geq 0 \end{cases} \tag{9}$$

3.2. Evaluation Index System

Following the principles of systematicness, dynamic comparability and effectiveness, this paper selects the following evaluation indicators:

3.2.1. Input Index

The transformation path of S&T achievements of equipment manufacturing industry follows the movement process of S&T activity preparation -S&T product research and development-S&T achievement transfer. The input index should reflect the preparation and activity process required by the industry in carrying out S&T activities. According to the characteristics of the industry and the transformation process of S&T achievements, the input index are divided into three parts: capital investment, personnel investment and institutional environment investment. Among them, capital investment includes internal expenditure of R&D funds, external expenditure of R&D funds, expenditure of purchasing domestic technology and expenditure of technological transformation; Personnel input includes the number of R & D personnel, the full-time equivalent of R&D personnel and the full-time equivalent of project personnel; Institutional environment investment includes the number of enterprises with R&D institutions, the number of institutions, the number of institutional personnel, institutional expenditure, the number of projects and project expenditure.

3.2.2. Output Index

The main production purpose and task of equipment manufacturing enterprises is to realize the commercial and economic value and social use value of their products. Therefore, it is necessary to measure their economic benefits. At the same time, it should also reflect the improvement of enterprise competitiveness brought by S&T progress. According to this characteristic, the output index are divided into three parts: economic output, knowledge output and enterprise competitiveness. Among them, economic output includes new product sales revenue and total profit; Knowledge output includes the number of patent applications and the number of effective invention patents; The competitiveness of enterprises is expressed by the export income of new products.

4. Evaluation of Transformation Efficiency of S&T Achievements in Equipment Manufacturing Industry

DEA- Malmquist is used to measure the transformation efficiency of S&T achievements in equipment manufacturing industry. Further calculate and decompose the Malmquist index to obtain the transformation efficiency of S&T achievements and its decomposition items: EFFCH index, TECHCH index, PECH index and SECH index.

Table 1. Transformation efficiency of S&T achievements of equipment manufacturing industry by industry from 2012 to 2018

Industry	EFFCH	TECHCH	PECH	SECH	TFPCH (M index)
Metal products industry	0.946	0.868	0.967	0.978	0.821
General equipment manufacturing	1.088	0.922	1.021	1.066	1.003
Special equipment manufacturing	1.117	0.927	1.073	1.041	1.036
Automobile manufacturing industry	0.938	0.955	0.918	1.022	0.896
Manufacturing of railway, ship, aerospace and other transportation equipment	1.000	0.933	1.000	1.000	0.933
Electrical machinery and equipment manufacturing	1.093	0.914	1.023	1.068	0.999
Computer, communication and other electronic equipment manufacturing	1.000	0.931	1.000	1.000	0.931
Instrument manufacturing	1.000	0.449	1.000	1.000	0.449
Total	1.021	0.842	0.999	1.021	0.859

The data in Table 1 are the results of the calculation of the transformation efficiency of S&T achievements in eight industries involved in the equipment manufacturing industry. It can be seen from TFPCH (M index) that the overall transformation efficiency of S&T achievements in the equipment manufacturing industry showed a distribution state of great difference and high numerical convergence from 2012 to 2018, indicating that there are individual differences and overall convergence in the transformation efficiency of S&T achievements among industries. Except that the M index of special equipment manufacturing industry (1.036) is significantly higher than that of other industries, and the M index of instrument manufacturing industry (0.449) is significantly lower than that of other industries, the M indexes of other industries are distributed around the efficiency boundary value 1. However, the m value of most industries is lower than 1, indicating that the equipment manufacturing industry as a whole has low efficiency in the transformation of S&T achievements. Among them, although the computer, communication and other electronic equipment manufacturing industry is in the leading position in the absolute amount of product R & D and final output, its transformation efficiency of S&T achievements is only the fifth in the industry, with a value of 0.931, which is in the state of low efficiency of transformation of S&T achievements. It shows that the output of S&T achievements in this industry is mainly based on its high input rather than high-efficiency production mode.

