Study on the Dynamic Efficiency of Listed Household Appliances Companies Based on the Malmquist-DEA Model

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Abstract

Based on data from16 listed household appliances companies, we use the Malmquist-DEA model to estimate the dynamic change of the total factor productivity (TFP) in the household appliance industry from 2002 to 2006, and analyze the scale efficiency and the input congestion level of household appliance industry. The results show that the TFP of household appliance industry was improved slightly, and the technical progress was obvious, but the pure technical efficiency and the scale efficiency were declining, and the input congestion degree was higher.

Keywords: Data Envelopment Analysis (DEA), Malmquist index, Household appliances industry, Efficiency, Input congestion

1. Introduction

China has become the world household appliance production country, and formed a series of famous domestic brands, but its development of the household appliance industry still has many problems such as low industry concentration and excessive competition, so it is very important to scientifically evaluate the efficiency of the household appliance industry, find out problems and constitute relative polices for the healthy development of China household appliance industry.

There are many evaluation methods to evaluate company performance and management efficiency, which can be divided into two sorts, parameter method and non-parameter method. The parameter method needs to set up specific efficiency frontier function and measure various parameters through samples when it is used to measure the efficiency level of the enterprise. Though this method considers the distribution of random error, but the specific function form will influence the result of the efficiency. The parameter method mainly includes stochastic frontier approach (SFA), distribution free approach (DFA) and thick frontier approach (TFA). The non-parameter method mainly includes linear programming method such as data envelopment analysis (DEA). The non-parameter method doesn't need to set up the frontier production function, doesn't bring system warp because of inaccurate function estimation, but it doesn't consider the random errors induced by data problem (such as extreme value) and measured error, and cannot expediently test the markedness of the result (Zhu, 2006, p.51-62). Farrell et al used DEA and Translog to measure the cost efficiency of the bank, and the research result showed that both have same relationship (Farrell, 1957, p.253-281). Seiford and Thrall's research showed that DEA was effective to estimate efficiency frontier (Seaford, 1990, p.7-38). However, Wheelock and Wilson thought that static CCR and BCC model only implemented landscape orientation analysis to samples in same term, and they couldn't analyze the efficiency change of DMU in different terms, but the Malmquist productivity index method was to use panel data and the concept of distance function to beg a productivity index which could be as portrait analysis, which could compensate deficiencies of static CCR and BCC model and complete the analysis.

Based on above analysis, in this article, we take 16 listed household appliance companies as samples, use the Malmquist-DEA model to estimate the dynamic change of the total factor productivity (TFP) in the household appliance industry from 2002 to 2006, and analyze the scale efficiency and the input congestion level of household appliance industry.

2. Mathematical model

The Malmquist index method is defined according to the input-output distance function put forward by R.W. Shephard, and it was put forward by Christensen and Cavers (Christensen, 1970, p.19-50 & Caves, 1982, 1393-1414), and further developed by Fare et al (Fare, 1992, p.158-160). General TFP index based on input under the condition of multi-input and multi-output can be denoted by the Malmquist productivity index.

2.1 The definition of the Malmquist index

The distance function is the reciprocal of Farrell technical efficiency, which can be looked upon the proportion that the production point (x, y) is compressed to the ideal minimum input point. $X_j = (x_{1j}, x_{2j}, ..., x_{mj})$ and

$Y_j = (y_{1j}, y_{2j}, ..., y_{sj})$ respectively represent the input vector and the output vector, and considering the changeless returns to scale (CRS) and input set on the production frontier with input strong disposability (shortened as CS input set), the distance function based on CS input set can be denoted as

$$D^t(y^t, x^t) = 1/F^t(y^t, x^t | C, S) \tag{1}$$

To get the Malmquist index, supposing that the input and output data in t and t+1 terms are respectively denoted by (x^t, y^t) and (x^{t+1}, y^{t+1}), the Malmquist index is

$$M^t(x^{t+1}, y^{t+1}, x^t, y^t) = \left\{ \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \right] \left[\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)} \right] \right\}^{1/2} \tag{2}$$

