Gray Relation Analysis of China's Manufacturing Export Trade and Technology Innovation Efficiency

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Abstract: Based on the overall data of China's large and medium-sized manufacturing enterprises from 1999 to 2017, the Gray Relation Analysis is used to study the relationship between export trade and technological innovation efficiency of Chinese manufacturing enterprises. Firstly, the Radial super-efficiency DEA model is used to calculate the technological innovation efficiency of the manufacturing industry. Then, the gray correlation coefficient between the export trade and the technological innovation efficiency is calculated. The results show that the gray relation correlation is large in different years between the export trade of China's manufacturing industry and the research and development efficiency of enterprises, and the interval is 0.37-1.13.The average correlation degree is 0.6, indicating that there is a certain correlation between the export trade of manufacturing enterprises and the efficiency of the research and development.In 2009, the gray relation correlation reached a peak of 1.13 which is not surpassed later years.It indicates that this relationship is easily affected by changes of the international environment.

Introduction

Since the reform and opening up, with the comparative advantages of demographic dividend and low labor price, China has made certain achievements in foreign trade, and has become one of the indispensable major economies in the global economic market. Earning foreign exchange for export goods is an important driving force for driving the country's economic development. The data shows that China’s exports to foreign economic trade in 2018 totaled more than 16 trillion yuan. At the same time, the National Bureau of Statistics data shows that China’s large and medium-sized manufacturing enterprises have steadily increased their the research and development investment in new products every year from 1999 to 2017. The growth of 35 times has promoted the technological innovation of enterprises. In terms of the number of patent applications, in 2019, the top 500 enterprises of China filed a total of 1,108,000 patents, an increase rate of 15.97% over the previous 2018. 405,600 invention patents of all patents were fullfiled an increase rate of 17.40% over the previous year, and the number of invention patents continued to grow for nine consecutive years[1].

At present, scholars have some main conclusions on the relations of export trade and technological innovation at home and abroad. For example, According to J. Damijan and M. Rojec (2008) ,neither product innovation nor process innovations had no influence on the company’s first entry into the export market[2].However, Bruno, Elena and Ester Martínez（2010）used Spanish manufacturing companies 1990 -1999 data as a sample to point out that product innovation can affect the decision of the enterprise to enter or not enter the market abroad to a certain extent[3]. O. Becker and H. Egger (2013) also found that product innovation of company plays an important role on the export decision-making on the basis of German manufacturing 1994 - 2004 data[4]. In China, some scholars have obtained some conclusions according to enterprises of China. For example,

Z.Y.Kang (2011) believes that there may be some complicated relationship between export trade and innovation. The scale of enterprises plays a regulatory role in the impact of export trade on technological innovation. The greater the scale of enterprise exports, the more obvious the promotion of independent innovation. Smaller corporate exports have an inhibitory effect on technological innovation[5].Based on the perspective of corporate strategic objectives and using the survey data of 14,000 high-tech enterprises in China in 2005-2008, F.C.Li(2013)got conclusions that" learning in export" will significantly inhibit independent research and development for the enterprises that pursue short-term profit maximization. But, "learning in export" strongly promotes independent research and development for the enterprises that pursue long-term performance[6].Researches on specific industries also shows that technological innovation has a positive effects on the export trade of high-tech industries[7,8,9],and there are differences in the impact of technology-intensive and capital-intensive industries[10].According to research by X.Y. Hu, X.H. Huang and X.Z. Li(2017), innovation behaviors of different natures have heterogeneous effects on exports, product innovation has nibbling effect, and process innovation has scale effect [11].

In view of scholars' different conclusions on export trade and technological innovation, this paper will focus on whether there is a correlation between export trade and manufacturing technology innovation efficiency of China's manufacturing industry and expand relevant research results.

