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Research on financing efficiency evaluation of new energy automobile industry based on DEA BCC model and Malmquist model

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ABSTRACT
since the establishment of the "green development concept", the financing efficiency of the new energy automobile industry, as an important engine to promote the coordinated development of green finance, has attracted widespread attention. Based on the industry chain statistics of tonghuashun Ifind financial database, this paper selects the relevant data of 613 listed companies from 2016 to 2022, and the remaining 331 effective decision-making units are processed. The financing efficiency of China's new energy automobile industry is measured and studied by using investment oriented variable return to scale BCC model and Malmquist index model. The research shows that the overall financing efficiency level of China's new energy automobile industry is not high, and the financing efficiency level shows a non-linear downward trend, the pure technical efficiency shows a non-linear downward trend, the scale efficiency rises non-linear, and the number of enterprises with increasing returns to scale rises non-linear. Technological progress is the main factor restricting the financing efficiency of China's new energy automobile industry. The lack of scale efficiency, technical efficiency and pure technical efficiency will also affect the financing efficiency of the new energy automobile industry.

KEYWORDS
financing efficiency; New energy automobile industry; DEA model; Malmquist index

1 Introduction and literature review

China announced "reach carbon peak and carbon neutrality" at the 75th United Nations General Assembly, pointing out the direction for the green and low-carbon development of the whole society. Carbon emissions from the automobile industry occupy an important position in the overall carbon emissions of society, and major countries and regions around the world have taken the automobile industry as an important starting point to promote carbon emission reduction. In this context, countries have introduced relevant policies to promote the development of new energy automobile industry.

However, China's new energy automobile industry started late compared with other countries. Although the Chinese government has implemented various policy subsidies to vigorously support the development of the new energy automobile industry, it is still facing R&D difficulties and difficulties in opening up a larger market. With various policy subsidies and a large amount of financial support, the development of China's new energy automobile industry is gradually narrowing the gap with other developed countries, but as an important industry in China, the new energy automobile industry must pay more attention to its own financing record, improve market competitiveness, and promote R&D innovation and orderly market activities.

Therefore, financing efficiency is very important to promote the rapid and healthy development of new energy automobile enterprises, and it is of great significance to study how to improve the financing efficiency of new energy automobile industry.

Zeng Kanglin[1] brought the concept of "financing efficiency" into the view of researchers. With the promulgation of the guiding opinions on building a green financial system in 2016, scholars' measurement of financing efficiency has gradually shifted to the field of environmental protection, and the financing efficiency of the new energy automobile industry has become a new focus. Xiong Zhengde[2] believes that the efficiency of debt financing of Listed Companies in the new energy automobile industry is low. Wang Hairong and Geng Chengxuan[3] believe that the pure technical efficiency of financing in the new energy automobile industry is lower than that of its financing scale. Hu Jiya[4] believes that the return on net assets of the new energy automobile industry is positively correlated with financial support and negatively correlated with equity financing. Chi Renyong, Ruan Hongpeng and Yu Jun[5] pointed out that government subsidies have a significant incentive effect on R&D and innovation of new energy and its automobile enterprises.

Through reading the literature, scholars mostly use "analytic hierarchy process", "fuzzy comprehensive evaluation method", "DEA model" and other methods to evaluate financing efficiency, and there are not many studies on the evaluation of financing efficiency from static and dynamic perspectives. At the same time, there are few studies on the financing efficiency of new energy automobile industry. Therefore, this paper uses DEA BCC model and Malmquist index model to measure the financing efficiency of new energy automobile industry from static and dynamic perspectives respectively, and puts forward effective suggestions for improving the financing efficiency of new energy automobile industry to promote the healthy development of new energy automobile industry.