Further decompose the transformation efficiency of S&T achievements to obtain EFFCH index and TECHCH index. As can be seen from table 1, except for the metal products industry and automobile manufacturing industry, the EFFCH index of other industries is greater than 1. Most

ISSN: 2688-8645

industries in the equipment manufacturing industry have a high management level of resource allocation, and their resource allocation structure has a positive effect on the transformation efficiency of S&T achievements. However, in terms of TECHCH index, there is not a complete corresponding relationship between the transformation efficiency of S&T achievements in various industries and the transformation technology level. There is a situation that the M index is greater than 1 but the TECHCH index is less than 1, indicating that the low efficiency of technology level has a negative effect on the transformation efficiency of S&T achievements. The EFFCH index and TECHCH index of metal products industry are 0.946 and 0.868 respectively, while the M index is 0.821, showing the level of technical efficiency > the change of technical level > the transformation efficiency of S&T achievements. The possible reason is that the internal technical level of the industry does not match the resource management to a certain extent, resulting in additional negative effects on the transformation of S&T achievements and further reducing the transformation efficiency. Similarly, the EFFCH index of other industries is mostly greater than the TECHCH index, indicating that the main reason for the low efficiency of the transformation of S&T achievements in these industries lies in the low level of science and technology.

The EFFCH index is further decomposed into PECH index and SECH index. In Table 1, the value of pure technical efficiency of each industry of equipment manufacturing industry is basically close to 1, indicating that the change of pure technical efficiency of equipment manufacturing industry has little impact on the change of technical efficiency. Among them, the PECH index of railway, ship, aerospace and other transportation equipment manufacturing industry, computer, communication and other electronic equipment manufacturing industry and instrument manufacturing industry is 1, indicating that the transformation efficiency of S&T achievements is neutral affected by the change of pure technical efficiency, and the production efficiency is not affected by the positive or negative effect of pure technical efficiency.

Table 2. Transformation Efficiency of S&T Achievements of Equipment Manufacturing Industry from 2012 to 2018

year	EFFCH	TECHCH	PECH	SECH	TFPCH(MIndex)
2012-2013	1.047	0.505	0.968	1.082	0.529
2013-2014	1.007	1.073	0.973	1.035	1.081
2014-2015	1.047	0.993	1.033	1.014	1.039
2015-2016	1.019	1.043	1.105	0.922	1.063
2016-2017	0.955	0.978	0.985	0.970	0.934
2017-2018	1.053	0.649	0.941	1.119	0.683
mean	1.021	0.842	0.999	1.021	0.859

It can be seen from table 2 that the overall m index of the industry has a dynamic change of first rising and then falling. From 2013 to 2016, the transformation efficiency of S&T achievements in this industry was above the boundary value of 1, and the transformation efficiency was DEA effective, 2012-2013 and 2016-2018 are non DEA effective, indicating that the transformation efficiency of S&T achievements is low. By observing the effch index and techch index, we can see that the value of the former is relatively stable, and DEA is effective in most years, while the latter is lower than the boundary value 1 in many years, indicating that the industry as a whole is more positively affected by the change of technical efficiency, while the change of technical level brings more negative effects.

From the PECH index and SECH index, they show the opposite trend of change. The reason may be that the equipment manufacturing industry is a combination of capital intensive, technology intensive and labor-intensive industries. The operation and development of the industry need

ISSN: 2688-8645

to be based on a large amount of resource investment, and its economic benefits mainly come from the extremely low marginal production cost after the formation of the industry. In the early stage of industrial development, high resource investment can bring huge economic benefits, but because enterprises need an adaptive process to optimize the allocation of input resources, the efficiency of resource allocation is low under high investment. With the further optimization of resource allocation, the efficiency of resource allocation is gradually improved at this time. However, under the influence of enterprise transformation, production environment and sales cycle, economies of scale are transformed into diseconomy of scale, resulting in the loss of scale efficiency, so that pure technical efficiency and scale efficiency fluctuate.

