Research and Development Efficiency of Chinese Agricultural Listed Companies——Based on DEA-Malmquist Model

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Abstract: In the new era, agricultural development has entered a new stage, and innovation in the agricultural industry has become more and more important. Based on the theory of technological innovation and the theory of technical efficiency, this paper uses the data of 36 agricultural-related listed companies in China from 2012 to 2015 and uses the DEA-Malmquist model to measure the total factor productivity. The empirical conclusion shows that, in 2012-2015, the average annual growth rate of R&D efficiency of listed companies involved in agriculture is negative.

1. Research Background

The fundamental direction of agricultural development lies in agricultural modernization, and the key factor of agricultural modernization lies in agricultural science and technology innovation. In recent years, China has attached great importance to agricultural science and technology innovation. In December 2016, the State Council issued the National Agricultural Modernization Plan (2016-2020), which proposed that the agricultural science and technology innovation capability should reach the leading level of developing countries in general. In 2017, the No.1 Document of the Central Government placed science and technology in a very high-profile position, and focused on “strengthening the drive of scientific and technological innovation to lead the development of modern agriculture” and proposed a series of policy measures.

At present, China's agricultural development has made great achievements, but its scientific and technological innovation capability still needs to be improved. As an important force for agricultural science and technology innovation, agriculture-listed enterprises play an important role in enhancing the ability of agricultural science and technology innovation, and strengthening the innovation ability of agriculture-related enterprises to fundamentally solve the development dilemma. R&D is an important link and source of innovation for innovation, and leads the development of innovation activities for agribusiness. R&D efficiency is an important factor to measure the innovation ability of agriculture-listed enterprises. Measuring and analyzing the research and development efficiency of agriculture-listed enterprises not only helps the agriculture-listed enterprises to find their own constraints, improve research and development efficiency, but also further promote the development of agricultural science and technology innovation.

Based on this, this paper will use the DEA-Malmquist index model to measure the research and development efficiency of China's agricultural listed companies, analyze the changes of its research and development efficiency, and further examine the impact of financing constraints on R&D efficiency, thus improving the agricultural listed companies and giving suggestions for R&D efficiency.

2. Related literature review

2.1. Foreign literature review

Foreign scholars mainly study the efficiency of agricultural R&D investment from a macro perspective, and believe that R&D is the key to transforming traditional agriculture (Anderson, 1994). However, less literature is specifically targeted at agribusinesses, and the literature has mainly evaluated the financing efficiency of agribusiness (Claracardone,2005; Columba,2010);

The foreign researches on the development efficiency are mainly concentrated in the fields of manufacturing enterprises and food enterprises. Hashimoto and Haneda (2008), JWBBos (2010), Fernando Jiménez-Sáez (2011) studied the research and development efficiency of Japanese pharmaceutical companies, EU manufacturing and Spanish food companies, and came out corresponding measures to improve the efficiency of enterprise R&D. Some scholars use the DEA model to evaluate the R&D efficiency of different companies (Mcgrath and Romeri, 1994).

2.2. Domestic literature review

There are few research literatures on the research and development efficiency of agriculture-related enterprises in China. The existing literature mainly uses traditional DEA models, regression models and related analysis methods to analyze the research and development efficiency of agricultural listed companies. Wei Changsheng and Huang Xiujuan (2015) used the 20 major agricultural listed companies of the Shenzhen Stock Exchange and the Shanghai Stock Exchange as research samples, and found that the efficiency of the R&D investment of agricultural listed companies was not optimal.

Regarding the R&D efficiency of other industries, domestic scholars mainly use the method of data envelopment analysis to study the R&D efficiency of enterprises with high technical content such as equipment manufacturing enterprises. Liang Laijun (2006), Li Haigang (2016) use the traditional DEA model to evaluate the research and development efficiency of biopharmaceutical listed companies, equipment manufacturing listed companies and innovative companies. On the basis of the traditional DEA model, some scholars use the three-stage DEA model combining SFA and DEA to empirically study the R&D input and output efficiency of high-tech industries under the conditions of eliminating environmental factors and random errors. Based on this, specific policies and recommendations for improving R&D efficiency are proposed (Li Hongwei, 2012).

