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Research on the Efficiency of China's Listed Home Appliance Industry—A Method Based on Three-Stage DEA

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Abstract

In this paper, 44 listed A-share household electrical appliance enterprises are used as samples, using a three-stage DEA method. The purpose is to remove the factors that affect the input variables, and then evaluate the technical efficiency of the company. The effect is significant in the removal of the environment and random factors; the pure efficiency of about 0.1 points to enhance, while the scale of efficiency has a very large decline in the proportion of 0.5 points down, before and after a great change. This shows that the removal of the environment and random factors to examine the operating efficiency of listed home appliances is necessary.

Keywords

Listed Household Electrical Appliance Enterprises, Business Performance Evaluation, Three-Stage DEA

1. Introduction

After the reform and opening up, along with the rapid development of China's economy, China's home appliance industry has developed rapidly, from the beginning of the original equipment manufacture to the establishment of free brands, such as Haier in the world is very well-known. With the development of home appliance industry, the industry is already very mature, which means that this is a highly competitive industry and is a Red Sea. At this time, the competition is not one aspect of technology competition, but all aspects. This time, the competition is not competition between domestic enterprises, but the global competition between enterprises. At this point, to enhance enterprises' core competitiveness is imperative. But China's current manufacturing industry is generally

the irrational capital structure, lack of growth capacity. Therefore, it is necessary to analyze the technical efficiency of household electrical appliance enterprises. This paper is from the industry point of view to study the efficiency between enterprises, and the use of data is from 44 home appliances listed companies. There is a demonstration of the effectiveness of the entire industry to promote the efficiency of refreshing and development is also very important. At present, the research methods of enterprise efficiency include Fuzzy Comprehensive Evaluation (FCE), Analytic Hierarchy Process (AHP), Stochastic Frontier Analysis (SFA) [1], and data envelopment analysis [2]. However, the above methods have their own shortcomings: fuzzy comprehensive evaluation (FCE) and stochastic frontier analysis (SFA) to consider the weight of additional subjective arbitrariness; and the Analytic Hierarchy Process (AHP) elements of choice are critical. Factor selection is unreasonable or the correlation between elements is not good; the results are not ideal, and may not get results. In order to remove the defects of the above methods, Charnel, Cooper, *et al.* [3] in 1978 founded the DEA-CCR model, which was the first proposed DEA model. However, the use of CCR model is conditional. It requires the sample to be constant, but the sample is usually variable in size.

Then, Banker, Charnes and Cooper put forward DEA-BCC model on the basis of CCR model [4]. This model is further divided into pure technical efficiency (SE) and scale efficiency, TE = PTE * SEO. Technical Efficiency refers to the percentage of the minimum cost and the actual cost required to produce a certain quantity of products in accordance with the established input ratio of the elements under the condition that the output scale is constant and the market price is constant. The DEA-BCC model is more specific and accurate to analyze the management level, but DEA-BCC also has its own shortcomings of customer service, it does not take into account the existence of external environmental factors, while SFA, which is based on DEA-BCC, is proposed by Timmer [5], and the stochastic frontier analysis (SFA) is proposed, which takes into account the effect of external model factors on efficiency. The use of three-stage DEA method is based on the DEA-BCC combined with a method of SFA.

DEA model has the advantage of non-parametric estimation and optimal efficiency evaluation index and input and output variables dimension selection has nothing to do, which also makes its application more convenient; the same time, DEA to avoid the parameters of the various restrictions, the use of linear programming to determine And whether the corresponding points of the decision-making unit are located on the frontier of effective production to measure the efficiency of each decision-making unit. Farrell (1957) was the first to use the DEA model for productivity analysis [6]. Chinese scholars engaged in DEA research began in 1986; Professor Wei Quanling in the domestic popularization and promotion of DEA method played a positive and important role [7]. DEA can be divided into single-stage DEA, two-stage DEA, three-stage DEA and other methods. Although the single-stage DEA method can evaluate the performance of multiple outputs, it neglects the influence of exogenous variables such as envi-

