Evaluation of Innovation Efficiency and Influencing Factors of Blockchain Listed Companies Based on DEA-Tobit Model

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Abstract. This paper uses the DEA-BCC model to measure the innovation efficiency of blockchain listed companies and further explores the factors influencing the innovation efficiency of blockchain companies using Tobit regression. It is found that: the innovation efficiency progress of blockchain enterprises is mainly driven by the improvement of technical efficiency, which is benefited from the growth of scale efficiency; the enterprises with lower innovation efficiency are mainly affected by the decline of pure technical efficiency; the decline of pure technical efficiency and the inability to allocate innovation resources effectively are the main factors restricting the innovation efficiency improvement of blockchain enterprises Government support has a persistent contribution to innovation efficiency gains, while tax burdens have a persistent inhibiting effect.

Keywords: blockchain; innovation efficiency; DEA; Tobit

1 Introduction

From the existing practice, blockchain technology, as an important driving force for social governance transformation, has been applied in various fields such as Internet of Things, education and insurance, and has become a new driving force for future digital economy growth. As a leader in the technology industry, it is also characterized by large project investments and long lead times when conducting research and development. Investing a lot of human and material resources in the early stage will not only affect the results of technology research and development, but also has a close relationship with the future return of the enterprise. Therefore, in order to enhance the innovation ability of domestic blockchain listed companies, it is especially urgent and necessary to effectively evaluate the innovation efficiency of blockchain listed companies and analyze the influencing factors of innovation efficiency and the intensity of their effects.

In recent years, the widespread use of blockchain technology in different companies has made data more accessible, creating favorable conditions for studying the innovation efficiency of Chinese blockchain listed companies. In view of the shortcomings of the above literature and the realistic needs of blockchain technology development in China, this paper measures the innovation efficiency of 43 blockchain listed companies based on DEA-Tobit model, which can further analyze the influencing factors of innovation efficiency of blockchain listed

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companies and thus propose the improvement path of innovation efficiency of blockchain listed companies.

2 Research methods and data description

2.1 DEA-Tobit model

To overcome the shortcomings of the one-stage DEA model that cannot measure the factors affecting performance and cannot remove environmental influences and random errors, Coelli et al.[1] established a two-stage method (Two-stage Method) based on the DEA analysis. That is, the first step uses DEA to evaluate the efficiency of the decision unit, and the second step uses the efficiency value in the previous step as the dependent variable and the influencing factors as the independent variables to build a model with Tobit regression model.

2.1.1 Step 1: Traditional DEA Model

Charnes, a famous operations researcher, established the DEA method for the first time to evaluate the relative effectiveness of DMUs under the "multiple input, multiple output" model[2], i.e., to judge the rationality and effectiveness of each unit input/output through a series of decisions. Its non-parametric efficiency evaluation method does not require artificially set specific functional forms and indicator assignments.Efficiency is more objective compared to other evaluation methods. Since then, BCC, CCGSS, CCW, CCWH, etc. have been developed from the basic DEA model CCR. Among them, the BCC model is commonly used to deal with the DMU effectiveness problem under the assumption of "variable returns to scale (VRS)"[3]. When the output is constant, the BCC model in pairwise form with minimal input orientation for each decision unit is represented as follows:

$$\underset{\theta,\lambda}{Min}[\theta-\varepsilon(e^t s^- + e^t s^+)]$$

$$s.t.\begin{cases} \sum_{i=1}^{n}\lambda_i y_{ir} - s^+ = y_{0r} \\ \sum_{i=1}^{n}\lambda_i x_{ij} + s^- = \theta x_{0j} \\ \sum_{i=1}^{n}\lambda_i = 1 \\ \lambda_i \geq 0; s^+ \geq 0; s^- \geq 0 \end{cases} \tag{1}$$