2.3. Literature review

From the existing research results, we can find out: First, scholars have less research on the research and development efficiency of agriculture-related enterprises. Second, in the evaluation method of R&D efficiency, domestic and foreign scholars mainly use DEA method and SFA method. Among them, DEA method is the most widely used, but it has sole application. In view of this, this paper selects the agricultural listed companies as the research object, selects the DEA-Malmquist index model combined research method, and evaluates the research and development efficiency of China's agricultural listed companies. In addition, the impact of financing constraints on the R&D efficiency of agricultural listed companies is considered based on the information asymmetry, strong asset specificity, long research and development cycle and natural risk of agricultural listed companies.

3. Research Design

3.1. Research Content

First, measure the total factor productivity of agricultural listed companies to measure their research and development efficiency. Second, according to the results of empirical analysis, it reveals the static level of real R&D efficiency of agricultural listed companies in China and its changes, and proposes corresponding suggestions on improving the R&D efficiency of agricultural listed companies from the two levels of enterprise and policy.

3.2. Research Method

3.2.1. Literature Research

Through the systematic review of the literature, this paper grasps the relevant theories and research progress, provides theoretical support for the research topic and research background, and lays a foundation for evaluating the research and development efficiency of China's agricultural listed companies. At the same time, in the process of combing the literature, the existing research and development efficiency evaluation indicators are used, and the characteristics of the research samples and the availability of the data are considered, and the evaluation index system suitable for this research is constructed.

3.2.2. Metrological Analysis

This paper uses the DEA-Malmquist model to dynamically evaluate the research and development efficiency of China's agricultural listed companies, and reveals the changes in the development of total factor productivity.

4. Model construction and indicators design

4.1. Research and Development Efficiency Measurement

4.1.1. Construction of models

This paper is based on the BCC model used to evaluate technical efficiency to calculate the Malmquist index. In addition, with the in-depth study of scholars, Färe et al. (1994) decomposed Malmquist Productivity Change (TFPCH) into the product of technological progress (TECHCH) and technological efficiency change (TECH). This method is used in this paper to calculate the productivity change using the geometric mean of the Malmquist production index for two periods.

$$M(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \times \left[\left(\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}\right)\right]^{1/2} \tag{1}$$

The right side of the equation is decomposed into two parts: (1) relative efficiency change (production observation distance from the maximum possible production distance change); (2) technology transition from t period to t+1. Improvements in relative efficiency changes are interpreted as catching up on the frontiers of production, and improvements in technological progress are interpreted as the result of innovation.

4.1.2. Indicators Design

(1) Output Variables

This paper selects the number of invention patent applications as one of the output indicators of R&D activities of agricultural listed companies. The ultimate goal of enterprise innovation activities is to improve business performance, so this paper selects the operating income after the price index is reduced as another output indicator.

(2) Input Variables

From the perspective of capital investment, R&D expenditure is the direct input to measure R&D activities. In order to eliminate the impact of the previous and current R&D investment, this paper selects the R&D capital stock to measure R&D expenditure and serves as an R&D investment indicator for agricultural listed companies.

From the perspective of labor input, R&D personnel is the direct input to measure R&D activities. Since most listed companies do not directly disclose the number of R&D personnel, this paper selects the number of technicians as the proxy variable for R&D personnel.

The variable settings are shown in Table 1.

Table 1. Variable Settings

Variable Type	Title	Unit	Description
Outout Variables	patent applications	Item	Number of invention patent applications
	Operating income	Ten Thousand yuan	Operating income after the price index is reduced
Input Variables	R & D expenditure	Ten Thousand yuan	R&D capital stock calculated by perpetual inventory method
	R & D personnel	Individual	Number of technicians

5. Empirical Research

5.1. Sample selection and data source

This paper takes the "Guidelines" revised by the China Securities Regulatory Commission in 2012 as the classification standard, and selects the relevant data of China's agricultural listed companies from 2012 to 2015 for research. The sample company comes from two sections of the document: one is agriculture, forestry, animal husbandry, fishery and its service sector. There are currently 43 listed companies; the second is the agricultural and sideline food processing industry sector, which currently has 38 listed companies. Besides, excluding one B-share listed company, 16 ST companies, 18 companies with less than 5 years of listing, and 11 companies that did not disclose R&D expenditures, the remaining 36 companies were used as research samples. The data comes from the annual report of the listed company, the website of the State Intellectual Property Office, and the China Statistical Yearbook (2013-2016). The basic information of the sample company is detailed in the appendix.

