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Pollution abatement costs change decomposition for airlines: An analysis from a dynamic perspective

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ABSTRACT

In this paper, we define the pollution abatement cost (PAC) as the ratio of the outputs when the undesirable outputs are freely disposed to the outputs when the undesirable outputs are weakly disposed. Then we propose a Dynamic Environmental DEA model to calculate the pollution abatement cost change indexes, which are decomposed into technical change index, input level change index and undesirable output production change index. An empirical study is done based on the actual data of 18 large global airlines from 2008 to 2014. The main findings are: (1) Delta Air Lines has the largest PAC changes. (2) Most airlines' PACs have decreased. (3) The financial crisis of 2008 and the application of biofuel aircrafts have important impacts on the PAC change.

1. Introduction

Airlines' carbon dioxide emissions have aroused many attentions in recent years. From the statistical data of International Civil Aviation Organization (ICAO), we know that about 2% of man-made carbon emissions are generated by air transport (ICAO, 2017). Furthermore, more evidences indicate that if the airlines do not take any mitigation measures, the total greenhouse gas emissions in air transport will be 400–600% higher in 2050 than in 2010. In this context, some policies have been proposed to control aircraft emissions to achieve the sustainable development of airline industry, such as European Union Emission Trading Scheme (EU ETS) and the "carbon neutral growth from 2020" strategy (CNG 2020 strategy). European Union (EU) enacted the 2008/101/EC decree in November 2008, in which international airline business was brought into the EU ETS. However, this scheme has not evolved into a global scheme because of the great controversy all over the world. The 38th Session of the ICAO Assembly adopted Resolution A38-18, the "carbon neutral growth from 2020" strategy (CNG 2020 strategy), to realize air transport's carbon-neutral growth. The core of this strategy is to integrate the Market-Based Measures (MBM) into the overall strategy and determine the road for the airlines to share the abatement costs (Cui and Li, 2017a).

The airlines need to burden the abatement costs of the pollutions, no matter under EU ETS or CNG2020 strategy. These costs have been changing over the years, which may be caused by many reasons. It is important for airlines to analyze these reasons to control the cost of pollutant reduction. One important way to know the reasons is to decompose the pollution abatement cost index and find the main improvement direction (Färe et al., 2016). The key questions to be answered include the followings: How to measure the pollution abatement costs reasonably? How to decompose the pollution abatement cost change index to explore the changing reasons of pollution abatement costs? By targeting these questions, this paper focuses on calculating and decomposing the pollution abatement cost change index for airlines.

As stated in Färe et al. (2016), four strategies can be available to reduce undesirable outputs: (1) reduce desirable output

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production, (2) input quality changes, (3) end of pipe abatement technologies, and (4) change in process abatement technologies. According to the principle of weak disposability, an increase of desirable outputs will be accompanied by the increase of undesirable outputs and the decrease of undesirable outputs will be accompanied by the decrease of desirable outputs. Therefore, in this paper, the pollution abatement costs are defined as the ratio of the outputs when the undesirable outputs are freely disposed to the outputs when the undesirable outputs are weakly disposed. And the pollution abatement cost change index can be decomposed into technical change index (TC), input level change index (IC) and undesirable output production change index (UPC), corresponding to the strategies (2)–(4) in Färe et al. (2016). The managers can know the role of the three strategies in reducing undesirable outputs after the pollution abatement cost change index is decomposed, and can take targeted measures to reduce undesirable outputs.

