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Economic Efficiency Measurement of Guangzhou Airport based on Stochastic Frontier Analysis Model

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Abstract. With the continuous development of economic globalization, airport economy has gradually become one of the mainstream forms of global economic development. Airport economy not only plays an important part in optimizing the structure of urban development and economic transformation, but also plays a major role in the rational exploitation of the urban landscape resources and the adjustment of mechanisms' relationship. However, in the development process of the airport economy, the theoretical scholars and practitioners have not systematically combed through its development efficiency and influencing factors, which leads to the development orientation of the airport economy being out of focus. In this paper, the stochastic frontier analysis model is used to analyze the economic efficiency of Guangzhou Airport. Based on the panel data of Guangzhou Airport, this paper applies the stochastic frontier model of simultaneous equations to analyze the economic efficiency of Guangzhou Airport and its influencing factors. Finally, it is concluded that the construction of airport infrastructure, the regional geographical location, the level of regional economic development, and regional science and technology education all affect the economic efficiency of Guangzhou Airport.

Keywords: Stochastic Frontier Analysis; Guangzhou; Airport Economy; Economic Efficiency.

1. Introduction

Guangzhou Airport is located at the boundary of Huadu District and Baiyun District. It is the most suitable area for commercial development of airport economy. As a hub airport, it has both international and national line flights. With regard to the advantages of the airport, Guangzhou Airport is an unavoidable hub port to transfer to Hong Kong and Macao, as well as to South Asia, Southeast Asia and Oceania. It is also the first super-large hub airport designed and built according to the concept of central airport in China. The status of Guangzhou Airport has been rising rapidly since 2004, when it was relocated from the central city of Guangzhou. At present, the passenger throughput ranks second in China (excluding Hong Kong), and the cargo and postal throughput ranks third in China (excluding Hong Kong). In the document the *"Eleventh Five-Year Plan" of Guangdong Airport Management Group and the* Expectation *for 2020*, the Baiyun International Airport would evolve into a highly developed and comprehensive aviation hub in Asia-Pacific area by 2020, with the passenger throughput and the cargo throughput becoming one of the top 15 and the top 10 of the worlds respectively. Although Guangzhou Baiyun Airport has established an air cargo terminal, the distance between the terminal and its customers is relatively far away. Therefore, in terms of time, it is difficult to respond to the needs of timeliness, convenience and instantaneity from the customers. For example, shorter lead time and distribution cycle make it impossible for industries to gather together, and lacking of convenient air transportation operation platform seriously restricts the development of traffic in the airport area.

With the accelerating process of economic globalization, airport economy has gradually become one of the mainstream forms of world economic development. In recent years, Guangzhou Airport economy is also in a state of rapid development. In the new economic era, the airport economy is a new economic form being equipped with high-technicalization, a product of regional economic integration and an important symbol of urban development. Its importance is mainly reflected in three aspects: First of all, the economic development of the airport is conducive to the promotion of the strategic development process of the city in which it is located. Second, the airport economy is

beneficial to the continuous transformation in the urban process. At the same time, the airport economy has facilitated the optimization and upgrading of the industrial structure in its surrounding areas, the continuous high-end oriented regional economy, the innovation of the value chain and the acceleration of the urban development process. Evently, the development of airport economy makes narrow the gap of wealth between the cities and the poor countrysides, and also undertakes the industrial transfer at home and abroad, and then boosted the development of the region.

