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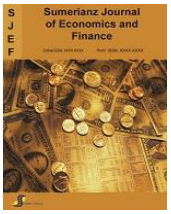

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Research on Operating Efficiency of Security Companies Based on Super-Efficiency DEA-Malmquist Index

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Abstract
In China's economic system, security companies are important participants, and their high operating efficiency can improve the country's economy. Based on the traditional CCR-DEA model, this paper uses super-efficiency DEA model and MALMQUIST index model to analyze the operational efficiency of 10 listed security companies in China from 2016 to 2020, it is found that the operating efficiency of security companies as a whole has a slight upward trend, and the improvement of business efficiency depends on technical efficiency, and relates to pure technical efficiency and scale efficiency.
Keywords: Super-efficient DEA; Malmquist index; Security company; Evaluation of business efficiency.

1. Introduction
One of the important industries to promote China's economic development is the securities industry. With the deepening reform of China's economic system, the development speed of China's security companies has gradually increased. However, there are still related problems in their operating conditions, such as asset size, profitability and management capacity, etc. At the same time, the epidemic of new type of coronary pneumonia intensified the downward pressure on the macro-economy, which had a negative impact on some security companies and reduced operating efficiency. In this situation, the objective evaluation of the efficiency of security companies can find problems and gradually solve them.

Domestic and foreign scholars have studied and discussed the operating efficiency of security companies in different degrees, and the relatively limited foreign related research literature has also laid some research foundation. Sathye (2003), take the Indian Security company as the object, through the Data envelopment analysis method (DEA) measurement its operating efficiency, indicates that Indian securities firms are more efficient than the global average. Beccali (2004), First measured and compared the operating efficiency of Italian and British securities firms based on SFA model, and pointed out that the higher the degree of internationalization, the higher the operating efficiency. Zhang *et al.* (2005), used DEA model to study the American securities industry from 1980 to 2000. He pointed to the overall inefficiency of the US securities industry, and an important reason for the decline in relative productivity is that most small firms cannot reach the production frontier of large firms. Similarly, Demirbag *et al.* (2016) used DEA model to study the efficiency of Turkish securities firms, and pointed out the importance of scale to the efficiency of firms. Through the empirical study, it is concluded that scale is very important to the efficiency of the company, and that affiliation and foreign ownership positively affect the efficiency. Compared with the domestic market, Li (2016) broke down the operating efficiency of 27 security companies in China by the Data envelopment analysis method (DEA) , and found that the technical efficiency is the main problem, and the scale efficiency problem is becoming more and more serious.Secondly, through the Malmquist index method, we find that the stockjobbers'technical level has improved and their development has been sustainable. Zhou and Yu (2017) combined the entropy method with the DEA method and Malmquist index method to analyze the horizontal static

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and vertical dynamic of 17 security companies in China, and pointed out that the sustainable development ability appeared obvious polarization, and the comprehensive efficiency and the production chain depend on pure technical efficiency and technical progress respectively, so we should commit ourselves to optimizing the allocation of resources and introducing advanced technology. Qin and Liu (2018) constructed a three-stage DEA model based on SBM revision to evaluate the operating efficiency of 79 security companies in China. Therefore, it is suggested that security companies should focus on their own efficiency and improve the environmental factors. Zhong (2019) evaluated the operating efficiency and benefit of 25 listed security companies in China by DEA method and Tobit model, and concluded that the operating efficiency of China's security companies is generally low, and the return on scale is not good, in order to improve this situation, the company advocates to open up business, focus on innovation, while focusing on risk control, optimization of internal governance.

The CCR ratio table was introduced by Banker *et al.* (1984) to obtain the optimal value of the Data envelopment analysis, and the separation of technology and scale efficiency was realized. Then, Anderson (1995) proposed super-efficiency DEA, which solved the problem that traditional DEA could not further evaluate and rank the decision-making units with simultaneous efficiency. Malmquiste (1953) was the first to propose the Malmquist Index, and then Färe *et al.* (1994) divided Malmquist index into pure technical efficiency change (Pech) , Scale Efficiency Change (Sech) and technology progress index (Tech).