ronmental factors, bad luck, error factors, which can affect the input index, so the calculated efficiency value is probably not accurate Which reflects the true value of management efficiency. The two-stage DEA method is a special case of DEA. It determines the influence of environmental factors on the first stage efficiency evaluation, but it results in non-stochastic, The three-stage DEA method is proposed by Fried *et al.* [8], which includes both environmental factors and statistical noise in input slack variables, and considers the effect of these two kinds of information on the efficiency of producers. As the three-stage DEA overcomes the shortcomings of single-stage DEA and two-stage DEA, it cannot make the non-operating factors (external environment and random error) homogeneity of decision making units, so that each decision unit is in the same environment and random circumstances, (Jondrow *et al.*, 1982) [9]. Therefore, when the object is homogeneous and non-operating factors, the three-stage DEA is often more superior. In addition, compared with the classical DEA method, the three-stage DEA method is more in line with the economic reality [10].

In view of the home appliance listed companies are facing very different external factors, such as company size, time to market, sales revenue growth, the local residents' income differences, only to the company and the different external factors after stripping, to the company's operating performance to make accurate and objective evaluation. The three-stage DEA can effectively eliminate the environmental factors and random factors such as uncontrollable factors on the efficiency of all sample companies will be placed in a homogeneous environment. Therefore, using three-stage DEA method to evaluate the performance of home appliance listed companies should be able to obtain more real and reliable research results.

Based on the above analysis, this paper takes 44 major listed companies listed on the Shanghai and Shenzhen Stock Exchanges as the sample, based on its financial data in 2015, using three-stage DEA method to study its technical efficiency, put forward to improve technical efficiency Effective recommendations, and strive to promote the home appliances industry to achieve sustained and rapid development of listed companies, but also for other industries listed companies to provide reference for the evaluation of business performance.

The structure of this paper is as follows: The second part is the research design, the construction of the three-stage DEA model, the selection of the sample and each index, and the explanation of the third part. The third part is the empirical analysis, including the performance evaluation of the home appliances listed companies as well as the feasibility analysis; the last part is the main conclusions of this paper and related policy recommendations.

2. Research and Design

2.1. Construction of Three-Stage DEA Model

In this paper, a three-stage DEA model combining DEA with SFA model proposed by Fried *et al.* (2002) is proposed. It can overcome the shortcomings of traditional one-stage DEA model and two-stage DEA model (DEA combined with

Tobit model), eliminate the influence of external environment factors and random errors contained in redundant variables on the efficiency level of decision unit, variable and output variables are more consistent, and thus more realistic and reliable reflection of the decision-making unit during the evaluation of the efficiency of the situation. The efficiency measurement model proposed by Fried *et al.* (2002) concretely consists of three stages:

1) Perform traditional DEA analysis based on raw input and output variables. The original input and output variables into the traditional DEA model, measure the efficiency of each decision-making unit. In the process of analysis, we use the input-oriented BCC-DEA model proposed by Banker *et al.* (1984). Based on the assumption of variable returns, we can study the efficiency of the decision-making unit. The measured technical efficiency can be decomposed into pure technical efficiency and economies of scale. Suppose that n decision making units are evaluated, the data includes m input variables and s output variables, Y_k is the technical efficiency of the Kth decision unit, y_{rk} is the rth output variable of the Kth decision unit, x_{ik} is the k And the ith input variable of each decision unit, λr and θi denote the weight coefficient of the rth output variable and the ith input variable respectively, U_k represents the scale compensation index of the kth decision unit. The input-oriented BCC-DEA model can be expressed as:

$$\begin{aligned}
&\mathrm{Max} Y_k = \sum_{r=1}^{s} \lambda_r y_{rk} - \mu_k;\ r = 1, 2, \cdots, s;\ k = 1, 2, \cdots, n \\
&s.t. \sum_{i=1}^{m} \theta_i x_{ik} = 1;\ i = 1, 2, \cdots, m \\
&\sum_{r=1}^{s} \lambda_r y_{rk} - \sum_{i=1}^{m} \theta_i \chi_{ik} - \mu_k \le 0 \\
&\lambda_r, \theta_i \ge 0.
\end{aligned} \tag{1}$$