2 Model and sample selection

(1) DEA model

DEA (Data Envelopment Analysis) method was first proposed by Charnes, Cooper and Rhodes in 1978. The initial data envelopment analysis was based on the assumption that the return to scale remained unchanged. Through the efficiency evaluation of each decision-making unit, it judged whether each decision-making unit was effective, and how to determine the best input and output of each decision-making unit. Based on the CCR model with constant returns to scale, banker et al. Established the BCC model with variable returns to scale assumption in 1984. This paper uses the investment oriented variable return to scale BCC model to measure the financing efficiency of China's new energy automobile industry, and uses deap2.1 software to measure the efficiency. For any DMU, the input oriented BCC model can be expressed as:

$\min[h-\varepsilon(e^t s^- + e^t s^+)]$

$$s.t\begin{cases}\sum_i^n \lambda_i y_{ir} - S^+ = y_{0r} \\ \sum_i^n \lambda_i X_{ir} + S^- = \varepsilon_0 X_{0j} \\ \sum_i^n \lambda_i = 1\end{cases}$$

i=1，2，……,n;j=1,2,……,m;r=1,2,……

n is the number of DMUs, X_{ij} is the input factor, Y_{ir} is the output factor, and $S^+$and S^- are relaxation variables. h* is the optimal solution. If h*=1 and s^{-*}=0, s^{+*}=0, Then the decision-making unit is DEA effective, if 0 is less than h* less than 1 and $s^{-*} \neq 0$, $s^{+*} \neq 0$, Then the decision-making unit is invalid, indicating that the enterprise has input redundancy and loss output.

(2) Malmquist index model

Malmquist total factor productivity index (tfpch) can be divided into technical efficiency change (effch) and technological progress (techch), among which technical efficiency change can be divided into pure technical efficiency change (Pech) and scale efficiency change (sech), which can more intuitively observe the composition of production rate. Under the assumption of variable returns to scale, the formula of Malmquist index model can be expressed as:

$$M\left(x^{t+1},y^{t+1},x^t,y^t\right)=\frac{D^{t+1}\left(x^{t+1},y^{t+}\right)/VRS}{D^t\left(x^t,y^t\right)/VRS}\cdot\frac{D^{t+1}\left(x^{t+1}y^{t+1}\right)/VRS}{D^{t+}\left(x^{t+1}y^{t+1}\right)/VRS}$$

$$=\frac{D^t\left(x^t,y^t\right)/VRS}{D^{t+1}\left(x^t,y^t\right)/CRS}\cdot\frac{D^t\left(x^{t+1},y^{t+1}\right)}{D^{t+1}\left(x^{t+1},y^{t+1}\right)}\cdot\frac{D^t\left(x^ty^t\right)}{D^{t+1}\left(x^ty^t\right)}$$

$=pech\times sech\times techch$

$D^t(x^t,y^t)$,$Dt(x^{t+1},y^{t+}1)$，It refers to the distance function of decision-making units in t period and T+1 period when the technology in t period is used as a reference; $D^t(x^{t+1},y^{t+1})$,$D^{t+1}(x^t,y^t)$，It refers to the distance function of decision-making units in t+1 period and t+1 period respectively. Among them, tfpch is greater than 1, indicating the growth of productivity from t period to t+1 period. Effch is greater than 1, indicating the improvement of technical efficiency, and vice versa, indicating the decline of technical efficiency. Techch greater than 1 indicates technological progress, and vice versa means technological decline. Pech is greater than 1, indicating that technology promotes productivity, and vice versa means suppression. Sech is greater than 1, indicating that the size of enterprises promotes productivity, and vice versa, it means that it inhibits productivity.

3 Index selection and sample selection

(1) lection of indicators

Based on Song GE's input index and output index selection method, this paper analyzes the financing efficiency of the new energy automobile industry from the perspective of financial analysis. The indicators of the evaluation system need to objectively reflect the financing efficiency of each decision-making unit, so this paper selects the following three input and output indicators.

(2) Sample selection

Based on the industrial chain statistics of tonghuashun Ifind financial database, this paper selects the total owner's equity, total liabilities, net cash flow of financing activities, net profit, total asset turnover rate and total operating income data of 613 listed companies to calculate and analyze the financing efficiency of China's new energy automobile industry. In order to ensure the integrity and effectiveness of the collected data, the samples are processed as follows:

Remove st and st * sample enterprises;

Excluding sample enterprises with serious lack of key data; (3) In order to maintain the feasibility of model operation, sample enterprises with zero and negative key data values are excluded. After processing the data, there are 331 effective decision-making units.

