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The impact of carbon emission fees on passenger demand and air fares: A game theoretic approach

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ABSTRACT

The implementation of an environmental market-based measure on U.S. aviation industry is studied. Under this policy, each airline pays a carbon fee for the carbon dioxide emissions it generates. The impact on ticket prices and corresponding market shares is investigated via the joint estimation of an air travel demand model and an airlines' behavior model. In the demand model, aggregate air traffic data is used to determine the marginal effects of flight attributes that are specific to itinerary, airline and airport on market share. The airline's behavior model incorporates the carbon fee in the airline marginal cost. After the implementation of the carbon policy, the increased cost forces airlines to adjust ticket prices in order to maximize profits. The results obtained by the proposed model indicate a moderate price increase which strongly depends on the per tonne carbon price. Air travel demand falls from 2.4% to 21% depending on the carbon price level.

1. Introduction

Along with safety and security, environmental protection is in the centre of the aviation industry aims. Recent statistics indicate that, if no mitigation action is taken, carbon dioxide (CO_2) emissions will continue to rise given the increasing trend of air traffic. Technological and operational efficiency improvements and the use of alternative fuels are widely believed to be promising long-term approaches to meet aviation's climate goals. Market-based instruments complement these measures and provide a cost-effective option to reduce emissions in the short term (Lee et al., 2013).

Market-based measures (MBM) put a price on aircraft emissions, with most existing instruments focusing on CO_2 emissions. Existing market-based measures include voluntary carbon offsetting, environmental charges at the airports and cap-and-trade policies. The largest cap-and-trade aviation policy is the European Emissions Trading Scheme (EU ETS), introduced in 2012 (European Union, 2008). Trade disputes at international level and opposition from many non-EU countries led to the amendment of the European regulation in 2014; EU ETS covers flights only within the European Economic Area until 2016 (European Union, 2014). This situation added a pressure on International Civil Aviation Organization (ICAO) to agree on a global market-based measure for aviation as part of a broader package of measures including new technology, more efficient operations and better use of infrastructure (ICAO, 2013).

A number of studies examined the impact of EU ETS on airlines network reconfiguration (Derigs and Illing, 2013; Hsu and Lin, 2005), tourism (Blanc and Winchester, 2012; Peeters and Dubois, 2010; Pentelow and Scott, 2011; Tol, 2007), airline operational characteristics (Brueckner and Zhang, 2010) and airline competition (Barbot et al., 2014). Other studies investigated the impact on ticket prices and demand change. Albers et al. (2009) examined the effect of EU ETS on airfares and passenger demand at individual route level. Assuming a carbon price of €20/tn, they found that additional costs may range from €1.5 to €26.8 per passenger. Under two scenarios of cost pass-through rate (35% and 100%) and using existing values of price elasticity, their results showed moderate price increase which could not initiate major route configuration. EU ETS has also been studied by Scheelhaase and Grimme (2007) and Scheelhaase et al. (2010) in terms of its economic impact on EU and non-EU airlines. The results indicated that EU airlines' environmental costs are higher, due to a wider coverage of operations within the EU region, losing a significant competitive

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advantage as compared to the non-EU airlines. Anger (2010) used a dynamic simulation model to investigate the impact of EU ETS on macroeconomic activity and CO_2 emissions. Under three allowance price scenarios and 100% cost pass-through rate, the author concluded that EU-ETS results in an increase of annual CO_2 emissions at low allowance prices but a fall of 0.30% at an allowance price of €40 in 2020 compared with no action scenarios. Lu (2009) examined the impact of environmental charges on air passenger demand using six intra-European short-haul routes in two city pairs. The potential demand reduction is higher for the low-cost carrier Easyjet compared to that of full service carriers, because of lower fares. Miyoshi (2014) investigated the changes in passenger demand and consumer welfare after the implementation of EU ETS on Annex I and non-Annex I airlines. The author constructed a logit model to estimate the impact of travel costs increase on market shares of a specific route. The results demonstrated that the EU ETS could be an effective instrument except for very low carbon prices. Malina et al. (2012) estimated the economic impact of EU ETS on US airlines. They used price elasticity values derived in other studies and assumed that fuel efficiency, fuel price and carbon price are annually increased. The authors found that under full cost pass-through, the CO_2 emissions from US airlines may increase by 32% between 2011 and 2020 in comparison to 35% for the reference scenario. Hofer et al. (2010) examined the effects of an air travel carbon emissions tax on travel-related carbon emissions in the US and concluded that the emissions tax increases ticket prices under an own-price elasticity value of −1.15. They also considered the air-automobile substitution effect, since some air travelers may divert to automobiles, assuming a cross-elasticity of 0.041. They showed that emission taxes may cause significant air-to-automobile diversion effects.

