Research on the Evaluation of Technological Innovation Efficiency of Different Industrial Enterprises in China

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ABSTRACT

This paper takes 21 kinds of industrial enterprises above designated size with different property rights in China from 2015 to 2017 as the research object. The construction input indicators are the full-time equivalent of R&D personnel, R&D expenditure, new product development expenditure while output indicators are the number of patent applications and new product sales. Revenue is used as an indicator system to measure the efficiency of technological innovation. Based on the investment perspective, the BC²-DEA model and the Malmquist-DEA model are used to calculate. The results show that the overall technological innovation efficiency of industrial enterprises above designated size in China has not reached the DEA efficiency. The reason is related to the disadvantages of the nature of the enterprise. For example, a wholly state-owned enterprise has no residual recourse and lacks of fundamental interest drive, which leads to its low efficiency in technological innovation. Finally, in view of the status quo of technological innovation efficiency of industrial enterprises above designated size in my country, appropriate suggestions for improving technological innovation efficiency are put forward.

Keywords: efficiency of technological innovation, DEA, industrial enterprises above designated size

1. INTRODUCTION

With the advance of reform and opening up, the driving force of China's economic development has changed from mainly relying on factor input and external demand to relying on innovation to drive and expand domestic demand. At this stage, the key is to promote the development of China's real economy quality to speed up the industrial transformation and upgrading, improve enterprise technology innovation ability (Huang Congying, 2019), and the technical innovation and transformation and upgrading are a collaborative process (yu-mei wang, 2018). The process of enterprise transformation and upgrading must pay attention to the role of technological innovation. The enterprises are the main body of technological innovation. Improving their technological innovation capabilities is crucial to the transformation and upgrading of China's industrial structure, at the same time, industrial enterprises above designated size of far-reaching influence on the economic development of our country. Therefore, improving the efficiency of technological innovation of industrial enterprises above designated size is crucial to the high-quality development of my country's economy. Enterprises of different properties have different capital, technology, and systems, so their access to resources and sources of technological innovation will be different, to explore the differences of different nature of the enterprise technology innovation efficiency and its causes, conducive to the rational allocation of resources, optimize the industrial structure Therefore, this paper intends to explore

the overall technological innovation efficiency of industrial enterprises with different properties in China and the differences in technological innovation efficiency of enterprises with different properties, in order to put forward some reasonable suggestions and countermeasures for improving the technological innovation efficiency of industrial enterprises with different properties in China.

2. LITERATURE REVIEW

2.1. Technical Innovation Efficiency Index System

For the construction of index system of technology innovation, scholars in our country is usually by divided into two categories, input and output indicators for input indicators, usually from human capital, such as choosing appropriate indicators, such as liu full personnel feng (2016) in research activities such as spending on science and technology activities at the end of the fixed assets as input indicators analyzed the innovation efficiency of China's high-tech development zone; Deng-zhen dong (2018) in research and development activities such as personnel or r&d professionals are all equivalent public sector enterprises r&d expenditures within r&d funding for professional and technical personnel strength and technical innovation funds for investment index, explores the

technological innovation efficiency of hubei province for the output indicators choice, common indicators divided into new product sales income (hong-chang mei, etc., 2016) patent application number (Chen Yuanzhi, 2018). The number of new product development projects (Xiao Wen et al.,2014) and the technical market turnover (Li Hongxi et al.,2016). Chinese scholars choose the appropriate indicators to study according to the characteristics of their respective research objects.

2.2. Research Methods of Technological Innovation Efficiency

Approach to the study of the technological innovation efficiency is roughly divided into the data envelopment analysis (DEA) and stochastic analysis of previous two methods, such as Liu Yongsong (2019) using the two-stage network DEA method to South Asia, we made empirical analysis on the innovation efficiency of southeast Asian nations, Shen Qiongdeng (2019), using the three stage DEA explores the technology innovation, system innovation and upgrading of industrial transformation in central China wang yan (2017), such as the relationship between the SFA model empirical analysis on the efficiency of technological innovation in the equipment manufacturing industry in xinjiang region and its influencing factors Yin Shuying (2016), such as using the stochastic frontier production function model is beyond, 2009 in 2013 to our country medicine enterprise has carried on the empirical research on the technological innovation efficiency of DEA is a non-parametric method, however, can handle multiple input multiple output problems, and do not need to provide a priori is a bit of weight information, therefore, the paper used DEA model for empirical analysis.