1.1 Research Status at Home and Abroad

In China, Ye Xiaojia and Sun Jingshui [1] set up an assessment criteria for the economic efficiency in terms of economic scale, economic structure, economic vitality, production efficiency, technical efficiency and resource efficiency, employing efficiency coefficietn methord to calculate the the economic efficiency of China. Zhou Xiaoyan and her partners [2] use stochastic frontier model to estimate the production efficiency in the Yangtze River Delta from 1990 to 2006 and decompose the growth rate of its total factor productivity. Wang Lei and Zhang Huayong [3]calculate the efficiency of resource allocation in various regions by decomposing the total productivity and using the covariance of productivity and market share to figure out a measure index for the effiency of resource allocation, meausre the effiency of resource allocation in different regions, and empirical analysises about the influence of the discrepancy and unbalance on the efficiency of resource allocation in the process of marketization are also conducted in the paper. Some scholars take energy consumption and environmental capacity as the new input factors into production function in traditional TFP analysis [4-6], and study the input-output efficiency of economic system. Zhao Haitao and his partners [7], and Hu Zhiyi [8], divide the operating efficiency of Chinese travel agencies into technological change rates and efficiency of resource allocation based on the panel data from 2001 to 2009, and find that the main driving force for the rise of TFP in Chinese travel agency industry is technological progress. The TFP value of travel agencies in the eastern and central regions is much higher than that in the western region, while the flat technological progress is the main factor that restricts the development of the western travel agency industry.

At abroad, in the research field of economic efficiency, Morey, R.C. and Dittman [9] (1995) employ DEA model and SFA model respectively to measure the efficiency of tourist hotels in the United States of America. According to the results of efficiency measurement, the management efficiency level of American hotel industry is relatively high. In Europe, efficiency and technological progress are divided into three aspects by Barros [10] (2006): pure technological progress, non-neutral technological progress and technical progress in the dispute on scale; and the efficiency of 15 hotels in Portugal from 1998 to 2002 is estimated through SFA model. The study finds that most hotels do not reach the most effective state, the overall efficiency is fairly low, and the waste of resources is rather serious. To dispose of the hazardous substances in OECD countries, Yörük B K and Zaim O [11] (2005) measure the economic growth efficiency of the green economy in OECD countries through the Malmquist-Lounberg Productivity Index.

There are mainly two methods to study the measurement of economic efficiency in the literature at home and abroad. First, comprehensive evaluation is used to measure through the construction of economic efficiency index system. The second is the parametric method that relies on econometric method and the non-parametric method that is based on mathematical programming. After making a general survey on the studies about economic efficiency from different perspectives by the scholars all around the world, it is obvious that they have achieved abundant researches, whereas there is still a long way to go in the researches on the economic efficiency of airport economy. Hence, this paper focuses on the measurement of Guangzhou Airport's economic efficiency with stochastic frontier analysis as its model.

2. Construction of Random Frontier Model

The concept of economic efficiency is widely used in the studies of economics. Economic efficiency refers to the economic benefits that can be obtained on the basis of certain economic costs,

which is the proportional relationship between input and output of factors of production. The standard meaning of economic efficiency is that resource allocation achieves the maximum value.

In the practical application of mathematical calculation, the frontier of the research needs to be determined. There are mainly two methods to determine: the first is to estimate the parameters of the frontier production function measured by the model and to measure the technical efficiency, that is called the, "statistical method" or "parameter method" for efficiency evaluation. The second method is to solve the linear programming in mathematics to determine the production frontier and measure the technical efficiency, which is mathematically called "mathematical programming method" or "non-parametric method". The parameter method has experienced two stages of development in the selection process of dependent production function: deterministic frontier model and stochastic frontier model. The stochastic frontier model is first proposed by Aigner & Chu, that is mainly used to measure the technical efficiency of multi-input and single output.

SFA model is a typical example of parametric method employed in the frontier analysis. Compared with the nonparametric methods, its main advantage is that it takes into account the influence of random factors on the output. The problem that SFA has to solve is to measure the technical efficiency of n decision-making units in T period (TE). Each decision-making unit is m inputs and a single output.

When using the panel stochastic frontier model, there are two kinds of estimation methods: two-step estimation and one-step estimation. The former uses SFA model to measure efficiency (the first step) , and then applies this efficiency to carry on the second step—regression analysis to the influence factor. The greatest defect of the two-step estimation is that the first step assumes that the technical efficiency submits to the same distribution, while the second step presumes that the technical efficiency has some kind of function relation with a series of other variables, which would result in a contradiction. However, the one-step method is to analyze the degree of influence on the technical invalid terms by associating the influencing factors with the distribution of the technical invalid terms. In view of what mentioned above, the paper employs one-step Maximum Likelihood Estimation to evaluate the economic efficiency of the airport and its influencing factors based on the stochastic frontier model with the support of panel data.

