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The change trend and influencing factors of civil aviation safety efficiency: The case of Chinese airline companies

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ABSTRACT

While the issue of civil aviation safety has attracted serious public concern, notably few studies have investigated civil aviation safety efficiency. In this paper, a definition of civil aviation safety efficiency is proposed for the first time. Inputs to the proposed civil aviation safety efficiency model are labor, capital, fund and technology. The outputs are the percent of the passenger turnover volume without accidents or incidents to the total passenger turnover volume and Net profit rate. Data Envelopment Analysis (DEA) and Malmquist index are used to calculate the civil aviation safety efficiency of ten Chinese airline companies from 2008 to 2012, and the Panel Regression Model is used to identify the important influencing factors of civil aviation safety efficiency. The results indicate that technology development is not the most important factor affecting the civil aviation safety efficiency of Chinese airlines. Instead, the most important factor is investments in training and developing aviation security staff and airline pilots. The research conclusions could provide guidance for decision makers on civil aviation safety.

1. Introduction

Aviation safety is a key factor for an airline's survival, reputation, international prestige and passenger confidence. In recent years, the civil aviation industry of China has grown enormously, and the safety situation has also improved significantly. However, the civil aviation accident rate is still higher than the average level worldwide. According to the statistical data available from Civil Aviation Resource Net, there were 6528 flight insecurity incidents in 2011, which accounted for 93% of total aviation insecurity incidents. Additionally, according to "2011 China's civil aviation safety accident statistical analysis report", there were 217 incidents in 2011, the number of general aviation accidents was four, and the number of missed general aircraft was one. Therefore, aviation safety has attracted the attention of the general public.

For the past several years, civil aviation safety has been a popular research topic, and the existing research has primarily evaluated civil aviation safety and the factors influencing it:

1. Evaluation of civil aviation safety: Existing literature has focused on evaluating civil aviation safety from several aspects, such as target level of safety (Li et al., 2009), cause identification system (Persing and Ng, 2009), performance of civil aviation safety supervisor (Chen, 2010), measuring safety in a changing civil aviation industry (Lofquist, 2010), aviation risk assessment (Brooker, 2011), and safety climate (Conner et al., 2011).
2. Analysis of factors influencing civil aviation safety: Most existing literature has focused on several influencing factors, such as passenger perceptions of exit row seating (Chang and Liao, 2008), aviation safety education of passengers (Chang and Liao, 2009), human errors and threats (Chen et al., 2009), major organizational changes (Herrera et al., 2009), relationship between safety management system and attitudes of employees (Remawi et al., 2011), cold season thunderstorms (Mäkelä et al., 2013), and use of personal electronic devices(Molesworth and Burgess, 2013).

The existing research primarily examines static evaluation of civil aviation safety and identification of the influencing factors, but the civil aviation safety efficiency of airline companies has not been evaluated. Civil aviation safety efficiency is defined to evaluate the effects of safety inputs believed to be vital to the safety performance of airline companies.

This paper is structured as follows: firstly, civil aviation safety efficiency is defined based on the literature summary; secondly, the civil aviation safety efficiencies of ten Chinese airline companies from 2008 to 2012 are evaluated through the DEA-Malmquist

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method; thirdly, the influencing factors of civil aviation safety efficiency are analyzed based on Panel Regression Analysis method; and finally, several conclusions are proposed based on the research results.

2. The definition

According to existing literature (Clinch and Healy, 2001; Martínez, 2011; Blomberg et al., 2012; Wu et al., 2012), civil aviation safety system is composed of source input, operating process and final output; therefore, this paper analyzes the definition of civil aviation safety efficiency from these three aspects:

2.1. Source input

In the operating process of civil aviation safety system, it is believed that the Source input not only consists of labor input (captain and other employees working on safety) but also inputs of funds and technology (Martínez, 2011). All of these inputs together impact the running of a civil aviation safety system.

2.2. Operating process

Civil aviation safety efficiency is an efficiency index (Wu et al., 2012). In general, efficiency is technical efficiency, and technical efficiency is the capacity to optimally use existing resources. In other words, it is the capacity to realize most outputs when the inputs are fixed or the capacity to realize least inputs when the outputs are fixed.