Among them. i=1,2,⋯,n; j=1,2,⋯,m; r=1,2,⋯,s; n is the number of decision units, m and s are the number of input and output variables, respectively. $x_{ij}\,(j=1,2,\cdots m)$ is the jth input factor for DMU_i . $y_{ir}\,(r=1,2,\cdots,s)$ is the sth output factor for DMU_i . θ is the effective value of the DMU. When $\theta=1$: DMU for weak DEA validity. DMU of economic activity is simultaneously optimal in terms of non-technical efficiency and scale efficiency; when $\theta=1$

and $s^+ = s^- = 0$, DMU for DEA is valid. DMU of economic activity is optimal for both technical efficiency and scale efficiency; When $\theta < 1$, the non-DEA is valid, the technical efficiency and scale efficiency of economic activities are not optimal. The effective value of the decision cell calculated by the BCC model It is called technical efficiency (TE) and can be further decomposed into the product of pure technical efficiency (PTE) and scale efficiency (SE). Technical efficiency refers to the ability to achieve maximum output with a given input or minimum input with a given output; scale efficiency refers to the degree of economies of scale compared to the efficient point of scale; and pure technical efficiency refers to the efficiency after excluding the scale factor.

2.1.2 Step 2: Tobit Model

Since the dependent variable (the efficiency value of each DMU) in the second step is between 0 and 1, and the use of traditional OLS models introduces serious bias and inconsistency in the parameter estimates, the Tobit model in the restricted dependent variable model is used for the regression [4]. The standard Tobit model is as follows:

$$Y_i^* = X_i\delta + \varepsilon_i, Y_i = Y_i^* \; if \; Y_i^* > 0, Y_i = 0 \; if \; Y_i^* \le 0 \tag{2}$$

Y_i^* is the latent dependent variable. Y_i is the observed dependent variable. X_i is the vector of independent variables, the δ is the vector of correlation coefficients, the ε_i is an interfering term (independent and $\varepsilon_i : N(0,\sigma)$), therefore $Y_i^* : N(X_i\delta,\sigma)$.

2.2 Evaluation index system construction

Referring to the "Enterprise Innovation Capability Evaluation Index System" introduced by the state in 2013, the article divides the innovation input indexes into human resource input and R&D expenditure input, and the innovation output indexes into innovation economic benefits and innovation knowledge achievements based on the previous research. It also combines the characteristics of blockchain listed companies and constructs the innovation efficiency evaluation index system of blockchain listed companies, as shown in Table 1.

Table 1. Blockchain listed companies' innovation efficiency evaluation index system

	Tier 1 Indicators	Secondary indicators
Innovation input	Human resource input	Number of R&D personnel
		Share of R&D personnel (%)
	R&D investment	R&D expenses (million yuan)
		Investment intensity of R&D expenditure (%)
Innovation Output	Innovative knowledge results	Number of annual patent applications (items)
		Annual number of granted patents (items)
	Innovative economic benefits	Operating income growth rate (%)
		Net profit (million yuan)
		Capital Accumulation Rate (%)

2.3 Data source and description

The sample data required for the study in this paper comes from the annual reports of 43 companies listed on the Shenzhen Stock Exchange in 2021 in the blockchain industry, excluding *ST and companies with incomplete data. The patent data is obtained from the patent search system of the comprehensive service platform of the State Intellectual Property Office. DEA requires that the selected index data cannot be negative, and the growth rate of operating income and net profit may be negative, so the original data are adjusted to the range of [0.1, 1] by referring to Xiong Zhengde's method.

3 Empirical Analysis

The special software DEAP2.1 developed by the Coelli group was chosen. , using Input-Oriented (Input-Oriented) to analyze the innovation efficiency and scale reward of 43 blockchain listed companies in Shenzhen Stock Exchange in 2021, and the results are shown in Table 2.

Table 2. Blockchain listed companies' innovation efficiency evaluation results in 2021