2.2 The decomposition of the Malmquist index

The Malmquist productivity change index can be decomposed as the technical efficiency change (TEC) and the technical change (TC) (Fare et al. 1992), and its computation formula is as follows

$$M^t(x^{t+1}, y^{t+1}, x^t, y^t) = \left\{ \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \right] \left[\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)} \right] \right\}^{1/2}$$

$$= \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)} \right]^{1/2}$$

$$= TEC(x^{t+1}, y^{t+1}, x^t, y^t) TC(x^{t+1}, y^{t+1}, x^t, y^t) \tag{3}$$

The Malmquist productivity index (TFP index) denotes that the change degree of total productivity from t term to t+1 term for the enterprise. M>1 represents the ascending productivity and M<1 represents the descending productivity.

The technical efficiency change (TEC) denotes the technical efficiency change degree from t term to t+1 term for the enterprise, which indicates the degree of efficiency chase. TEC>1 denotes the technical efficiency reduces the difference with the optimal DMU, and TEC<1 denotes the technical efficiency increases the difference with the optimal decision making unit (DMU).

The technical change (TC) denotes that the technical change degree from t term to t+1 term, which represents the movement of production frontier between two terms and indicates the degree of technical advancement or technical innovation. TC>1 denotes the technical advancement, and TC<1 represents the technology possesses recessionary tendency.

When returns to scale are changeable, the technical efficiency index can be decomposed as the pure technical efficiency index and the scale efficiency index. The pure efficiency index reflects the difference of technical level operation between the present production point and the production frontier of scale returns change, and the scale efficiency reflects the difference between the production frontier of changeless scale returns and the production frontier of change scale returns.

The improvement of technical efficiency and the enhancement of technical level are the headspring to increase TFP. The Malmquist productivity index is bigger than 1, which indicates the enhancement of TFP level. In three sorts of index to compose Malmquist productivity index, if one certain index is bigger than 1, which indicates it is the headspring to increase TFP, whereas, it is the root to reduce TFP.

2.3 Using the DEA model to solve the distance function

The key to compute Malmquist index is to beg the distance function, and we can utilize DEA to find out the distance function, which can avoid the problem of system warp when selecting the form and variable of the boundary production function, and effects of non-technical factors such as unreasonable price system on the distance function, and it is very good method (Yu, 2004, 827-831).

The distance function is the reciprocal of the Farrell technical efficiency, so we can translate the solvent of distance function into the solvent of efficiency function. Suppose that in J DMUs, the input vector of DMU_j in t term is $X_{jt} = (x_{1,jt}, x_{2,jt}, ..., x_{m,jt})$, and the output vector is $Y_{jt} = (y_{1,jt}, y_{2,jt}, ..., y_{s,jt})$, so when returns to scale are changeless, the relative efficiency of DMU_j based on input can be solved by the following linear programming.

$$[D^t(y^t,x^t)]^{-1}=F^t(y^t,x^t)=\min\theta$$
$$s.t\begin{cases}\sum_{j=1}^{J}\lambda_{j,t}x_{j,t}\le\theta x_{j,t}\\ \sum_{j=1}^{J}\lambda_{j,t}y_{j,t}\ge y_{j,t}\\ \lambda_{j,t}\ge 0,\ j=1,2,\ldots,J\end{cases}\tag{4}$$

$$[D^t(y^{t+1},x^{t+1})]^{-1}=F^t(y^{t+1},x^{t+1})=\min\theta$$
$$s.t\begin{cases}\sum_{j=1}^{J}\lambda_{j,t}x_{j,t}\le\theta x_{j,t+1}\\ \sum_{j=1}^{J}\lambda_{j,t}y_{j,t}\ge y_{j,t+1}\\ \lambda_{j,t}\ge 0,\ j=1,2,\ldots,J\end{cases}\tag{5}$$