The model can be represented as

$$lny_{it} = lnf(X_{it}, \beta_i) + V_{it} - \mu_{it} \ \ (i = 1,2,\cdots,n\,; t = 1,2,\cdots,T\,) \tag{1}$$

$$\varepsilon_{it} = V_{it} - U_{it} \tag{2}$$

In formula (1), in formula (2), $f(X_{it}, \beta_i)$ is a production function.ε_{it} is an error term. It is made up of two parts, one of which is V_{it}, the impact of random factors on output.The other part is U_{it}, the impact of technical inefficiency on output. V_{it} and U_{it} in formula (2) submit to independent and uncorrelated distribution. V_{it} complies with the standard normal distribution N $(0,\sigma_v^2)$, yet U_{it} gennearlly assumes to coincide with the semi−normal distribution or truncated normal distribution $N^+(m_i, \sigma_u^2)$.

In order to evaluate economic efficiency more accurately, the extended model such as Battese&Coelli is adopted, that is, adding inefficient functions to the stochastic frontier model and using the maximum likelihood method to estimate them, which is also called one-step maximum likelihood estimation method. The models are as follows:

$$m_i = \delta_v + \delta_i \mathcal{Z}_i + \omega_i \tag{3}$$

$$TE_{it} = \exp(-u_{it}) \tag{4}$$

In the models, $\mathcal{Z}_i$ is the influence factor of technical inefficiency.δ is the parameters of the equation to be estimated. If δ>0, then $\mathcal{Z}$ has a negative effect on efficiency. Conversely, if δ<0,

then Z has a positive effect on efficiency with ω_i working as the stochastic perturbation term of the technical inefficient equation. TE is technical efficiency. According to the variance of V_{it} and U_{it}, $\gamma=\sigma_u^2/(\sigma_u^2+\sigma_v^2)(0\leq\gamma\leq1)$, if $\gamma=0$,it means that the frontier output is completely determined by the random disturbance term, so it is not necessary to adopt the stochastic frontier analysis. And when γ gets closer to 1, it is more suitable to apply SFA model method to analyze.

3. Research Data and Variables

Through the previous introduction on the fundamental principles of SFA model, it is evident that a stochastic frontier production function model needs to be established to measure the economic efficiency and explore its influencing factors. Therefore, the data for analysis and the variables involved in the model are supposed to be introduced in details as follows.

3.1 Data Sources

In this paper, the airport economy of Guangzhou City in Guangdong Province is selected as the cross section of panel data. In view of the changes happenning to the accounting system in Guangzhou Statistical Yearbook, 2012-2017 is chosen as the time dimension. All the data in this paper are based upon Guangzhou Statistical Yearbook (2012-2017).

3.2 Input and Output Variables

(1) Output variable: The output variable of this paper needs to reflect the economic level of the airport. Here, the GDP of Guangzhou's annual airport gross domestic product is chosen as the dependent variable, which is easy to measure and can reflect the economic level, and is less affected by the market.

(2) Input variable: The previous theoretical analyses and relevant studies indicate that the domestic and foreign scholars usually divide the economic input variables into capital input and labor input. In this paper, the number of employees in Guangzhou Baiyun Airport is used to replace the amount of labor involvement (donated as L), and the operating cost of Guangzhou Baiyun Airport is taken as the capital input (donated as K).

3.3 Efficiency Influencing Factor Variable

This paper analyzes the economic efficiency of Guangzhou Airport from four major factors: infrastructure construction, regional geographical location, level of regional economic development and level of regional science and technology education.

(1) Airport Infrastructure Construction (AIC): The infrastructure construction of Guangzhou Airport can effectively provide a favorable foundation for the flights of Guangzhou Aircraft, thus efficiently driving and supporting the economic development of the airport economy.

