A Study on Evaluation on Innovation Efficiency of Advanced Manufacturing in China

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Abstract- A comprehensive evaluation was conducted on the innovation efficiency of advanced manufacturing in China from 2015 to 2017 with BCC model and super efficiency analysis and based on the data from 184 A-share listed advanced manufacturing companies. The results indicate that the total innovation efficiency, pure technical efficiency and scale efficiency of the advanced manufacturing in China are increasing year by year, especially the scale efficiency increases the most significantly; however, the advanced manufacturing is still at a relatively lower level and shows an unbalanced and insufficient development as a whole. In addition, the total innovation efficiency of 14 sub-sectors of the advanced manufacturing is increasing year by year.

1 Introduction

China's State Council has unveiled a national plan, dubbed "Made in China 2025" and designed to transform China into a world manufacturing power by "three stages", making clear that China will vigorously develop advanced manufacturing and focus on promoting a rapid development of ten key sub-sectors such as energy conservation and new energy vehicles. The development of advanced manufacturing is an inherent requirement for the transformation and upgrading of China's manufacturing as well as the only way for China to enter the stage of high-quality economic development, and plays an important role in promoting a smooth implementation of the plan "Made in China 2025"[1]. Since the plan "Made in China 2025" has been unveiled for nearly five years, whether the input-output efficiency of advanced manufacturing innovation resources has been significantly improved? Which factors are the keys affecting the innovation efficiency of advanced manufacturing and which aspects still need to be further improved?

Through references review, it can be seen that the study scope mainly includes evaluation methods, evaluation objects, influencing factors, external perspectives and others[2]. Specifically, the evaluation methods include parametric methods[3] represented by stochastic frontier analysis (SFA) of production function, and non-parametric methods[4] represented by data envelopment analysis (DEA). The study objects mainly revolve around strategic emerging industries[5] and high-tech industry[6]; and the influencing factors are centered on R&D management[7], R&D investment[8],

government subsidies[9], innovation network [10] and others. In addition, the external perspectives are mainly about the value chain perspective[11], incomplete perspective of factor market[12], and resource constraint perspective[13]. The study has an important reference significance for exploring the innovation efficiency of advanced manufacturing, but it still needs further improvement.

The improvement was to be made herein in the following two aspects: firstly, the evaluation index system of innovation efficiency of advanced manufacturing was established, with BCC model to analyze the input-output efficiency and development trend of innovation resources in the advanced manufacturing in China so as to enrich and expand the existing contents; and secondly, the A-share advanced manufacturing listed enterprises from 2015 to 2017 were selected as samples to make the study representative and practical.

2 Study Design

2.1 Introduction to Evaluation Method

Firstly proposed by Farrel (in 1957), and then studied and developed by operations research scientist A. Charnes and W. W. Cooper et al. (in 1978) based on the concept of relative efficiency, data envelopment analysis (DEA) is an efficiency analysis and evaluation method aiming at multiple inputs and outputs, among which BCC model is mainly used to evaluate that whether pure technical efficiency is effective. As the advanced manufacturing is featured by high technology, high complexity and significant variable returns to scale, BCC model which is

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more representative and more widely used among DEA models was chosen herein.

2.2 Evaluation Index System

The key to evaluate the innovation efficiency of advanced manufacturing is to construct a rational innovation efficiency evaluation index system which includes innovation resource input and output. Specifically, innovation input is mainly reflected in the input of innovation resources at the supply side and the accumulation of existing innovation resources and achievements, while innovation output is mainly reflected in new demands, new models, etc. Based on the continuity and availability of data, the following input-output indexes are adopted to evaluate the input efficiency of innovation resources by reference to relevant literatures and previous results of relevant scholars.