The difference between the BCC-DEA model and the CCR-DEA model is that the variable is added μ_k, and the state of the scale compensation of each decision unit can be judged. $\mu_k > 0$, indicating that the decision-making unit is in the state of diminishing returns to scale; $\mu_k = 0$, indicating that the decision-making unit in the scale of constant returns state; $\mu_k < 0$, said the decision-making unit is increasing returns to scale state.

2) The SFA method was used to eliminate the influence of environmental factors and random errors. Firstly, based on the stochastic frontier production function, the reasonable environment variables are selected as the explanatory variables. The redundancy variables (the difference between the ideal input and the actual input) of the m input variables of the n decision-making units analyzed by the traditional DEA model in the first stage, establish the following multiple linear regression model:

$$S_{ik} = f^i\left(z_k; \beta^i\right) + v_{ik} + \mu_{ik} \tag{2}$$

where S_{ik} is the redundant variable of the ith input variable of the kth decision unit (*i.e.*, input redundancy); $f^i\left(z_k; \beta^i\right)$ is the impact of the environment variable on the input redundancy S_{ik}; $Z_K = \left(Z_{1K}, Z_{2K}, \cdots, Z_{PK}\right)$ is the observable environment variable; Parameter vector β^i is the unknown parameter to be es-

timated; $v_{ik}+\mu_{ik}$ is the combined error term, where v_{ik} is the random error, the general assumption $v_{ik} \sim N\left(0, \delta_{vi}^2\right)$, and reflect the management inefficiency. Then, the input variables are adjusted by using the results of (2). All the decision elements are adjusted to the same environmental conditions, and the effect of random error interference is eliminated, so that the actual input value of eliminating environmental factors and random errors is calculated. The adjustment is as follows:

$$\hat{x}_{ik} = x_{ik} + \left[\max_k\left(z_k\hat{\beta}^i\right) - z_k\hat{\beta}^i\right] + \left[\max_k\left(\hat{v}_{ik}\right) - \hat{v}_{ik}\right] \tag{3}$$

where $\hat{x}_{ik}$ and x_{ik} are the adjusted input values and the adjusted input values, $\hat{\beta}^i$ is the estimated coefficient of environmental variables, $\max_k\left(z_k\hat{\beta}^i\right) - z_k\hat{\beta}^i$ is all the decision-making unit adjusted to homogeneous environmental conditions, $\max_k\left(\hat{v}_{ik}\right) - \hat{v}_{ik}$ that all decision-making unit of the random Error adjustment to the same state, thereby eliminating the impact of accidental factors.

DEA analysis was performed on the adjusted input-output variables. The efficiency of each decision unit is calculated by using the BCC-DEA model. The efficiency value of the decision unit is the efficiency value which is eliminated by the environmental factor and random error.

2.2. Sample Selection

This paper selects 44 major home appliances companies listed in the Shanghai and Shenzhen stock markets as the sample, and uses three stages DEA to study the industry classification of the stock market by using the three-stage DEA model for business performance measurement and evaluation.

2.3. The Selection and Description of Variables

The variables selected in this paper are listed in Table 1.

2.3.1. Selection of Input Variables

Investment indicators to fully reflect the company's investment, so this paper selected the following three input indicators: 1) The number of employees, employees are the main creators of corporate wealth, and also, household electrical appliance enterprises are labor-intensive industries, so the number of employees can better reflect the company's business activities; 2) Net fixed assets, fixed assets in the production process can play a long-term role, and in the home appliance industry, fixed assets account for a large proportion of assets, so using the net

Table 1. A three-stage DEA list of variables.