To sum up, most of the methods used in the analysis of business efficiency at home and abroad are traditional DEA methods, which analyze technical efficiency, scale efficiency, etc., compared with the traditional DEA, the super-efficiency DEA can further distinguish the advantages and disadvantages of the order when the unit efficiency is 1, and the results are more accurate and objective. The three indexes of Malmquist index are more detailed and objective to describe the change of business efficiency.

As mentioned above, most DEA methods at home and abroad are used to analyze the technical efficiency, scale efficiency and so on. When the efficiency value is 1, the order can be clearly distinguished to make the analysis more accurate and objective.The second level index derived from Malmquist Index can describe the change of operating efficiency more concretely. Therefore, we use the Super-Efficiency DEA-Malmquist index to evaluate the static and dynamic operating efficiency of 10 listed security companies in China. It can get targeted measures and measures to improve the operating efficiency of security companies to provide reference.

2. Research Methodology

2.1. CCR-DEA Model

DEA is a kind of non-parametric efficiency evaluation method. The decision making unit of DEA has the characteristics of multi-input and multi-output, and gets relative efficiency, which is measured by assuming the effective production frontier of each DMU output index with the linear programming method (Wei, 2000). The traditional DEA includes CCR model based on scale-reward invariance hypothesis and BCC model based on scale-reward variability hypothesis. In this paper, the CCR model is used to get the returns to scale of each decision-making unit. The returns to scale greater than 1 means the returns to scale decrease, the returns to scale less than 1 means the returns to scale increase, and the returns to scale equal to 1 means the same.

2.2. Super-Efficient DEA

The traditional CCR model cannot be further evaluated when multiple decision units exist simultaneously, but the super-efficiency DEA model can make up this deficiency. Therefore, on the basis of selecting CCR model, this paper uses super-efficiency DEA model to optimize it, and the super-efficiency DEA formula is (1). The input factor set and the output factor set are represented by X_j、Y_j respectively. The θ is the efficiency of the decision making unit (DMU).

In the super-efficiency DEA model, from the point of view of effective DMU, the increase of input will increase the output level, and the super-efficiency value is the proportion of input increase, so it is efficient when $\theta \geq 1$, and the larger the θ is, the higher the efficiency is.

$$\begin{cases} \sum_{\substack{j=1 \\ j\neq k}}^{n} X_j\lambda_j \leq \theta X_k \\ \sum_{\substack{j=1 \\ j\neq k}}^{n} Y_j\lambda_j \leq \theta Y_k \\ \theta, \lambda_j \geq 0, j = 1,2,\cdots,n \end{cases} \quad (1)$$

2.3. Malmquist Index Model

The super-efficiency DEA model can only compare the efficiency values of different decision-making units in the same period, and can not study the change of efficiency values in different periods. The MALMQUIST index model can reflect the relationship among total efficiency, technical efficiency and total factor production efficiency index.

The MALMQUIST index can be expressed as follows:

$$\text{tfp} = M_{t+1}(X_{t+1}, Y_{t+1}, X_t, Y_t) = \left[\frac{D_c^t(X_{t+1},Y_{t+1})}{D_c^t(X_t,Y_t)} \times \frac{D_c^{t+1}(X_{t+1},Y_{t+1})}{D_c^{t+1}(X_t,Y_t)}\right]^{\frac{1}{2}} \quad (2)$$

In the formula, (X_{t+1}, Y_{t+1}) and (X_t, Y_t) are input and output variables in t+1 and t periods respectively, and D_c^t and D_c^{t+1} are output distance functions under technical conditions in t+1 and t periods.