5.2. Variable descriptive statistics

In 2012-2015, the research and development expenditures and R&D personnel input changes of 36 agricultural listed companies in China are shown in Table 2.

Table 2. Variable descriptive statistics

Variables	Maximum	Minimum	Average	Standard Deviation
Patent Applications (item)	156	0	11	29
Operating Income (hundred million)	684.3865	1.9656	61.6489	135.3980
R&D Expenditures (hundred million)	24.9289	0.0030	2.8066	4.8729
R&D Technicians (number)	2.394	0.019	0.472	0.553

6. Empirical Research Results

Research and development efficiency of agricultural listed companies

Using the DEAP2.1 software package to measure the R&D efficiency of agricultural listed companies, the following results are obtained:

It can be seen from Table 3 that during the period of 2012-2015, the total factor productivity of China's agricultural listed companies grew at an average annual rate of -1.0%, showing a general decline. Among them, the technical efficiency increased by 5.4% annually; the technical level increased by -6.0% annually. In terms of industry categories, the average annual growth rate of R&D total factor productivity of listed companies in traditional agricultural listed companies and agricultural and sideline food processing industries was 4.6% and -2.5%, respectively, and technical efficiency increased by 12.4% and 2.7%, respectively, and the technical level increased by -5.6% and -5.4% respectively. It can be seen that the improvement of the technical efficiency of traditional agricultural listed companies plays a leading role in the growth of R&D total factor productivity, while the decline of the technology of listed companies in the agricultural and sideline food processing industry has led to a decline in the total factor productivity of research and development.

Table 3. Malmquist Productivity Indexes for 36 Agricultural Companies Listed

Types	Sample Company	Technical efficiency Variation	Technical Level Variation	Pure technical efficiency Variation	Scale efficiency Variation	Total factor productivity Variation
Traditional agriculture	Longping High-Tech	1.066	0.899	1.183	0.901	0.959
	Denghai Seed Industry	1.145	0.909	1.222	0.937	1.041
	Winall Hi-tech Seed	1.783	0.852	1.728	1.032	1.519
	Starmap Medicine & Technology	0.906	0.932	0.89	1.018	0.844
	Gansu Yasheng Industrial	0.985	0.956	1.05	0.938	0.942
	Gansu Dunhuang Seed Group	0.673	1.019	0.627	1.073	0.686
	Wanxiang Doneed	0.9	0.852	0.714	1.26	0.767
	Xinjiang Sayram Modern Agriculture	0.89	0.899	0.998	0.892	0.801
	Fujian Yongan Forestry Group	1.402	0.872	1.44	0.973	1.222
	Fujian Sunner Development	0.746	1.217	0.951	0.785	0.908
	Henan Huaying Agricultural Development	1.127	0.851	1.176	0.958	0.959
	Shandong Yisheng Livestock&poultry breeding	0.767	1.152	0.9	0.852	0.884
	Chuying Agro-Pastoral	1.477	0.933	1.592	0.928	1.379
	Xinjiang Western Animal Husbandry	1.642	0.875	1.613	1.018	1.437
	Hunan new five feng	0.785	1.077	0.837	0.938	0.846
	Dalian Zhangzidao Fishery Group	1.637	1.052	1.512	1.083	1.722
	Dalian Yiqiao Fishery Goup	1.178	0.86	1	1.178	1.013
	Zhanjiang Guolian Aquatic Products	1.22	0.898	1.29	0.946	1.096
	Shandong Homey Aquatic Development	1.157	0.878	1.137	1.017	1.016
	Hefei Fengle Seed	0.993	0.887	1.023	0.971	0.881
	Average	1.124	0.944	1.144	0.985	1.046
Agricultural and sideline	New Hope Group	0.942	0.935	1	0.942	0.881
	Henan Shuanghui	0.935	0.882	1.102	0.848	0.825