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

2. Literature review

In recent years, the emissions control costs of air transport have been a popular topic. Lu and Morrell (2001) applied the dose-response method to estimate the social cost of each engine exhaust pollutant during different flight modes and concluded that the current emissions related charges are lower than the actual social costs of their respective externalities. Schipper et al. (2001) discussed some types of environmental externalities in air transportation and presented a cause-effect relation between air transport output and environmental degradation. Carlsson and Hammar (2002) explored the possibilities of using incentive-based environmental regulations of CO_2 emissions from international civil aviation and found that an emission charge and a tradable emission permit system in which the permits were auctioned had more or less the same characteristics. Schipper et al. (2003) summarized how the presence of external costs affected the welfare effect of the liberalization of airline markets. Mendes and Santos (2008) estimated the impacts of multisector policies, the emission charges and emission trading scheme on air transport emission control and found that stringent emission charges or an isolated emission trading scheme would be better instruments. Vespermann and Wald (2011) analyzed the economic and ecological impacts of the EU ETS and found that the EU ETS would induce low competition distortions among airlines.

The above analysis indicates that many scholars have undertaken substantial initiatives to do qualitative and quantitative study on the emissions control costs of air transport. However, it is unfortunate that little research has focused on decomposing the pollution abatement costs (PAC) of airlines. Cui et al. (2016a) proposed a Dynamic Environmental DEA model to analyze the impacts of the EU ETS emission limits on airline pollution abatement costs, and they found that although the airlines have a longer buffer period when the actual emissions are from 2005 to 2007, few other differences existed regarding the emission limits of the baseline 2004–2006 period. Cui et al. (2017) investigated the impacts of the EU ETS on the pollution abatement costs of 12 European airlines during 2012–2014. Cui (2017) explored the impacts of the CNG2020 strategy on the pollution abatement costs of 29 global airlines. However, they had not decomposed the pollution abatement costs change.

Then, we will review the studies on airline production process. Since Schefczyk (1993) used standard DEA (Data Envelopment Analysis) to evaluate the efficiency of 15 international airlines during 1989–1992, the DEA models had been a more popular method to discuss airline production process. Some papers 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). Some other papers had utilized some modified models, such as directional economic environmental distance function in Adler et al. (2013), bootstrapped DEA in Arjomandi and Seufert (2014), virtual frontier benevolent DEA cross efficiency Model in Cui and Li (2015) and unoriented network DEA in Mallikarjun(2015). In recent years, many non-radial DEA models have been the basic methods, such as the Range Adjusted Measure (RAM) model in Li et al. (2016b), the Slacks-Based Measure (SBM) model in Chang et al. (2014), Li et al. (2015), Li et al. (2016a), and Li and Cui (2017). Furthermore, some DEA models combining radial DEA model and non-radial DEA models have been applied in evaluating airline efficiency, such as Network Epsilon-Based Measure (EBM) with managerial disposability in Cui and Li (2017b) and Dynamic EBM in Cui and Li (2017c).

However, in the airline production process, some carry-over activities have effects on the process between two consecutive terms or two consecutive years. The process of this term or this year will affect the process of next term or next year. Few papers have considered the effect of carry-over activities between two terms. Some activities may not generate total effects in current term, and may play some role in the next term, such as capital factor in Tone and Tsutsui (2010). Capital stock can denote the existing capital resources of the airline, reflecting the production and operation scale of the airline 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 capital invested in the airline in the next year, and it also can be considered as an input of the next year. Therefore, how to deal with the connecting activities is important in analyzing airline production process. Li et al. (2016b), Cui et al. (2016a) and Cui et al. (2016b) have considered this problem and proposed some dynamic models to depict the production process of airlines. And we are inspired by these papers in the selection of the inputs, outputs and dynamic factors.

There are two different definitions of pollution abatement costs (PAC). For the first one, PAC is defined as the difference between the desirable outputs when the undesirable outputs are freely disposed and the desirable outputs when the undesirable outputs are weakly disposed. This definition was proposed by Färe et al. (2007) and had been applied in airline industry (Cui, 2017; Cui et al., 2017). Another one is from Färe et al. (2016), in which PAC is defined as the ratio of the desirable outputs when the undesirable outputs are unregulated to the desirable outputs when the undesirable outputs are regulated. In Färe et al. (2016), when the undesirable outputs are unregulated, they have not been considered in the model. When the undesirable outputs are regulated, the disposability mode is free disposability, that is, the undesirable outputs are considered as inputs. Comparing these two different