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Study on Information Security Industry Efficiency Measurement Based on DEA-GRA

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Abstract. The operational efficiency of information security enterprises is of great significance to China's information security and even economic security. This paper constructs a DEA-GRA model to calculate the BCC efficiency decomposition of 30 listed companies and gives the amount of input redundancy and output insufficiency of non-DEA effective enterprises. This study also explores the grey correlation between the efficiency of super-efficient technologies and the environmental factors of where firms produce and sell. The results of the study show that the vast majority of non-DEA effective decision-making units in 2022 are in a state of decreasing size. The grey correlation analysis shows that the industrial cluster effect and scientific and technological investment in the production place, and the degree of development of the information security industry in the operation place have an important impact on the technical efficiency of information security enterprises.

Keywords: Information Security Industry; Data Envelopment Analysis; Grey Correlation Analysis; Operational Efficiency.

1. Introduction

In recent years, China's information technology has gradually grown into an indispensable and important part of the national economy. The continuous development of new quality productivity cannot be separated from the escort of the information security industry. The development of enterprises is a direct reflection of industrial development. In the development process of information security enterprises, there are many problems that need to be solved, for example, enterprises need to understand their performance in the industry competition and the direction of efficiency improvement; moreover, they need to understand the potential relationship between the operational efficiency and the various environmental conditions in the place of operation, in order to optimise the deployment of resources in the country [1]. Therefore, this study will explore the operational efficiency of major information security enterprises in China and analyse the extent to which the macro-environment at the place of operation affects operational efficiency, with a view to answering the above questions for information security enterprises.

2. Analysis of the current situation

Information security industry is part of the information technology industry, and network security is an important content of information security in the Internet era. The small overall scale of the industry, few professionals and weak supply of upstream basic hardware are the main bottlenecks in the development of China's network security industry at present [2]. From the macro perspective of regional economy, information technology industry is mainly gathered in the eastern region. Among the three major economic circles in the eastern region of China, the competitiveness of new-generation information technology industry in the Bohai Rim is higher than that in the Yangtze River Delta and Pearl River Delta regions [3]. That is to say, it shows that each enterprise can improve its performance by adjusting the distribution of investment and business activities in different parts of

the country. However, there is little literature on efficiency analysis and regional economic analysis of information security enterprises. In terms of the characteristics of the information security industry, in addition to inheriting the high requirements of the general new-generation information technology industry for the development of the electronic information manufacturing industry and science and education in the operating regions, it also focuses on the size of the market demand as reflected in the degree of penetration of information technology in the production and life of the operating regions.

At present, scholars apply DEA model to study the efficiency of enterprises more widely, the relevant literature is rich in research content. There is also a large amount of literature based on the financial data of listed companies combined with the DEA method for corporate efficiency analysis. Among them, many studies focus on the innovation efficiency of science and technology enterprises [4]. For example, Qu Guojun focuses on the technological innovation efficiency of listed companies, constructs three types of input-output-environmental indicators, examines the pure technical efficiency, comprehensive efficiency, and scale efficiency in DEA analysis, and concludes that the scale inefficiency is the main reason for the overall low technological innovation efficiency [5].

However, the sample of decision-making units in this study is limited, so it is not appropriate to use the regression method used in many studies. This study wants to use the GRA method to investigate the grey correlation between firm efficiency and environment, and the impact of environmental factors on firm efficiency.

On the basis of the comprehensive understanding of the above studies, this paper will conduct empirical analysis on the efficiency measurement of China's information security enterprises listed companies, measure the efficiency of each enterprise and analyse the input redundancy and output insufficiency of non-DEA effective enterprises, i.e., to find out the short boards of the enterprises and the space for improvement, and to provide improvement suggestions for these enterprises [6]. On the basis of obtaining the supertechnical efficiency of enterprises, the relationship between the efficiency and its main business income and expenditure location is analysed, so as to provide suggestions for enterprises to balance the investment in various places. Therefore, the differences between this paper and other existing studies are: firstly, this paper takes information security listed companies as the research object to explore the DEA effective situation of each enterprise in this segment, and to explore the degree of influence of each environmental factor on the efficiency of enterprises in this segment; secondly, when exploring the influence of the environment on the efficiency of enterprises, the explanatory variables are not constructed based on the environmental factors of the place of incorporation, but are constructed based on the environmental factors of the enterprise's production place or sales place. Secondly, when exploring the influence of environment on enterprise efficiency, the explanatory variables are not constructed based on the environmental factors of the place of registration, but based on the place of production or sales of enterprises [7]. This is more in line with the actual situation of macro-environmental factors affecting enterprises.

