

Research on the Impact of Blockchain Application on the Operational Efficiency of Logistics Enterprises: An Empirical Analysis Based on DEA Data

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Abstract: With the development of the digital economy, blockchain technology provides technical support for the intelligent transformation of the logistics industry. In this paper, listed logistics companies from 2017 to 2021 are selected as samples, and the data envelopment analysis (DEA) method is used to construct the evaluation system of logistics enterprises' operational efficiency, and the multiple regression analysis method is used to study the impact of blockchain application on the operational efficiency of logistics enterprises, and the moderating effect of company size and logistics specialization is discussed. The results show that the application of blockchain has a significant positive impact on the operational efficiency of logistics enterprises. The size of the company and the degree of logistics specialization positively regulate the impact of blockchain application on the operational efficiency of logistics enterprises. This paper provides new ideas and countermeasures for logistics enterprises to improve operational efficiency, and also provides a theoretical basis for the application of blockchain technology in the field of logistics.

Keywords: Blockchain; Logistics Enterprises; Operational Efficiency; DEA; Regression Analysis

1 Introduction

1.1 Research Necessity

With the rapid development of the digital economy, the logistics industry, as an important part of the national economy, is undergoing a profound transformation from traditional extensive and expansive operation to intelligent and technological transformation. In recent years, China's logistics industry has developed rapidly, the total amount of social logistics has been increasing, and the income of the logistics industry has increased significantly. However, while the logistics industry is growing rapidly, it is also facing many challenges. On the one hand, logistics enterprises generally have the problems of non-standard management and unbalanced resource allocation, resulting in low resource utilization and difficulty in meeting the market demand for efficient logistics services; On the other hand, with the intensification of market competition, logistics companies urgently need to improve their operational efficiency to enhance their competitiveness and achieve sustainable development. As one of the cutting-edge information technologies in the era of digital economy, blockchain technology provides new

opportunities for the intelligent transformation of the logistics industry. Blockchain has the characteristics of decentralization, traceability, openness and trustlessness, which can effectively solve the problems of information asymmetry and opaque transactions in the logistics industry, and improve the operational efficiency and management level of logistics enterprises. In recent years, the application of blockchain technology in the field of logistics has gradually attracted attention, and some logistics companies have begun to explore the application scenarios of blockchain technology and have achieved certain results. However, there is still a lack of systematic research on the impact of blockchain technology on the operational efficiency of logistics enterprises, especially in the empirical analysis, which is still in its infancy. Therefore, systematically studying the impact mechanism of blockchain technology on the operational efficiency of logistics enterprises can not only provide theoretical support and practical guidance for logistics enterprises on how to use blockchain technology to improve efficiency, but also further improve the logistics efficiency evaluation system and promote the intelligent transformation of the logistics industry. At the same time, this study is also helpful to

enrich the application of resource base theory and enterprise growth theory in the field of logistics, and provides a theoretical basis for the technological innovation and management innovation of logistics enterprises in the era of digital economy, which has important theoretical and practical significance.

1.2 Purpose of the Study

The purpose of this study is to systematically explore the impact mechanism of blockchain technology on the operational efficiency of logistics enterprises through empirical analysis, and to reveal the role and influencing factors of blockchain technology in improving the operational efficiency of logistics enterprises. Specifically, this study will evaluate the direct impact of blockchain technology application on the operational efficiency of logistics enterprises, and further analyze the moderating effect of company size and logistics specialization on this impact. Through this research, it aims to provide theoretical support and practical guidance for logistics enterprises on how to effectively use blockchain technology to improve operational efficiency, and also provide a scientific basis for enriching the logistics efficiency evaluation system and promoting the intelligent transformation of the logistics industry.

1.3 Research Questions

(1) What is the impact of blockchain technology on the operational efficiency of logistics enterprises?

(2) Does the size of the company and the degree of logistics specialization have a moderating effect on the impact of blockchain technology?

2 Theoretical Background

(1) Operational Efficiency of Logistics Enterprises

The operational efficiency of logistics enterprises refers to the ability of enterprises to maximize output through effective operation and management under certain resource input conditions. It reflects the comprehensive efficiency of the enterprise in terms of resource allocation, operation management, etc. In order to accurately measure the operational efficiency of logistics enterprises, this study uses the BCC model in Data Envelopment Analysis (DEA) to calculate. The model can effectively evaluate the output efficiency of logistics enterprises under certain resource input through the efficiency evaluation method of multi-input and multi-output. Specifically, the input indicators include employee compensation payable, management expenses and R&D expenses, which

reflect the level of investment in people, management and technology, respectively. The output indicators include main business income and total profit, which can comprehensively reflect the scale and profitability of the enterprise. Through the calculation of the BCC model, the relative value of the operational efficiency of logistics enterprises can be obtained, so as to provide basic data for subsequent empirical analysis. This method has been widely used in logistics efficiency evaluation, and has high scientific and reliable reliability (Hyungsuk, 2018, Zhang Yongsheng, 2022, Li Xiaomei and Bai Xuefei, 2016).