(2) Regional Geographical Location (RGL): Guangzhou Airport is an inevitable hub port to transfer to Hong Kong, Macao, South Asia, Southeast Asia and Oceania, and Baiyun International Airport is one of the three major hubs in China, with an excellent geographical location.

(3) Level of Regional Economic Development (LOED): Generally speaking, the regional economic development level of the airport area is relatively high, which can provide a large amount of capital and a great deal of infrastructure support for the development of the airport economy and create a fertile development environment.

(4) Level of Regional Science and Technology Education (RSTE): Generally speaking, the development of airport economy is greatly affected by the level of regional science and technology education. Therefore, it is necessary to consider the development of regional economy when studying the economic efficiency of the airport. And in recent years, the economic development of Baiyun District in Guangzhou has been significantly developed.

4. Empirical Analysis

The key to evaluate the efficiency through the stochastic frontier model that estimated by one-step method is to construct the frontier production function and the inefficient function. Generally speaking, transcendental logarithmic production functions usually have strict requirements on the data size. Considering that the time period studied in this paper is from 2012 to 2017, finite transcendental logarithmic functions are chosen with specific production functions and inefficient functions as follows:

Production function:

$$\mathrm{Ln}(GDP_{it}) = \beta_0 + \beta_t l + \frac{1}{2}\beta_{it} l^2 + \beta_k Ln(K_{tl}) + \beta_t Ln(L_{it}) + \beta_{tk} lLn(K_{it}) + \beta_{it} lLn(L_{it}) + \frac{1}{2}\beta_{kk}(LnK_{it})^2 + \frac{1}{2}\beta_{ll}(LnL_{it})^2 + V_{it} - U_{it}$$

In the function above, *K* and *L* are capital input and labor force input, and *t* represents the level of technological progress.

According to the influencing factors of the airport's economic efficiency mentioned above, the inefficient function equation is constructed as follows

$$m_{it} = \delta_v + \delta_1 JCJS_{it} + \delta_2 LOCA_{it} + \delta_3 ECNO_{it} + \delta_4 EDU_{it} + \omega_{it}$$

Table 1. signifies the descriptive statistics of index variables in the model

Variable	N	Min	Max	Mean	Standard Deviation
LnGDP	72	5.71	9.10	7.73	0.88
LnK	72	6.06	10.12	8.50	0.95
LnL	72	4.40	6.75	5.48	0.67
AIC	72	0.11	1.72	0.58	0.43
RGL	72	0.01	0.33	0.09	0.08
LOED	72	219.90	263.5	239.42	9.44
RSTE	72	0.06	1.62	0.56	0.42

4.1 Model Testing

In order to test the effectiveness of the production function and the inefficiency function for estimating the economic efficiency of the airport, the likelihood ratio (LR) test is carried out. LR is defined as: LR=-2Ln[L(H0)/L(H1)] with L(H0) and L(H1) actting as the values of the null hypotheses and alternative hypotheses, and the LR~X^2 (K) k refers to the degree of freedom. The paper sets out four assumptions as shown in Table 2. The results of LR test in Table 2 are obtained by employing Frontier4.1 software. Hypotheses 1 to 4 are refuted at a significant level of 1%. This indicates that: (1) The finite transcendental logarithmic production function set in this paper is suitable for the study; (2) There is an inefficient item in the calculation of the airport's economic efficiency, which requires inefficiency analysis; (3) The economic efficiency of the airport changes with time, and there would be technological progress in the calculation of the airport's economic efficiency;

Table 2. Results of Model Hypothesis Testing

Null hypothesis	*Logarithmic Likelihood Value*	*LR Statistics*	*Critical Value*	*Conclusion*
suppose 1$\beta_t - \beta_{tt} - \beta_{tk} - \beta_{tl} - \beta_{kk} - 0$	50.49	60.86	16.81	refuted **
suppose 2$\gamma - \delta_1 - \delta_2 - \delta_3 - \delta_4 - 0$	31.02	99.80	16.81	refuted **
suppose 3$\beta_t - \beta_{tt} - \beta_{tk} - \beta_{tl} - 0$	68.66	24.52	13.28	refuted **
suppose 4$\beta_{tk} - \beta_{tl} - 0$	58.21	45.42	9.21	refuted **

Note: The value of the unconstrained logarithmic likelihood function is 80 and 92, "**" Likelihood ratio test for 1% significant level.

