ЭКОНОМИЧЕСКИЕ НАУКИ

MEASURING THE EFFICIENCY OF TECHNOLOGICAL INNOVATION IN CHINA'S HIGH-TECH INDUSTRY BASED ON THE DEA-MALMQUIST INDEX METHOD

Xu Xiaoyun
PhD graduate student, Economic faculty,
Belarusian State University,
Minsk
Korotkevich Alexey Ivanovich
PhD of Economic Sciences, Head of the Department of Banking,
Belarusian State University,
Minsk
DOI: 10.31618/asj.2707-9864.2020.2.42.44

Abstract. This article uses DEA data envelopment analysis method, combined with Malmquist index, through the analysis of China's high-tech industry scientific research input and output data from 2008 to 2018, obtained the Malmquist index of comprehensive innovation efficiency of China's high-tech industry in the past 10 years, then analyzes the efficiency of technological innovation in China's high-tech industry, and puts forward optimization and policy recommendations.

Keywords. DEA, Malmquist index, high technology, innovation

1 Introduction

Industry is the backbone of the social economy, and high-tech industries are the industrial clusters that produce high-tech products. The development of high-tech and basic industries is essential to promote the upgrading of industrial structure and increase labor productivity and resource utilization.

China's high-tech industry started relatively late, but after decades of rapid development, the level of scientific research has approached or reached the world's advanced level and has great development potential. Technological innovation is the driving force for the development of high-tech industries, and innovation efficiency is related to the development strategy, resource allocation, and structural optimization of the entire industrial industry. Therefore, studying the innovation efficiency of China's high-tech industries is crucial to promoting the construction of an innovative society.

This article studies the innovation efficiency of China's high-tech industry, which is a typical efficiency evaluation problem of multi-factor decision-making. At the same time, because this article uses the panel data of China's high-tech industry (5 industries) from 2008 to 2018, it is suitable to use DEA-based Malmquist Index method is used to measure innovation efficiency. By using the DEA-Malmquist index efficiency evaluation method to measure the scientific research activities of the five types of high-tech industries, to study the changes in the efficiency of China's scientific and technological innovation in the past 10 years, and to propose optimization suggestions based on the current development strategies of China's high-tech industries and the international situation.

2 DEA-Malmquist efficiency evaluation model

The Input-Output Method, founded by the famous economist Wassily Leontief, is widely used to study issues in the national economy and analyze the balance between production inputs and product distribution among various departments. Data Envelopment Analysis (DEA) based on the "input-output model" is a non-parametric method for evaluating production efficiency in operations research. It can be used to evaluate multi-objective decision-making problems, and it can calculate efficiency while considering scale Profit factor, get comprehensive efficiency evaluation results with research significance.

The mathematical description of the DEA-Malmquist index efficiency evaluation model is as follows:

$$M_0 = \left(x_{t+1}, y_{t+1}, x_t, y_t\right) = \sqrt{\left[\frac{D_0^t\left(x_{t+1}, y_{t+1}\right)}{D_0^t\left(x_t, y_t\right)} \times \frac{D_0^{t+1}\left(x_{t+1}, y_t\right)}{D_0^{t+1}\left(x_t, y_t\right)}\right]} \quad (1)$$

For the period from t to t+1, the measurement of innovation efficiency can be measured by the following Malmquist index.

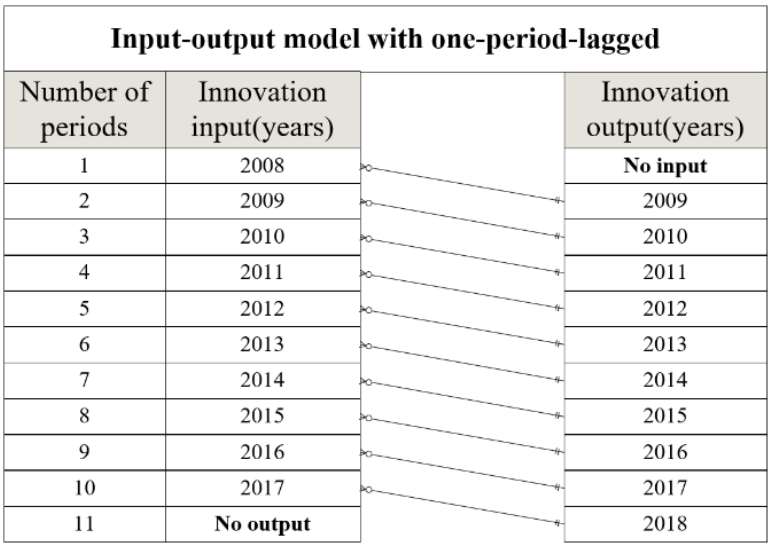
Among them: (y_{t+1}) and (x_t, y_t) are the input and output in periods t+1 and t respectively; D_0^t and D_0^{t+1} represent periods t and period t+1 refers to the distance function of technological innovation T^t in period t. If the calculation result of this function is greater than 1, it indicates that the rate of technological innovation increases from period t to period t+1. This paper uses the linear programming method to calculate the distance function related to innovation input and innovation output to measure the Malmquist index to illustrate the innovation efficiency of high-tech industries.