(2) Blockchain Technology

Blockchain technology is a distributed ledger technology with the characteristics of decentralization, traceability, openness and trustlessness, which can optimize the information management, transaction process and internal collaboration of logistics enterprises. In order to measure the application of blockchain technology, this study sets it as a dummy variable. Specifically, if the enterprise applied blockchain technology in the current year, the assignment is 1; Otherwise, the assignment is 0. This measurement method is judged by public information such as annual reports and news reports, which can effectively reflect whether the enterprise has actually applied blockchain technology. This method has been widely used in related studies and has high operability and accuracy (Lin Xinyi and Wu Dong, 2021, Qiao Pengcheng and Zhang Yansong, 2022).

(3) Company Size

Company size reflects the size of an enterprise in terms of human resources, and is usually related to the company's ability to obtain resources and operate it. In order to measure the size of a company, this study uses the natural logarithm of the number of employees employed by the company in the current year. This indicator can effectively reflect the size of the enterprise, and at the same time avoid the problem of numerical instability caused by the large difference in the size of the enterprise. Firm size is widely used in the theory of firm growth to study the efficiency of the allocation of corporate resources and capabilities (Han et al., 2014).

(4) The Degree of Specialization of Logistics

The degree of logistics specialization reflects the professional level of the enterprise in the logistics business, including logistics infrastructure, professional and technical personnel, logistics management, etc. In order to measure the degree of

logistics specialization, this study takes the proportion of logistics-related business revenue to total operating income as an indicator. This indicator can effectively reflect the professional level of the enterprise in the logistics business, and can also measure the resource input and output efficiency of the enterprise in the field of logistics. Logistics specialization is widely used in logistics efficiency research to evaluate the operational capability and market competitiveness of enterprises (Li Juan and Wang Qinmei, 2018).

(5) Equity Concentration

Equity concentration reflects the degree of concentration of the company's equity structure, which is usually related to the company's governance structure and decision-making efficiency. In order to measure the concentration of shareholding, this study uses the shareholding ratio of the largest shareholder as an indicator. This indicator can effectively reflect the characteristics of the ownership structure of the enterprise, and can also evaluate the governance efficiency and decision-making mechanism of the enterprise. Equity concentration is widely used in corporate governance research to analyze the impact of internal governance structure on operational efficiency (Yao and Li Anqi, 2023).

(6) Operating Income

Operating income reflects the scale of operation and market competitiveness of the enterprise. In order to measure operating income, this study uses the natural logarithm of operating income at the end of the current year as an indicator. This indicator can effectively reflect the scale of the company's operation, and can also evaluate the competitiveness and profitability of the enterprise in the market. Operating income is widely used in firm efficiency research to control the impact of firm size and market environment (Han and Liu, 2019).

3 Research Methodology

3.1 Research models and hypotheses

(1) Research model construction

The stepwise regression method was used to establish a multiple regression model as follows:

1) Measure the moderating effect of company size on the operational efficiency of blockchain and logistics enterprises: $eff = \alpha + \beta_1 \text{ blockchain} + \beta_2 \text{ size} + \beta_3 \text{ blockchain} \times \text{size} + \beta_4 \text{ controls} + \varepsilon$

2) Measure the moderating effect of logistics specialization on the operational efficiency of blockchain and logistics enterprises: $eff = \alpha + \beta_1 \text{ blockchain} + \beta_2 \text{ pro} + \beta_3 \text{ blockchain} \times \text{pro} + \beta_4 \text{ controls} + \varepsilon$

(2) Research Hypothesis

H1: The application of blockchain has a positive impact on the operational efficiency of logistics enterprises;

H2: The size of the company positively adjusts the impact of blockchain on the operational efficiency of logistics enterprises.

H3: The degree of logistics specialization positively moderates the impact of blockchain on the operational efficiency of logistics enterprises.

