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Airline efficiency measures using a Dynamic Epsilon-Based Measure model

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A B S T R A C T

In this paper, we focus on measuring airline dynamic efficiency. Number of Employees and Aviation Kerosene are chosen as the inputs. Revenue Tonne Kilometers, Revenue Passenger Kilometers and Total Revenue are the outputs. Capital Stock is selected as the dynamic factor. A new model, Dynamic Epsilon-Based Measure (DEBM) model, is proposed to evaluate the dynamic efficiencies of 19 airlines from 2009 to 2014. The main findings are: 1. Scandinavian, Emirates and Cathay Pacific are the benchmarking airlines among the 19 airlines. 2. The highest efficiency change index happens in 2010, which has close relationships with the financial crisis of 2008. 3. The output-oriented DEBM and non-oriented DEBM do well in reflecting the efficiency differences, while the input-oriented DEBM and output-oriented DEBM have good performance in mirroring yearly efficiency change.

1. Introduction

The development of airlines is affected by many things, economic troubles, natural disasters and man-made disasters. In the last few years, the high oil price raised the operating costs of airlines and influenced the net profit of airline industry. According to the annual reviews of the International Air Transport Association (IATA, 2015), in the period of 2010–2014, the average price of a barrel of oil was $79, $111, $111.8, $124.5 and $116.6, respectively. The high oil price increased the operating cost of airlines, and the industry net profit was always fluctuating consequently. During 2010–2014, the net profits of the airline industry were $19.2 billion, $8.8 billion, $7.6 billion, $10.6 billion and $16.4 billion, respectively (IATA, 2015). However, the total Revenue Passenger Kilometers in the same period were 400 billion, 438 billion, 458 billion, 482.7 billion and 512.2 billion, respectively (IATA, 2015). The average growth rate was 5.61%. The increasing Revenue Passenger Kilometers, the fluctuating oil price and the floating profits indicate that airlines are urgent to improve efficiency to cope with external challenges.

Airline efficiency can measure the relationships between the airlines' inputs and outputs in a certain year. The airlines with the optimal efficiency can apply fixed inputs to produce maximum outputs, or when the outputs are fixed, they can minimize the inputs (Li et al., 2015). Some papers applied radial Data Envelopment Analysis (DEA) models to measure airline efficiency, such as standard DEA model in Wang et al. (2011), but the models neglected the effect of non-radial slacks in the efficiency. For another, some airline efficiency papers employed non-radial DEA models, such as Slacks-Based Measure (SBM) model in Li et al. (2015) and the Range Adjusted Measure (RAM) model in Li et al. (2016a). However, for these non-radial models, the slacks are not necessarily proportional to the inputs or outputs, the projected airlines may lose the

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proportionality in the original inputs or outputs. Therefore, it is necessary to compile the radial DEA and non-radial DEA into a composite model to integrate their advantages, such as the Epsilon-Based Measure (EBM) in Tone and Tsutsui (2010a). Furthermore, for airlines, some carry-over activities exist in two consecutive years, and these carry-over activities have direct effects on airline efficiency, such as capital stock. Capital stock can denote the airline's existing capital resources, reflecting the airline's production and operation scale in a certain year. In this sense, it can be treated as an output of current year. For another, it is the sum total of all kinds of capitals invested by the airline in the next year, so it can be considered as an input of the next year too. Therefore, how to deal with the carry-over activities is important in measuring airline efficiency.

In this case, the key questions to be answered include the followings: How can one measure airline efficiency considering connecting activities? How to compile the radial efficiency and non-radial efficiency in airline efficiency? By targeting these questions, this paper focuses on evaluating airline dynamic efficiency.

The remainder of this paper is organized as: Section 2 proposes the literature review. Section 3 introduces the methodology. Section 4 is the case study. Section 5 summarizes the conclusions.