3. Models and Methods

3.1 Input-Oriented Super-Efficient BCC Firm Efficiency Measurement Measurement

Data Envelopment Analysis (DEA) is a non-parametric method for evaluating the relative efficiency of multiple-input multiple-output homogeneous decision-making units (DMUs). The measurement idea is to compare the input and output levels of the DMU with the projection on the effective frontier, and the result is taken as the relative efficiency of the DMU.

Considering that the information security industry is greatly affected by the scale effect, in order to analyse the impact of the scale effect on the efficiency of enterprises, the BCC model with variable scale efficiency is used [8]. The model has the expression TE = SE × PTE. where TE represents the technical efficiency, i.e. the ratio of the output value of the DMU under a certain level of technology and input level to the production frontier (optimal output value). And PTE (Pure Technical Efficiency) is obtained by separating SE (Scale Efficiency) from TE (Technical Efficiency). This efficiency is

solved by the BCC model of DEA. Taking the above considerations into account, this paper uses the input-oriented super-efficient BCC model to measure the efficiency of these firms.

3.2 Ineffective Decision Unit Relaxation Measurement

Since BCC is a radial measurement model, only equal proportional improvement of decision units can be proposed. On this basis, in order to solve the relaxation improvement of DMUs, a non-radial angle based relaxation volume method (SBM) is used to calculate the relaxation improvement of each firm. In this model, it no longer cares about the calculated efficiency value, but only the value of the input and output slack when the planning solution reaches the optimal solution, which represents the slack improvement of the decision-making unit [9].

3.3 Grey correlation analysis

Grey correlation analysis determines the degree of correlation between two sequences by quantifying the degree of similarity between the trend and shape of the sequence curves composed of the explanatory variables and the explanatory variables. Grey correlation analysis first constructs a sequence of explanatory variables, and multiple explanatory variables. The sequence is normalized by the polarization method, and the normalized sequence $x_i(k)$ of the explanatory variables and $x_0(k)$ of the explanatory variables are obtained, and the grey correlation between $x_i(k)$ and $x_0(k)$ is calculated:

$$\gamma_{0i} = \frac{1}{n}\sum_{k=1}^{n} \frac{\min_i \min_k |x_0(k) - x_i(k)| + p \max_i \max_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + p \max_i \max_k |x_0(k) - x_i(k)|} \quad (1)$$

Where is the coefficient of discrimination coefficient, generally take 0.5. calculated $\gamma_{0i} \in (0, 1)$, the closer to 1, it means that the sequence $x_i(k)$ and $x_0(k)$ grey correlation is the greater, that is, the macro-environmental factors of the business efficiency of that macro-environmental factors have a greater impact on the enterprise's business efficiency.

4. Indicator system establishment and data sources

4.1 Construction of enterprise efficiency measurement index system based on financial data

Information security enterprise is a technology-intensive enterprise, and its production and operation process requires comprehensive inputs of human, material and financial resources in economic operation and technological innovation. Its business output results should also be reflected from market performance, operating income and other aspects. Considering that the DEA method requires indicators to form multiple inputs and multiple outputs, and the indicators are as streamlined as possible, drawing on the results of Mao Yunshi, Wu Renqun and others [10], we constructed the DEA efficiency measurement indicator system as shown in Table 1.

Table 1 DEA analysis indicator construction and its meaning

Tier 1 indicators	Secondary indicators	Explanation of Indicators
Input indicators	Intangible assets	Enterprises' financial capacity for technological innovation
	Number of R&D staff	Reflects the enterprise's investment in R&D manpower
	Net fixed assets	Factor of company's economic scale
	Main business cost	Reflects capital investment capacity
Output indicators	Revenue from main business	Profitability of the enterprise
	Net profit	Important indicator of enterprise efficiency
	Earnings per share	Enterprise capital market recognition

4.2 Construction of macro-environmental indicator system

Macro-environmental factors are not subject to change by the subjective will of the enterprise, but they have a significant impact on the business activities and performance of the enterprise. Some indicators of macro-environmental factors affect the production segment of the enterprise's activities, while others affect the distribution segment. For indicators affecting the production chain, the place of production is said to be the place of association of the indicator; and vice versa, the place of sales is said to be the place of association of the indicator [11]. The construction of macro-environmental factor indicators for GRA analysis is shown in Table 2:

Table 2 Construction of macro-environmental factor indicators

Indicator meaning	Sign	Indicator data	Affiliated
Level of electronic information manufacturing industry	X1	Total profit of electronic information industry manufacturing	Production area
Percentage of university graduates	X2	Number of university students per 10,000 people	Production area
Market size of sales to enterprises	X3	Number of computers in use at the end of the enterprise period	Sales area
R&d intensity	X4	R&d investment/gross regional product	Production area
Industry cluster effect	X5	Information security revenue	Production area
Degree of development of information industry	X6	Revenue of software and information technology service industry	Sales area
Market size of sales to individuals	X7	/gross regional product	Sales area
Per capita investment in education	X8	Number of mobile internet users	Production area

4.3 Data sources and description

The financial data of each enterprise comes from the RESSET database, using the 2022 annual report data. Macro data are adopted from the 2023 China Statistical Yearbook and the 2022 National Statistical Bulletin on Science and Technology Investment. All data describe the economic and social situation in 2022.

The business engaged by information security enterprises covers information security products and information security services, and the products include software industry and information security equipment manufacturing. Specific segments include information security, network security, cryptography, and security master chips. Based on the above understanding, this study retrieves enterprises whose main business is information security industry from A-share listed enterprises, and excludes enterprises in ST or ST* status at the end of 2022, and excludes enterprises listed in 2022, and finally obtains 30 information security enterprises.

5. Empirical analysis

5.1 Analysis of DEA efficiency across enterprises

Flatten and normalise negative output indicators. Calculate the super-efficient technical efficiency, pure technical efficiency and scale efficiency of the 30 firms. And accordingly the returns to scale are analysed. The results of the analysis and calculation are shown in Table 3.

Table 3 Super-efficient technical efficiency and BCC efficiency of each listed company

Company Name	Super-efficiency Technical Efficiency	Pure technical efficiency	Scale efficiency	Rewards of scale analysis
Aerospace Development	0.7188	0.7707	0.9327	DRS
Hengbao	0.9149	1	0.9149	DRS
Tianrongxin	0.5123	0.5565	0.9205	DRS
Dentsu Network Security	0.9238	1	0.9238	DRS
Taiji	0.8573	1	0.8573	DRS
Leike Defence	0.6065	0.6208	0.977	IRS
Qixingchen	0.9528	1	0.9528	DRS
Huasoft Technology	3.1015	1	1	CRS
Zhongxin Saike	1.0235	1	1	CRS
Ruiming Technology	0.8932	0.9929	0.8996	DRS
Jida Zhengyuan	1.5332	1	1	CRS
Nethub Technology	0.9458	1	0.9458	DRS
Nationz Technologies	0.9033	0.9418	0.9591	DRS
Guotou Intelligence	0.6925	0.7683	0.9013	DRS
Tiangui Technology	2.3944	1	1	CRS
RENZIHANG	0.718	0.8506	0.8441	DRS
Cyclone Information	0.7798	0.9604	0.8119	DRS
Zhaozhi Technology	1.8533	1	1	CRS
Creative Information	0.7772	1	0.7772	DRS
Greentech	0.9381	0.9507	0.9868	DRS
Flying Integrity	2.4028	1	1	CRS
Silicon Integrated Services (SIS)	1.1922	1	1	CRS
Digital Authentication	1.394	1	1	CRS
Xiling Information	3.2809	1	1	CRS
Zhongfu Information	0.8383	0.8553	0.9801	DRS
Datang Telecom	0.8767	1	0.8767	DRS
Orient Communications	1.0372	1	1	CRS
Three Six Zero	1.085	1	1	CRS
Shanshi Netcom	1.0499	1	1	CRS
CloudSurge	1.0625	1	1	CRS

From the empirical results, the average scale efficiency of the above companies is greater than the average pure technical efficiency, indicating that the scale factor plays a dominant role in the technical efficiency of the information security industry in 2022. among the 30 companies, 13 companies such as HASoft Technology and Xiling Information are on the frontier of comprehensive efficiency, and their resource allocation and technical management are relatively efficient. Further comparison of the efficiency differences of the above companies. Xiling Information is ranked first with a super-efficiency value of 3.2809. Its resource utilisation and development are on the leading edge. In terms of returns to scale, 13 companies have unchanged returns to scale and are at the point of optimal returns to scale, and only 1 company, Leike Defence, has incremental returns to scale, indicating that there is room for improvement in the inputs of this company, and that an increase in the right amount of inputs will lead to a higher percentage of increase in returns. The remaining 16 enterprises have decreasing returns to scale. The remaining 16 enterprises have decreasing returns to scale, indicating that these enterprises should reduce their production scale if they want to improve their efficiency.