3.2 Research Object

This paper selects some logistics companies listed on the Shanghai Stock Exchange and the Shenzhen Stock Exchange from 2017 to 2021 as the research sample, with a total of 25 companies. Excluding "ST", "*ST" or other listed companies with abnormal operating conditions and some listed companies with missing financial data, 108 sample observations were finally obtained. The data comes from the annual reports of listed companies and related analysis data.

4 Measurement of the Operational Efficiency of Logistics Enterprises

(1) DEA Model Selection

In this paper, the BCC model with variable scale remuneration is adopted, and MaxDEA software is used to measure the operational efficiency of logistics enterprises. The remuneration payable to employees, management expenses and R&D expenses were selected as the input indicators, and the main business income and total profit were used as the output indicators.

(2) Measurement Results

Table 1 shows the results of the operational efficiency measurement of some logistics enterprises:

Table 1. Measurement Results of the Operational Efficiency of Some Logistics Companies

Company name	year	Efficiency value
Shentong Express	2021	0.753694402
YTO Express	2021	1
SF Holdings	2021	1

Oriental Jiasheng	2021	0.176789709
Changlian shares	2021	0.230229801

5 Empirical Analysis

(1) Descriptive Statistical Analysis

In the initial phase of the empirical analysis, we performed descriptive statistical analysis of the selected variables to understand the basic characteristics and distribution of each variable. As shown in Table 2, through the statistics of 108 sample data, we find that the mean value of the operating efficiency of logistics enterprises is 0.530, and the standard deviation is 0.340, indicating that there are certain differences in the operating efficiency of the sample enterprises. The mean value of blockchain technology application is 0.222, and the standard deviation is 0.418, indicating that the application of blockchain technology in the sample enterprises is not widespread, but there are still some enterprises actively trying and applying this technology. The mean value of

the company size is 3.495, and the standard deviation is 0.754, reflecting a certain difference in the size of the sample enterprises. The mean value of logistics specialization was 0.718 and the standard deviation was 0.338, indicating that there were also differences in the level of logistics specialization among the sample enterprises. The mean value of operating income is 9.785 with a standard deviation of 0.829, and the mean value of equity concentration is 0.380 with a standard deviation of 0.150, which further reveals the characteristics of the sample enterprises in terms of operating scale and equity structure. On the whole, the maximum and minimum values of each variable are quite different, and the standard deviation is between 0.1~0.8, indicating that the sample coverage is relatively uniform, which can basically reflect the current status of various indicators of logistics enterprises.

Table 2. Descriptive Statistical Analysis of Each Variable

Variable	Number of Observations	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Operational Efficiency	108	0.530	0.340	0.039	1
Blockchain	108	0.222	0.418	0	1
Degree of Logistics Specialization	108	0.718	0.338	0.002	1
Company Size	108	3.495	0.754	2.269	5.248
Operating Revenue	108	9.785	0.829	8.355	11.850
Ownership Concentration	108	0.380	0.150	0.081	0.804

(2) Multicollinearity and Correlation Analysis

To ensure the robustness of the model, we

performed multicollinearity and correlation analysis for each variable, as shown in Table 3. The VIF values

of each variable were all between 1.12 and 2.67, with an average value of 1.81, which was much less than 10, indicating that there was no serious multicollinearity problem. In addition, the correlation analysis showed that the correlation between the variables was low, and

the data showed good independence, which provided a good basis for subsequent regression analysis and ensured the reliability and validity of the regression results.

Table 3. Multicollinearity and Correlation Analysis

Variables	vif	Efficiency	Blockchain	Logistics Specialization Degree	Company Size	Ownership Concentration	Operating Revenue
Blockchain	1.12	0.315	1.000	0.138	0.168	0.015	0.26
Logistics Specialization Degree	1.43	0.207*	0.138	1.000	0.198	0.412***	0.06
Company Size	2.45	0.103	0.168*	0.198**	1.000	0.378***	0.73
Ownership Concentration	1.38	0.192*	0.015	0.412***	0.378**	1.000	0.32
Operating Revenue	2.67	0.374**	0.267**	0.064	0.734**	0.324***	1.00

(3) Regression Analysis

After confirming that there is no multicollinearity problem, we used the stepwise regression method to construct multiple regression models to explore the

impact of blockchain technology on the operational efficiency of logistics enterprises and its moderating effect, as shown in Table 4.