When $M_{t+1}(X_{t+1}, Y_{t+1}, X_t, Y_t) > 1$, the Total factor productivity was up; When $M_{t+1}(X_{t+1}, Y_{t+1}, X_t, Y_t) < 1$, the Total factor productivity was down; and when $M_{t+1}(X_{t+1}, Y_{t+1}, X_t, Y_t) = 1$, the Total factor productivity was unchanged.

If the scale is the same, we decompose the MALMQUIST index (tfp) into two indices: technical efficiency change index (Effch) and technological progress index (Tech) , and tfp $= M_{t+1}(X_{t+1}, Y_{t+1}, X_t, Y_t) = Effch \times Tech$.

It's broken down as follows:

$$Effch = \frac{D_c^t(X_{t+1}, Y_{t+1})}{D_c^t(X_t, Y_t)} \quad (3)$$

$$\text{Tech} = \left[\frac{D_c^t(X_{t+1}, Y_{t+1})}{D_c^{t+1}(X_{t+1}, Y_{t+1})} \times \frac{D_c^t(X_t, Y_t)}{D_c^{t+1}(X_t, Y_t)}\right]^{\frac{1}{2}} \quad (4)$$

Given variable returns to scale, pure technical efficiency index (Pech) and Scale Efficiency Index (Sech) can be derived from technical efficiency change index (EFFCH) .The formula is:

$$pech = \frac{D_v^{t+1}(X_{t+1}, Y_{t+1})}{D_v^{t+1}(X_t, Y_t)} \quad (5)$$

$$\text{sech} = \left[\frac{D_v^{t+1}(X_{t+1}, Y_{t+1})/D_c^{t+1}(X_{t+1}, Y_{t+1})}{D_v^t(X_t, Y_t)/D_c^t(X_t, Y_t)} \times \frac{D_v^{t+1}(X_{t+1}, Y_{t+1})/D_c^{t+1}(X_{t+1}, Y_{t+1})}{D_v^t(X_t, Y_t)/D_c^t(X_t, Y_t)}\right]^{\frac{1}{2}} \quad (6)$$

In the formula, $D_v^{t+1}(X_{t+1}, Y_{t+1})$ represents the output distance function under technical conditions in t+1 period with variable returns to scale.

The formula for the Total factor productivity is:

$$\text{tfp} = Effch \times Tech = pech \times sech \times Tech \quad (7)$$

3. Construction of Index System and Data Source

3.1. Selection of Decision Unit

The selected decision-making units are 10 representative listed security companies in China, they are CITIC Securities, Huatai Securities, Oriental wealth, general securities, Guotai Junan Securities, GUANGFA securities, Guoxin Securities, founder securities, China Merchants Securities, Guojin Securities.

3.2. Identification of Input/Output Indicators

This paper studies the Evaluation Index System of operating efficiency of security companies is divided into two parts, namely input index and Output Index. According to the data principles such as smoothness and systematicness, the paper selects the financial indexes of the securities company as the evaluation indexes, such as net profit, total operating income, total assets, asset-liability ratio and total operating cost. Among them, total assets, total operating costs and asset-liability ratio as input indicato, such as Table-1.

Table-1. Input-output indicators of operating efficiency of security companies

Input Indicator	Output Indicator
Total assets	Revenue
Operating costs	NET profit
Ratio of assets to liabilities	

3.3. Data Sources

All the data collected in this paper according to the index system come from the financial index data of the security companies from *Netease Finance* website (Anonymous).

4. Results and Discussion

4.1. Static Analysis of Super-Efficiency CCR-DEA

This paper selects the input-output panel data of 10 listed security companies in China from 2016 to 2020, uses MATLAB software to calculate the value of returns to scale, and uses MAX DEA software to calculate the value of super-efficiency. The collation results are shown in Table 2, Table 3, Table 4, and Figure 1 respectively.