5.2 Analysis of relaxation values of DEA ineffective enterprises

SBM is the efficiency measure based on slack variables. The significance is that if the DMU can reach the efficiency frontier by only reducing certain inputs by a certain amount or by only increasing certain outputs by a certain amount, the reduction is input redundancy; the increase is output deficiency.

When there is input redundancy or output insufficiency, it indicates that the company's efficiency is non-efficient, and a company with non-efficient SBM can refer to the results of the analysis of input redundancy and output insufficiency shown in Table 4, and adjust the input quantity of each input factor and the output target of each output to achieve the effective improvement of its own efficiency. All firms do not have output shortfalls in main business income, indicating that all SBM ineffective firms are ineffective due to the fact that net profit and earnings per share do not reach the production frontier.

5.3 Analysis of the impact of macro factors on the efficiency of enterprises where they operate

Many enterprises provided their distribution of cost of main business and income from main business in seven regions of the country. Calculate the impact of macro-environmental factors on the enterprise where the associated place is the place of production and the place of sale respectively. Let the proportion of the distribution of the enterprise's main business cost (income) in each region of the country be $\alpha 1, \alpha 2, \alpha 3, \alpha 4, \alpha 5, \alpha 6, \alpha 7$, Table 4 below demonstrates the main operating Cost of main business/10,000 Yuan; Revenue from main business/Yuan; and Net profit/10,000 Yuan.

Table 4 Calculation of Input Redundancy and Output Insufficiency for Undirected SBM Ineffective Firms

Company Name	SBM Efficiency	Cost of main business/10,000 Yuan	Revenue from main business/Yuan	Net profit/10,000 Yuan
Aerospace Development	0.5053	48437.66	0	0.00
Tianrongxin	0.4528	152777.22	0	0.00
Leike Defence	0.2873	22872.13	0	75952.27
Ruiming Technology	0.6085	13994.30	0	11224.83
National Technology	0.5501	0.00	0	0.00
Guotou Intelligence	0.5121	18133.68	0	0.00
RENZIHANG	0.5055	3535.34	0	3070.67
Cyclone Information	0.6257	62472.03	0	48283.85
Green Alliance Technology	0.6627	0.00	0	5700.05
Zhongfu Information	0.1615	447.15	0	40984.59

The sum of the ith macro-environmental indicator for each province in each of the seven regions is $c_{i1}, c_{i2}, c_{i3}, c_{i4}, c_{i5}, c_{i6}, c_{i7}$, respectively, so that the listed company is affected by the ith macro-environmental factor can be expressed as:

$$I_i = \sum_{j=1}^{7} \alpha_j c_{ij} \tag{2}$$

Examining the structure of the financial data published by the above 30 listed companies regarding their main business costs and revenues, a total of 13 companies provided their main business costs and revenues classified by the seven regions. The grey correlation between each factor and the super-efficiency of the firms was calculated in terms of GRA as shown in Table 5.

It can be seen that the correlation between each factor and efficiency is high. Generally, the grey correlation is greater than 0.7 can be regarded as an important factor, so it can be seen that six factors such as the degree of development of regional information industry are important factors affecting the efficiency of enterprises. The correlation of the other two factors is also close to 0.7.

Based on the results of the above GRA calculation, the following analyses are made: from the viewpoint of the influence of the environmental factors on the efficiency of the enterprise's sales place, the degree of development of the regional information industry and the size of the private sales market have a greater impact on the efficiency of the enterprise. This also indicates that the degree of development of regional information industry can be recognised as an indicator factor for measuring the size of sales market.

In terms of the impact of environmental factors on enterprise efficiency, the number of regional university graduates, R&D intensity and industry cluster effect have a greater impact on the technical efficiency of enterprises, while the level of electronic information manufacturing industry and per capita investment in education have a slightly smaller impact on efficiency. This suggests that the number of university graduates in a region is a more direct reflection of the role of education development in supporting information security enterprises than per capita investment in education, and that the R&D funding represented by R&D intensity is also a direct indication of a strong technological innovation atmosphere in a region, which includes regional financial support for R&D, the concentration of technologically innovative talents, and the regional industrial structure bias towards technologically innovative industries, and so on.