5. Conclusion

This paper uses DEA-Malmquist model to calculate the transformation efficiency of S&T achievements of equipment manufacturing industry from 2012 to 2018, which shows that the transformation efficiency of S&T achievements of equipment manufacturing industry as a whole and its eight sub-industries is low. Although a large amount of resources have been invested in S&T activities and the level of resource allocation management is relatively high, the transformation efficiency of S&T achievements in equipment manufacturing industry is relatively backward due to the relatively backward technical level of the industry, the weak transformation ability of S&T products and the lack of production technology for rapid transformation and rapid circulation of S&T achievements.

Therefore, this paper puts forward the following countermeasures:

(1) Make rational use of government support and optimize the allocation of government funds. Government departments help improve the convenience of enterprise financing loans, expand product sales channels, promote market standardization, form a good environment for the development of the industry, and finally have a positive effect on the transformation efficiency of S&T achievements in the equipment manufacturing industry.

(2) Strengthen industry university research cooperation and enhance technical exchanges. Actively encourage learning and research units to participate in the S&T activities of social production departments, transfer talents and introduce technology, improve the S&T R & D and application ability of enterprises, and then improve the transformation efficiency of S&T achievements.

(3) Encourage foreign capital to participate in high-quality development, optimize the utilization of foreign capital, gradually lead foreign capital to high-end industries in the value chain, promote domestic enterprises to participate in international market competition, absorb and integrate foreign advanced technology and production ideas, and improve the technical level of domestic equipment manufacturing industry.

(4) To expand the technology trading market and improve the technology transfer capacity, we should expand the scale of the technology trading market and the coverage of trading products, further improve the management system of technology patents and intellectual property rights, clarify the ownership of S&T achievements, promote interdisciplinary and departmental cooperation, and help improve the transformation efficiency of S&T achievements.

Acknowledgments

The authors are very grateful for the support by the Key Projects of Natural Science Research in Anhui Universities (KJ2019A0660), Key University Level Scientific Research Projects of Anhui University of Finance and Economics (ACKYB20011), Anhui Philosophy and Social Science Planning Project (AHSKY2020D41).

ISSN: 2688-8645

References

[1] Anderson.T.R, Aim T U, Lavoie F F.Measuring the efficiency of university technology transfer[J]. Technovation, 2007, 27(5):306-318.

[2] Artz K W, Norman P M, Hatfield D E, et al. A Longitudinal Study of the Impact of R&D， Patents, and Product Innovation on Firm Performance[J]. Journal of product innovation management, 2010, 27(5):725-740.

[3] Birgit Pikkemaat, Mike Peters, Bernhard Fabian Bichler. Innovation research in tourism: Research streams and actions for the future[J]. Journal of Hospitality and Tourism Management, 2019:184-196.

[4] Feng Yao.Research on the transformation efficiency of scientific and technological achievements in China's high-tech industry based on DEA method [J]. Academic Exchange,2011(03):101-105.

[5] Xiao Renqiao, Qian Li, Chen Zhongwei.Research on innovation efficiency and its influencing factors of China's high-tech industry [J]. Journal of Management Science,2012(05):87-100.

[6] Dong Jie, Huang Fujie.Research on the transformation efficiency of sci-tech achievements and its influencing factors -- An Empirical Analysis Based on stochastic frontier function [J]. Journal of Soft Science, 2012(10):15-20.

[7] Siegel D, Waldman D, Link A. Assessing the Impact of Organizational Practices on the Productivity of University Technology Transfer Offices: An Exploratory Study[J]. Research Policy, 1999, 32 (1): 27-48.

[8] Chapple W, Lockett A, Siegel D, et al. Assessing the relative performance of U.K. university technology transfer offices: parametric and non-parametric evidence[J]. Research Policy,2005, 34 (3): 369-384.

[9] He bin, fan Shuo Evolution and influencing factors of transformation efficiency of S&T achievements in Chinese Universities -- Analysis Based on bootstrap DEA method and panel Tobit model [J]. Science of Science and Mannagement of S.&T.,2013(10):85-94.

[10] He Jingtong, Feng Yao. An empirical study on the transformation efficiency of scientific and technological achievements in China's high-tech industry-Based on DEA-Malmquist index method [J]. Social Sciences in Yunnan,2011(04):93-98.