4.2 Elastic Analysis of Factors in Airport

In order to analyze the function of the airport's production factors in the economic development of Guangzhou, this paper brings in the elasticity coefficient of factor output, and then obtains the output elasticity of the capital and labor factors in the Guangzhou airport economy from 2012 to 2017.

Table 3. Economic factors output elasticity of Guangzhou Airport

Year	2012	2013	2014	2015	2016	2017
ε_l	0.355	0.327	0.299	0.270	0.255	0.234
ε_k	0.609	0.648	0.689	0.727	0.748	0.774

As shown in Table 3, the sum of capital output elasticity and labor output elasticity from 2012-2015 is less than 1, manifesting that the return to scale of the development of the airport economy is in decline. That is because of the investment of lagre amounts of money and infrastructures at the earlier stage of development, meanwhile, the weak foundation, techonological level and economic production efficiency lead to the decreasing of industrial scale returns. However, according to the trend of annual change of return to scale, from 0.964 in 2012 to 1.008 in 2017, the number gradually tends to be invariable, which means capitals and labor force have a mobilizing and facilitating effect on the airport economy. In the meantime, it can be illustrated from Table 3 above that the output elasticity of Guangzhou airport capital is greater than that of labor force, which indicates that the development of airport economy mainly depends on the capital input from the airport, but less on the labor force.

4.3 An Analysis of the Influencing Factors of the Airport's the Economic Efficiency

(1) The impact of airport infrastructure construction on the economic efficiency of the airport first decreases progressively and then increases. The reason is that the airport economy is a kind of export-oriented economy, the Guangzhou airport economy started relatively late, being under development with backward tecnologies; during the initial period, the allocation of resources was not sufficient which results in a passive state in the competition at home and abroad and low production efficiency. However, with the gradual development of Guangzhou's economy, Guangzhou becomes the first-tier and world-famous city, which helps improve the exploitation and utilization ratio of the airport and the economic development of the airport has gradually tended to be orderly and reasonable, and its economic efficiency has also been facilitated. Therefore, the construction of airport infrastructure needs to be further strengthened and the economic efficiency be further improved.

(2) The influence of regional geographical location on the airport's economic efficiency is positive. In recent years, the economic development of Guangzhou Airport has benefited from its geographical location for Baiyun District is located in the north and west of Guangzhou, and also lies in the east, west and north of Guangzhou's vital communication line as the transportation hub of Guangzhou.

(3) The effect of regional economic development on the airport's economic efficiency is positive. Compared with other influencing factors, the regional economic development has the greatest influence coefficient on efficiency, which means that how to maintain a high level of regional economic development is the key to improve the efficiency of airport economy in the future.

(4) The impact of regional science and technology education on the economic efficiency of the airport is positive. Scientific and technological talents are the motive force to directly promote the development, transformation and application of production technology in the economic industry of the airport, and have higher labor productivity and creativity. At the present stage, the advantages of human resources are getting revealed so as to accelerate the improvement of economic efficiency.

5. Conclusion

Taking the panel data of Guangzhou Airport from 2012 to 2017 as a sample, the paper applies the stochastic frontier model that constructed by the finite transcendental logarithmic production function and inefficient production function to evaluate the economic efficiency of Guangzhou Airport reasonably and analyze the production factors and the influencing factors of the airport economy. It is found that the development pattern of Guangzhou Airport is capital-intensive. In recent years, the elasticity of capital output has been far greater than that of labor output, and the economic development is in the stage of diminishing returns to scale, which indicates that the allocation structure of the airport economy's input facors is unreasonable. The influence of airport infrastructure construction on economic efficiency of the airport represents as a "U"shape and nonlinear relationship. The regional geographical location, the level of regional economic development, and the level of regional science and technology education can improve the economic efficiency of the airport to a certain extent, which demonstrates a significant positive relationship.

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