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Measuring the rebound effects in air transport: The impact of jet fuel prices and air carriers' fuel efficiency improvement of the European airlines

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A R T I C L E I N F O

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A B S T R A C T

This paper attempts to measure the rebound effect (RE) or take back effect of jet fuel prices for air transport by using the unbalanced panel data of the airlines of the Association of European Airlines (AEA) from 1986 to 2013. Three equations are set and modelled simultaneously: (1) traffic demand, (2) aircraft, and (3) fuel efficiency. We consider endogenous changes in fuel efficiency, and the impact of environmental policy such as the EU ETS is also included. Our results show the smaller short run RE, but much larger RE in a long run of air transport. The short-run RE for 1986–1999 is 2.9% and 2.1% for 2000–2013, while the long-run RE is 49% for 1986–1999 and 19% for 2000–2013, respectively. It indicates the effectiveness of the regulation or economic instrument to reduce emissions (fuel consumption) in the air transport market by improving fuel efficiency due to the large RE compared to other sectors.

1. Introduction

We attempt to measure the RE (or take back effect) of the jet fuel prices for air transport by using unbalanced panel data of the airlines of the Association of European Airlines (AEA) from 1986 to 2013. We consider endogenous changes in fuel efficiency. The impact of an environmental policy such as the EU ETS is also included.

As a result of increasing environmental pressures and market volatilities (demand, fuel prices and foreign exchange rates), airlines are required to explore strategies for simultaneously managing their economic and environmental (emission) performance, two objectives that can support and also contradict each other. Volatile fuel prices and carbon emission concerns have the potential to influence operational practices; for example, the fuel cost accounts for the range of 15–25% of the total operating costs during 1993–2008 (Brueckner and Zhang, 2010), and it is around 14% in the low fuel price period in 2016 in the US market by using US Department of Transportation data (2017).

Several strategies, such as fuel and carbon allowance hedging as well as fleet choice, to improve airlines' fuel efficiency, reduce both their fuel cost and their emissions. However, those strategies also involve uncertainty and risk (Turner and Lim, 2015) due to the volatility of fuel prices and the low market price of the carbon allowance. Another abatement option, the use of alternative fuels, such as bio fuel, is still expensive, and is estimated to be between USD50 and 400 per tonne of CO_2 in the US (Winchester et al., 2013). CO_2 reduction would generate costs in the short run, particularly capital costs (i.e. the depreciation of new aircrafts). However, new and

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fuel-efficient aircrafts might also become available to operate more cheaply and therefore overall more cost-efficiently (Miyoshi, 2014). Since 2008 these trade-offs have (at least in the European context) become even more complex, with legislation being adopted that regulates the inclusion of aviation in the EU Emission Trading Scheme (EU ETS) (European Commission, 2006).

Meanwhile, the RE may occur when there is an energy efficiency improvement, and it typically reduces the direct fuel savings obtained from efficiency improvements (Gillingham, 2014) by leading the additional fuel use due to the lower cost providing cheaper fares. It might lead to demand increase as a result. Within the air transport literature, there are few studies about the rebound effects of the jet fuel price with respect to fuel efficiency, based on our limited knowledge. Wadud (2015) performs a decomposition analysis of the key factors of the jet fuel demand using simultaneous equation models with the US domestic air transport data from 1979 to 2012. He estimates a direct effect of the jet fuel price on fuel efficiency of about 2.4% and 3.7% for the long-run elasticity. The positive impact of jet fuel prices on fuel efficiency improvement as well as the load factor is discussed.

Expected aviation emissions are often forecasted following an aggregated method in the previous studies (IATA, 2013; ICAO, 2013), by adopting several scenarios and changing the fuel efficiency improvement rate. Elasticity is one of the key parameters to predict the demand. Furthermore, a closer look at the rebound effect is important, since a potentially large RE has severe repercussions for the effectiveness of a policy aimed at the penetration of energy efficiency (Berhout et al., 2000). In this respect, it is worth investigating the RE with respect to the jet fuel prices due to the fuel efficiency of air transport. Hence, this paper aims to fill the gap in the literature by attempting to quantify the RE of the jet fuel prices on air carriers' fuel efficiency over time. Panel data of European carriers of the Association of European Airlines (AEA) between 1986 and 2013 are used for the analysis. The short-run and long-run elasticities are estimated by simultaneous equations. Our largest interest and objective is to estimate the RE of the jet fuel prices with respect to aircraft fuel efficiency improvement by using the panel data. We focus only on the direct REs throughout this paper.