2.3. Final output

Not only safety performance but an airline's business performance should also be considered in the final outputs of civil aviation safety system (Camanho and Dyson, 2008). Airline companies are ultimately profit-making companies; therefore, flying safely is crucial to making profits, and the inputs on safety could drive an airline's profitability.

Based on the above, civil aviation safety efficiency is defined as the capacity to realize the best safety and business performance of an airline when the inputs are fixed, or the capacity to realize least inputs when safety and business performance of the airline are fixed.

3. The evaluation of civil aviation safety efficiency

3.1. The inputs and outputs

According to the literature summary and the reality of aviation industry, this paper constructs an index system of inputs and outputs.

3.1.1. The inputs

Labor input. Labor input is defined as the number of staff working on safe flights. This input includes the safety officers deployed in the preflight, flying and post-flight stages.

Capital input. Capital input is defined as the fixed assets input on safety. It includes new investments in safety control, safety maintenance and safety communication equipment, as well as in other safety hardware.

Fund input. Fund input is defined as the investments in safety software and safety staffs. It includes the investments in safety technology import, safety operation procedure import, the upgrade of safety control system, the introduction of safety talents, the training of safety staffs, and other investments in safety software and safety staffs.

Technology input. Technology input is defined as the investments in research and development of safety technology. It only contains an airline company's own R&D investments, excluding any on technology import.

3.1.2. The outputs

The percent of the passenger turnover volume without accidents or incidents to the total passenger turnover volume. Passenger turnover volume is defined as the product of the number of carried passengers and the flying distance of each passenger. According to the Safety Management Manual of International Civil Aviation Organization (ICAO, 2013), an *accident* is an occurrence during the operation of an aircraft which entails: (1) a fatality or serious injury; (2) substantial damage to the aircraft involving structural failure, or requiring major repair; or (3) the aircraft is missing or is completely inaccessible. An *incident* is an occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation. A serious incident is an incident involving circumstances indicating that an accident nearly occurred. In the detailed classification of Civil Aviation Administration of China (CAAC, 2014), there are three types of accidents: extraordinarily serious accidents, serious accidents and general accidents. Furthermore, Civil Aviation Administration of China specifies 86 situations as an incident.

Net profit rate. It is defined as the ratio of the Net profit to the revenue of the main business. It is meant to reflect the business performance of airline companies.

3.2. DEA and Malmquist index

Data Envelopment Analysis (Charnes et al., 1978; Coelli et al., 2005; Zhou et al., 2008; Cui et al., 2014; Cui and Li, 2014) is a data planning method to evaluate the relative efficiency of decision-making units which have multiple inputs and multiple outputs. It has been applied to the study of innovation, model development and practical application.

3.2.1. Data Envelopment Analysis model

Suppose there are n decision making units (DMU) and every DMU has m inputs and s outputs. For DMU j, the ith input is marked as x_{ij} $(i = 1, 2, \cdots, m)$ and the rth output is marked as y_{rj} $(r = 1, 2, \cdots, s)$.

The efficiency of the dth DMU is

$$\theta_d = \max \frac{u^T Y_d}{v^T X_d}$$
$$s.t. \frac{u^T Y_i}{v^T X_i} \leqslant 1, \quad i = 1, 2, \cdots, n$$
$$u \geqslant 0, v \geqslant 0$$

u, v are the output and input weight vectors, $X_d = [x_{1d}, x_{2d}, \cdots, x_{md}], Y_d = [y_{1d}, x_{2d}, \cdots, x_{sd}]$.

In many literatures, θ_d is defined as technical efficiency (Fare et al., 1994).

3.2.2. Malmquist index

According to literature (Caves et al., 1984), Malmquist index is defined to reflect how the efficiency changes over time. If x^t stands for the inputs of time t and y^t stands for the outputs of time t, Malmquist index can be defined as

$$M_{it} = \frac{D_i^t(x^t, y^t)}{D_i^t(x^{t+1}, y^{t+1})} \quad (1)$$

x^{t+1}, y^{t+1} stand for the inputs and outputs of time $t + 1$. The definition of $D_i^t(x^t, y^t)$ is

$$D_i^t(x^t, y^t) = \frac{1}{\theta_d(x^t, y^t)} \quad (2)$$

$\theta_d(x^t, y^t)$ is the technical efficiency of time t.