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Efficiency measurement of Chinese airports with flight delays by directional distance function

L.W. Fan [a], F. Wu [b], P. Zhou [b,*]

[a] Business School, Hohai University, 8 Focheng West Road, Nanjing 211100, China
[b] College of Economics and Management, Nanjing University of Aeronautics and Astronautics, 29 Yudao Street, Nanjing 210016, China

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ABSTRACT

This paper employs directional distance function to evaluate the technical efficiency of twenty major Chinese airports from 2006 to 2009 within a joint production framework of desirable and undesirable output (i.e. flight delays). The results indicate that the overall average efficiencies of Chinese airports increased over the period of time. The international hub airports are found to operate at higher efficiency level, which indicates that these airports run well in producing more desirable outputs and controlling flight delays. Although the average efficiency score of listed airports is higher than non-listed ones, the difference between the two group is statistically insignificant. A comparison between the results without and with flight delays show that several airports experienced significant changes in their efficiency scores after considering undesirable output.

1. Introduction

The civil aviation transport industry in China has experienced fast growth. According to Civil Aviation Administration of China, civil aviation passenger throughput reached 230 million people in 2009, 44.3% more than that in 2006. The growth in air transportation has created both opportunity and challenge for Chinese airports. How to digest huge passenger size, enhance customer satisfaction and survive in the competition with high-speed train has drawn more attention from airport operators. In the case of Chinese airports, flight delay seems to be one main source of customer complaints. The Statistics of China Civil Aviation (2007–2011) show that the flight delay rates in main airports were higher than 10% during the period of 2006–2010. Actually, many airports in the world are suffering airport congestion. The global flight delay rate list released by Forbes in 2010 showed that the top five airports in flight delay rate were respectively Beijing Capital International Airport, Dubai International Airport, Sheremetyevo International Airport, Cairo International Airport and Leonardo Da Vinci International Airport.

According to Gillen and Lall (2001), airport industry needs to continuously monitor the operational performance of airports. Benchmarking has been widely accepted as a useful tool for assessing the performance of airport operations (Oum and Yu, 2004). For an airport operator, the most popular benchmark indicator may be air traffic volume, i.e., the number of aircraft movements, passengers, and cargo throughput (Pathomsiri et al., 2008), which can be considered as desirable outputs. On the other hand, flight delays may be treated as an undesirable output. Considering flight delays may better reflect the operational status of airports (Lozano and Gutiérrez, 2011). Without considering flight delays, congested airports might be found to be efficient (Pathomsiri et al., 2008).

The purpose of this paper is to assess the efficiency of Chinese airports by considering both desirable and undesirable outputs (i.e. flight delays). Through integrating flight delays, this work may provide a relatively fair perspective in evaluating Chinese airport operating efficiency. The rest of this paper is organized as follows. Section 2 provides a brief literature review of airport efficiency evaluation. Section 3 introduces the methods employed. Section 4 describes the data and Section 5 presents the results of our empirical study. Section 6 concludes this study.

* Corresponding author. Tel.: +86 25 84893751; fax: +86 25 84892751.
E-mail addresses: cemzp@nuaa.edu.cn, rocy_zhou@hotmail.com (P. Zhou).

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2. Literature review

As airports become more commercially-oriented, the systematic analysis of airport performance has become a common activity within the airport industry (Graham, 2003). Data envelopment analysis (DEA), a well-established nonparametric frontier technique to efficiency evaluation, has been widely used in assessing airport efficiency.[1] For instance, Gillen and Lall (1997) defined airports as producing two separate classes of services (terminal services and movements) and then set a couple of variables to measure terminals and airside operations by adopting DEA model. Barros and Sampaio (2004) provided a summary of output and input measures in airport performance measurement and used DEA to evaluate the efficiency of Portuguese airports. Barros and Dieke (2007) empirically assess the financial and operational performance of a number of Italian airports with DEA. Barros (2008) used two-stage DEA to evaluate the performance driver of Argentine airports from 2006 to 2009. Fung et al. (2008) employed DEA to evaluate the operating efficiency of twenty-five Chinese airports during 1995–2004. Andrew and Zhang (2009) assessed the productivity of twenty-five major Chinese airports in 1995–2006 with DEA. More recently, Zhang et al. (2012) evaluated the technical efficiency of 37 airport airsides with DEA.

A common feature of the previous studies mentioned above is that they only take into account desirable outputs in airport efficiency evaluation. In recent years, incorporating environmental factors (pollution) into benchmarking analysis when evaluating airports efficiency/productivity has become a new topic. For example, Yu (2004) used DEA and directional distance function to assess operating efficiency of fourteen airports in Taiwan during 1994–2000 by considering noise as undesirable outputs. Yu et al. (2008) employed directional distance function and Malmquist-Luenberger productivity index to measure the productivity changes of Taiwan airports in 1995–1999 by considering airport noise. Martini et al. (2013) considered both noise and local air pollution to assess airport productivity of 33 Italian airports.