3 Research data and evaluation indicators

3.1 Data selection

The time span of the research data in this paper is 10 years. In order to more accurately represent the input-output relationship, this paper chooses the lag period of the input-output model to be 1 period [1], that is, the innovation input indicator data is from 2008 to 2017, corresponding to the innovation output data is from 2009 to 2018, and the "exponential smoothing

method" is used to predict some missing data, as shown in Figure 1.



Input-output model with one-period-lagged		
Number of periods	Innovation input(years)	Innovation output(years)
1	2008	**No input**
2	2009	2009
3	2010	2010
4	2011	2011
5	2012	2012
6	2013	2013
7	2014	2014
8	2015	2015
9	2016	2016
10	2017	2017
11	**No output**	2018

Figure 1 The input-output model with a lag of one period

The data used in this study are from the "China High-tech Industry Statistical Yearbook" published by the National Bureau of Statistics of the corresponding year and the official website of the National Bureau of Statistics [2].

3.2 Evaluation indicators of scientific and technological innovation efficiency

According to the description in the latest Chinese "Classification of National Economic Industries" (GB/T4752—2017), high-tech industries (manufacturing industries) refer to manufacturing industries with relatively high R&D investment intensity in the national economic industries, including the following 6 categories: Pharmaceutical manufacturing; aviation, spacecraft and equipment manufacturing; electronic and communication equipment manufacturing; computer and office equipment manufacturing; medical equipment and instrumentation systems; information chemical manufacturing (newly added). Due to the availability of data, this paper selects only five categories for research, namely: aerospace equipment manufacturing, electronic and communication equipment manufacturing, computer equipment manufacturing, medical equipment and pharmaceutical manufacturing; the information chemical manufacturing industry is temporarily not studied.

According to the classification of the complex giant system theory [3], technological innovation is divided into three categories: knowledge innovation, technological innovation and management innovation. Therefore, innovation input and output indicators will be jointly explained by multidimensional data such as knowledge, capital, technology, and markets. This article chooses the following indicators to represent innovation input and innovation output.

Innovation investment indicators include full-time equivalent of R&D personnel (X1), R&D expenditure (X2), and new product technology development expenditure (X3). Innovation output indicators are represented by the number of patent applications (Y1) and the sales revenue of new products (Y2).

The evaluation index information of innovation efficiency is shown in Table 1.

Table 1

Evaluation indicators of scientific and technological innovation efficiency

	INDEX	VARIABLE	DESCRIPTION
Innovation input	Full-time equivalent of R&D personnel	X1	Full-time equivalent of scientific research personnel during the period
	R&D funding	X2	Funds invested in scientific research during the period
	New product technology development funding	X3	New product technology development funding during the period
Innovation output	Number of patent applications	Y1	Number of patent applications for scientific research projects during the period
	New product sales revenue	Y2	New product market sales during the period

4 Empirical study of innovation efficiency based on DEA-Malmquist index

This article uses DEAP 2.1 developed and maintained by the University of Queensland as an analysis tool. By inputting the R&D input and output indicators of China's high-tech industry from 2008 to 2018, the Malmquist index of the comprehensive innovation efficiency of China's high-tech industry in the past 10 years is obtained, including annual Comprehensive and detailed indicators such as EFFCH

(Technology Change Rate Index), TECHCH (Technology Update Change Rate Index), PECH (Pure Technology Update Change Rate Index), SECH (Scale Change Rate Index), TFPCH (Comprehensive Productivity Change Index), etc. [4], then analyze the changes in China's high-tech industry innovation index, the efficiency of technological innovation input and output, and the reasons for the different levels of innovation.