Table-2. 2016-2020 super efficiency values and returns to scale of 10 security companies in China

The company Name	2016		2017		2018		2019		2020		Mean value	Rank
	Super efficiency rate value	Returns to scale	Super efficiency rate value	Returns to scale	Super efficiency rate value	Returns to scale	Super efficiency rate value	Returns to scale	Super efficiency rate value	Returns to scale		
CITIC Securities	1.426	-	1.662	-	1.496	-	1.345	-	1.486	-	1.483	1
Huatai securities	0.901	irs	0.981	irs	0.950	irs	1.059	-	0.957	-	0.970	8
The riches of the east	0.974	irs	0.727	irs	1.098	-	1.300	-	2.176	-	1.255	3
Everbright Securities	0.802	irs	0.790	irs	0.751	irs	0.772	irs	1.005	-	0.824	9
Guotai Junan Securities	1.358	-	1.214	-	1.109	-	0.962	irs	0.985	irs	1.126	4
GF Securities	0.923	irs	1.046	-	0.923	irs	1.102	-	1.202	-	1.039	6
Guosen Securities	0.958	drs	0.969	irs	1.003	-	1.019	-	0.946	irs	0.979	7
Founder Securities	0.791	irs	0.655	irs	0.709	irs	0.709	irs	0.806	irs	0.734	10
China Merchants	1.051	-	0.929	irs	1.291	-	1.073	-	0.982	drs	1.065	5
Guojin securities	1.231	-	1.507	-	1.087	-	1.267	-	1.201	-	1.259	2
Annual mean	1.042		1.048		1.042		1.061		1.175		1.073	

Note:"-"indicates constant returns to scale,"IRS"indicates increasing returns to scale, and"DRS"indicates decreasing returns to scale.

According to the value of super efficiency and the average value of the whole super efficiency from 2016 to 2020(Table 2) , the average value of the whole super efficiency of China's listed security companies is effective, which is between 1 and 1.1, indicating that the general operating efficiency is not high. According to the annual average value of super efficiency of each year, from 2016 to 2020, the annual average value of super efficiency of China's security companies is more than 1, reaching DEA efficiency, but the efficiency value is mostly between 1 ~ 1.1, which shows that the annual average efficiency is not high. From the annual average, we can see that 2018 is lower than 2017, and 2017, 2019 and 2020 are higher than the previous year. As far as the value of super-efficiency of each securities company is concerned, the highest super-efficiency value in 2020 is oriental wealth, whose super-efficiency value exceeds 2, and its relative to the previous year's increase is also the biggest. During the past five years, the number of security companies that reached DEA efficiency in 2019 was the largest, and all security companies except the majority of securities, Guotai Junan Securities and founder securities reached DEA efficiency, which means that the input and output are all on the frontier of production, and there is no invalid input, and the most efficient securities company for CITIC Securities, CITIC Securities in 2019 that the best operating conditions. Other securities firms that are not valid may have technical inefficiencies or input redundancies.

According to the change of returns to scale, there are 27 times of constant returns to scale from 2016 to 2020, which shows that the input and output are optimal, and DEA invalidation is included, which may be caused by the change of technical efficiency. Except for the constant returns to scale in 5 years, most of them show increasing returns to scale. Diminishing returns to scale occurred only twice. The increasing returns to scale indicates that the securities company has the prospect of development, and should actively expand its scale to improve its operating efficiency. Diminishing returns to scale, on the contrary, suggest that an increase in inputs reduces returns.