Research Design and Data Selection

Research Design. The research process of this paper consists of two parts. One is to measure the efficiency of enterprise technology innovation of China's manufacturing industry using the Radial super-efficiency DEA model(Data Envelopment Analysis, DEA), and the other is to study the Gray Relation Degree between export trade and technological innovation efficiency.

Data Selection. According to many research conclusions at home and abroad, the company's research and development investment mainly includes capital investment and personnel input. Capital investment is used for the development of new technology, so it is measured by developing new product funds, which is named RDF. Personnel input is measured by the full-time equivalent of the test development personnel, which is called RDP. The research and development output is measured by sales revenue of new products. The sales revenue refers to the special income that manufacturing companies receive in the separate sales of new products, which is called RDQ. Exports are measured by industrial exports of manufactured goods, which is expressed by EX. The data of all indicators in this paper are from large and medium-sized manufacturing enterprises. As shown in table 1.

Table 1. Personnel input (RDP),capital investment (RDF), output (RDQ) and export trade (EX) data from 1999 to 2017

Time	RDP [ten thousand person]	RDF [ten thousand RMB]	RDQ [ten thousand RMB]	EX [hundred Million $]
1999	303000	303000	55500490	174990
2000	329413	329413	76413741	223743
2001	379321	379321	87940000	239760
2002	424259	424259	108380000	297056
2003	478066	6389593	140980000	403416
2004	438164	8209592	204212346	552777
2005	606376	14571958	240970910	712916
2006	695668	18629418	312328084	916017
2007	857649	24533448	409761681	1156267
2008	1014223	30955692	512916075	1352736
2009	1158839	36546131	579780546	1138483

2010	1369908	44206917	728638982	1496069
2011	1587164	56971680	886502359	1797836
2012	1818585	65718382	981921709	1948156
2013	1976735	74406399	1125619063	2101736
2014	2037661	79532787	1236008147	2229601
2015	1985983	79788542	1290765862	2169541
2016	1964441	89037617	1473363553	1992444
2017	1931419	100640571	1599569497	2145638

Empirical Analysis

Estimation of the Efficiency of Technological Innovation in Manufacturing Enterprises. In this paper, we select the Radial super-efficiency DEA model to measure technological innovation efficiency of manufacturing enterprises.The basic idea is that for DEA effective decision making unit, the radial super-efficiency model performs a second calculation on its production frontier, making its efficiency value exceed 1, and the efficiency value can be compared and sorted.For dea-ineffective decision making unit, the radial super-efficiency model does not change its production frontier, maintaining its efficiency value unchanged. In this way, all decision making units can be arranged in order according to the efficiency value, which is convenient for comparative analysis.

This paper focuses on the increase of export brought by increasing the RDP and RDF from the manufacturing enterprises,rather than the increasing of exports caused by external factors. Therefore,the Radial super-efficiency DEA model is chosen instead of the non-radial model.

Using the DEA-solver software,we get the enterprise technology innovation efficiency which is defined as S . The calculation results are shown in table 2 below.

Table 2. Technological innovation efficiency (S)of China's manufacturing enterprises (keeping two decimal places)

Time	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
S	0.71	0.79	0.86	0.84	0.91	1.46	1.40	0.90	1.32	0.93
Time	2009	2010	2011	2012	2013	2014	2015	2016	2017	
S	0.99	0.91	0.93	0.88	0.81	0.80	0.94	0.97	0.95	

The results in table 2 show that the technological innovation efficiency of China's manufacturing enterprises had been increasing rapidly since 1999, and reached the maximum in 2004. From 2003 to 2007, the technological innovation efficiency of enterprises was at the best stage, with a high level.However, it has been slowly declining since 2008. Although it is still at a low level in the later period, it has not entered the ultra-high level of technological innovation efficiency.