Input variable	Output variable	Environment variable
x_1 —Number of employees at the end of the year	Y_1 —Main business income	Z_1 —Listing date
x_2 —Net fixed assets	Y_2 —Net profit	Z_2 —YoY growth in operating income
x_3 —Cost of main operations		Z_3 —GDP per capita of enterprises in the province

asset value at the end of the period to indicate the size of the firm. 3) The main business costs, which must be invested in the production of direct costs, reflecting the most important input of a company's business activities.

2.3.2. The Selection of Output Indicators

The choice of output variables should reflect the company's operating results. Therefore, this paper selects the following two output indicators from the two aspects of growth ability and profitability: 1) main business income (Y_1), reflecting the cost of the main business; 2) net profit, reflecting the company's profitability and business performance.

2.3.3. Selection of Environment Variables

Environmental variables should select those factors that affect the technical efficiency of listed cultural companies, but cannot control and change in a short time. Taking into account the characteristics of the development of cultural industries, this paper selected the following factors as environmental variables: 1) time to market $(Z1)$, the company listed sooner, the earlier capital funds can help the development of enterprises, the development of enterprises is essential (in the paper, time to market less than one year as a year); 2) operating income year on year growth rate $(Z2)$, although in the same industry, but because of the development of enterprises there is a growth cycle, the growth rate of different enterprises is not the same, this year with operating income growth rate does not reflect the development of enterprises stage; 3) the per capita GDP of the province $(Z3)$, which is a criterion for measuring the level of economic development and the standard of living of the people. It is very important for the attraction of the labor force to preheat talent, and the per capita GDP reflects the external environment, the good or bad. The data of the environment variables selected in this paper are derived from the data.

When the DEA model is used to evaluate the efficiency, both input and output indicators must meet the hypothesis of "co-directivity", that is, the input and output indicators should meet the positive correlation and reflect the causal relationship between input and output indicators, Making the evaluation more convincing (James *et al.*, 1989). Therefore, the Spearman correlation test of each input and output index is carried out. The results are shown in **Table 2**: the input and output of the correlation coefficient between the positive, to meet the DEA model "isotropic" hypothesis.

3. The Empirical Analysis

3.1. The First Stage DEA Treatment

Using DEAP2.1 software 44 listed companies operating performance and scale of state compensation research, the results shown in **Table 3**: Ignoring the external environment and the impact of random factors, the mean value of the combined technical efficiency, the pure technical efficiency mean and the scale efficiency of the listed companies in our country's home appliance industry were 0.736, 0.837 and 0.883 respectively in 2015. Among them, the five listed compa-

nies (macro, new defence, boss appliances, skyworth digital, skyworth digital, Zhejiang a.u.) of each efficiency values are 1, technical efficiency is relatively effective; And despite the pure technical efficiency of 11 listed companies (Gree Electric, Qingdao Haier, TCL Group, Hisense Electric, Little Swan A, nine Yang shares, Chunlan shares, Taiwan Nuclear Power, Tianyung electromechanical, Yikai Kang, Canature) is 1, its scale efficiency is not 1, resulting in inefficient operating performance; The rest company's pure technical efficiency and scale efficiency are not the best situation, and there is room to continue to improve.

Table 2. Spearman correlation analysis of input and output indicators.

Output indicators investment target	*X*1	*X*2	*X*3
*Y*1	995** (0.000)	621** (0.000)	975** (0.000)
*Y*2	744** (0.000)	439** (0.000)	773** (0.000)

Note: ***indicates that the correlation is significant when the confidence level (double test) is 0.01; **indicates that the correlation is significant when the confidence level (double test) is 0.05; *indicates that the correlation is significant when the confidence level (double test) is 0.1.

Table 3. SFA before the adjustment of cultural listed companies' efficiency evaluation.