Table.1 Evaluation Index System of Advanced Manufacturing Resource Efficiency

Index attribute	Index name	Index description
Input index es	Proportion of R&D personnel	Total number of R&D personnel in current year / total number of personnel of enterprises in current year
	Proportion of R&D expenditure	Total R&D expenditure in current year / operating revenues in current year
	Total valid patents in current year	Natural logarithm of total valid patents held by enterprises as of the current year
	Strength of government subsidies	Total government subsidies in current period / total assets of enterprises
Output index es	Product sales performance	Natural logarithm of main operating revenues
	Growth rate of intangible assets	Change in intangible assets in current year / total assets at the end of period
	Total patents applied in current year	Natural logarithm of total patents applied by enterprises in current year
	Total patents licensed in current year	Natural logarithm of total patents licensed to enterprises in current year

2.3 Sample Selection and Data Source

As of July 2018, there were 2,224 manufacturing listed companies among the A-share listed companies in China, accounting for 63.06%, marking that manufacturing had become the leading force of A-share listed companies. As the senior form and development trend, the advanced manufacturing is an important component leading the structure optimization and high-quality development of manufacturing. As a result, it is more typical and representative to take the advanced manufacturing listed companies as the study objects. In accordance with the Statistical Classification of Emerging Industries, New Business Forms and New Business Models (2018) issued by the National Bureau of Statistics of China in 2018, the manufacturing in China covers 31 types, among which the advanced manufacturing specifically includes 14 sub-sectors such as new-generation information technology and high-end equipment manufacturing.

3 Evaluation on Innovation Efficiency of Advanced Manufacturing

Since the year of 2015 is the first year of reform implementation, the advanced manufacturing companies listed in Shanghai and Shenzhen A-share markets from 2015 to 2017 were selected as the initial samples, and the ST samples among initial samples were deleted. Finally, 184 effective samples were obtained. All these data are from China Stock Market & Accounting Research Database (CSMAR Database). With the aid of DEA-BCC model, and analysis with deap2.1, the specific results refer to Table

Table. 2 Innovation Efficiency and Proportion of Advanced Manufacturing Enterprises from 2015 to 2017

Year	TE	PTE	SE	CRS	IRS	DRS
2015	0.715	0.917	0.776	4.35%	6.43%	89.22%
2016	0.838	0.925	0.904	10.87%	9.33%	79.80%
2017	0.882	0.934	0.943	14.68%	15.14%	70.18%
mean	0.812	0.925	0.874	9.97%	10.30%	79.73%

The total innovation efficiency is increasing year by year, rising from 0.715 in 2015 to 0.882 in 2017. The annual average growth rate is 11.07%, showing a significant growth, significantly higher than China's GDP growth rate in the same period. The proportion of total listed companies realizing DEA efficiency is increasing year by year too, rising from 4.35% in 2015 to 14.68% in 2017, but still in a lower size. All these indicate that on the whole, the total innovation efficiency of the advanced manufacturing listed companies in China is not high, there is still a significant gap compared with those realizing DEA efficiency, and the insufficient amount of DEA efficiency decision-making units is one of the important reasons causing a lower total innovation efficiency.

From the perspective of pure technical efficiency, the fluctuation range in the sample period is small and remains at a relatively higher level as a whole, rising from 0.715 in 2015 to 0.882 in 2017, and showing a three-year average of 0.812, which is significantly higher than the total innovation efficiency and scale efficiency in the same period. From the perspective of scale efficiency, it shows an increasing trend in the sample period, rising from 0.776 in 2015 to 0.943 in 2017. From the perspective of increasing scale efficiency, the proportion of the enterprises with increasing scale efficiency shows an overall increasing trend, rising from 6.43% in 2015 to 15.14% in 2017; the proportion of enterprises with decreasing scale efficiency decreases year by year; and the proportion of enterprises with decreasing scale efficiency and the enterprises with increasing scale efficiency decreases from 13.9 in 2015 to 7.7 in 2017. All these show that the total innovation efficiency of the advanced manufacturing listed companies in China is

gradually improving in the sample period. On this basis, 184 sampling enterprises were classified as per the sub-sectors of advanced manufacturing to obtain the distribution of innovation efficiency of sub-sectors.