4.1 Analysis of the overall Malmquist innovation efficiency change index of the high-tech industry

According to the system design, input the 10 years of scientific and technological research and development indicators, and obtain the comprehensive innovation efficiency change index TFPCH (Total Factor Productivity Change) and the index composition of the five industries in the high-tech industry. The summary results are shown in Table 2.

Table 2

Malmquist index summary of annual means

YEAR	PERIOD	EFFCH	TECHCH	PECH	SECH	TFPCH
2008-2009	1	-	-	-	-	-
2009-2010	2	0.802	0.863	0.909	0.882	0.692
2010-2011	3	1.182	1.420	1.039	1.138	1.679
2011-2012	4	1.115	0.802	1.004	1.111	0.901
2012-2013	5	0.929	0.969	0.986	0.942	0.900
2013-2014	6	1.010	1.063	0.962	1.050	1.074
2014-2015	7	1.089	0.870	0.994	1.096	0.947
2015-2016	8	0.991	1.080	0.995	0.996	1.070
2016-2017	9	0.942	1.241	0.974	0.967	1.169
2017-2018	10	1.130	0.906	1.026	1.101	1.024
Average Value		1.021	1.021	0.988	1.031	1.047

Figure 2 is drawn based on the TFP parameters in the statistical results of Table 2 to show the changes in the overall innovation efficiency of the high-tech industry. Each year's TFP parameter is the rate of change of the innovation efficiency index of the current year compared to the previous year.

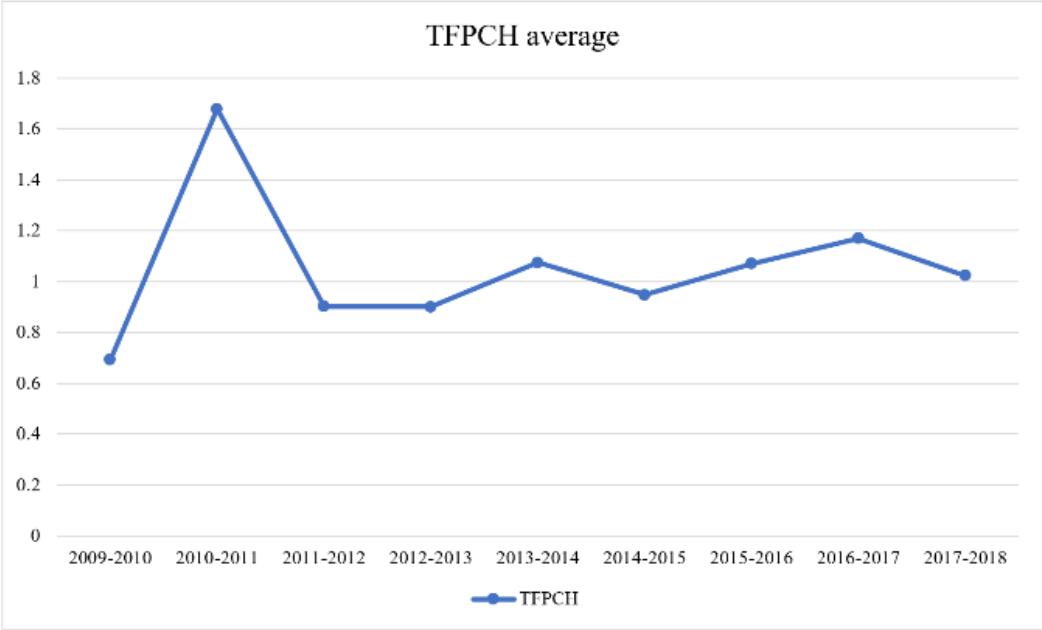


Figure 2 The overall innovation efficiency change rate of the high-tech industry TFPCH

On the whole, the average TFP change rate of the comprehensive innovation index is 1.047, indicating that the comprehensive innovation efficiency of China's high-tech industry has been steadily improving in the past 10 years, innovation activities have continued to increase, and the level of science and technology has also been continuously improved.

From the perspective of annual changes, the change rate of China's high-tech industry comprehensive innovation index 2010-2011 was particularly different, reaching 1.677, indicating that the current high-tech industry comprehensive innovation TFP efficiency increased by 67.9% compared with 2009-2010, which was mainly due to "The global financial crisis" in 2008 led to a decrease in innovation input and output indicators for the current period (2008, 2009). With the recovery of the economic level and the increase in the scale of R&D investment in 2010, it directly led to a substantial increase in the innovation efficiency of high-tech industries in 2010-2011.