Company name	TE1	PTE1	SE1	Scale compensation	Company name	TE1	PTE1	SE1	Scale compensation
Gree appliances	0.825	1	0.825	drs	MACRO	1	1	1	-
Qingdao Haier	0.894	1	0.894	drs	Feile audio	0.735	0.754	0.975	drs
TCL Group	0.733	1	0.733	drs	Meng F Lee	0.289	0.342	0.844	irs
Hisense Electric	0.886	1	0.886	drs	Reco Defense	1	1	1	-
Hisense Kelon	0.716	0.843	0.85	drs	Guosheng financial control	0.725	0.906	0.8	irs
Little Swan	0.925	1	0.925	drs	Boss electrical appliances	1	1	1	-
Meiling electrical appliances	0.748	0.83	0.901	drs	Shun Wei shares	0.523	0.62	0.844	irs
Haili shares	0.754	0.776	0.971	drs	Skyworth digital	1	1	1	-
Supor	0.884	0.998	0.885	drs	Chunlan shares	0.544	1	0.544	irs
Huayi compression	0.657	0.684	0.959	drs	Kingsun photoelectric	0.59	0.758	0.78	irs
Joyoung	0.965	1	0.965	drs	Oriental heating	0.556	0.667	0.834	irs
New Po shares	0.644	0.68	0.947	drs	Nuclear power of the Taiwan Strait	0.827	1	0.827	irs
Siu Chi shares	0.672	0.697	0.965	drs	Jia Wei shares	0.618	0.679	0.911	irs
Aucma	0.727	0.736	0.988	irs	Hals	0.601	0.768	0.783	irs
Whirlpool	0.796	0.825	0.965	drs	The Wright	0.492	0.644	0.764	irs
Omar electrical appliances	0.66	0.667	0.989	drs	Snow Wright	0.569	0.776	0.733	irs
Sunrise East	0.7	0.733	0.955	irs	Zhejiang a.u.	1	1	1	-
Million and electrical	0.739	0.741	0.997	irs	Electrical and Mechanical	0.756	1	0.756	irs
Sunlight lighting	0.643	0.645	0.998	irs	And crystal technology	0.507	0.713	0.711	irs
Foshan lighting	0.713	0.735	0.97	irs	Clothing meters Kang	0.809	1	0.809	irs
Ai Shida	0.721	0.767	0.94	irs	LG Health	0.707	0.982	0.72	irs
Vantage shares	0.843	0.852	0.99	irs	Canature	0.701	1	0.701	irs

Note: TE stands for technical efficiency before SFA adjustment, PTE stands for pure technical efficiency before SFA adjustment, SE stands for SFA scale efficiency before adjustment. Where, TE = PTE * SE; irs for the scale returns, dr for the scale of diminishing returns, one for the same size of remuneration; the input relaxation variables are ≤0.

3.2. The Second Stage DEA Treatment

In order to eliminate the influence of external factors on corporate debt financing efficiency, the absolute value of the input slack variables of each DMU before SFA adjustment and the above three environment variables are taken as explanatory variables and explanatory variables respectively, and the SFA regression model is substituted. And use Jondrow's method to separate the management factors and random factors, excluding their impact on the input relaxation variables. In this paper, we use Frontier 4.1 software to estimate the parameters of SFA model. The regression results are shown in Table 4.

As can be seen from Table 4, the environmental variables selected in this paper all pass the significance test and are significant at the 1% level, indicating that the external environmental factors have significant effects on the input relaxation variables; the R value represents the ratio of the variance of the management technology inefficiency to the total variance. The R value of each input slack variable in Table 4 is 0.9999, which is significant at the level of 1%. This indicates that there are obvious differences in management efficiency among different companies, and that the influence of management factors on input redundancy is dominant. It is necessary to use the SFA model to separate management factors and external factors.

