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An evaluation of the world's major airlines' technical and environmental performance

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ABSTRACT

In this empirical study, we apply bootstrapped data envelopment analysis (DEA) models under variable returns to scale to examine both the environmental and technical efficiencies of airlines. Using the regional classification of the International Air Transport Association (IATA), we chose 48 of the world's major full-service and low-cost carriers from six different regions, and then estimated their performance over the period 2007–2010. Our empirical results show that many of the most technically efficient airlines are from China and North Asia, whilst many of the best environmental performers are from Europe. We also found that although the number of environmentally oriented full-service carriers is increasing, low-cost carriers are still more environmentally oriented. Our findings show that almost all the low-cost carriers are technically operating under increasing returns to scale in all the studied years. However, this result was quite the opposite of what we found for the largest airlines.

1. Introduction

In the last decade, global public consciousness about the aviation industry's environmental performance has increased. Under the Kyoto Protocol 1997, which came into force in February 2005, thirty-seven industrialized countries and the European Community (EC) agreed on binding targets to reduce greenhouse gas (GHG) emissions on average by 5% over the period 2008 to 2012 compared to their respective emission levels of 1990 (UNFCCC, 2011). According to IPCC (2007)[1], approximately 3% of the anthropogenic global warming in 2007 was attributable to aviation emissions, with a predicted contribution of 5% until 2050.

Although researchers have shown an increased interest in financial and service performance of the aviation industry in recent years (see, inter alia, Assaf, 2009; Rey et al., 2009; Assaf, 2011), far too little attention has been paid to the environmental performance of the aviation sector. The present study estimates and compares both technical (service) and environmental efficiencies of the world's major airlines.[2] According to Koopmans (1951), a producer is technically efficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input; and if a reduction in any input requires an increase in at least one other input or a decrease in at least one output. A producer is environmentally efficient (compared to other firms) if it is producing the lowest amount of undesirable output per unit of desirable output.

Environmental efficiency analyses of the sector are particularly pertinent and timely because first, this helps policy makers to identify leaders and laggers amongst the companies and to take measures that address environmentally poor performances (Färe et al., 1996; Tyteca, 1996). Second, airlines need to know about their relative environmental efficiencies in the market in order to eliminate existing shortcomings and show higher performance. The aviation industry has been included in the EU's emission trading scheme (EU-ETS, from January 2012) and the Australian emission trading scheme (AUS-ETS, from July 2012). These schemes place even greater pressure on the aviation industry and highlight the need for tools to undertake accurate and objective measurement of the performance of airlines with respect to the environment. Third, not only the airlines but also their shareholders have an interest in airlines' environmental efficiency for their future investment decisions. Recent policy changes, such as the EU-ETS and AUS-ETS, may cause additional cash outflows and expenses for airlines, reducing their annual profits in the near future. Finally, environmentally conscious travellers may purchase services from the more environmentally friendly airlines in order to reduce their carbon footprint.

This study uses carbon dioxide equivalent (CO_2-e) emission as an undesirable output of the airlines in the DEA models to analyse the environmental performance of the aviation sector (Jin et al., 2014; Lu et al., 2013; Wang et al., 2014; Wu et al., 2013). Hence, an airline is

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[1] Intergovernmental Panel on Climate Change.

[2] There has been an increasing amount of literature on the correlation between technical efficiency of the airlines and other variables such as union density, age of fleet, size of aircraft, stage length, percent of passengers flying internationally, load factor, and legacy (for example, Coelli et al., 1999; Greer, 2009; Oum et al., 2005). However this study has a primary focus on the evaluation of the airlines' environmental efficiency.

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considered as environmentally efficient if it produces the lowest amount of CO_2-e per unit of desirable output. DEA is a well-known non-parametric approach to evaluating the relative efficiency of decision-making units (here: airlines). Its main advantage over parametric approaches (such as stochastic frontier analysis) is that it can readily incorporate multiple inputs and outputs (Barros and Garcia-del-Barrio, 2008; Lu, 2012). In this study, bootstrapped DEA models under variable returns to scale are utilised providing a comprehensive and robust analysis of airlines' technical and environmental efficiencies.[3] The remainder of this paper is structured as follows: Section 2 provides a brief literature review. Section 3 articulates existing institutional and regulatory frameworks relevant to the study. The methodology is presented in Section 4. Section 5 explains the data and Section 6 discusses the results, and is followed by some concluding remarks in Section 7.

2. Literature review

By following Farrell's (1957) original setting for efficiency evaluation, Charnes et al. (1978) were the first to introduce DEA as an efficiency measure. This became a recognized nonparametric methodology aimed at evaluating comparable entities' relative efficiency given multiple inputs and outputs. DEA models have been widely applied within the field of airlines' efficiency (for example, Assaf and Josiassen, 2011; Barros and Peypoch, 2009; Greer, 2006, 2009; Markovits-Somogyi, 2011; Ray, 2008). In the literature that evaluates airlines' operational performance, various regions have been considered; for example, see Schefczyk (1993), Scheraga (2004), and Michaelides et al. (2009) for the world region, and Barros and Peypoch (2009) and Charnes et al. (1996) for European and Latin American regions. There are also some in-country studies for the UK (Assaf and Josiassen, 2011) and US (Greer, 2008, 2009), and even studies focusing on the domestic routes of a single company (Coli et al., 2011).