2. Literature review

Since Schefczyk (1993) used standard Data Envelopment Analysis (DEA) to evaluate the efficiencies of 15 international airlines during 1989–1992, the radial DEA models had been a popular method in airline efficiency. Some papers on airline efficiency directly applied the standard DEA, such as Capobianco and Fernandes (2004), Bhadra (2009), Hong and Zhang (2010), Ouellette et al. (2010) and Wang et al. (2011). Capobianco and Fernandes (2004) applied standard DEA to evaluate the efficiencies of 53 international airlines during 1993–1997, and found that large airline companies used capital efficiently to generate return with a low level of fixed assets. Bhadra (2009) used standard DEA model to measure the efficiencies of 13 US airlines from 1985 to 2006, and thought that efficiency tended to be affected by block hours and reducing block hours would increase efficiency. Wang et al. (2011) utilized standard DEA to analyze the efficiencies of 30 airlines in 2006, and concluded that airline efficiency was not just related to the number of committees and non-executive directors, but also affected by the external factors.

Many papers had combined standard DEA model with other methods, such as Malmquist Productivity Index and standard DEA in Distexhe and Perelman (1994) and Sickles et al. (2002), Stochastic Frontier Approach and standard DEA in Good et al. (1995), Fisher Productivity Index and standard DEA in Ray and Mukherjee (1996), Free Disposal Hull and standard DEA in Alam and Sickles (1998), Tobit Analysis and standard DEA in Fethi et al. (2000), Chiou and Chen (2006) and Greer (2009), Full Disposal Hull and standard DEA in Semenick Alam and Sickles (2000), Bootstrapped Tobit Regression and standard DEA in Barros and Peypoch (2009) and Merkert and Hensher (2011), Balance Score Card and standard DEA in Wu and Liao (2014), etc. Good et al. (1995) employed standard DEA and Stochastic Frontier Approach to measure 16 European and US airlines during 1976–1986, and found that European carriers under deregulation were as productively efficient as their American counterparts. Sickles et al. (2002) combined standard DEA, Stochastic Frontier Approach and Malmquist Productivity Index to analyze the efficiencies of 16 European airlines during 1977–1990, and found that semi-parametric and nonparametric methods indicated significant slack in resource utilization in the East European carriers relative to their Western counterparts. Barros and Peypoch (2009) used standard DEA and Bootstrapped Truncated Regression to evaluate 27 European airlines from 2000 to 2005, and concluded that population demographics and membership in an alliance network influenced airline efficiency.

Some airline efficiency papers have utilized some modified models, such as Bootstrapped DEA in Arjomandi and Seufert (2014), Virtual Frontier Benevolent DEA Cross Efficiency model in Cui and Li (2015), Unoriented Network DEA in Mallikarjun (2015) and Dynamic Environmental DEA in Cui et al. (2016a). Cui and Li (2015) proposed a Virtual Frontier Benevolent DEA Cross Efficiency model to measure 11 international airlines during 2008–2012, and thought that capital efficiency was an important factor in driving efficiency. Cui et al. (2016a) proposed a Dynamic Environmental DEA to evaluate 18 international airlines during 2008–2014, and found that the airlines could adapt the requirements of the European Union Emission Trading Scheme in the long term by making their own adjustments.

The radial models in these papers neglect the effects of non-radial slacks in the efficiency (Tone and Tsutsui, 2010b), so the airlines cannot be identified as completely efficient when the efficiency is 1 but the slacks are not zero. Furthermore, for airline efficiency in radial models, most of the inputs are employees and fuels, these inputs are partly substitutional and may not change proportionally. Therefore, radial models have some shortcomings in evaluating airline efficiency.

In recent years, many non-radial DEA models are taken as the basic method to assess airline efficiency, such as the Slacks-Based Measure (SBM) models in Chang et al. (2014), Lozano and Gutiérrez (2014), Tavassoli et al. (2014), Li et al. (2015, 2016b), Cui et al. (2016b), Cui and Li (2016), and the Range Adjusted Measure (RAM) model in Li et al. (2016a). Chang et al. (2014) applied a SBM DEA model to analyze 27 international airlines in 2010, and found that fuel consumption and revenue structure were major causes of inefficient airlines. Lozano and Gutiérrez (2014) built a two-stage SBM model to measure 16 European airlines, and concluded that Network DEA approach had more discriminative power than the single-process DEA. Li et al. (2015) proposed a Virtual Frontier Network SBM model to evaluate the efficiencies of 22 international airlines from 2008 to 2012, and found that most airlines' overall efficiency increased from 2008 to 2009. Li et al. (2016a) built Network SBM model with weak disposability and Network SBM model with strong disposability to analyze the efficiencies of 22 international airlines during 2008–2012, and summarized that the model with weak disposability