From 2010 to 2018, three of the annual innovation efficiency TFP indexes were between 0.9 and 1.0, and the innovation efficiency index was relatively stable,

mainly due to the weak technological change index of the current scientific research activities. In the last three years, all were greater than 1.0, indicating that China's innovation efficiency has continued to improve, mainly due to the increase in the level of scientific research technology and the scale of scientific research breakthroughs.

4.2 Malmquist innovation efficiency index analysis of various industries in the high-tech industry

According to the analysis results of the DEAP software, the comprehensive innovation index change rate information table of each industry in the high-tech industry is compiled, as shown in Table 3.

Table 3

Malmquist index summary of firm means

INDUSTRY	FIRM	EFFCH	TECHCH	PECH	SECH	TFPCH
Electronics and communications manufacturing	1	1.003	1.055	1.000	1.003	1.058
Computer equipment manufacturing	2	1.000	1.005	1.000	1.000	1.005
Aerospace manufacturing	3	1.150	1.015	1.000	1.150	1.167
Medical device manufacturing	4	1.000	0.946	1.000	1.000	0.946
Pharmaceutical manufacturing	5	0.933	1.004	0.936	0.996	0.936

Among them, according to the TFPCH parameters in Table 3, the innovation efficiency change rate of 5 industries in the high-tech industry in the past 10 years is obtained, and an intuitive chart is drawn, as shown in Figure 3.

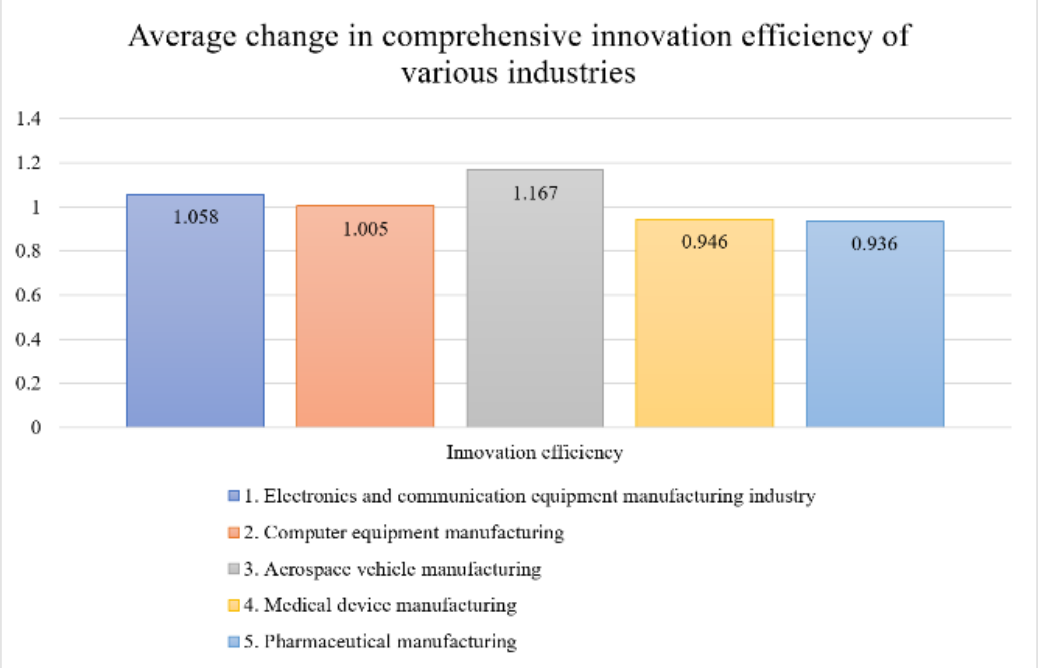


Figure 3 The average value of TFPCH in the innovation efficiency change rate of each industry in the high-tech industry

It can be seen intuitively from Figure 3 that in the past 10 years, China has made tremendous progress in the communications equipment manufacturing, computer equipment manufacturing, and aerospace vehicle manufacturing industries. Innovation efficiency has increased year by year, and the level of science and technology has also been continuously improved. Among them, the innovation efficiency of the aerospace manufacturing industry has increased the most. It can be seen from Table 3 that it is mainly caused by SECH (R&D investment scale) and EFFCH (renewal of scientific research technology), indicating that China has invested huge funds in the aerospace field and technical support, and achieved outstanding achievements.