Table 1 Selection of indicators

Indicator type	indicator name	indicator meaning
Input indicators	Total owner's equity	Reflecting the scale and financing preference of enterprise equity financing
	Total liabilities	Reflecting the scale of corporate debt financing
	Cash outflow from financing activities	The scale of investment in financing by enterprises
Output indicators	Net profit	Net profit reflects the profitability directly
	Total asset turnover	The total asset turnover rate can measure the operating situation and is suitable for evaluating the operating quality and utilization effect of all assets of the company
	Total operating income	Higher total operating income shows that the enterprise is on the right track of production and operation, has better prospects and expansion capabilities, and has higher effectiveness in the use of funds

4 Analysis of empirical results

(1) Static empirical analysis of financing efficiency of China's new energy automobile industry

Using DEA model method, the relevant data of 331 effective decision-making units from 2016 to 2022 are calculated through software deap2.1. Based on the input oriented BCC model, the comprehensive technical efficiency, pure technical efficiency, scale technical efficiency and scale compensation of sample enterprises from 2016 to 2022 are obtained. The static analysis results are shown in table 2.

Table 2 static empirical research results of financing efficiency of China's new energy automobile industry

Year		2016	2017	2018	2019	2020	2021	2022
Comprehensive technical efficiency	mean value	0.54	0.50	0.52	0.50	0.51	0.49	0.52
	DEA effective number	24	17	24	26	21	20	20
	Proportion	7.30%	5.10%	7.30%	7.90%	6.30%	6.00%	6.00%
pure technical efficiency	mean value	0.60	0.57	0.59	0.58	0.57	0.55	0.56
	DEA effective number	43	37	42	49	42	33	36
	Proportion	13.00%	11.20%	12.70%	15.00%	12.70%	10.00%	10.90%
Scale efficiency	mean value	0.91	0.88	0.90	0.88	0.91	0.90	0.93
	DEA effective number	34	23	30	33	27	27	29
	Proportion	10.30%	6.90%	9.10%	10.00%	8.20%	8.20%	8.80%
Returns to scale	Number of incremental Enterprises	127	89	121	162	179	208	234
	Proportion of incremental Enterprises	38.40%	26.90%	36.60%	48.90%	54.10%	62.80%	70.70%
	Number of diminishing Enterprises	160	215	172	133	113	94	64
	Proportion of diminishing Enterprises	48.30%	65.00%	52.00%	40.20%	34.10%	28.40%	19.30%
	Number of unchanged Enterprises	44	27	38	36	39	29	33
	Proportion of unchanged Enterprises	13.30%	8.20%	11.50%	10.90%	11.80%	8.80%	10.00%

Comprehensive technical efficiency reflects the current comprehensive utilization level of existing resources, and reflects the current overall financing efficiency. According to table 2, the average comprehensive technical efficiency of China's new energy automobile industry did not reach the effective level from 2016 to 2022, and the financing efficiency showed a non-linear downward trend. From 2016 to 2022, the year with the largest number of effective enterprises in comprehensive technical efficiency among 331 decision-making units was 2016, with 24 enterprises, accounting for only 7.30% of all effective decision-making units. Therefore, the overall financing efficiency of China's new energy automobile industry is at a low level. Pure technical efficiency reflects the comprehensive utilization level of enterprises' current technical ability and management ability. As can be seen from table 2, the average pure technical efficiency level of China's new energy automobile industry has a non-linear downward trend, which has dropped from 0.60 in 2016 to 0.56 in 2022, indicating that China's new energy automobile industry has the problems of bloated institutions, untimely system updates, information asymmetry and other reasons, such as the decline of management level and R&D investment, and the insufficient level of technology utilization caused by the change of market demand. Scale efficiency reflects the matching degree between the input and output of the enterprise and the current scale. From 2016 to 2022, the scale efficiency of China's new energy automobile industry was in a non-linear upward trend, rising from 0.91 in 2016 to 0.93 in 2022, but the number of effective enterprises with scale efficiency decreased slightly. The reason may be that after seven years of rapid development, the scale of enterprises in China's new energy automobile industry has gradually expanded, and the input and output level of some enterprises can not match the current scale, resulting in a decline in the number of effective enterprises with scale efficiency in China's new energy automobile industry.