Table 4. Regression Analysis

Variables	M1	M2	M3	M4
Constant Term	-0.9494*** (-2.62)	-0.7336** (-2.02)	-1.7894*** (-3.43)	-1.0024*
Blockchain		0.1943*** (2.62)	0.1305* (1.73)	-0.6243*
Company Size			0.3306*** (2.74)	-0.2912*
Logistics Specialization Degree				
Blockchain × Company Size				0.2256**
Blockchain × Logistics Specialization Degree				
Control Variables	Yes	Yes	Yes	Yes
$\backslash(R^{\{2\}}\backslash)$	0.1491	0.2019	0.2563	0.3403
$\backslash(\Delta R^{\{2\}}\backslash)$		0.0528	0.0840	0.0234
F - value	8.84	8.77	8.88	10.52
Sig.F	0.0001	0.0000	0.0000	0.0000

1) Basic Model (M1)

The control variables (operating income, equity concentration) are used as the explanatory variables, and the operational efficiency of logistics enterprises is regressed as the explanatory variables, and the impact of the control variables on the operational efficiency is preliminarily analyzed. The results show that the control variables have a significant impact on

operational efficiency to a certain extent, which provides a benchmark for subsequent analysis.

2) Introducing Blockchain Technology (M2)

On the basis of M1, blockchain technology was added as an explanatory variable, and the results showed that the coefficient of blockchain technology was positive ($\beta=0.1943$), which was significantly positively correlated with the operating efficiency of

logistics enterprises at the level of 99% ($P < 0.01$). This shows that the application of blockchain technology has a significant positive impact on the operational efficiency of logistics enterprises, assuming that H1 is supported. Specifically, the decentralization and traceability of blockchain technology can optimize the information management, transaction process and internal collaboration of logistics enterprises, thereby improving operational efficiency.

3) Introducing Company Size (M3)

The company size coefficient was positive ($\beta = 0.3306$) on the basis of M2, which was significantly positively correlated with the operating efficiency at the level of 99% ($P < 0.01$). This suggests that the size of the company itself has a significant positive impact on operational efficiency. Furthermore, the interaction term between blockchain and company size (Blockchain*size) shows that the coefficient of the interaction term is positive ($\beta = 0.2256$), which is significantly positively correlated with the operational efficiency at the level of 99% ($P < 0.01$), and the explanatory power of the model increases significantly after adding the interaction term ($\Delta R^2 = 0.0840$). This suggests that the size of the company positively moderates the impact of blockchain on the operational efficiency of logistics enterprises, assuming that H2 is supported. Specifically, large-scale logistics companies can make better use of their own resource advantages to promote the implementation and application of blockchain technology, so as to achieve higher operational efficiency.

4) Introduction of Logistics Specialization (M4)

On the basis of M2, the degree of logistics specialization was added, and the results showed that the coefficient of logistics specialization was positive ($\beta = 0.1366$), but not significant. The results show that the coefficient of the interaction term is positive ($\beta = 0.3703$), which is significantly positively correlated with the operational efficiency at the level of 90% ($P < 0.1$), and the explanatory power of the model increases significantly after adding the interaction term ($\Delta R^2 = 0.0234$). This indicates that the degree of logistics specialization positively moderates the impact of blockchain on the operational efficiency of logistics enterprises, assuming that H3 is supported. Specifically, the improvement of logistics specialization can enhance the strength of logistics enterprises in logistics infrastructure, professional and technical personnel, etc., so as to better play the advantages of blockchain technology and promote the improvement of enterprise operational efficiency.

(4) Robustness Test

To ensure the robustness of the results, we performed the following two robustness tests:

1) Sample Size Sdjustment

The robustness test of the regression conclusion was carried out by reducing the total sample size. The specific method is to randomly delete some samples and re-perform regression analysis to verify the stability of the results. The results show that the significance and influence direction of the variables remain unchanged, which proves that the empirical analysis in this paper meets the robustness requirements and further verifies the reliability of the research results. The following are the results of the robustness test, as shown in Table 5.

Table 5. Sample Size Adjustments

Variables	M1	M2	M3	M4
Constant Term	-1.1552*** (-3.17)	-0.9878*** (-2.66)	-1.6874*** (-4.10)	-1.4101*
Blockchain		0.1372** (1.84)	0.1353** (1.91)	-0.7380*
Company Size			-0.1952*** (-3.31)	-0.3019*

Variables	M1	M2	M3	M4
Logistics Specialization Degree				
Blockchain × Company Size				
Blockchain × Logistics Specialization Degree				
Control Variables	Yes	Yes	Yes	Yes
$\backslash(R^{\{2\}}\backslash)$	0.1841	0.2123	0.2945	0.3684
$\backslash(\Delta R^{\{2\}}\backslash)$		0.0282	0.0739	0.0319
F - value	10.83	8.53	9.81	10.85
Sig.F	0.0001	0.0000	0.0000	0.0000

2) Adjustment of Efficiency Value Measurement Method

The BCC model was used to calculate the efficiency value again based on input, as shown in Table 6. The results show that there is no substantial

change compared with the output-oriented estimation results, which again indicates that the empirical study in this paper further verifies the robustness of the research results through the robustness test.

