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Airline efficiency with optimal employee allocation: An Input-shared Network Range Adjusted Measure

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ABSTRACT

Airline's departments can be divided into three stages based on their roles: Operations, Services and Sales. Some inputs are shared among these stages such as employees. However, different airlines have different employee allocation proportion among the three stages, and it is important for the airlines to realize the optimal allocation proportions in the pursuit of high airline efficiency. Focusing on this problem, we propose an Input-shared Network Range Adjusted Measure model to calculate the efficiencies of 29 airlines from 2008 to 2015. The main findings are: 1. With the shared input, airline efficiency has a large improvement against that without shared input. 2. Eva Air has the highest overall efficiency among these 29 airlines. 3. Most airlines' average efficiencies in Operations and Services are larger than Sales. 4. Different airlines' employee optimal allocation proportions have a large difference and most airlines' largest allocation proportions should be in Sales. 5. It is reasonable to set average stage weights for the three stage.

1. Introduction

In recent years, with the rapid development of world economy, airline industry has experienced a rapid growth. According to the statistical data of International Air Transport Association (IATA), in 2015, global airlines safely transported about 3.5 billion people and the total fleet was about 26,000 aircrafts (IATA, 2017). As a comparison, the corresponding data in 2008 were 2.493 billion and 22,982 aircrafts. The rapid growth intensifies the competition among airlines. According to the annual report of IATA, in the period of 2011–2015, the annual increase rates of Available Seat Kilometers (ASK) in each year are 4%, 5%, 5% and 6.7%. The increasing ASK means that more airlines and aircrafts have been put into operations. However, during the period of 2011–2015, the total passenger revenues of global airlines were 512 billion dollars, 531 billion dollars, 539 billion dollars, 539 billion dollars and 518 billion dollars. The increase rate of passenger revenue falls behind the increase of ASK. Hence, the airlines are facing an increasingly competitive market, and improving efficiency is identified as an important way to survive in the rat race (Li et al., 2015).

Most airlines are composed of a few departments. For example, China Eastern Airlines have its transport control department, information department, marketing department, flight services department and finance department. Transport control department, information department and finance department are for operations, flight services department is for services and marketing department is for sales. Each stage (operations, services or sales) has its own input. For example, the sales stage's input should be sales cost, which is for maintaining and expanding market. However, some inputs are shared among these stages, such as employees. Each stage need employees, and some employees are engaged in operating, some are engaged in services and some are for sales. However, for the same stage, different airlines have different number of employees. For the different departments in one airline, the number of employees also has a large difference. In 2013, the employee proportions of China Southern Airlines for operations, services and sales were 0.527, 0.252 and 0.220. The corresponding proportions for China Eastern Airlines became 0.663, 0.278 and 0.058. Obviously, the different proportions have close relationships with the actual production status. In some existing efficiency papers, number of employees was defined as the input of operations, such as Li et al. (2015) and Cui and Li (2016). However, in practice, the number of employees also contains the employees from services and sales. Therefore, it may be unreasonable to set number of employees as the input of operations as it should be a shared input. For another, for airlines, it is important to know whether the current allocation proportions are optimal and what are the optimal allocation proportions in the pursuit of high efficiency. In this paper, we focus on exploring the optimal allocation proportions of the different stages (such as operations, services and sales) on the premise of optimal efficiency. This does

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not mean that every employee is required to do the jobs in operations, services and sales. Inversely, we explore that if the current employee number is invariable, how many employees should be engaged in operations? How many for services or sales? For airlines, if they want to adjust the allocation proportions, they don't need to require the employees to do the jobs in each stage, and they can adjust by hiring or firing employees for the optimal efficiency. Therefore, we select Number of Employees as the input in the empirical study (Section 4).

The key questions to be answered include the followings: Are the actual employee allocation proportions optimal from the angle of efficiency? How to apply an input-shared model to depict the employee allocation? In order to optimize the overall efficiency, which allocation proportion is best for the airlines? By targeting these questions, in this paper, we propose an Input-shared Network Range Adjusted Measure model to evaluate the efficiencies of 29 international airlines during 2008–2015.

The remainder of this paper is organized as: Section 2 proposes the literature review; Section 3 is the methodology. Section 4 presents the case study. Section 5 is the discussion; Section 6 summarizes the conclusions.

2. Literature review

Airline efficiency has been a popular topic in recent years and Data Envelopment Analysis (DEA) is the most popular method to evaluate it. Li et al. (2015) and Li et al. (2016a) had summarized the object airlines, the periods, the methods and the key outcomes of existing airline efficiency papers from 1979 to 2015. We focus on the airline efficiency papers in year 2016 and 2017 and find that non-radial DEA models have been widely used in airline efficiency, such as Slack-Based Measure model and Range Adjusted Measure model. The radial DEA models can get the efficiency simply and directly, but they neglect the effects of non-radial slacks in the efficiency, so the airlines cannot be identified as completely efficient when the efficiency is 1 but the slacks are not zero (Cui and Li, 2017a).