Listed Companies	PTE	SE	TE	TYPE
Changshan Beiming	0.568	0.994	0.565	drs
Newland	0.312	0.993	0.310	drs
Guangdong Advertising Group	0.809	0.976	0.790	drs
XGD	0.722	0.834	0.602	drs
Hanwei Electronics	1.000	1.000	1.000	-
Visual China	1.000	1.000	1.000	-
HyUnion Holding	0.916	0.995	0.911	irs
Digital China Information	0.383	0.990	0.379	irs
Genimous Technology Co., Ltd.	1.000	1.000	1.000	-
JC Interconnect	0.457	0.988	0.452	irs
Hand Enterprise Solutions	0.211	0.981	0.206	drs
Feitian Technologies	1.000	1.000	1.000	-
Client Service	0.738	0.889	0.656	drs
Beijing Certificate Authority	0.435	0.933	0.406	drs
Tungkong Inc.	1.000	0.999	0.999	drs
Hengbao Co., Ltd.	1.000	1.000	1.000	-
E-hualu	0.532	0.928	0.494	drs
Leo Group	1.000	1.000	1.000	-
2345 Network Holding Group	0.753	0.762	0.574	drs
Westone	0.668	0.823	0.549	drs
Transfar Zhilian	1.000	1.000	1.000	-
DHC Software	0.217	0.988	0.214	irs
GRG Banking	1.000	1.000	1.000	-
BGI Genomics	0.920	0.988	0.908	drs
Akcome Science and Technology	1.000	1.000	1.000	-
Montnets Cloud Technology	0.629	0.997	0.627	drs
YGsoft	1.000	1.000	1.000	-
Giant Network	0.486	0.698	0.339	drs

Thunisoft	1.000	0.462	0.462	drs
Tongtech	0.745	0.556	0.414	drs
HopeRun Software	0.653	0.971	0.634	irs
VRV Software	0.397	0.777	0.308	drs
Ysstech	0.545	0.469	0.256	drs
Boss Software	0.637	0.656	0.418	drs
Shunwang Technology	0.406	0.997	0.405	drs
Iflytek	1.000	1.000	1.000	-
Glodon	0.683	0.911	0.622	drs
S.F. Holding	1.000	1.000	1.000	-
Century Huatong	0.335	0.999	0.334	irs
Precision Information	1.000	1.000	1.000	-
Global Infotech	1.000	1.000	1.000	-
Forms Syntron	0.719	0.951	0.684	irs
Kingnet Network	0.910	0.453	0.412	drs

Note: 1) TE, PTE and SE stand for combined technical efficiency, pure technical efficiency and scale efficiency, respectively, TE = PTE × SE; 2) irs is increasing returns to scale, drs is decreasing returns to scale, and - is constant returns to scale.

3.1 Overall analysis of innovation efficiency

DEA effectiveness is defined as a combined efficiency value of 1, when the firm achieves both relative balance and relative optimality in terms of innovation inputs and innovation outputs. Non-DEA effective means that the overall efficiency value is not 1, when the company invests too much in innovation cost or personnel, or not enough output with the existing input, so that the balance between innovation input and innovation output is lost, and does not reach the optimal state. From the overall situation, the average value of the overall efficiency of the sample enterprises is lower than 0.7 (as shown in Table 3). Among them: only 14 enterprises achieved DEA validity, accounting for 32.56% of the total sample; among the non-DEA valid enterprises, 2 achieved pure technical efficiency validity but not scale validity; the average pure technical efficiency of enterprises was 0.739, which was lower than the scale efficiency of 0.906.

Table 3. Overall evaluation of innovation capability of sample enterprise**s**

The project	Comprehensive efficiency	Pure technical efficiency	Scale efficiency
Number of DEA valid enterprises	14	16	14
Number of non-DEA valid companies	29	27	29
Ave.	0.673	0.739	0.906

In addition, as can be seen from Table 4, from the distribution of DEA values, only 39.53% of the total sample had DEA values greater than 0.8, and the rest of the companies fell in the 0 to 0.8 range.

Table 4. Classification of innovation capabilities of sample companies

The project	Strong	stronger	General	weaker	weak
DEA value	1	0.8-1	0.5-0.8	0.3-0.5	<0.3
Number of corresponding enterprises	14	3	10	13	3
Percentage/%	32.56	6.98	23.26	30.23	6.98

The results of the study show that only 14 of the sample enterprises have reached the relative optimum in terms of innovation input and innovation output, 2 enterprises' innovation efficiency is constrained by the scale of the enterprise, and nearly 2/3 of the enterprises have the double trouble of unreasonable innovation input and too low innovation output.

3.2 Internal analysis of innovation efficiency

Based on the general analysis, the following is a specific analysis of the blockchain industry from three aspects: overall efficiency and pure technical efficiency, payoffs for scale, and the internal blockchain industry.