The TFPCH index of the medical device manufacturing industry and the pharmaceutical manufacturing industry is below 1.0, indicating that China's research and development foundation in this field is relatively weak and the innovation efficiency is not high in the past 10 years. These two fields have always been weak industries in China's industry and require more capital investment and R&D accumulation. According to the "Made in China 2025" plan, "biomedicine and high-performance medical devices" are priority areas of technology for development. In the next 10 years, the comprehensive innovation index of China's pharmaceutical and medical fields may increase rapidly.

5 Conclusions and recommendations

This paper adopts DEA data envelopment analysis method, combined with Malmquist index, and DEAP 2.1 software. By analyzing the scientific research data of China's high-tech industry from 2008 to 2018, the Malmquist index of the comprehensive innovation efficiency of China's high-tech industry in the past 10 years is obtained, including Annual comprehensive and detailed indicators such as EFFCH (technical change rate), TECHCH (technical update rate of change), PECH (pure technical efficiency change rate), SECH (scale change rate), TFPCH (comprehensive production change rate), etc., and then detailed It analyzes the changes in the overall innovation index of China's high-tech industry and the changes in the sub-industry innovation index, and analyzes the specific reasons for these changes.

The overall innovation efficiency of China's high-tech industry has been increasing year by year. The electronics and communications manufacturing, aerospace, and computer equipment manufacturing industries have developed well, and the innovation index has increased rapidly. However, the comprehensive innovation efficiency index of the medical device manufacturing and pharmaceutical manufacturing industries has not increased significantly, and there is a problem of low innovation efficiency. Based on the above research results, in order to improve the innovation level of China's high-tech industry, the following optimization opinions and policy recommendations for scientific research activities are proposed:

First, increase scientific research investment. For the electronics and communications manufacturing, and computer equipment manufacturing industries, investment in research and development should be increased, which will help enhance the industry's innovation level. In the field of aerospace manufacturing, technology introduction and talent investment should be increased. While maintaining R&D funding, the level of innovation will be even greater. For the fields of pharmaceutical manufacturing and medical devices, it is necessary to increase investment in basic research and development facilities, promote talent training and introduction, and strengthen financial support, which will benefit the level of technological innovation in these two fields and enhance industry competitiveness.

Second, reasonable resource allocation. The continuous improvement of China's technological level is due to the rapid development of China's economy, which has invested a lot of capital and manpower in high-tech fields, but excessive resource investment has caused a waste of resources in some areas. Therefore, under current conditions, improving resource utilization and optimizing the industrial structure are one of the urgent problems in China's industrial sector.

Third, take the path of sustainable development. While vigorously developing industry, we must also pay attention to the protection of the ecological environment. The development of high-tech industries has a stimulating effect on all industrial sectors and is a key development area in China under the current severe international environment. High-tech industries are generally accompanied by problems such as high pollution and high energy consumption. How to develop green, sustainable, and environmentally friendly production technologies on the premise of improving the industrial level and improving industrial competitiveness is related to the development of the entire society and China's future sustainable competitiveness.

References

1. Dan Wang, Xinli Zhao (2016) "The Time Lags Effects of Innovation Input on Output in National Innovation Systems: The Case of China", Discrete Dynamics in Nature and Society, 15.

2. National Bureau of Statistics of China. http://www.stats.gov.cn/.

3. Qian Xuesen, Yu Jingyuan, Dai Ruwei (1990) A new scientific field-open complex giant system and its methodology. Journal of Nature 1: 3-10.

4. Li Meijuan, Chen Guohong (2003) Research and Application of Data Envelopment Analysis (DEA). China Engineering Science 6: 88-94.

5. Wu Qi, Wu Chunyou (2009) Research on Energy Efficiency Evaluation Model Based on DEA. Management Science 1:103-112.

6. Yang Qingke, Duan Xuejun (2014) Research on the Spatiotemporal Measurement and Provincial Differences of High-tech Industry Development Efficiency Based on DEA-Malmquist Model. Economic Geography 7: 103-110.

7. Wang Haifeng, Luo Yafei, Fan Xiaoyang (2010) International comparison of R&D innovation evaluation based on super-efficiency DEA and Malmquist index. Science of Science and Management of Science and Technology 4: 42-49.