Applied Energy 199 (2017) 13–24

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Carbon neutral growth from 2020 strategy and airline environmental inefficiency: A Network Range Adjusted Environmental Data Envelopment Analysis

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HIGHLIGHTS

- Network Range Adjusted Environmental DEA is proposed.
- The impacts of CNG2020 strategy on airline environmental inefficiency are analyzed.
- The decrease of operating expenses slacks is one reason for inefficiency decrease.
- The feasible expansion decrease of total revenue is another reason.

ARTICLE INFO

Article history:
Received 12 December 2016
Received in revised form 13 April 2017
Accepted 26 April 2017

Keywords:
Network Range Adjusted Environmental DEA
Airline environmental inefficiency
CNG2020 strategy
Emission rights

ABSTRACT

In this paper, we analyze the impacts of the Carbon Neutral Growth from 2020 strategy (CNG2020 strategy) on airline environmental inefficiency based on the predicted data of 29 international airlines during 2021–2023. The data is predicted through BP neural network. Following the principle of CNG2020 strategy, we calculate the emission limit for each airline. Then we propose a new model, Network Range Adjusted Environmental DEA, to discuss the environmental inefficiency change between the conditions with CNG2020 strategy and without CNG2020 strategy. The main findings are: 1. Garuda Indonesia has the largest inefficiency during 2021–2023, while Singapore is the benchmarking airline with the best performance. 2. For most airlines, CNG2020 strategy has a positive impact on their efficiency improvement. 3. The decrease of operating expenses slacks and the feasible expansion of total revenue are the main reasons for inefficiency decrease.

1. Introduction

In recent years, the carbon dioxide emissions of airline industry have caused great attentions. According to the statistical data of the International Air Transport Association (IATA), in 2014, air transport was responsible for about 2% of man-made carbon emissions annually [1]. Although this proportion is relatively small, the industry recognizes that it must work even harder on behalf of the environment to achieve long-term sustainability. Furthermore, the International Civil Aviation Organization (ICAO) predicts that in the absence of mitigation measures, driven by a seven-fold increase in air traffic, total greenhouse gas (GHG) emissions associated with aviation will be 400–600% higher in 2050 than in 2010 [1]. European Union (EU) enacted the 2008/101/EC decree in November 2008, in which international airline business was brought into the European Union Emission Trading System (EU ETS). From January 1, 2012, each international flight taking-off and landing in European Union would be given an emission permit [2]. This policy causes great controversy all over the world and it has not become a global action framework.

On October 6, 2016, the 39th conference of International Civil Aviation Organization in Montreal adopted a resolution in which the member states of ICAO must work together to achieve aviation carbon neutral growth from 2020, the resolution was called "Carbon Neutral Growth from 2020" and could be labeled as "CNG2020 strategy" for short. CNG2020 strategy is the first global market mechanism on emission reduction for a special industry, whose core is to build a series of market-based measures, such as levies, emissions trading systems, and carbon offsetting [1].

There are three phases for CNG2020 strategy: pilot phase (from 2021 through 2023), first phase (from 2024 through 2026)

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http://dx.doi.org/10.1016/j.apenergy.2017.04.072
0306-2619/

and second phase (from 2027 through 2035). The member states voluntarily decide to join the scheme in pilot phase and first phase, but they are mandatorily to participate in second phase, except some exempted states. The emission baseline is the emission volume of international aviation in 2019 and 2020. According to the analyses of ICAO, the estimated quantity to be offset to achieve the carbon neutral growth from 2020 would be of the order of 142 to 174 million tons of CO_2 in 2025; and 443 to 596 million tons of CO_2 in 2035, with these ranges being determined by the definitions of nine scenarios for CO_2 trends assessment from the most optimistic scenario to the less optimistic one [1].

CNG2020 strategy has some differences between the EU ETS. For example, CNG2020 strategy focuses on the international aviation emissions of the airlines, while the EU ETS pays close attentions to the airlines' emissions in Europe. This different basic orientation may lead to different effects in controlling emissions. Furthermore, the CNG2020 strategy is promoted by International Civil Aviation Organization, a subsidiary of the United Nations; its execution gets the consent of all members. However, the EU ETS is a mechanism pushed by the EU unilaterally and many non-EU countries are clearly against it. Therefore, CNG2020 strategy is a global carbon scheme and it is necessary to analyze its impacts on the airlines.

However, none of existing papers has focused on CNG2020 strategy and its impacts on airline environmental performance. We apply airline environmental inefficiency as the index to represent airline environmental performance, which can describe the relationships between airlines' environment inputs and outputs. We define airline environmental inefficiency as the efficiency distance from the actual allocation of a particular airline to the optimal frontier, which may be caused by various factors specific to the airline. Similar with the profit inefficiency in Cooper et al. [3], airline environmental inefficiency is the amount by which the observed environmental efficiency of an airline deviates from the maximum environmental efficiency. If the environmental inefficiency of one airline is larger than other airlines, it has a greater potential to improve environmental efficiency. The measurement of airline environmental inefficiency is particularly important for airlines. An airline is usually interested in changing input and output quantities if this leads to more economic gains and less environmental wastes. Airline environmental inefficiency measures how close the airline is to the optimal environmental efficiency.