3.2.1Comprehensive efficiency and pure technical efficiency analysis

The remaining 29 firms must make corresponding adjustments in innovation input or innovation output to reach the effective status. Among them, Tungkong Inc. The pure technical efficiency of Newland, JC Interconnect, DHC Software and Century Huatong is greater than 0.9, which is close to the optimal scale. Newland, JC Interconnect, DHC Software, and Century Huatong have scale efficiency greater than 0.9, which is close to the optimal scale, but their overall efficiency is lower than 0.5, because the pure technical efficiency is too low, and these companies have significant problems in business management or business technology.

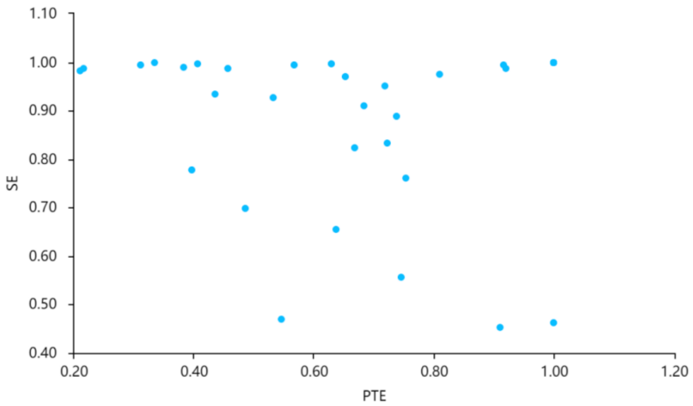

Fig. 1. Distribution of PTE and SE efficiency values

3.2.2 Pay-for-Scale Analysis

For the decision unit, there are three cases of scale payoff: one is constant scale payoff, that is, increasing or decreasing the input has no effect on the scale payoff, reaching the optimal state; the second is increasing scale payoff, that is, increasing the input will benefit the output, and increasing the input by one unit will bring more than one unit of output; the third is decreasing scale payoff, which is the opposite of increasing scale payoff. The payoffs of scale can be used to determine the returns to scale and further explore the causes of inefficiency of scale.

As can be seen from Figure 2, among the sample enterprises, there are 14 enterprises with constant returns to scale, accounting for 32.56% of the total number of enterprises, that is, 14 enterprises have reached the optimal scale; there are 7 enterprises with increasing returns to scale, accounting for 16.28% of the total sample, indicating that these enterprises still have room for improvement in terms of innovation input, and appropriate increase in input will bring more innovation output; there are more enterprises with decreasing scale, with 22 There are more decreasing scale enterprises, 22 enterprises, accounting for 51.16% of the total sample.

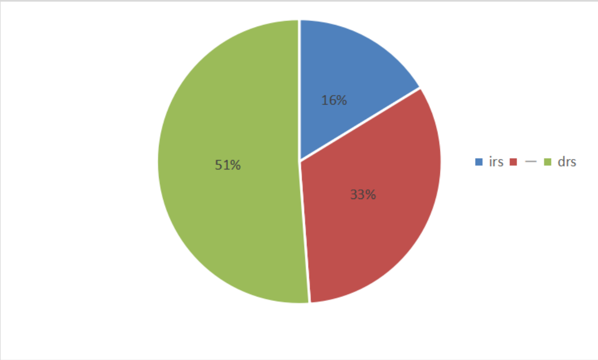

Fig. 2. The scale of compensation enterprises accounted for the situation

4 Analysis of influencing factors based on Tobit model

Drawing from previous studies, the factors influencing the innovation efficiency of blockchain companies are classified into three major levels: enterprise, government and external environment. Enterprise level includes the education level of employees and enterprise scale, the education level of employees is expressed by the ratio of master's and doctoral staff, and the enterprise scale is expressed by the logarithm of the total annual equity of the enterprise; government level includes government subsidies and taxes, and government subsidies are expressed by the logarithm of the enterprise's science and technology funding subsidies, and the tax burden is expressed by the ratio of taxes payable and business income of the enterprise; external environment level includes regional economy and The external environment includes regional economic and industrial development. The regional economy is represented by the logarithm of the annual GDP of each province, and the industrial development is represented by the share of tertiary industry in the province. Based on this, a Tobit panel regression model of the factors influencing the innovation efficiency of blockchain enterprises is constructed, and the regression results are shown in Table 5.