And the regression coefficients of each input slack variable are further investigated. Because the environment variable is the regression of each input slack variable, the regression coefficient is negative, which means that the increase of the environment variable is beneficial to the reduction of the input slack variable, that is, the negative coefficient can reduce the waste of investment and improve the business performance. If the regression coefficient is positive, it indicates that the increase of environmental variables is not conducive to the improvement of business performance. The following describes the impact of the three environmental variables on the slack variables:

1) Time to market. This variable has a significant positive correlation with the number of employees and the relaxation value of fixed assets. In other words, the

Table 4. SFA regression results for each input slack variable.

Ind variable Dep variable	SLACK ($X1$)	SLACK ($X2$)	SLACK ($X3$)
$B0$	−24,390***	−331,264***	−780***
$Z1$	1839***	−8679***	93***
$Z2$	−52***	−1700***	−18***
$Z3$	−3519***	2726***	−313***
σ^2	0.99E + 10***	0.45E + 12***	−0.32E + 08***
R	0.9999***	0.9999***	0.9999***
L	−538	−622	−410
LR value	20.15	22.90	23.97

Note: ***indicates that the correlation is significant when the confidence level (double test) is 0.01; **indicates that the correlation is significant when the confidence level (double test) is 0.05; *indicates that the correlation is significant when the confidence level (double test) is 0.1.

sooner the company's time to market, the number of employees and the size of the company's slack variable is greater, the more conducive to the improvement of technical efficiency. On the contrary, the main business costs will be reduced, and the improvement of technical efficiency will have a certain role in promoting. This conclusion is consistent with theoretical expectations. Because the sooner the listing of the company the more likely to over-expansion.

2) Operating income year-on-year growth rate. This variable has a significant negative correlation with the number of employees, the net fixed assets and the cost of relaxation of the main business variables. In other words, the greater the growth rate of operating income year on year, the smaller slack variables of the number of employees, net fixed assets and cost of the main business of the relaxation of the smaller variables, and the more conducive to improving technical efficiency.

3) Enterprise province GDP per capital. This variable was significantly negatively correlated with the number of employees, the cost of core business slack, and the positive correlation between the variable of net fixed value of assets. This means that with the increase in GDP per capital, the number of employees, the cost of relaxation of the main business variables to reduce the fixed-asset net value of the relaxation variable increases. This is in line with expectations. GDP is directly related to local wage levels, land rent and other cost costs are positively correlated. The higher the per capital GDP of enterprises in the province, the more emphasis on the number of employees and operating costs of control.

3.3. The Third Stage DEA Treatment

Because of these environmental variables on the impact of the sample companies are positive and negative, so that may lead to heterogeneous external factors appear unequal efficiency of the company sort. Therefore, the original input variables must be adjusted so that all companies on the same business environment and luck after the evaluation to accurately examine the efficiency level. For all companies to face the same operating environment and luck, this paper based on the results obtained in Table 4 to adjust the original input variables, the adjusted input variables and the original output variables using Max-DEA software to run BC^2 model again. Get the third stage of the company's efficiency and scale pay status, the results shown in Table 5.

By comparing the observed Table 3 and Table 5 can be found in the frontier of the efficiency of listed companies in the elimination of environmental variables and random factors by the impact of five (MACRO, Recco, Boss Electric, Skyworth Digital, Zhejiang a.u.) For the three (Gree, Qingdao Haier, TCL Group): from which you can see, excluding environmental variables and random factors in the front of the technical efficiency, and after adjustment all the technology is not in the forefront of Gree other, Qingdao Haier, TCL Group in theforefront of technology. This means that, compared to the SFA before the adjustment, Gree, Qingdao Haier, TCL Group was promoted to the frontier efficiency, indicating that the relative adverse environmental factors reduce the company's MACRO,

Table 5. SFA adjusted efficiency of listed companies after the appliance evaluation.