The key questions to be answered include the followings: How to predict the emission volume for a single airline in the years after 2020? How to analyze the impacts of the CNG2020 strategy on airline environmental inefficiency? How can one evaluate airline environmental inefficiency when the emission limit is considered? By targeting these questions, we will discuss the influence of CNG2020 strategy on the environmental inefficiencies of global airlines.

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

Many papers have analyzed the impacts of EU ETS on airline performance. In recent years, Scheelhaase et al. [4] presented the model to analyze the impact of including aviation into the EU ETS on the competition between European and non-European network airlines. Ares [5] analyzed the impact of EU ETS on the development of airline industry from the aspects of ticket price, emission reduction and subsidies acquisition, etc. Buhr [6] examined the temporal conditions for institutional entrepreneurship and did an empirical case study of how aviation was targeted for its climate change impact by inclusion in the EU ETS. Tsai et al. [7] presented a mixed activity-based costing decision model for green airline fleet planning under the constraints of the EU ETS, and found that the cost trends of carbon emissions and the changes in profits of different flight routes appeared to be similar. Derigs and Illing [8] analyzed the profit situation and the emission reduction prospect after aviation was included in the EU ETS. Cui et al. [9] analyzed the impacts of the EU ETS emission limits on airline performance, which were calculated based on the historical emission data of 2004–2006. Some papers have discussed the market-based measures to deal with CO_2 abatement in the airline industry, such as carbon emissions taxation [10–12], renewable fuel [13–15] and other mitigation options [16]. However, none of existing papers has discussed the impacts of CNG2020 strategy on airline environmental performance. Although there are some similarities between the EU ETS and the CNG2020 strategy, more differences exist between the two schemes, as introduced in Introduction.

In order to investigate the impacts of CNG2020 strategy on airline environmental inefficiency, we summarize the papers on airline performance. Airline performance has been a popular topic since Morrell and Taneja [17]. Many papers have applied Data Envelopment Analysis (DEA) as the basic model to evaluate airline performance [18–24]. In recent years, Bhadra [25] applied standard DEA to 13 US airlines and concluded that efficiency tended to be affected by block hours, reducing them would increase efficiency. Wang et al. [26] used standard DEA to analyze 30 airlines in 2006 and found that the performance of carriers was not just related to the number of committees and non-executive directors, but also affected by the external factors. Cui and Li [27] proposed a Virtual Frontier Benevolent DEA Cross Efficiency Model to evaluate the efficiencies of 11 international airlines during 2008–2012, and discovered that capital efficiency was an important factor in driving energy efficiency. Cui and Li [28] applied standard DEA model to calculate the civil aviation safety efficiencies of 10 Chinese airlines from 2008 to 2012.

Standard DEA is a kind of radial model and it neglects the effect of non-radial slacks in the efficiency. In recent years, many non-radial DEA models are taken as the basic method to assess airline efficiency. Chang et al. [29] applied Slacks-Based Measure model to analyze 27 international airlines in 2010 and concluded that fuel consumption and revenue structure were major causes of inefficient airlines. Cui et al. [30] proposed a Virtual Frontier Dynamic Slacks Based Measure to calculate the energy efficiencies of 21 airlines from 2008 to 2012. Li et al. [31] built a Virtual Frontier Dynamic Range Adjusted Measure (RAM) to calculate the energy efficiencies of 22 airlines from 2008 to 2012.

However, above models treat the production system as a black box when measuring efficiency, ignoring its internal structure. As stated by Li et al. [32], most airlines comprise several divisions and divisional efficiency is important when exploring the development of overall airline efficiency. Hence, in recent years, many DEA models with network structure have been applied to measure airline efficiency. Tavassoli et al. [33] used network Slacks-Based Measure to evaluate the efficiency of 11 Middle Eastern airlines. Lozano and Gutiérrez [34] employed a two-stage Slacks-Based Measure model to measure the efficiency of 16 European airlines, and the results showed that Network DEA approach had more discriminative power than the single-process DEA. Li et al. [32] utilized a Virtual Frontier Network Slacks-Based Measure to analyze 22 international airlines during 2008–2012, and found that most airlines' overall efficiency increased from 2008 to 2009. The stages, the inputs and the outputs of the network airline efficiency papers are shown in Table 1.

These previous studies in Table 1 lay a suitable foundation for this paper by exploring the internal structure of airline performance. In the previous papers, airline production system is divided