Compared with radial DEA models, the non-radial DEA models can show the slacks of the inputs and outputs, and can provide more important references for firm managers (Cui and Li, 2017a). Li et al. (2015) built a Virtual Frontier Network Slack-Based Measure to evaluate the efficiencies of 22 airlines from 2008 to 2012, and discovered that most airlines' efficiencies had increased in the period. Cui et al. (2016) proposed a Virtual Frontier Dynamic Slacks-Based Measure to calculate the efficiencies of 21 airlines from 2008 to 2012, and found that the difference between full-service carriers and low-cost carriers had no significant effects on airline efficiency. Li et al. (2016b) proposed a Virtual Frontier Range Adjusted Measure to evaluate the efficiencies of 22 airlines from 2008 to 2012, and concluded that Air Greenland exhibited the highest efficiency, while the efficiency score of Air France-KLM was at the bottom of the 22 airlines. The virtual frontiers in these papers are built to differentiate the efficient Decision-Making Units (DMUs). These papers built a set of virtual DMUs as the virtual frontier (on the virtual frontier, the inputs of the DMUs are less than the minimum inputs and the outputs are larger than the maximum outputs of the actual DMUs) and defined the virtual frontier as the reference frontier. Then all the DMUs' efficiency value is less than 1, so the original efficient DMUs are inefficient and the efficiencies can be differentiated. Cui and Li (2017b) applied two models, Network Range Adjusted Measure with natural disposability and Network Range Adjusted Measure with managerial disposability, to discuss the impacts of the “Carbon Neutral Growth from 2020” strategy (CNG2020 strategy) on airline efficiency, and found that the indices related with undesirable output would have a larger role in deciding benchmarking airline under natural disposability. Li and Cui (2017) proposed a Network Range Adjusted Environmental DEA to explore the impacts of CNG2020 strategy on airline environmental inefficiency, and summarized that CNG2020 strategy would have a positive impact on most airlines' efficiency improvement.

However, for these non-radial models, the slacks are not necessarily proportional to the inputs or outputs, the projected airlines may lose the proportionality in the original inputs or outputs. Therefore, when the airline efficiency change is evaluated over time, the non-zero pattern of slacks in the current term may significantly differ from that of the next term and the model cannot tell which pattern is reasonable, which may cause difficulty in determining the direction of efficiency improvement (Cui and Li, 2017a). Therefore, some papers tried to compile the radial model and non-radial model into a composite model to evaluate airline efficiency, such as Epsilon-based Measure model (EBM) in Cui and Li (2017a) and Xu and Cui (2017). Cui and Li (2017a) proposed a Dynamic Epsilon-Based Measure to evaluate the dynamic efficiencies of 19 airlines from 2009 to 2014, and got that the highest efficiency change index happened in 2010. Xu and Cui (2017) integrated with Network Epsilon-based Measure and Network Slacks-based Measure to assess the overall efficiency and divisional efficiency of 19 international airlines from 2008 to 2014, and concluded that most airlines' efficiencies kept steady during the period. EBM model was proposed by Tone and Tsutsui (2010) to compile the radial model and non-radial model into a composite model, which can solve the disadvantages of radial models and non-radial models. Tone and Tsutsui (2010) complied the Charnes-Cooper-Rhodes model and Slacks-Based Measure into Epsilon-based Measure model. This idea has been applied in airline efficiency evaluation.

Furthermore, as introduced in the Introduction, most airlines are composed of a few departments, and different departments belong to different stages. Some departments are for operations, some departments are for services and some departments are for Sales. As stated in Li et al. (2015), stage efficiency is important to explore the development of airline efficiency. Hence, in recent years, many DEA models with network structure have been applied to measure airline efficiency. We summarize them and show their stages, the inputs and the outputs in Table 1.

These previous studies in Table 1 lay a suitable foundation for this paper in exploring the internal structure of airline performance, such as fleet size should be set as the input of Services instead of Operations. In this paper, airline efficiency is divided into three stages: Operations, Services and Sales. We follow Mallikarjun (2015), Li et al. (2015), Li et al. (2016a), Cui and Li (2017b, 2017c) and Li and Cui (2017), and believe that fleet size is a site characteristic and accounts for airline's operating conditions that are not under the control of the operating management. Therefore, it is reasonable to set fleet size as the input of Services.

However, existing papers have not considered the input-shared multi-stage production process in airline efficiency. In this paper, we set Number of Employees as the shared input. An Input-shared Network Range Adjusted Measure model is built to measure the efficiencies of 29 international airlines from 2008 to 2015. Finally, some conclusions are drawn from the results. Because the input-shared Epsilon-Based Measure model is very complex, we have not considered the model to compile the radial model and non-radial model in evaluating airline efficiency. As shown in Tone and Tsutsui (2010), the non-oriented EBM model is non-linear programming, which must be solved through calculating the largest eigenvalue and eigenvector of the affinity matrix. Therefore, the input-shared EBM model will be more complicated than the original EBM model, which should an important research direction in the future. In order to illustrate the idea of shared input, we will select a linear non-radial model (Range Adjusted Measure) as the basic model. Furthermore, network DEA envelops the entire sample, it is also sensitive to the presence of outliers. For this problem, Ferreira et al. (2016) has applied partial frontiers to solve it in airport efficiency evaluation. These two problem may be the important topics in the further research.