$$[D^{t+1}(y^t,x^t)]^{-1}=F^{t+1}(y^t,x^t)=\min\theta$$
$$s.t\begin{cases}\sum_{j=1}^{J}\lambda_{j+1,t}x_{j,t+1}\le\theta x_{j,t}\\ \sum_{j=1}^{J}\lambda_{j+1,t}y_{j,t+1}\ge y_{j,t}\\ \lambda_{j,t+1}\ge 0,\ j=1,2,\ldots,J\end{cases}\tag{6}$$

$$[D^{t+1}(y^{t+1},x^{t+1})]^{-1}=F^{t+1}(y^{t+1},x^{t+1})=\min\theta$$
$$s.t\begin{cases}\sum_{j=1}^{J}\lambda_{j+1,t}x_{j,t+1}\le\theta x_{j,t+1}\\ \sum_{j=1}^{J}\lambda_{j+1,t}y_{j,t+1}\ge y_{j,t+1}\\ \lambda_{j,t+1}\ge 0,\ j=1,2,\ldots,J\end{cases}\tag{7}$$

To further measure the pure technical efficiency and scale efficiency of the household appliance industry, we need to measure the distance function under the condition of changeable returns to scale. Adding the restriction condition of $\sum_{j=1}^{J}\lambda_{j,T}=1$ in the formulas (4) and (7), we can obtain the distance function $D^t(y^t,x^t)$ based on the (V, S) input set.

3. The empirical analysis of dynamic efficiency for listed household appliances companies

3.1 The setup of model variables and the selection of sample data

In this article, we select 16 listed companies which mainly manage household appliance as samples and take their year reports from 2002 to 2006 as reference data (data from www.jrj.com). These listed household appliance companies include Hisense, Chunlan, Aucma, Xiahua, Little Swan, Haier, Kelong, Meiling, Konka, Changhong, Ningbo Fuda, Meidi, Shenzhen Huafa, S Sam Sung, Gree and Soyea Technology.

According to scholars Ye, Shiqi, Yan, Caiping, and Mo, Jianfang’s research, the selection of DEA index should follow the principle of objective, simplification, association and diversity, and the smaller and better indexes should be as the input indexes and bigger and better indexes should be as the output indexes in the evaluation by DEA (Ye, 2004). According to above principles, in this article, we select total assets, sum of employee, main business cost as input variables, and select net profit and main business income as output variables. First, we utilize 5 years’ panel data to figure out the Malmquist productivity index which can reflect the dynamic efficiency change, and judge the change of TFP and the resources of this change. Second, we adopt the BBC model to compute the technical efficiency, the pure technical efficiency and scale efficiency of various companies from 2002 to 2006, and judge returns to scale and the input congestion degree of various companies. We use the software of DEAP2.1 to solve involved linear programming problems.

3.2 Analysis of empirical results

3.2.1 Analysis of Malmquist productivity index

Table 1 shows the total schema of efficiency change of 16 companies from 2002 to 2006, and various indexes in the table take data of 2002 as the basic and all efficiency indexes in the that term are 1. The TFP indexes in the following four years are respectively 0.895, 1.219, 1.269 and 0.981, which mean is 1.08. In 2002-2003, the TFP index declined, and the TFP index ascended in 2003-2005. TFP index in 5 years was still slightly ascended.

TFP can be decomposed as TEC and TC. As viewed from the reason to influence the TFP change, the declined reason of TFP in 16 listed companies comes from retrograde technology and reduced efficiency. In 2003-2005, thought the technical efficiency is still decrease, but the influence of technical advancement is very obvious, which induces the rise of TFP, and the technical advancement makes the total production possibility boundary move forth, and the technical research and development developed by the country and the household appliance industry can explain that. In 2005-2006, the decrease of TFP mainly came from the retrograde technology, and though the technical efficiency had been improved to a certain extent, but the influence of retrograde technology was very obvious. As viewed from five years' situation, the TFP slightly ascended, the technical advancement was obvious, but the technical efficiency descended.