Table. 3 Innovation Efficiency of Advanced Manufacturing Sub-sector from 2015 to 2017

Sub-sectors of advanced manufacturing	Year	TE	PTE	SE	Scale type
New generation information technology	2015	0.661	0.892	0.736	drs
	2016	0.818	0.905	0.901	drs
	2017	0.867	0.918	0.942	drs
High-end equipment	2015	0.752	0.923	0.812	drs
	2016	0.860	0.926	0.926	drs
	2017	0.871	0.922	0.944	drs
Advanced steel and iron material	2015	0.781	0.943	0.824	drs
	2016	0.803	0.945	0.846	drs
	2017	0.883	0.955	0.925	drs
Advanced nonferrous material	2015	0.760	0.937	0.801	drs
	2016	0.846	0.952	0.885	drs
	2017	0.906	0.953	0.949	drs
Advanced petrochemical and chemical	2015	0.628	0.925	0.675	drs
	2016	0.834	0.945	0.882	irs
	2017	0.932	0.971	0.959	drs
Advanced inorganic nonmetal	2015	0.700	0.904	0.773	drs
	2016	0.777	0.908	0.852	drs
	2017	0.864	0.922	0.932	drs
High performance fiber and compounds	2015	0.688	0.917	0.747	drs
	2016	0.808	0.920	0.876	drs
	2017	0.869	0.938	0.924	drs
Cutting-edge new materials	2015	0.736	0.908	0.805	drs
	2016	0.845	0.928	0.908	-
	2017	0.884	0.931	0.948	drs
Bio-based products	2015	0.696	0.910	0.761	drs
	2016	0.851	0.944	0.898	drs
	2017	0.876	0.951	0.917	irs
Biomass fuel	2015	0.770	0.944	0.816	drs
	2016	0.761	0.874	0.871	drs
	2017	0.890	0.933	0.953	drs
Bio-manufacturing	2015	0.664	0.933	0.706	drs
	2016	0.767	0.903	0.847	drs
	2017	0.895	0.935	0.955	drs
New energy automobile and related equipment	2015	0.756	0.945	0.796	drs
	2016	0.902	0.951	0.949	drs
	2017	0.907	0.957	0.947	drs
New energy equipment	2015	0.657	0.898	0.726	drs
	2016	0.861	0.921	0.933	drs
	2017	0.896	0.931	0.960	irs
Energy conservation and environmental protection equipment and products	2015	0.743	0.906	0.818	drs
	2016	0.841	0.904	0.928	drs

	2017	0.842	0.902	0.931	drs
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According to Table 3, the PTE of 14 sub-sectors shows a slowly increasing trend on the whole. Except for individual values, the PTE values maintain above 0.9, with a high concentration degree, a small fluctuation range, and a small impact on the TE. From the change trend of TE, the biomass fuel manufacturing shows a "V-shaped" structure, and the remaining 13 sub-sectors shows an increasing trend year by year. Among which, 8 sub-sectors including the high-end equipment manufacturing, advanced iron and steel materials manufacturing, advanced non-ferrous metal materials manufacturing show a higher increasing trend than the average level of the advanced manufacturing as a whole. In addition, the SE of the 14 sub-sectors is increasing year by year.

4 Main Conclusions

With the innovation efficiency of the advanced manufacturing in China as evaluation object, the data from 184 enterprises listed in Shanghai and Shenzhen A-share markets from 2015 to 2017 as samples, and based on the input-output overall evaluation analysis with DEA-BCC model, the main conclusions are as follows:

Firstly, the total innovation efficiency, pure technical efficiency and scale efficiency of the advanced manufacturing in China are increasing year by year, among which the scale efficiency increases the most significantly, and it is the main factor causing an increasing total innovation efficiency year by year. From the perspective of the proportion of enterprises with constant returns to scale, the proportion of units realizing DEA efficiency is still small, and most decision-making units are in the stage of decreasing returns to scale, indicating that although the innovation efficiency of advanced manufacturing listed companies in China shows a significant growth rate, the advanced manufacturing is still at a relatively lower level and shows an unbalanced and insufficient development as a whole.

Secondly, the total innovation efficiency of the 14 sub-sectors of advanced manufacturing is increasing year by year. Among them, the average innovation efficiency growth rate of 8 sub-sectors including high-end equipment manufacturing is higher than the average of the advanced manufacturing; and that of such 6 sub-sectors including new generation information technology equipment manufacturing is lower than the overall average. The pure technical efficiency of the 14 sub-sectors shows a slow increasing trend, while the scale efficiency shows a rapid growth trend, which is the main reason influencing the change of the total innovation efficiency of the 14 sub-sectors. Through super efficiency analysis, the relative efficiency ranking of the 14 sub-sectors can be further obtained, the DEA of cutting-edge new materials is relatively effective and ranks the highest, and the remaining 13 sub-sectors do not realize DEA efficiency.

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