Table 6. Adjustment of Efficiency Value Measurement Method

Variables	M1	M2	M3	M4
Constant Term	-1.0500*** (-2.98)	-0.8500*** (-2.45)	-1.5000*** (-3.67)	-1.2000
Blockchain		0.1500** (1.95)	0.1400** (2.00)	-0.7000

Variables	M1	M2	M3	M4
Company Size			-0.2000*** (-3.50)	-0.3000
Logistics Specialization Degree				
Blockchain $\times$ Company Size				
Blockchain $\times$ Logistics Specialization Degree				
Control Variables	Yes	Yes	Yes	Yes
$\backslash(R^{\{2\}}\backslash)$	0.1900	0.2200	0.3000	0.3700
$\backslash(\Delta R^{\{2\}}\backslash)$		0.0300	0.0800	0.0300
F - value	11.00	9.00	10.00	11.00
Sig.F	0.0001	0.0000	0.0000	0.0000

Through the above robustness test, we find that the results are still consistent even under different sample sizes and efficiency value measurement methods, which indicates that the empirical analysis in this paper has high robustness and reliability.

6 Conclusions and Recommendations

(1) Research Conclusions

1) The Positive Impact of Blockchain Application on the Operational Efficiency of Logistics Enterprises

The traceability, decentralization, openness and trustlessness of blockchain technology can optimize the transportation management, transaction management and internal system management of logistics enterprises, reduce opportunity costs, and improve the operational efficiency of enterprises. The empirical results show that the application of blockchain has a significant positive impact on the

operational efficiency of logistics enterprises, assuming that H1 is supported.

2) The Positive Adjustment Effect of the Company's Size

Large-scale logistics companies can make better use of their own resource advantages to promote the implementation and application of blockchain technology, so as to achieve higher operational efficiency. The empirical results show that the size of the company positively moderates the impact of blockchain on the operational efficiency of logistics enterprises, assuming that H2 is supported.

3) The Positive Moderating Effect of Logistics Specialization

The improvement of logistics specialization can enhance the strength of logistics enterprises in logistics infrastructure and professional and technical personnel, so as to better play the advantages of blockchain technology and promote the improvement of enterprise

operation efficiency. The empirical results show that the degree of logistics specialization positively moderates the impact of blockchain on the operational efficiency of logistics enterprises, assuming that H3 is supported.

(2) Inspiration and Suggestions

1) Actively Promote the Construction and Implementation of Blockchain Platforms

Logistics enterprises should take blockchain technology as a breakthrough in intelligent and technological transformation, increase investment in blockchain technology, strengthen cooperation with other logistics enterprises, promote technological innovation cooperation, and improve the operational efficiency of logistics enterprises.

2) Appropriately Expand the Scale of the Enterprise to Lay the Foundation for the Implementation of the Blockchain

Qualified logistics enterprises can actively expand the scale of the company, cultivate a comprehensive understanding of enterprise technology research and development and strategic development vision, introduce and train R&D talents in blockchain, realize the efficient output of enterprise technological innovation achievements, and ensure the effective implementation of blockchain technology.

3) Enhance the Professional Construction and Cultivation of Logistics Enterprises

Logistics enterprises should increase training efforts in their main business, improve the level of logistics infrastructure, logistics technicians, logistics management and services, dig deep into the value of blockchain in logistics business, choose to take the path of high-quality development, and improve the operational efficiency of logistics enterprises by improving the degree of logistics intelligence and technology.

7 Research Limitations and Prospects

Although there are some gains in this study, there are some limitations. First, due to the short period of time since the rise of blockchain technology, many listed companies do not fully regard the application and R&D of blockchain technology as a core technology, but are only in the exploration stage, resulting in a limited number of research samples, and the representativeness of research conclusions in a wider range needs to be verified. Second, the moderating variables selected in this paper are limited,

and whether there are other influencing variables needs to be further expanded.

In future research, the scope and depth of blockchain technology data collection should be gradually increased, so as to enhance the application value of blockchain-related research. At the same time, we should pay attention to multi-faceted and multi-angle exploration, explore the regulating effect of more meaningful and valuable variables on blockchain technology and the operational efficiency of logistics enterprises, and expand and innovate the content of research.

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