Several researchers have also taken airport congestion into consideration in airport benchmarking analysis by incorporating flight delays. For example, Pathomsiri et al. (2008) evaluated the operational efficiency of fifty American airports with undesirable outputs and found that the productivity growth may be exaggerated without consideration of undesirable outputs. Lozano and Gutiérrez (2011) analyzed the operating efficiency of thirty-nine Spanish airports by slacks-based DEA model with flight delays as undesirable output. Their empirical results showed that the efficiency scores after considering undesirable outputs seem to better reflect the operational status of airports. More recently, Lozano et al. (2013) proposed a network DEA approach by considering flight delays to study Spanish airports.

Our literature review shows that none of previous studies had analyzed the efficiency of Chinese airports by considering flight delays as undesirable output. It is the purpose of this study to fill in this gap by using directional distance function and DEA to measure the efficiency of Chinese airports.

3. Methodology

One airport may be treated as a production unit which employs multiple inputs, e.g. capital (runway length, terminal area, apron area, number of baggage claim, number of check-in desk) and labor, to yield both desirable outputs, e.g. air passengers and cargo throughput, and undesirable outputs, e.g. flight delays.[2] This paper aims to assess Chinese airport efficiency within a joint production framework of desirable and undesirable outputs. Two desirable outputs, namely air passenger and air cargo, and one undesirable output, namely flight delays, are employed in this paper. Regarding inputs, we choose three capital inputs, namely runway length, terminal area and number of baggage claim, by considering the special characteristics and availability of data. The runway length can help capture the effect of airside configuration on airport efficiency (Fung et al., 2008), and the terminal area represents the capital investment that airport managers can utilize (Pathomsiri et al., 2008). The number of baggage claim is also an important input which can influence delays and volume of passengers. The labor input is excluded in our study due to the following reasons. First, the number of labor force in airport activities changes dynamically so that the reported employment data may not truly reflect the actual utilization of labor input in airport operations (Oum and Yu, 2004; Pels et al., 2001). Second, the labor force structure in airport is quite complicate as shown in Tovar and Martín-Cejas (2010). On the other hand, Fung et al. (2008) pointed that if labor and capital are assumed to be completely substitutable, the use of capital by itself can still yield a consistent estimate of airport efficiency.

Let L, S, B, P, C and D represent runway length, terminal area, number of baggage claim, number of air passenger, number of air cargo and flight delays, respectively. Then the production possibility set can be described as:

$$T(L,S,B) = \{(P,C,D) : (L,S,B)\text{can produce}(P,C,D)\} \quad (1)$$

In order to well characterize the joint production process of desirable and undesirable outputs, the production possibility set should satisfy some standard axioms as suggested by Färe et al. (2007).

(1) $T(L, S, B)$ is convex and compact which implies that finite inputs produce finite outputs.
(2) $T(0,0,0) = (0,0,0)$, which means that zero inputs yield zero outputs.
(3) Null-jointness, i.e. if $(P, C, D) \in T(L, S, B)$ and $D = 0$, then $(P, C) = 0$.
(4) Strong disposability of inputs and desirable outputs, i.e. if $(P, C, D) \in T(L, S, B)$ and $(P', C') \le (P, C)$ (or $(L', S', B') \ge (L, S, B)$), the $(P', C', D) \in T(L, S, B)$ (or$(P, C, D) \in T(L', S', B')$).
(5) Weak disposability of desirable and undesirable outputs, i.e. if $(P, C, D) \in T(L, S, B)$ and, then $(\theta P, \theta C, \theta D) \in P(L, S, B)$.

The assumption of null-jointness means that the production of desirable outputs will inevitably generate undesirable outputs as byproduct. In this paper, null-jointness implies that flight delays cannot be avoided as long as there are airport operations.[3] The

[1] The parametric counterpart of DEA, i.e. stochastic frontier analysis, has also been used in assessing the efficiency and productivity of airports. An example is the recent study by Chow and Fung (2012).

[2] As Pathomsiri et al. (2008) pointed out, some flight delays are not due to random shocks rather than management inefficiency. Since it is impossible to quantify the delays from random shocks, we implicitly assume that all the flight delays are due to managerial inefficiency in this study. As a result, the efficiency scores obtained should be interpreted with this limitation in mind.

[3] Theoretically speaking, flight delays as an undesirable output may not satisfy the null-jointness property since it is possible for an airport to achieve zero flight delay through managerial efforts. However, in the case of China airports, none of them have achieved zero flight delays which implicitly indicate the infeasibility of zero flight delay without ceasing airport operations. Nevertheless, in the long run it is also possible for China airports to achieve zero flight delays by improving their operation and management levels. This should be treated as a limitation of imposing null-jointness property on flight delays.