The Analysis of Technical Efficiency of Airlines in China

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Abstract—In recent years, the airlines industry develops pretty fast. However, the profit of airlines does not match with the inputs. So the purpose of this paper is that evaluating how serious the problem is by measuring the technical efficiency of airlines in China with the Stochastic Frontier Analysis. We choose 6 airlines as the research samples due to their 86.68% market shares. After that we build a Cobb-Douglas production function regression model and measure the technical efficiency. The results are as follows: the technical efficiency of airlines in China by SFA and find out the average of it is in a medium level. However, the different airlines show different technical efficiency: the large airlines have higher technical efficiency but less increasing rate of technical efficiency than the small ones. Besides, the airline industry shows decreasing returns to scale, which means the output does not match the level of inputs. Finally, there is an inputs adding order to increase the output- capital, fuel and labor.

Keywords- Technical Efficiency; Airlines; SFA; Cobb-Douglas; Regression Analysis (key words)

I. INTRODUCTION

In the past ten years, the Chinese airlines industry developed rapidly- there are 31 airlines (only the civil air transportation companies, not including the general airlines) in 2003 but 46 in 2013 in the air transportation industry in China. The revenue of the transportation of the total airlines is 366.38 billion RMB in 2013, which is about 4.47 times than that in 2003. However, 7 airlines bankrupted, more than 10 airlines combined and about 20 airlines established during this period. So it is necessary for us to find out the reason why some airlines run well, comparing with others operates badly. Is that caused by the lack of technical efficiency in the airlines operation? To answer the above question, we use Stochastic Frontier Analysis (SFA) to measure the technical efficiency of airlines in China first. And then find out the how much the inputs contribute to the output from the empirical result.

In the next section, we will review the previous literatures first. After that, we will present the methodology and data. In section 4, we measure the technical efficiency in the production system. Finally, we will make a conclusion in section 5.

II. LITERATURE REVIEW

In this part, we will start to review the literatures about the technical efficiency of the airlines. Then we will go through the research about the function form because of the restriction of the SFA approach.

A. The literature about the technical efficiency of the airlines

The technical efficiency of the airlines could be measured by data envelop analysis (DEA) or stochastic frontier analysis (SFA). The former one is a non-parameter approach which does not need a function form to show the relationship between the input and output, while the latter one does.

From the aspect of DEA, Charnes et al.(1978) firstly introduced this approach as a non-parametric mathematical technique for measuring the relative efficiency of peer decision making units (DMUs) with multiple inputs and multiple outputs. It is neither required a specific function form nor the amount of the output variable. Schefczyk (1993) calculated the efficiency scores of 15 airlines by DEA and shown the operation performance of the airlines based on those results.

However, the scholars did not satisfy with the only result of the efficiency score because it may not reflect the relationship among the input variables. Aigner et al.(1977) introduced a stochastic frontier production function to estimate the technical efficiency. They divided the technical efficiency from the error term of the regression using the cross-section data or time varying data. Schmidt and Sickles(1984) used the US airlines data to estimate the technical efficiency by within estimator, GLS and MLE. Cornwell et al.(1990) developed Schmidt and Sickles(1984)'s approach and estimated the technical efficiency of eight US airlines by production frontier model with a flexible function form including time and seasons variables. They added seasons as dummy variables which were unique with other scholars. Additionally, the production could be flexible with the time and other input variables because of the translog form. Barla and Perelman(1989) used the production frontier approach to compare the technical performances of US airlines operating in deregulated markets with those European and other carriers under strong regulation. They found all the airlines shown almost the same efficiency in normal but the efficiency of airlines in deregulated markets would be better than those under regulation during a crisis, i.e. fuel crisis et. Charnes et al.(1996) divided the airlines industry in Latin American into international and domestic segments and tested the efficiency by robustly efficient parametric frontier approach that incorporates stochastic features into the parametric frontier without making any arbitrary assumptions about the distribution of inefficiencies. The authors shown there were three advantages of the REPF, such as log-linear functions, embedding prior information into the estimation process via additional constraints and incorporating stochastic features into the parametric frontier. Coelli et al.(1999) measured the technical efficiency from stochastic frontier production functions which have been adjusted to account for environmental influences such as network conditions, geographical factors, etc. They considered two alternative approaches to this problem. One assumed that the environmental factors influence the shape of the technology, while the other one assumed that they directly influence the degree of technical inefficiency. Both sets of results suggested that Asian/Oceanic airlines were technically more efficient than European and North American airlines but that the differences were essentially due to more favorable environmental conditions.