4.2. Dynamic Analysis of the Malmquist Index

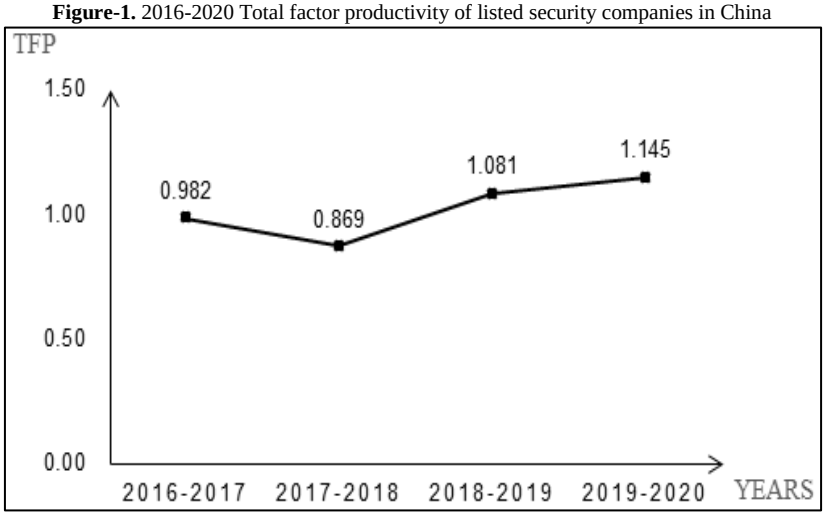
In order to evaluate the operating efficiency of security companies more comprehensively, this paper estimates the technical efficiency index (Effch) , technical progress change index (Techch) , pure technical efficiency change index (Pech) and Scale Efficiency Change Index (Sech) of 10 listed security companies in China from 2016 to 2020 by using Max DEA software. The results are shown in Table 3 and Figure 1.

Table-3. Average Total factor productivity of 10 listed security companies in China

Year	Technical Efficiency	Technological Progress	Pure technical efficiency	Scale efficiency	Total factor productivity
2016-2017	1.009	1.000	1.009	0.970	0.982
2017-2018	0.946	1.000	0.946	0.915	0.869
2018-2019	1.024	1.000	1.024	1.055	1.081
2019-2020	1.028	1.003	1.026	1.109	1.145
Mean value	1.002	1.001	1.001	1.012	1.019

According to the data in Table 3, the Total factor productivity of securities firms between 2016 and 2018 is less than 1, indicating that the operating efficiency of securities firms has declined during that period, with a larger decline between 2017 and 2018; Total factor productivity between 2018 and 2020 is more than 1, it shows that the operating efficiency of security companies is rising, and 2019-2020 a larger increase, Total factor productivity trends as shown in Figure 1.

Figure-1. 2016-2020 Total factor productivity of listed security companies in China



From 2016 to 2020, the average value of each decomposition index of China's security companies showed an upward trend, in which the average annual increase of Total factor productivity was 1.9% , indicating that the operating efficiency of security companies as a whole has improved, and the index of changes in scale efficiency has increased by an average of 1.2 per cent per year, reflecting an improvement in scale efficiency. The Change Index of pure technical efficiency and the technical progress index increased by 0.1% annually, indicating that the overall achievement of technological progress is small. And the technical efficiency change index has increased by 0.2% annually, reflecting the improvement of technical efficiency. From the decomposition indices for the period 2016-2020. Only the technical efficiency change index and the pure technical efficiency change index decreased in 2017-2018 and increased in the remaining years, and increased in the other years. The technical progress change index did not change in the period 2016-2019, the 0.3 per cent increase in 2019-2020 reflects an increase in the technological innovation capacity of securities firms during this period, while the index of changes in scale efficiency decreased between 2016-2018 and increased between 2018-2020, indicating the optimal input-output mix in the previous two years, the next two-year input-output mix is not optimal.

In addition, this paper estimates the Total factor productivity of securities firms in 2016-2020, as shown in Table 4 below.