TEC can be decomposed as PE and SE under changeable returns to scale. From Table 1, we can see that except that the SE in 2004 and the PE in 2006 are bigger than 1, others are all smaller than 1. That indicates in the sampling term, except for the contribution of technical advancement to TFP, PE and SE decrease the enhancement of TFP. The PE equal value of five years is 0.971 and the SE equal value of five years is 0.987, which indicates that 16 listed companies had not achieved the state with optimal scale, the input-output proportion should be optimized, and the input factor utilization rate presents the declined tendency.

As viewed from various household appliance enterprises, from Table 2 in 16 listed companies, the number of company which TFP ascends is 11, the number of technical advancement is 15, and the number of descended efficiency is 8. The technical advancement of household appliance enterprise is marketable, but the efficiency drop is very obvious, and the TFP presents ascending tendency as a whole. In recent years, most household appliance enterprises develop large-scale technical research and development, which improves the technical advancement of the household appliance industry, but in this industry without high concentration, the competition is always very intense. After China joined WTO, the household appliance enterprise would directly face the competition from international industrial monopolization, which would seriously influence the enhancement of technical efficiency in the household appliance industry.

In Table 2, the number of the household appliance enterprise with reduced PE is only 6, the number of reduced SE is 6, the PE and SE of other enterprises are stable, and the enterprise with reduced efficiency seriously influence the efficiency change, which induces the PE and SE of 16 listed companies all are in the descending tendency in five years. And the descending of PE and SE would directly influence the change of the technical efficiency index.

As viewed from Malmquist productivity index and its decomposition result, the TFP of household appliance enterprise continues to enhance, the technical advancement is marketable, but the problem of deficient efficiency still exists. Next, we will analyze this problem from two aspects such as returns to scale and input congestion degree.

3.2.2 Analysis of returns to scale

From Table 3, the values of technical efficiency, PE and SE in 2002-2006 all present the tendency of first descending and then ascending to different extents, which is similar with the conclusion showed by the Malmquist index. In five years, the proportion of the company with changeless returns to scale basically accords with the tendency of first decrease and then increase, the number of the company with the degressive returns to scale basically accords with the ascending tendency, and the number of the company with the increaseing returns to scale basically accords with changeless. The proportions of the company in the stage of changeless returns to scale in five years are respectively 56.25%, 56.25%, 43.75%, 31.25% and 43.75%. Only the proportions of the company in the stage of changeless returns to scale in 2002 and 2003 exceed 50%, which indicates that the companies which achieve the reasonable production state of scale returns are relative less. The transformation of total scale returns stage in the household appliance industry influences the total scale efficiency, which induces the total scale efficiency in five years presents descending tendency.

From the situation of scale return of 16 companies showed in Table 4, we can see that in five years, the companies which always are in the descending state of scale returns in four years include Ningbo Fuda and Meidi, the company which always are in the descending state of scale returns in three years is Chunlan, and the degression of scale returns of these companies indirectly influences the scale efficiency situation of the whole industry. Hisense, Little Swan, Haier, Shenzhen Huafa, and Soyea Technology are in the optimal state of scale returns all along in five years.

3.2.3 Analysis of input congestion

As Table 5, totally speaking, the input congestion degree of 16 listed companies presents ascending tendency. In 2002, the input congestion degrees of total capital, main business cost and sum of employee respectively achieve 1.7%, 0.00% and 0.41%, but these numbers in 2006 respectively are 0.38%, 0.38% and 4.71%. The input congestion degree of employee sum in 2004 achieves 16.73%, and the input congestion degree of main business cost in 2005 achieves 11.44%. So years of 2004 and 2005 are two years with high input congestion degree, and the degree has descending tendency in 2006. To analyze the reason of high input congestion degree in 2004 and 2005, we list input redundancy situation of 16 listed companies in 2004-2005 in Table 6.

From Table 6, the large-scale increase of employee input congestion degree in 2004 is mainly induced by the input redundancies from Kelong, Changhong and Konka. The large-scale increase of input congestion degree of main business cost in 2005 is mainly induced by the large-scale increase of main business cost from Kelong, Changhong and Xiahua. At the same time, according to Table 6, the congestion degree of input factors by other companies in these two years can offer certain decision-making references for the company.