The rest of this paper is structured as follows. Section 2 reviews the previous studies about aviation jet fuel efficiency as well as studies from the transport literature that consider the RE. Section 3 explains the data and methodology used, and the empirical implementation and model specifications. The estimated results are presented in Section 4. Section 5 concludes with a discussion.

2. Previous studies about air transport fuel efficiency development and the rebound effect

Jet fuel efficiency is usually expressed as a ratio metric, which measures the amount of fuel consumed to yield a unit of output. Outputs are generally expressed in the previous studies as fuel consumption per tonne kilometre or seat kilometre, for instance. Fuel cost is the major part of airlines' expenditure (Pearce, 2013); hence, fuel consumption is analysed to examine airlines' efficiency as the key input factor (Adler et al., 2013; Barros and Couto, 2013; Arjomandi and Seufert, 2014). Fuel efficiency has increased over the period studied (Borros and Couto, 2013). It improved by about 1.5% per year for the IATA members between 2000 and 2015 (Alonso et al., 2014) and by about 2% annually for the AEA members between 1986 and 2006 (Miyoshi and Merkert, 2015). There is a large difference among airlines. The fuel efficiency improvement is connected to cost saving in nature.

Zou et al. (2014) investigate fuel efficiency among 15 large carriers in the US and the large differences among them, suggesting potential cost saving from improved efficiency. Economies of scale measured by size should also be a driver of efficiency, but again there are some corporate cultures that prevent companies from improving their efficiency. Technology has a strong impact on the relative efficiency of various airlines (Kwan et al., 2014); however, technological improvement will not be enough to decrease the jet fuel demand unless there is radical technology change (Cheze et al., 2011). Furthermore, alternative fuel is still expensive; for instance, the abatement cost of bio fuel is estimated to be between $50 and $400 per tonne (Winchester et al., 2013). When the fuel price increases, carriers will take steps to use fuel more efficiently by leveraging other outputs, according to the US data from 1996 to 2006 (Ryerson and Hansen, 2013). Using simultaneous equation models with the US data between 1982 and 2012, Wadud (2015) also determines that increases in the jet fuel price improve fuel efficiency.

Rapid increases in air fares occur when the fuel price increases, but a slower response in the opposite direction is shown due to air fares having statistically significant asymmetric effects on the aviation demand (Wadud, 2015). Airlines have been adopting any possible strategy to survive in the competitive environment for increasing their revenue and reducing costs. Meanwhile, air transport has become a commodity rather than an expensive service due to the liberalization and the emergence of low-cost carriers (LCCs) over a period of more than two decades. Indeed, the income elasticity of air travel has gradually increased over time, since the markets have increasingly matured worldwide (Gallet and Doucouliagos, 2014). In addition, the air transport traffic in terms of revenue tonne kilometres increased 4.2 times compared to the 2010 value under the central demand forecast (ICAO, 2013). Fuel consumption, as well as the carbon emissions, will thus increase accordingly. The ICAO set a 2% annual fuel efficiency improvement as its aspirational goal. The fuel efficiency development in air transport and the relationship with the traffic growth, the regulation, and the carbon emissions are widely discussed; however, not for the RE.

Extensive literatures study the REs of the energy price. The definitions of the RE vary among researchers (Greening et al., 2000). Greening et al. (2000) review more than 75 studies to estimate the rebound effects of various energy source activities in the US. They argue that the definitions depend on the boundaries used to describe the effect, and the measured size of the behavioural response varies. Furthermore, the rebound is not large enough to mitigate the importance of energy efficiency as a way of reducing carbon emissions. Climate policies that rely only on energy efficiency technologies may need reinforcement by market instruments, such as a fuel tax and other incentive mechanisms.

Berkhout et al. (2000) define RE as follows: technological progress makes equipment more energy efficient. Less energy is required to produce the same product using the same amount of equipment, ceteris paribus. However, the unit cost might fall as the equipment becomes more energy-efficient. A price decrease normally leads to increased consumption. Part of the ceteris paribus gain