Table 5 GRA correlation order

Sign	Indicator meaning	Grey correlation	Correlation ranking
X1	Level of electronic information manufacturing industry	0.6875	8
X2	Percentage of university graduates	0.7387	4
X3	Market size of sales to enterprises	0.7324	6
X4	R&d intensity	0.7375	5
X5	Industry cluster effect	0.7388	3
X6	Degree of development of information industry	0.7678	1
X7	Market size of sales to individuals	0.7596	2
X8	Per capita investment in education	0.6924	7

6. Discussions

In the DEA analysis of the Information Security industry in 2022, non-effective decision-making units generally show diminishing returns to scale, reflecting the existence of overproduction in the industry. During periods of insufficient demand, firms should scale back inputs to improve operational efficiency and learn from the advanced practices of efficient firms in production, operations, management and product innovation. To improve operational efficiency, enterprises need to optimise production scale guided by the scale effect, refer to SBM analysis to reduce input redundancy, and improve the economic efficiency of insufficient output. Enterprises should enhance the technical qualifications of employees and optimise intangible assets, and learn from the business management models of effective enterprises. In addition, enterprises should rationally allocate internal resources, formulate nationwide production and marketing distribution strategies, and select regions with significant industrial agglomeration effects and high R&D intensity as production and R&D centres, such as Beijing, Lu, Guangdong, etc., while sales locations should be preferred to those regions with developed information industries and many Internet users, such as Guangdong, Beijing, Suzhou, etc., in order to maximize the use of high-quality technological talents and innovative environments.

7. Conclusions

In order to objectively reflect the operating efficiency of listed companies in the information security industry within this industry, this paper applies the BCC model to measure the technical efficiency situation, the pure technical efficiency situation and the scale efficiency situation of 30 listed companies in the information security industry. The results of the study found that most of the non-DEA effective companies are in the state of decreasing scale efficiency in 2022. 13 companies out of 30 companies reach the technical efficiency effective. In the unguided SBM analysis of input redundancy or output shortfalls, it is found that each non-DMU ineffective unit only no longer has output shortfalls in its main business revenue. Analyse the relationship between the pure technical efficiency of enterprise super-efficiency and eight indicators such as the degree of development of

information industry and the number of mobile Internet users in each region. It is found that six indicators, such as the degree of development of information industry in the place of sales, the number of mobile Internet users, the number of computers in use at the end of the period, and the effect of industrial clustering in the place of production, the percentage of university students, and the intensity of R&D have an important influence on the technical efficiency of enterprises.

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References

[1] Zhang, Z. (2022). Research on the development trends and countermeasures of China's cybersecurity industry. Journal of Beijing University of Technology (Social Science Edition), 22(3), 75-85.

[2] Yin, T., & Cao, Z. (2022). The clustering of information technology industry, upgrading of industrial structure, and high-quality economic development. Statistics & Decision, 38(4), 129-134.

[3] Li, X., Zhao, H., & Cheng, G. (2021). Competitiveness evaluation and regional differences in the next-generation information technology industry in the three major economic circles. Soft Science, 35(8), 106-112.

[4] Yu, C., Wang, C., Zhuang, W., et al. (2018). Evaluation of the next-generation information technology industry from the perspective of dynamic evolution. Information Science, 36(5), 110-113.

[5] Qu, G., Song, L., & Guo, Y. (2018). Research on the technological innovation efficiency of listed companies in China: Based on the three-stage DEA method. Macroeconomic Research, 2018(6), 97-106.

[6] Fu, N., Su, Y., & Guo, X. (2023). Evaluation of innovation efficiency of smart manufacturing enterprises based on two-stage super-efficiency DEA. Science & Technology Progress and Policy, 2023, 1-11.

[7] Chen, J., & Duan, J. (2020). Comparative study of the operational efficiency of China's fintech companies based on the three-stage DEA. Finance Theory & Practice, 2020(6), 20-27.

[8] Du, B., & Chen, L. (2022). Research on the factors influencing and optimizing paths for the high-quality development of China's technology service industry: A comprehensive analysis based on the GRA model and CRITIC weighting method. Science & Technology Management Research, 42(9), 91-98.

[9] Ma, Q., Liu, Y., & Zhou, Y. (2023). Analysis of factors influencing urban unemployment scale in China based on the GRA model. China Business Review, 2023(3), 80-82.

[10] Mao, Y., & Li, Y. (2017). Comparative study on the merger performance of high-tech enterprises and traditional enterprises based on DEA after the financial crisis: Taking listed manufacturing companies on China's A-share market as an example. Journal of Southeast University (Philosophy and Social Science Edition), 19(4), 38-51+146.

[11] Wu, R. (2018). Efficiency evaluation of listed publishing companies based on the Malmquist index. Science & Technology and Publishing, 2018(12), 114-118.