2.3. Empirical Research on Technological Innovation Efficiency of Industrial Enterprises

The empirical research on the technological innovation efficiency of industrial enterprises is basically based on different research objects to construct different index systems and use different methods to calculate. Yan Meng et al. (2015) used DEA methods to empirically analyze the technology of industrial enterprises in my country from 2011 to 2013. Regional differences in innovation efficiency. Chen Yuanzhi et al. (2018) used DEA to compare the technological innovation efficiency of large and medium-sized enterprises and high-tech enterprises in my country from 2009 to 2015. Xiao Wen et al. (2014) used the SFA model to study the impact of government

expenditure and R&D management on the efficiency of technological innovation from 2000 to 2009.

3. RESEARCH DESIGN

This article is mainly to evaluate and analyze the technological innovation efficiency of industrial enterprises of different natures in my country. Therefore, according to the different types of enterprise registration, 21 types of industrial enterprises above designated size of different natures in my country are selected as the samples for this study, calculate the three years from 2015 to 2017, based on the technological innovation efficiency of existing literature research on technological innovation efficiency index, combined with the availability and scientific principles of data, the paper will use R&D personnel of full-time equivalent ,R&D funds, Spending on new product development as input indicators, the number of patent applications and new product sales income as a measure of the technological innovation efficiency of output indicators. All index data from CSMAR database. To make the data comparable, using 2015 as the base period, the input index of R&D funds and new product development funds using GDP figures for the deflator, the two output indexes with producer price index for the deflator.

4. EMPIRICAL RESULTS AND ANALYSIS

4.1. Measurement and Analysis of Technological Innovation Efficiency of Different Industrial Enterprises Based on BC Model

Based on the input perspective, this paper uses the variable return to scale DEA model (BC² model) to measure the technological innovation efficiency of 21 types of industrial enterprises above designated size from 2015 to 2017. There are three input variables and two output variables. The panel data after the deduction calculation is calculated using DEAP2.1 software. Among them, crste represents the overall efficiency of the company, vrste represents the pure technical efficiency of the company, and scale represents the scale efficiency of the company; Drs, -, irs respectively represent the diminishing, constant, and increasing state of the company's return to scale during the calculation period; at the same time, the comprehensive efficiency (that is, technical Innovation efficiency) = pure technical efficiency $\times$ scale efficiency. The calculation results are shown in Table 1:

Table 1 Calculation results of BC² model for industrial enterprises of different nature

The enterprise type	crste	vrste	scale	
Domestic enterprises	0.803	1.000	0.803	drs

State-owned enterprises (soes)	0.895	0.903	0.991	drs
Table 1, cont				
Collective owned enterprise	0.733	1.000	0.733	drs
Joint stock cooperative enterprise	0.953	0.953	1.000	-
consortium	0.877	0.888	0.988	drs
State-owned joint venture	1.000	1.000	1.000	-
Limited Liability (Company)	0.645	0.814	0.793	drs
Wholly State-owned (company)	0.713	0.747	0.954	drs
Limited Stock (company)	0.818	0.887	0.922	drs
The private enterprise	1.000	1.000	1.000	-
Other domestic enterprises	0.995	1.000	0.995	drs
Hong Kong, Macao and Taiwan investment enterprises	0.919	1.000	0.919	drs
A joint venture between the mainland and Hong Kong, Macao and Taiwan	0.848	0.906	0.936	drs
The mainland and Hong Kong, Macao and Taiwan cooperative enterprises	0.825	0.880	0.937	drs
Hong Kong, Macao and Taiwan sole proprietorship enterprises	1.000	1.000	1.000	-
Hong Kong, Macao and Taiwan Investment Co., LTD.	0.787	0.843	0.934	drs
Foreign-invested enterprise	0.864	1.000	0.864	drs
Sino-foreign joint venture	0.978	1.000	0.978	drs
Chinese-foreign contractual joint ventures	0.818	0.871	0.939	drs
The foreign capital enterprise	0.753	0.838	0.899	drs
Foreign investment Limited (company)	0.608	0.865	0.703	drs
The average	0.849	0.924	0.918	