As well as the geographical differentiation, special attention is drawn to the operational efficiency differences between full-service carriers (FSCs) and low-cost carriers (LCCs) (for example, Assaf and Josiassen, 2012; Barbot et al., 2008; Change and Yu, 2012; Gillen and Morrison, 2003; Greer, 2006).[4] Gillen and Morrison (2003) argue that FSCs have greater financial resources, significant economies of scale and more sophisticated technologies, with the potential to be more technically efficient than LCCs (see also Chang and Yu, 2012). However, Greer (2006), Barbot et al. (2008), and Assaf and Josiassen (2012) state that LCCs are generally more technically efficient than FSCs, mostly because of their low-cost business models. Extensive research has been carried out on the airlines' technical efficiency, but no single study exists that considers their environmental efficiency.

There has been an increasing interest in applying DEA models for quantifying the environmental performance of different industries in the last decade. The common procedures for applying DEA to measure environmental performance are first to incorporate undesirable outputs in the traditional DEA framework, and then to calculate the output-orientated environmental efficiencies. For instance, Jung et al. (2001) and Kumar-Mandal and Madheswaran (2010) utilised this method in their investigations of overall efficiency in the oil and cement industries, respectively.[5] The present study extends the airline efficiency literature by including CO_2-e as an undesirable output, and thus gives consideration to both the environmental and operational performance of FSCs and LCCs. This undesirable output has been used broadly in other areas, such as the electricity industry and agricultural industry, but not the airline industry. See, for example, Lansink and Silva (2003) and Sueyoshi and Goto (2012) as well as Zhou et al. (2008) for a comprehensive literature survey of DEA studies related to energy and the environment. In the context of airline operations, Coli et al. (2011) incorporate the number of delayed flights as an undesirable output in their sample of an Italian airline's 42 domestic routes. Yu (2004) also includes the level of noise as an undesirable output in their efficiency study of Taiwanese airports.

3. Institutional and regulatory framework

Air transportation is a highly regulated and monitored industry. Institutional settings and regulatory frameworks impact significantly on airlines' operations and thus on their technical and environmental efficiency. This section will position airlines within the current context of evolving climate policy, regulations and institutions as the background against which findings of this study have to be considered.

Domestic GHG emissions from the aviation industry are included in the national GHG inventories of Annex 1 countries (for example, EU countries, the US, Japan, Russia, and so on)[6] covered under the Kyoto Protocol. Emissions from international air traffic, however, are not included in the respective national emission targets under the Kyoto Protocol, nor discussed in post-Kyoto emission reduction negations (Gössling and Upham, 2009). The responsibility for reducing aviation emissions in Annex 1 countries was deferred to the International Civil Aviation Organization (ICAO, 1997) which rejected the idea of a global ETS (emission trading scheme) during their annual assembly in 2004, but "endorsed the inclusion of aviation in existing national/regional ETS as more cost-effective measure than fuel taxes" (Gössling and Upham, 2009, p. 9). Despite its position, the ICAO withdrew from this idea and decided that airlines should not be included in the EU-ETS (Environment News Service, 2007; Transport and Environment, 2007) as a response to the EU Parliament's November 2007 reading which mentioned a 10% emission reduction based on 2004–2006 average airline emissions to commence in 2011 (EU Parliament, 2007).

In Europe, from the beginning of 2012, all international and regional flights have been subject to the EU-ETS. For the calendar year 2012 the emission cap for each airline was set at 97% and will decrease to 95% for the 2013–2020 trading period (subject to revision) compared to their historical 2004–2005 CO_2 emission levels. Fifteen percent of the allowances is auctioned (Euractive, 2012). In contrast to the mandatory EU-ETS in the US, the Chicago Climate Exchange (CCX), a voluntary permit trading exists, using legally binding targets but no requirements to join.

There is a legal decision that could impact on North-American airlines' CO_2 emissions. The US Senate Committee of Environment and Public Works gave approval to the Lieberman–Warner Climate Security Bill in 2007 and forwarded it to the US Senate to be considered. The Bill aimed to create a nationwide ETS for the aviation industry in the US similar to the one in the EU, however in mid-2008 under the pressure of the Republicans it was abandoned (Gössling et al., 2008).

In July 2011 the Australian Government released its climate change plans: securing a clean energy future (Australian Government, 2011a). In late July 2011 the exposure draft of the Clean Energy Bill 2011 was released, and related exposure drafts of Bills and their commentary were

[3] The bootstrap method, proposed by Simar and Wilson (1998, 2000a, 2000b), allows for determining the statistical properties of the non-parametric estimators in the multi-input and multi-output case, and therefore for constructing confidence intervals for DEA efficiency scores.

[4] In general, FSCs have mixed fleets; provide long and short haul flights together with code-sharing and network alliances; provide full services and business class whilst their operating and maintenance costs are high. LCC, however, are characterized by having a uniform fleet; provide short haul flights with no frills and economy class only in order to achieve the lowest operating and maintenance costs (Gillen and Morrison, 2003).

[5] Amongst other studies, Lu et al. (2013) and Jin et al. (2014) used CO_2 emission as an undesirable output in their studies of CO_2 emission efficiency of OECD countries and APEC economies, respectively. Wu et al. (2013) also used this output in an investigation of cost performance of CO_2 reduction. See also Wang et al. (2014) for a meta-frontier DEA analysis of energy efficiency.

[6] A complete list of Annex 1 countries can be found at: http://unfccc.int/parties_and_observers/parties/annex_i/items/2774.php.