Table-4. 2016-2020 Malmquist Index of 10 listed security companies in China and its decomposition

Dmu	Technical Efficiency	Technological Progress	Pure technical efficiency	Scale efficiency	Total factor productivity
CITIC Securities	1.044	1.000	1.005	1.038	1.044
Huatai securities	1.024	1.000	1.005	1.017	1.024
The riches of the east	1.144	1.006	1.007	1.111	1.154
Everbright Securities	1.000	1.000	0.994	1.001	1.000
Guotai Junan Securities	0.987	1.000	0.979	1.005	0.987
GF Securities	1.030	1.000	1.009	1.014	1.030
Guosen Securities	1.006	1.000	1.013	0.990	1.006
Founder Securities	0.973	1.000	1.018	0.952	0.973
China Merchants Securities	0.986	1.000	0.996	0.989	0.986
Guojin securities	0.989	1.000	0.983	1.007	0.989
Ensemble average	1.018	1.001	1.001	1.012	1.019

Based on the average Malmquist index of securities firms and its decomposition results (Table 4) , most of the 10 securities firms listed between 2016 and 2020 Total factor productivity more than 1. Combined with an overall mean of more than 1, the Total factor productivity of securities firms as a whole has grown. It means that the overall sustainability of development capacity has increased, which also means that the common role of most security companies will affect the overall efficiency of the changes.

In Table 4, it is obvious that the technological progress index of Oriental wealth is 1, which indicates that the technological innovation ability of oriental wealth has increased, and the technological innovation ability of other security companies has not changed too much. In addition, the Total factor productivity of Guotai Junan Securities, founder securities, Merchants Securities and Guojin Securities declined, and the technical efficiency has been reduced. It means that changes in technical efficiency will cause the Total factor productivity to change in the same direction. This means that the change of technical efficiency will affect the operating efficiency of security companies. Further analysis found that the scale efficiency of Guotai Junan Securities and Guojin securities increased. Moreover, the pure technical efficiency of founder securities increases while the scale efficiency decreases. Obviously, the technical efficiency is influenced by both the pure technical efficiency and the scale efficiency. Therefore, improving the management and enlarging the scale of the company can influence the technical efficiency by improving the pure technical efficiency and the scale efficiency respectively.

5. Conclusions and Recommendations

5.1. Conclusion

Based on the static and dynamic analysis of the data of 10 listed security companies in China from 2016 to 2010, the following conclusions are drawn:

According to the static analysis of super-efficiency DEA, the average annual super-efficiency of 10 listed security companies in China from 2016 to 2020 shows an upward trend, the average super-efficiency is 1.073 < 1.1, so they are not in the high-efficiency period, means that business efficiency can continue to improve.

- From the static analysis of the change of returns to scale, we can see that from 2016 to 2020, listed security companies in the scale of increasing returns to the majority of the situation. And the scale efficiency develops well, which indicates that the security companies generally have the development potential.
- According to the MALMQUIST index dynamic analysis, the annual average is more than 1, indicating that the overall operating efficiency of security companies has improved, and the rest of the time, except 2017-2018, showed an upward trend.
- According to the MALMQUIST index decomposition of different securities firms in the dynamic analysis, the growth of Total factor productivity means the increase of sustainable development ability, and the change of overall efficiency depends on all securities firms, not only one securities firm.
- According to the dynamic analysis, the reason of the decrease of the operating efficiency of Guotai Junan Securities, founder securities, Merchants Securities and Guojin securities lies in the decrease of the technical efficiency. However, the decrease of pure technical efficiency or scale efficiency will affect the decrease of technical efficiency.

5.2. Advice

According to the above analysis and conclusions, in order to improve the operating efficiency of security companies, this paper puts forward the following several corresponding measures for reference.

- Enhancing technological innovation capability and multi-application of new technologies. In the case of better scale efficiency, the effect of scale expansion is very small, so we should develop new technology, improve innovation ability to enhance technical efficiency, thus improve business efficiency.
- Appropriately expanding the scale and further improving the operating efficiency. For the security companies with low scale efficiency, they can enlarge their scale appropriately, which is the best combination of input and output, so as to improve the operating efficiency.
- Refine the management and optimize the management system. For the pure technical efficiency decline of the security companies should optimize the management system, improve the company's operating conditions to promote operational efficiency.

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