food processing industry	Development					
	Xinjiang Tecon Animal Husbandry Bio-Technology	1.083	0.86	1.178	0.919	0.932
	Tech-bank Food Company	1.179	0.899	1.28	0.922	1.061
	Zhengbang Agriculture Pakistan Pvt	0.931	0.9	0.996	0.934	0.838
	Dalian Tianbao Green Foods Company	0.927	0.886	0.82	1.131	0.821
	Baoling Bao Company	0.987	0.842	0.989	0.998	0.831
	Guangdong Haid Group	1.103	0.882	1.189	0.928	0.973
	Shandong Delisi Food Company	1.174	0.899	1.184	0.991	1.055
	Beijing Dabeinong Technology Company	0.767	0.854	0.799	0.96	0.655
	Jinzi Ham Company	0.933	1.058	0.718	1.3	0.987
	Chenguang Biotechnology Company	1	0.96	1	1	0.96
	Harbin High-Tech Group	1.083	1.278	0.89	1.218	1.384
	Jinjian Cereals Industry	1	1.043	1	1	1.043
	Xinjiang Guannong Fruit & Antler Group	1	0.979	1	1	0.979
	Tongwei Company	1.393	0.985	1.319	1.057	1.373
	Average	1.027	0.946	1.029	1.009	0.975
Total		1.054	0.94	1.064	0.99	0.99

As shown in Table 4, during the period of 2012-2015, the total factor productivity of R&D showed a downward trend first, followed by short-term growth. Specifically, during the period of 2012-2013 and 2013-2014, R&D total factor productivity changes, technical efficiency changes, and technical level changes were all less than 1; in 2014-2015, R&D total factor productivity changes and technical efficiency changes were greater than 1, technology level changes were less than 1. It can be seen that the reduction of technical efficiency and the regression of technology lead to a decline in the development of total factor productivity, while the substantial increase in technological efficiency in the later period has led to a short-term growth in total factor productivity.

Table 4. Time evolution of total factor productivity index

	Technical efficiency Variation	Technical Level Variation	Pure technical efficiency Variation	Scale efficiency Variation	Total factor productivity Variation
2012-2013	0.982	0.967	0.947	1.036	0.95
2013-2014	0.936	0.934	0.959	0.976	0.874
2014-2015	1.273	0.919	1.327	0.959	1.169
Average	1.054	0.94	1.064	0.99	0.99

7. Conclusion and Suggestion

7.1. Research Conclusion

Based on reviewing the research status at home and abroad, this paper uses the DEA-Malmquist index model to evaluate the R&D efficiency of 36 listed companies in China, and further analyzes the impact of financing constraints on R&D efficiency. The main conclusions of this paper are as follows:

In general, from 2012 to 2015, the average annual growth rate of R&D of R&D of listed companies in agriculture-related companies was negative, mainly due to negative technical changes, which was interpreted as a large technological innovation environment that was not performing well, and technological progressed slowly in the agricultural industry. This may also be attributed to the public's lack of interest in agricultural innovation and research on the low return rate and long cycle of agriculture. It also confirms the reason why government subsidies can promote the efficiency of R&D for listed companies. Due to the increase of technical efficiency, the traditional agricultural listed companies have changed their total factor productivity more than the agricultural and sideline food processing industry. This may be caused by the fact that the agricultural and sideline food processing industry is superior to the traditional agricultural listed companies in terms of management and institutional level, and the change in technical efficiency is to examine the ratio of the current technical efficiency to the previous period, so it is the leading factor in the change of technical efficiency.

7.2. Suggestions

First, we should create a good environment for agricultural innovation, so that technological advancement can promote the efficiency of research and development. Second, the government should continue to increase subsidies for listed companies related to agriculture, in order to stimulate the enthusiasm of enterprise innovation, and may need to lead the government to conduct basic innovation research to eliminate the inhibition of R&D innovation by strong externalities of agriculture.

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