China has implemented the strategy of rejuvenating the country through science and education since 1995.This great strategy directly promotes science and technology research funds investment and personnel input. In particular, the "Decision of the Central Committee of the Communist Party of China on Strengthening Technological Innovation, Developing High Technology, and Realizing Industrialization of Production" issued by China in 1999 directly promoted the enthusiasm and investment of enterprises in research and development of new products, and brought the rise in the efficiency of technological innovation in enterprises. However, the global economic crisis of 2008 caused the global economy to be hit hard. Although China is properly handled in the face of the economic crisis, it cannot completely escape the harm caused by the economic crisis. The research and development efficiency of China's manufacturing enterprises has declined greatly in 2008 and keeping the subsequent downturn.

Gray Relation Analysis of Export Trade and Technological Innovation Efficiency. First of all, the data of technological innovation efficiency and export trade are dimensionlessly processed

to make the data dimension consistent. Technological innovation efficiency is named S and export trade is named EX.The process includes four steps.Firstly, we obtain the average value of S and the average value of EX.Secondly,S and EX are separately divided by its owe average value to obtain new mean values which are called AS and AEX.Thirdly,calculating the absolute value of difference between AS and AEX in 1999-2017, which is expressed by AD, and then we get the maximum value called MAX and the minimum value called MIN from AD.Finally,according to the Eq.1,we can get the Gray Relation Coefficient which is expressed by GRC.

$$GRC = \frac{MIN + \rho * MAX}{S + \rho * MAX} \tag{1}$$

In the Eq.1, ρ is the relation coefficient, $0 \le \rho \le 1$, and generally $\rho = 0.5$[12]. The Gray Relation Degree[13] is the average value of the gray relation coefficient,which is called GRD.The calculation results are shown in table 3 below.

Table 3. Grey relation coefficient and Grey relation degree between export trade and technological innovation efficiency (keeping two decimal places)

Time	AS	AEX	AD	GRC	Time	AS	AEX	AD	GRC	GRD
1999	0.74	0.14	0.60	0.55	2009	1.03	0.94	0.09	1.13	0.60
2000	0.82	0.18	0.63	0.53	2010	0.95	1.23	0.29	0.8	
2001	0.89	0.2	0.69	0.5	2011	0,96	1.48	0.52	0.6	
2002	0.87	0,24	0.63	0.53	2012	0.92	1.61	0.69	0.5	
2003	0.95	0.33	0.61	0.54	2013	0.84	1.73	0.89	0.43	
2004	1.52	0.46	1.06	0.37	2014	0.83	1.84	1.01	0.39	
2005	1.45	0.59	0.86	0.43	2015	0.98	1.79	0.81	0.45	
2006	0.93	0.76	0.17	0.96	2016	1.01	1.64	0.63	0.53	
2007	1.37	0.95	0.42	0.67	2017	0.98	1.77	0.79	0.46	
2008	0,96	1.12	0.15	1						

Table 3 shows that the gray relation coefficient(GRC) of export trade and the efficiency of enterprise technology innovation is different in different years,mainly due to the macro factors of policies and data itself. A gray relation degree(GRD)greater than 0 indicates that there is a correlation between the research objects, and the closer to 1 indicates the higher the degree of correlation. GRD is 0.6, indicating that there is a certain correlation between the export trade of manufacturing enterprises and the efficiency of enterprise technology innovation, but this relationship is easy to be affected by the change from external environment. When the external market environment is sluggish, both export trade and investment are affected, which in turn will affect the company's research and development activities.

Summary

According to the radial super-efficiency DEA model measurement and gray relation analysis ,we find that capital investment and personnel investment play an important role in the efficiency of technological innovation, and export trade of enterprises has a significant impact on the efficiency of technological innovation. The gray relation coefficient will fluctuate greatly with the year, but such fluctuations are susceptible to the international policy environment.

In the process of enterprise development, its own technological innovation efficiency plays an import role. And it is also necessary to pay attention to current affairs policies and the international environment, because different national policies and international economic atmosphere have different effects on the export trade of enterprises, especially in the gloomy economic situation. So, the enterprises that focus on innovation and follow the trend of the global economy will have better development.

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