Company name	TE3	PTE3	SE3	Scale compensation	Company name	TE3	PTE3	SE3	Scale compensation
Gree appliances	1	1	1	-	MACRO	0.377	0.948	0.398	irs
Qingdao Haier	1	1	1	-	Feile audio	0.425	0.95	0.448	irs
TCL Group	1	1	1	-	Meng F Lee	0.16	1	0.16	irs
Hisense Electric	0.756	1	0.756	irs	Reco Defense	0.23	1	0.23	irs
Hisense Kelon	0.776	1	0.776	irs	Guosheng financial control	0.129	0.957	0.135	irs
Little Swan	0.646	0.962	0.672	irs	Boss electrical appliances	0.669	1	0.669	irs
Meiling electrical appliances	0.317	0.87	0.364	irs	Shun Wei shares	0.152	0.995	0.153	irs
Haili shares	0.462	0.945	0.489	irs	Skyworth digital	0.377	1	0.377	irs
Supor	0.632	1	0.632	irs	Chunlan shares	0.037	1	0.037	irs
Huayi compression	0.52	1	0.52	irs	Kingsun photoelectric	0.11	0.972	0.113	irs
Joyoung	0.516	0.955	0.54	irs	Oriental heating	0.12	0.965	0.124	irs
New Po shares	0.496	0.98	0.507	irs	Nuclear power of the Taiwan Strait	0.056	1	0.056	irs
Siu Chi shares	0.424	0.857	0.495	irs	Jia Wei shares	0.21	0.922	0.228	irs
Aucma	0.369	1	0.369	irs	Hals	0.099	0.979	0.101	irs
Whirlpool	0.453	0.93	0.488	irs	The Wright	0.091	0.964	0.094	irs
Omar electrical appliances	0.423	0.957	0.442	irs	Snow Wright	0.104	0.977	0.106	irs
Sunrise East	0.28	0.937	0.299	irs	Zhejiang a.u.	0.164	1	0.164	irs
Million and electrical	0.398	0.96	0.415	irs	Electrical and Mechanical	0.114	0.998	0.114	irs
Sunlight lighting	0.398	0.972	0.409	irs	And crystal technology	0.1	0.955	0.104	irs
Foshan lighting	0.292	0.931	0.314	irs	Clothing meters Kang	0.11	0.971	0.113	irs
Ai Shida	0.265	0.999	0.265	irs	LG Health	0.058	0.973	0.059	irs
Vantage shares	0.372	0.96	0.388	irs	Canature	0.08	0.989	0.081	irs

Note: TE3 represents the integrated technical efficiency after adjustment, PTE3 represents the purely technical efficiency after adjustment, and SE3 is the adjusted scale efficiency. Where, TE3 = PTE3 × SE3: calculation results show that the table DEA value of 1.0000 companies corresponding to the S+. S− are 0, the corresponding company DEA effective.

Recco Defense, Boss Electric, Skyworth Digital, Listed companies that are at the frontier of technological efficiency before the adjustment are not able to remain at the frontier of technical efficiency after SFA adjustment, indicating that their prior good technical efficiency does not fully reflect their own real technical efficiency, Its favorable environment, including Macro, Recco Defense, Skyworth Digital, Zhejiang a.u., four US companies technical efficiency decreased significantly, operating performance vulnerable to external factors. Overall, the company's comprehensive technical efficiency has big difference, the maximum and minimum difference between the value is 0.92, indicating that there is an imbalance between the development of various home appliances listed companies; For the size of the company's remuneration, the adjustment of investment causes the scale of income status change: removing the scale efficiency the three listed companies which have reached the optimal, other companies are in the scale of increasing returns, the proportion of Avenue 93.19%. Indicating that the scale of production of these companies also need to be reasonably expanded; 34.1% of the listed companies are in the pure technical efficiency state, indicat-

ing that there is still much room for improvement in the internal governance level of the home appliances listed companies.