From the comprehensive efficiency of state-owned associated enterprises, private enterprises and Hong Kong, Macao and Taiwan owned enterprise in comprehensive DEA effective area, and the comprehensive efficiency of foreign-funded companies limited by shares value minimum of only 0.608, this and XiaoRenQiao (2015), the empirical results conform to this may be associated with foreign investment co., LTD, it is a foreign investment may be a better introduction of foreign technology, but it may be in the company's internal governance in relation to other property companies caused by defects. State-owned joint ventures, Hong Kong, Macao and Taiwan individual proprietorship enterprises to achieve comprehensive effective DEA may be because of its relative in capital, technology and institution arrangement other enterprises have some significant advantages, at the same time, Hong Kong, Macao and Taiwan owned enterprise may also can be in Hong Kong, Macao and Taiwan regions have advantages of technological innovation directly into mainland area, relative to other property companies may on the transformation of technological innovation achievements have certain time advantage. And the private enterprise is relatively state-owned consortium and Hong Kong, Macao and Taiwan owned enterprise in such aspects

as capital, technology is not dominant, but the clarity of property rights of private enterprise, innovation of residual claims and residual control, thus in the innovation cost reduce research and development of new products has a strong power, this may be a private enterprise technological innovation efficiency is the key to achieve comprehensive DEA effective. However, the value of technological innovation efficiency of 21 industrial enterprises with different properties is 0.849, indicating that the technological innovation efficiency of industrial enterprises in China has not yet reached the optimal level, and there is still a certain potential for improvement.

From the perspective of returns to scale, t the vast majority of industrial enterprises are in the stage of diminishing returns to scale, and only four types of enterprises are in the stage of constant returns to scale. This shows that the different properties of the vast number of industrial enterprises in our country exists shortage of input redundancy and output, can be in the future through downsizing to improve efficiency of technological innovation.

From the perspective of pure technical efficiency, the overall pure technical efficiency is 0.924, indicating that the overall technological innovation utilization of China's industrial enterprises is relatively good, but there is still some room for improvement. However, the pure technical efficiency of the sole state-owned enterprise is only 0.747, which is seriously lower than the average level, which may be related to the nature of the sole state-owned enterprise,

which has no residual claim and lacks the fundamental interest-driven mechanism.

From the perspective of scale efficiency, scale efficiency is the effect of the configuration of the industrial structure on the output unit. It reflects the gap between the existing scale and the optimal scale under the premise of a certain system and management level. In the three years from 2015 to 2017, the scale efficiency of industrial enterprises above designated size in my country was 0.918, which did not reach 1, indicating that the overall scale efficiency has not yet reached the optimal, and the overall scale efficiency has not been achieved.

4.2. Measurement and Analysis of Technological Innovation Efficiency of Different Industrial Enterprises Based on Malmquist Index

In order to further analyze the change of technological innovation efficiency of industrial enterprises above a certain scale in China from 2015 to 2017, this paper uses the Malmquist index to decompose the total factor productivity. The panel data of input-output indicators of 21 different types of industrial enterprises above designated size from 2015 to 2017 are calculated using DEAP2.1 software. Table 7 shows the calculation results.

Table 2 Measured results of technological innovation efficiency of industrial enterprises of different nature based on Malmquist

Type of enterprise	effch	techch	pech	sech	tfpch
Domestic enterprises	1.050	0.999	1.000	1.050	1.049
State-owned enterprises (soes)	0.897	1.036	0.950	0.945	0.930
Collective owned enterprise	1.168	1.415	1.000	1.168	1.653
Joint stock cooperative enterprise	0.911	1.008	0.925	0.985	0.918
consortium	0.962	0.891	0.974	0.988	0.858
State-owned joint venture	1.000	0.720	1.000	1.000	0.720
Limited Liability (Company)	1.105	0.979	1.055	1.047	1.081
Wholly State-owned (company)	1.032	0.997	1.033	0.999	1.029
Limited Stock (company)	1.072	0.992	1.056	1.015	1.063
The private enterprise	1.000	1.028	1.000	1.000	1.028