4. Conclusions

In this article, we adopt 80 panel data of 16 listed household appliance companies from 2002 to 2006, and utilize the Malmquist-DEA model to empirically analyze their TFP, technical efficiency, returns to scale and input congestion. Following conclusions can be obtained. The TFP of 16 listed companies was improved slightly, and technical advancement was marketable, but the PE and SE basically presented descending tendency and the input congestion degree was higher.

In 2002-2006, the TFP of 16 listed companies was improved slightly, and the reason mainly is that the technical advancement in the household appliance industry was marketable, but the efficiency change index presented descending tendency. In recent years, China takes up with the technical innovation in the household appliance industry, and many household appliance enterprises increase technical input to develop the product with high technical content, which improve the industrial technical level, but the industrial environment with low industrial concentration and excessive competition still influences the factor distribution efficiency of the household appliance industry.

Through the decomposition of technical efficiency change index, we find that in five years, PE and SE presented descending tendency to different extents, and the quantity of the company which was in the optimal state of scale returns decreased and the quantity of the company which was in the descending state of scale returns increased, which influenced the scale efficiency of the household appliance industry. The reason of that problem may be that many accumulative problems such as low industrial concentration and excessive competition can not be solved essentially, so for the future development of China household appliance industry, the key is to distribute factors reasonably, enhance factor utilization rate and enhance the management level and scale economy.

As viewed from the analysis of input congestion degree, the input congestion degree in five years presented ascending tendency, and years of 2004 and 2005 were two years with high input congestion degree, and the redundant input factors were mainly represented in the main business cost and employee quantity. The increase of main business cost was mainly influenced by the price rise of energy, materials and upper fittings.

The DMU selected in this article is China household appliance making enterprise which can reflect the production frontier of China household appliance industry. If we want to truly evaluate China household appliance industrial efficiency and obtain more accurate analysis, we should bring transnational household appliance companies into the analysis system, which may open out more contents on the deeper layer. Furthermore, though DEA has many advantages but Wu, Wenjiang had pointed out the general model of DEA still had limitations (Wu, 2002), so the further work of this article is to study how to more scientifically and reasonably select index system, and add decision-maker' favor information into the DEA model as the restrictive condition for more reasonably evaluating the dynamic efficiency of DMU.

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Table 1. Malmquist productivity index and decomposition results from 2002 to 2006

Year	TEC	TC	PE	SE	TFP
2002	1	1	1	1	1
2003	0.984	0.91	0.991	0.993	0.895
2004	0.932	1.308	0.931	1.001	1.219
2005	0.87	1.46	0.895	0.971	1.269
2006	1.056	0.929	1.074	0.983	0.981
Mean	0.958	1.127	0.971	0.987	1.08

Note: EF represents the change index of technical efficiency, TE represents the technical change index, PE represents the efficiency index of pure technology, SE represents the scale efficiency index and TEP represents the index of TFP.

Table 2. Analysis of Malmquist productivity index from data of 16 listed household appliances companies

Company	TEC	TC	PE	SE	TFP
1	1	0.991	1	1	0.991
2	0.926	1.024	0.924	1.003	0.948
3	0.842	1.081	0.847	0.994	0.911
4	1.002	1.074	1.008	0.994	1.076
5	1	1.099	1	1	1.099
6	1	1.267	1	1	1.267
7	0.987	1.254	0.982	1.004	1.237
8	0.995	1.141	0.995	1	1.135
9	0.871	1.113	0.873	0.998	0.97

10	0.922	1.217	0.923	0.999	1.122
11	1.002	1.146	1	1.002	1.149
12	0.953	1.054	1	0.953	1.004
13	1	1.172	1	1	1.172
14	0.854	1.11	1	0.854	0.949
15	1	1.168	1	1	1.168
16	1	1.163	1	1	1.163
Mean	0.958	1.127	0.971	0.987	1.08