B. The literature about different function forms

As mentioned above, the SFA approach is a parameter approach, so it is required a specific and exact function form. In previous research, the scholars showed the advantages of different production function forms in different researching purpose: Cobb-Douglas function form is the general function form and was used widely by the scholars. Besides, Oum and Zhang(1995) used translog function to calculate the inputs allocative efficiency and technical efficiency of the telecommunication industry in US. It would be clearly shown that the time variable and interactive relationship of each input variables by a translog function form.

In a summary, the technical efficiency could be measured in the production system. Besides, the function form need to be chose seriously by the different purposes.

III. DATA AND METHODOLOGY

In this paper, we will choose six airlines - China Eastern Airline, China Southern Airline, Air China, Hainan Airline, Shandong Airline and Shanghai Airline- as the samples not only due to the data available of the six public companies, but also the summary RTK of the six airlines making up 86.68% of the total RTK in China airlines industry in 2013. Moreover, some airlines were belongs to some of the six airlines. For example, Shenzhen Airlines belongs to the Air China and Xiamen Airlines belongs to the China Southern Airlines. So we believe we the six airlines could represent most parts of the airline industry in China. Some data (2001-2002 of Air China and 2009-2013 of Shanghai Airlines) are lack because they were not reported at that time. Last, the input expense of each airline per year is adjusted by the CPI (based on the 2001).

The technical efficiency is an effectiveness with which a given set of inputs is used to produce an output. So it could be measured from the production function of the firm. In airlines industry, the most important input maybe could be capital, labor and material (fuel) because no matter the quantities or the prices of them are made up most parts of the input quantity or expenses. So we use these three variables as the input variables and the revenue ton kilometers of each airline as the output variable. In detail, the capital variable, labor variable and material variable are the total aircrafts expenses, the total salary and the total fuel expenses respectively.

A. Data statistic description

From table 1, it is clearly shown that the gap between min value and max value is large, which means the samples are different scale airlines. It could be represent the airlines industry well in our research.

TABLE I DATA STATISTIC DESCRIPTION IN TOTAL

UNIT: MILLION

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
RTK	71	5,530	5,220	181	17,700
total aircrafts expenses	71	2,780	2,370	152	7,790
total salary	71	1,570	1,650	59	7,390
total fuel expenses	71	8,580	8,070	410,	28,200

TABLE II DATA STATISTIC DESCRIPTION OF EACH AIRLINE

		average RTK per year (ton kilometer)	**average aircrafts expenses per year (Yuan)**	**average salary expenses per year (Yuan)**	**average fuel expenses per year (Yuan)**
China Eastern	amount	7,949,389,231	1,817,865,502	4,045,136,574	12,125,328,687
	rank	3	3	3	3
China Southern	amount	8,736,223,846	1,927,691,029	4,871,311,421	14,711,464,914
	rank	2	2	2	2
Air China	amount	11,238,242,727	4,407,385,840	5,034,682,404	15,653,126,778
	rank	1	1	1	1
Hainan Airline	amount	2,491,255,068	671,295,825	1,059,324,500	3,891,012,238
	rank	4	4	4	4
Shandong Airline	amount	803,444,862	244,053,675	417,558,124	1,397,277,299
	rank	6	6	6	6
Shanghai Airline	amount	1,196,247,900	316,226,743	884,550,614	2,386,159,832
	rank	5	5	5	5

From table 2, we see the large airlines (Air China, China Eastern or China Southern) input much more than the small ones and of course get more output. In addition, the relationship between input and output is positive, which means the more resource inputs, the more RTK outputs. However, same unit input would not get the same output, which means the technical efficiency of each airline is different.

B. Methodology: SFA based Cobb-Douglas production function

In this paper, we want to not only calculate the technical efficiency of airlines but also know the relationship between the inputs and output. So we choose SFA instead of DEA because the SFA could get the results by a regression model.

Due to the SFA is a parametric method, we choose the Cobb-Douglas production function to build the SFA model. The Cobb-Douglas production function is a function to describe the production of a firm with following form: $y = A\prod_{i=1}^{L} x_i^{\beta_i}$, where y is output, and xi is the ith input, there are L inputs and A is the total factor productivity. And by logarithmic, we could discovery the relationship between the increasing input and output. After logarithmic, the production function form is: $\ln y = \beta_0 + \sum_{i=1}^{L} \beta_i \ln x_i$

In this paper, the SFA regression model based on logarithmic production function of each airline is setting as following:

$$\ln y = \beta_0 + \beta_1 \ln K + \beta_2 \ln L + \beta_3 \ln F + v - u$$

Where y is revenue ton kilometer of the airline to represent the output, K is total aircraft expenses to represent the capital input, L is the total salary to represent the labor input, F is the total fuel expenses to represent the material input, u is the technical efficiency, v is the error term，βi is the model coefficient.