Return to scale refers to the change in output caused by the change of various production factors in an enterprise in the same proportion when other factors remain unchanged. Increasing returns to scale means that the proportion of output increase is greater than that of input factors, unchanged returns to scale means that the proportion of output increase is equal to that of input factors, and decreasing returns to scale means that the proportion of output increase is

less than that of input factors. According to table 2, from 2016 to 2022, the number of enterprises with increasing returns to scale in China's new energy automobile industry showed a non-linear upward trend, and the number of enterprises with decreasing returns to scale showed a non-linear downward trend. Taking 2019 as the boundary, the number of enterprises with increasing returns to scale in each year before that year is less than that of enterprises with decreasing returns to scale, and the number of enterprises with increasing returns to scale in each year after that year is greater than that of enterprises with decreasing returns to scale. It shows that the overall capital utilization efficiency of China's new energy automobile industry is improving. On the whole, the scale efficiency of China's new energy automobile industry is higher than that of pure technical efficiency and comprehensive technical efficiency. Comprehensive technical efficiency= pure technical efficiency * scale efficiency, so the main reason for the low level of financing efficiency of China's new energy automobile industry is the insufficient efficiency of pure technical level, that is, the insufficient level of technology utilization and management ability.

（2） Dynamic Empirical Analysis of financing efficiency of new energy vehicles in China

Further analyze the dynamic changes in the financing efficiency of China's new energy automobile industry from 2016 to 2022, and adopt the DEA Malmquist index model method to make an empirical analysis on the dynamic changes in the financing efficiency of China's new energy automobile industry. The results of the dynamic change analysis are shown in Table 3.

Table 3 dynamic empirical research results of financing efficiency of China's new energy automobile industry

year	effch	techch	pech	sech	tfpch
2016-2017	0.941	1.007	0.969	0.971	0.947
2017-2018	1.053	0.897	1.040	1.012	0.945
2018-2019	0.939	0.983	0.960	0.978	0.923
2019-2020	1.043	0.877	1.012	1.031	0.915
2020-2021	0.961	1.081	0.960	1.001	1.038
2021-2022	1.064	0.856	1.030	1.033	0.911
mean	0.999	0.947	0.995	1.004	0.946

According to the empirical results of Malmquist index of sample enterprises in new energy automobile industry in Table 3, the changes of total factor productivity and its decomposition indicators of sample enterprises from 2016 to 2022 are obtained, as shown in Figure 1.

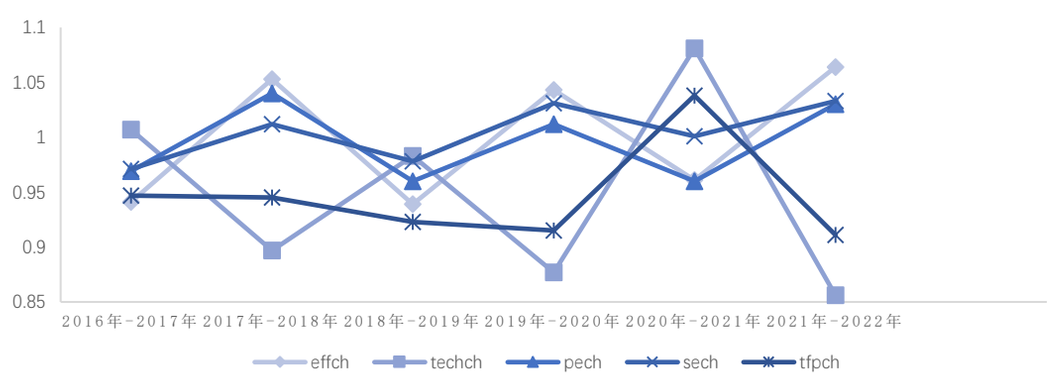

Figure 1 changes in total factor productivity and its decomposition indicators of sample enterprises from 2016 to 2022

According to table 3, the technical efficiency of China's new energy automobile industry has decreased by 0.1% in seven years. From 2016 to 2022, the average technological progress of China's new energy automobile industry was 0.947, and the technology declined by 5.3% in seven years. Pure technical efficiency decreased by 0.5%, scale efficiency increased by 0.4%, and total factor productivity decreased by 5.4%. Further analysis shows that the negative impact of technological progress on total factor productivity is greater than that of technological efficiency and pure technological efficiency. Scale efficiency contributes 0.4% to the financing efficiency of the new energy automobile industry.