From Table 3, it can be seen that the average technical efficiency of household appliance listed companies is 0.736 before adjustment of input variables, 0.358 after adjustment, the technical efficiency increases from 0.837 to 0.971, the scale efficiency decreases from 0.883 to 0.368, The pure technical efficiency has a small increase, but the scale efficiency value of the decline is obvious, and thus lower the value of technical efficiency. In summary, after excluding external factors, the average efficiency value of listed companies has changed. The external environmental variables and stochastic factors have indeed affected the performance of China's household electrical appliance companies, and thus once again confirmed the use of Three-stage DEA method to make home appliances listed companies in the same external environment to evaluate the feasibility and necessity.

4. Conclusion and Implications

1) After the SFA adjustment, the pure technical efficiency of the listed companies of home appliance has a small increase, but the value of the scale efficiency drops obviously, and the value of the technical efficiency is also lowered. The efficiency of the integrated technology shows that the external environment of the company is closely related to the efficiency of the company: the time to market is positively related to the efficiency of the company, while the revenue growth rate is negatively related to the efficiency of the company. Therefore, it is a useful way to improve the performance of listed companies in home appliance industry by improving the external environment factors and utilizing the favorable external factors to fully explore the efficiency of listed companies. 2) The level of internal management of listed companies of household appliances is relatively good, but there is room for further improvement. This shows that China's household electrical appliance listed companies in the internal governance efficiency are at a good level, but have not yet reached the optimal state; the development of resources should be more scientific and rational planning to avoid waste of resources, and constantly strengthen the development of household electrical appliances and innovation; 3) Expanding the scale of production to improve the performance of listed companies in the home appliance industry is an effective way, because the vast majority of home appliance industry listed companies are still in the state of increasing returns to scale, so the household appliances listed companies should break the local market boundaries to promote the integration of household electrical appliance industry resources, through appropriate expansion of the scale to enhance the company's operating performance.

References

[1] Aigner, D.J., Lovell, C.A. and Schmidt, K. (1977) Formulation and Estimation of Empirical Application Function on Models. *Journal of Econometrics*, **6**, 21-37. https://doi.org/10.1016/0304-4076(77)90052-5

[2] Charmes, A. (1978) Measuring the Efficiency of Decision Making Units. *Europe Journal of Operational Research*, **2**, 429-444. https://doi.org/10.1016/0377-2217(78)90138-8

[3] Banker, R.D., Charmes, A. and Cooper, W.W. (1984) Some Models for Estimating Technical and Scale Inefficiencies in Data envelopment Analysis. *Management Science*, **30**, 1078-1092. https://doi.org/10.1287/mnsc.30.9.1078

[4] Coelli, T., Rao, P. and Battese, E. (1998) An Introduction to Efficiency and Productivity Analysis. Springer, New York. https://doi.org/10.1007/978-1-4615-5493-6

[5] Timmer, C.P. (1971) Using a Probabilistic: Frontier Production Function to Measure Technical Efficiency. *Journal of Political Economy*, **79**, 776-794. https://doi.org/10.1086/259787

[6] Farrell, M.J. (1957) The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society*, **120**, 253-290. https://doi.org/10.2307/2343100

[7] Wei, Q.L. (1988) DEA Method for Evaluating Relative Effectiveness. Renmin University of China Press, Beijing.

[8] Fried, H.O., Lovell, C.A.K. and Schmidt, S.S. (2002) Accounting for Environmental Effects and Statistical Noise in Data Envelopment Analysis. *Journal of Productivity Analysis*, **17**, 157-174. https://doi.org/10.1023/A:1013548723393

[9] James, J. (1982) On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model. *Journal of Econometrics*, **19**, 233-238. https://doi.org/10.1016/0304-4076(82)90004-5

[10] Bai, J.H. and Jiang, W.X. (2011) Study on Regional Innovation Efficiency Considering Environmental Factors—Based on Three-Stage DEA Method. *Finance & Trade Economics*, **10**, 104-112.