Table 5. results of Tobit regression analysis

Explanatory variables	Standard Deviation	Coefficient estimates	P value
Employee Education Level	0.218	0.126	0.048
Enterprise size	0.107	0.078	0.221
Government subsidies	0.076	0.588***	0.000
Tax burden	3.252	-11.849***	0.001
Regional Economy	0.329	-0.251	0.420
Industrial development	1.186	-2.235**	0.016

Note: * is significant at the 10% level, ** is significant at the 5% level, and *** is significant at the 1% level.

The analysis of the regression results from Tobit model leads to the following conclusions:

There is a significant positive relationship between employee education and firm innovation efficiency, indicating that hiring highly educated employees does promote technological progress and innovation. In essence, hiring highly educated employees is actually a means of knowledge stock for the company, so the results also prove that knowledge stock is crucial for the smooth development of innovation activities.

Enterprise size has a positive influence on the innovation efficiency of blockchain enterprises, with a low influence coefficient of 0.078, and the effect of enterprise size on the innovation efficiency of blockchain enterprises is not obvious.

Government support has a highly significant positive impact on the innovation efficiency of blockchain companies. The subsidies for research funding broaden the sources of funds for the subsequent R&D activities of blockchain enterprises, and at the same time effectively compensate the positive externalities of the innovation activities of blockchain enterprises and promote the spillover of R&D achievements.

Tax burden has a highly significant negative impact on the innovation efficiency of blockchain firms with an impact coefficient of -11.849, which is significant at the 1% level. Innovation in blockchain companies is highly uncertain, and the failure of innovation can lead to a large waste of human resources and capital of the company. To maintain profitability under the pressure of higher taxes capacity, blockchain companies may focus more on the application and mass production of old technologies, and the investment and research and development of new technologies are significantly reduced. This short-sighted behavior will thus reduce the innovation investment of blockchain companies, which in turn will affect the efficiency of innovation.

The level of regional economic development has a negative impact on the innovation efficiency of blockchain enterprises, which does not pass the significance test with an impact coefficient of -0.251. The improvement of regional economic development level is accompanied by the increasing innovation input, but the innovation output fails to achieve synchronous growth, and the innovation input fails to achieve efficient utilization, which leads to negative innovation efficiency growth [5].

Industrial development has a significant negative impact on the innovation efficiency of blockchain companies with an impact coefficient of -2.235. It is mainly due to the saturation of factor inputs in regions with high level of industrial development, which plays a suppressive role in the improvement of innovation efficiency of blockchain enterprises.

5 Conclusions

In this paper, a two-step approach is used to study the innovation efficiency of listed companies in China's blockchain industry. The following main conclusions were drawn from the analysis.

(1) The progress of innovation efficiency of blockchain enterprises is mainly driven by the improvement of technical efficiency, which benefits from the growth of scale efficiency; the enterprises with lower innovation efficiency are mainly affected by the decline of pure technical efficiency; the decline of pure technical efficiency and the inability to allocate innovation resources effectively are the main factors restricting the improvement of innovation efficiency of blockchain enterprises.

(2) Based on the evaluation of innovation efficiency, a panel Tobit regression model is further used to analyze the factors influencing the innovation efficiency of blockchain enterprises, and it is found that government support has a continuous significant positive effect on the innovation efficiency improvement of blockchain enterprises, while tax burden has a continuous significant negative effect.

Based on the empirical results of the article, the following two recommendations are made in the context of the current situation of China's blockchain industry development.

(1) To improve the performance of infrastructure and promote the implementation of innovative technology achievements. Play the role of government promotion, adhere to innovation policy support, increase financial investment, and promote collaborative research to improve the performance of blockchain infrastructure.

(2) Strengthen the construction of talent team. Establish a sound blockchain talent gradient cultivation mechanism to blockchain enterprise talent demand as the guide. Encourage universities to offer teaching courses related to blockchain, cultivate professionals and composite talents with cross-discipline, knowledge integration and technology integration, and provide intellectual support and talent reserve for blockchain development; suggest to establish a cross mechanism of multidisciplinary synergy with an open attitude, enhance the knowledge of blockchain, drive industrialization with engineering, and cultivate talent echelon.

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