IV. Results

A. Results of regression

We use the panel data of six airlines from 2001-2013 to estimate the technical efficiency and get the result in table 3 and 4 by Frontier 4.1 (Battese and Coelli, 1992):

TABLE III THE SFA REGRESSION RESULT BY COBB-DOUGLAS PRODUCTION FUNCTION

	coefficient	**standard-error**	**t-ratio**
β_0	3.1860	0.9383	3.3955***
β_1	0.5731	0.0908	6.3108***
β_2	0.0606	0.0327	1.8544**
β_3	0.2564	0.0872	2.9401***
σ^2	0.0272	0.0075	3.6312***
γ	0.5757	0.1408	4.0893***
μ	0.2502	0.1244	2.0103**
η	0.0831	0.0150	5.5439***
log likelihood function	47.5051	LR test of the one-sided error	41.6309

*** means the coefficient passes the 1% Student's t-distribution-test, ** means the coefficient passes the 5% Student's t-distribution-test

From the table 3, first, we could know all the estimation coefficients pass the 1% Student's t-distribution-test except β_2 and μ (they pass 5% Student's t-distribution-test). The log likelihood ratio is 47.5051, which passes the X^2 distribution (P=0.9). So we believe the result of regression is good.

Second, γ=0.5757 means there is 57.57% gap between the frontier production and real production so it is necessary to measure the technical efficiency. μ=0.2502 means the technical efficiency is between 0 and 1 because of $TE = e^{-\mu}$. Also, η=0.0831 means there is 8.31% technical increasing change with the time t.

Third, β_1, β_2 and β_3 are all positive, which means the output would increase when the input increases. Specifically, the capital increases one unit, the RTK will increase 57.31 while the input of labor and fuel does not change. The same are other inputs. Also, the capital contributes the most RTK, then is the fuel and last is the labor. However, $\beta_1 + \beta_2 + \beta_3 = 0.8901 < 1$ means there are decreasing returns to scale of the total airlines.

Finally, due to $\beta_1 > \beta_3 > \beta_2$, it means the contribution to the output is capital, fuel and labor in order. So the airlines could be get much more output by adding the inputs with the above order.

B. Results of technical efficiency

From the table 4, the average technical efficiency of six airlines is 0.6239 which is in a medium level. The difference of technical efficiency between big airline and small airline is clear enough as well. The highest technical efficiency is Air China, which is almost 2 times than the lowest one- Shanghai airline. And the China Eastern and China Southern airline rank 2 and 4 while Shandong Airline ranks only 5. So we may say the big airline is better than small one in technical efficiency.

Second, there is an increasing technical efficiency trend for each airline from 2001- 2013. It means the technical level of each airline becomes better year by year. The administrators of each airline pay attention to improve the technical change as well.

Third, the technical efficiency increasing rate of small airlines is faster than the large ones. It means with the development of the small airlines, they became larger and the difference between the small ones and large ones is closer.

TABLE VI THE TECHNICAL EFFICIENCY RESULT OF EACH AIRLINE (2001-2013)

	Eastern	**Southern**	**Air China**	**Hainan**	**Shandong**	**Shanghai**
2001	0.5510	0.4904	-	0.5394	0.3172	0.3263
2002	0.5777	0.5190	-	0.5666	0.3476	0.3568
2003	0.6035	0.5468	0.7331	0.5928	0.3781	0.3873
2004	0.6283	0.5737	0.7514	0.6180	0.4086	0.4177
2005	0.6520	0.5997	0.7687	0.6421	0.4388	0.4477
2006	0.6745	0.6246	0.7850	0.6652	0.4685	0.4773
2007	0.6960	0.6484	0.8002	0.6871	0.4977	0.5063
2008	0.7164	0.6712	0.8145	0.7080	0.5261	0.5345
2009	0.7357	0.6929	0.8279	0.7277	0.5537	-
2010	0.7539	0.7134	0.8405	0.7464	0.5804	-
2011	0.7710	0.7329	0.8522	0.7640	0.6062	-
2012	0.7872	0.7512	0.8631	0.7805	0.6308	-
2013	0.8023	0.7685	0.8732	0.7961	0.6544	-
Average	0.6884	0.6410	0.8100	0.6795	0.4929	0.4317
Rank	2	4	1	3	5	6

V. CONCLUSIONS

In this paper, we measure the technical efficiency of airlines in China by SFA and find out the average of it is in a medium level. However, different airlines show different technical efficiency: the large airlines have higher technical efficiency but less increasing rate of technical efficiency than the small ones. In addition, the trend of technical efficiency of airlines in China is going up every year. Besides, the airline industry shows decreasing returns to scale, which means the output does not match the level of inputs. Finally, there is an inputs adding order to increase the output- capital, fuel and labor. With this order, the airlines could get more profits by spending some cost but different input factors.

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