Table 2, cont					
Other domestic enterprises	0.838	1.019	0.837	1.001	0.854
Hong Kong, Macao and Taiwan investment enterprises	1.006	0.979	1.000	1.006	0.986
A joint venture between the mainland and Hong Kong, Macao and Taiwan	1.016	0.969	0.983	1.034	0.985
The mainland and Hong Kong, Macao and Taiwan cooperative enterprises	1.049	0.965	1.027	1.022	1.013
Hong Kong, Macao and Taiwan sole proprietorship enterprises	1.000	0.973	1.000	1.000	0.973
Hong Kong, Macao and Taiwan Investment Co., LTD.	0.966	0.971	0.934	1.034	0.938
Foreign-invested enterprise	1.017	0.959	1.000	1.017	0.975
Sino-foreign joint venture	1.011	0.980	1.000	1.011	0.991
Chinese-foreign contractual joint ventures	1.044	0.967	1.010	1.033	1.009
The foreign capital enterprise	1.022	0.947	0.979	1.044	0.967
Foreign investment Limited (company)	1.078	0.906	0.915	1.178	0.976
The average	1.009	0.980	0.984	1.024	0.989

From the calculated results, the average value of Malmquist index of 21 industrial enterprises of different sizes was 0.989, indicating an overall downward trend at an average annual rate of 1.1%. By Malmquist index can be decomposed into two aspects of the comprehensive technical efficiency change and technological progress, can be inferred from the table data associated with a decrease in total factor productivity of technical progress index, it shows that with the advent of the era of knowledge economy, science and technology innovation become the competitive advantage of enterprises, technological progress to promote the industrial enterprises above designated size the decisive factors in technological innovation efficiency. Although at the same time, China's industrial enterprises above designated size technological innovation efficiency is on the decline, the cause of all kinds of enterprise technology innovation efficiency decline each are not identical, such as the joint stock cooperative system enterprises technological innovation efficiency decline is caused by a comprehensive technical efficiency change index fell, and Hong Kong, Macao and Taiwan investment holding co., LTD., because of the comprehensive changes in technical efficiency and technical progress index decreased.

From the perspective of technological progress, in addition to state-owned enterprises, collective enterprises, joint-stock cooperative system enterprises, private enterprises and other domestic enterprises technological progress index greater than 1, the other are less than 1, it may be related to the rapid economic development of our country at present stage, the economic environment of enterprises and environmental regulation makes the enterprise is not

consistent with the original technology and economic development, the state-owned enterprises and collective enterprises in the capital, the policy has a relative to other types of other obvious advantages, so in the economic situation changes, for the use of new technology may have a greater advantage. Private enterprises are consistent in innovation residual recourse and residual control right and may pay more attention to pursuing technological progress to reduce costs.

From the perspective of pure technical efficiency changes, the overall pure technical efficiency value is less than 1, which is consistent with the results of the BC² model. This is also one of the important factors affecting the efficiency of technological innovation of industrial enterprises above designated size in my country.

5. CONCLUSIONS AND IMPLICATIONS

This paper explores the technological innovation efficiency of China's large-scale industries from 2015 to 2017 by constructing an index system with input indexes as full-time equivalent of R&D personnel, R&D expenditure and new product development expenditure, and output indexes as patent applications and sales income of new products. The study found that (1) the technology innovation of industrial enterprises above designated size in China basic return to scale in the scale decline stage, only a few types of enterprise's technological innovation in the stage of constant return to scale, and downsizing may be above designated size industrial enterprises technological innovation efficiency in China one of the path of ascension. (2) The overall technological innovation efficiency of my country's industrial enterprises above designated size has not yet reached the DEA optimal because pure technical efficiency and scale efficiency are both lower than 1. In the future, improving the technological innovation efficiency of industrial enterprises above designated size should start from improving both pure technical efficiency and scale efficiency. Start with all aspects. (3) Judging from the results of the Malmquist index, the overall industrial enterprises above designated size in technological innovation efficiency due to technical progress and pure technical efficiency change index fell into decline, follow era technology development trend, promote enterprise technology progress and technology utilization, perhaps can improve the efficiency of technology innovation of industrial enterprises above designated size in China. (4) Enterprises of different natures have different technologies, capital, autonomous management rights and internal interest driving mechanism. Enterprises of different natures should take advantage of their own advantages and strive to improve the rate of technology research and development and conversion rate. The establishment of an appropriate internal r&d incentive mechanism may improve the technological innovation efficiency of industrial enterprises above the scale in China.

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