Table 3. The number of the company which was in different stage of scale income in each year and their efficiency estimation results

Year	Scale income state and enterprise quantity			values of efficiency parameter		
	-	drs	irs	crste	vrste	se
2002	9	3	4	0.955	0.96	0.994
2003	9	5	2	0.942	0.955	0.987
2004	7	4	5	0.883	0.895	0.988
2005	5	5	6	0.795	0.824	0.96
2006	7	4	5	0.833	0.878	0.953

Note: "-" in the table represents the scale income is changeless, "drs" represents the scale income decreases by degrees, "irs" represents the scale income increases by degrees, "crste" represents the technical efficiency, "vrste" represents the pure technical efficiency, and "se" represents the scale efficiency.

Table 4. Returns to scale of 16 listed household appliances companies from 2002 to 2006

Company	No.	2002	2003	2004	2005	2006
Hisense	1	-	-	-	-	-
Chunlan	2	drs	-	drs	irs	drs
Aucma	3	irs	irs	irs	irs	drs
Xiahua	4	irs	irs	irs	irs	irs
Little Swan	5	-	-	-	-	-
Haier	6	-	-	-	-	-
Kelong	7	drs	drs	irs	irs	irs
Meiling	8	irs	-	drs	irs	irs
Konka	9	irs	drs	irs	irs	irs
Changhong	10	-	drs	irs	drs	irs
Ningbo Fuda	11	drs	drs	drs	drs	-
Meidi	12	-	drs	drs	drs	drs
Shenzhen Huafa	13	-	-	-	-	-
S Sam Sung	14	-	-	-	drs	drs
Gree	15	-	-	-	drs	-
Soyea Technology	16	-	-	-	-	-

Table 5. Situations of input congestion of 16 listed household appliances companies

Year	Assets		Costs of main businesses		Sum of employees	
	s_1^-	%	s_2^-	%	s_3^-	%
2002	0.085	1.70%	0	0.00%	0.029	0.41%
2003	0	0.00%	0	0.00%	0.245	3.04%
2004	0.159	2.18%	0	0.00%	1.732	16.73%
2005	0.123	1.76%	0.487	11.44%	0.457	5.08%
2006	0.027	0.38%	0.02	0.38%	0.524	4.71%

Table 6. Situations of input congestion of 16 listed household appliances companies from 2004 to 2005

Company	No.	2004			2005		
		Assets	Costs of main businesses	Sum of employees	Assets	Costs of main businesses	Sum of employees
Hisense	1	0.00	0.00	0.00	0.00	0.00	0.00
Chunlan	2	0.41	0.00	0.00	0.94	0.00	0.00
Aucma	3	0.15	0.00	0.00	0.91	0.00	0.00
Xiahua	4	0.00	0.00	0.00	0.00	3.08	0.00
Little Swan	5	0.00	0.00	0.00	0.00	0.00	0.00
Haier	6	0.00	0.00	0.00	0.00	0.00	0.00
Kelong	7	1.99	0.00	13.20	0.00	2.16	5.51
Meiling	8	0.00	0.00	0.00	0.00	0.00	0.00
Konka	9	0.00	0.00	5.91	0.00	2.56	0.56
Changhong	10	0.00	0.00	8.61	0.00	0.00	1.24
Ningbo Fuda	11	0.00	0.00	0.00	0.12	0.00	0.00
Meidi	12	0.00	0.00	0.00	0.00	0.00	0.00
Shenzhen Huafa	13	0.00	0.00	0.00	0.00	0.00	0.00
S Sam Sung	14	0.00	0.00	0.00	0.00	0.00	0.00
Gree	15	0.00	0.00	0.00	0.00	0.00	0.00
Soyea Technology	16	0.00	0.00	0.00	0.00	0.00	0.00
Mean		0.16	0.00	1.73	0.12	0.49	0.46
Degree of input congestion		2.18%	0.00%	16.73%	1.76%	11.44%	5.08%