According to figure 1, in the changes of total factor productivity and its decomposition indicators from 2016 to 2017, the value of technological progress is the largest, that is, technological progress contributes 7% to the financing efficiency of the new energy automobile industry, but due to the lack of technical efficiency, pure technical efficiency and scale efficiency, the overall financing efficiency is insufficient. In the changes of total factor productivity and its decomposition indicators from 2017 to 2018, technology recession is the main reason for the low financing efficiency of China's new energy automobile industry from 2017 to 2018. In the changes of total factor productivity and its decomposition indicators from 2018 to 2019, technical efficiency, technological progress, pure technical efficiency and scale efficiency are insufficient, which lowers the level of financing efficiency as a whole, resulting in a substantial decline in the level of

financing efficiency of China's new energy automobile industry from 2018 to 2019. In the changes of total factor productivity and its decomposition indicators from 2019 to 2020, there is a serious technological recession, with a level of 12.3%, resulting in a reduction of 8.5% in financing efficiency. From 2020 to 2021, the financing efficiency of China's new energy automobile industry increased by 3.8%, technological progress contributed 8.1%, scale efficiency contributed 0.1%, and technological progress contributed more. In the changes of total factor productivity and its decomposition indicators from 2021 to 2022, due to the 14.4% technology recession, the financing efficiency of China's new energy automobile industry decreased by 5.4% from 2021 to 2022.

5 Conclusions and policy recommendations

（1） Conclusion

This paper uses the relevant data of 331 listed companies in the new energy automobile industry from 2016 to 2022, uses DEA BCC model and Malmquist index model to evaluate the financing efficiency of China's new energy automobile industry from static and dynamic perspectives, and draws the following conclusions:

(1) The average comprehensive technical efficiency of China's new energy automobile industry has not reached an effective level from 2016 to 2022, and the overall financing efficiency needs to be improved. Pure technical efficiency shows a non-linear downward trend, and the level of pure technical efficiency is insufficient. Scale efficiency is in a non-linear upward trend, but the number of effective enterprises with scale efficiency has declined slightly. The number of enterprises with returns to scale shows a non-linear growth, and the overall capital utilization efficiency of China's new energy automobile industry is improving.

(2) From 2016 to 2022, the financing efficiency level of China's new energy automobile industry decreased by an average of 5.4%, of which the technical efficiency decreased by 0.1, the technical recession by 5.3%, the pure technical efficiency decreased by 0.5%, and the scale efficiency increased by 0.4%. From 2016 to 2017, technological progress played a positive role in promoting the level of financing efficiency. From 2017 to 2018, the technological recession lowered the level of financing efficiency. From 2018 to 2019, the technical efficiency, technological progress, pure technical efficiency and scale efficiency were insufficient, which lowered the level of financing efficiency as a whole. From 2019 to 2020, the technological recession lowered the level of financing efficiency. The main driving force for the rise of financing efficiency level from 2020 to 2021 is technological progress. From 2021 to 2022, the financing efficiency level of China's new energy automobile industry declined due to technological recession.

（2） Policy recommendations

First, from the perspective of enterprises, first of all, enterprises should fully recognize the great role of technology in promoting industrial development, increase R&D investment, improve technological innovation ability and technological utilization efficiency, so as to promote the long-term development of new energy automobile industry. Then, enterprises should improve the quality of products and services, improve internal management level, improve profitability, and improve financing efficiency. Secondly, enterprises should not only pay attention to economic benefits and ignore social benefits, but should form a development model with social benefits as the main and economic benefits as the supplement, form a principled situation of unification of social benefits and economic benefits, and make more contributions to the development of the country and society. Thirdly, in order to improve the financing efficiency of the new energy automobile industry, enterprises should choose reasonable financing methods and financing structure, learn advanced testing, allocate funds reasonably, reduce financing costs and improve financing efficiency. Finally, enterprises with low scale efficiency should avoid the problems of disorderly expansion and institutional redundancy, and improve the matching degree between input and output and the current scale.

Second, from the perspective of the government, the government should improve and improve the financial industry regulations, actively implement sound policies conducive to the long-term development of the new energy automobile industry, and improve the ability of financial governance. The government should improve the utilization rate of subsidies for the new energy automobile industry and make funds flow to enterprises with stronger technological innovation ability and more prominent social benefits. In order to ensure the healthy development of the new energy automobile industry, the government should make reasonable and effective supervision, avoid monopoly factors caused by the unlimited expansion of some enterprises, crack down on "rent seeking behavior" for short-term benefits, maximize the financing efficiency of the new energy automobile industry, and promote the long-term healthy development of the new energy automobile industry.

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