This paper considers the hypothetical implementation of a market-based environmental policy on U.S. flights, where airlines pay an extra fee, referred to as "carbon fee", based on their CO_2 emissions. The impact of this policy is assessed using an empirical demand and supply model following Berry (1994). The interaction of passengers' behavior and airline decision is taken into account by the joint estimation of demand and supply parameters. The demand side is studied by discrete choice models, using market-level data over a large number of Origin and Destination cities without a need for consumer-level data. On the supply side, airlines offer several differentiated flight connections and set their ticket prices under Bertrand competition. The carbon fee increases airlines costs. If airlines maintain ticket prices levels, profits will fall. However, it is expected that a portion of the carbon cost will be passed onto the passengers, resulting in increased prices and lower demand. Estimation of price and demand adjustments caused by the introduction of the carbon fee is the main objective of this paper. More specifically, aggregate air traffic data is used while air travel demand is modeled by discrete choice models of consumer behavior. Most known aggregate demand models employ linear regression of passenger traffic and thus do not consider travelers' behavioral decisions (Bhadra and Kee, 2008; Kopsch, 2012; Mumbower et al., 2014; Sivrikaya and Tunç, 2013; Wei and Hansen, 2006). This research uses a nested logit model for air travel demand where the utility of the passenger for a specific connection is formed by a number of observed flight characteristics. The model accounts for the fact that not all flight characteristics are observed by the researcher and, thus, a single term capturing unobserved (to the analyst) characteristics is also included. On the supply side, a linear model is assumed for the marginal cost of each airline connection. The marginal cost is determined up to a vector of several cost shifters. After the implementation of the environmental policy, carbon costs are added to the airlines' marginal cost. Contrary to existing studies, the impact of the market-based policy on air travel demand is not based on given values of price elasticity of demand. Posterior policy prices are determined from the computation of the new equilibrium in demand and supply. Then price elasticity and market shares are obtained from the demand model. Airline cost pass-through behavior is an important determinant of the impact of the market-based measures. Most of existing studies assume a fixed percentage of cost pass-through. In this study, cost pass-through rate is determined by the demand and supply model and consequently depends on a number of factors, including market structure and level of competition.

The implementation of a market-based environmental policy is considered on the US airline network and a large number of domestic flight connections. Our results identify the key factors that influence the environmental policy such as itinerary distance and number of stops. Longer flights and indirect flights experience the greatest impact on ticket prices increase and demand fall due to the larger amount of CO_2 emissions.

2. Modeling framework

In this section the proposed modeling framework is described following Berry (1994). Nested logit models are employed for the representation of passenger behavior allowing for unobserved flight characteristics in the utility of travelers. On the supply side, airlines act as profit maximizers that settle over prices given by a Bertrand Nash equilibrium. Carbon fee is introduced as a shifter of marginal cost.

2.1. Passenger perspective

In a given network, there is a set of Origin-Destination (O-D) cities and a set of airlines which link them by direct or indirect itineraries. An O-D city pair is regarded as a "market". Our basic unit of observation is the unique combination of the itinerary and the ticketing carrier, i.e. "Origin-Connecting-Destination airports and ticketing airline" and is referred to as "airline connection". A passenger who wants to travel within a market m may choose to travel by air, travel by another transport mode or not travel. If the passenger decides to travel by air, he/she chooses among several airline connections j ($j = 1, 2, \dots, n$). If the passenger chooses not to travel by air, we say that the non-air alternative is picked ($j = 0$). The share of passengers choosing the non-air alternative is denoted by MS_0. This choice formulation suggests the use of a nested logit model, where the choice set of a passenger is partitioned into two nests: (i) air and (ii) non-air. The air nest includes all airline connections. The non-air nest includes travelling by other transportation modes (such as car, train, etc) or not travelling at all. The utility U_{ij} that a passenger i obtains when choosing alternative j is given by:

$$U_{ij} = x_j\beta - \alpha p_j + \xi_j + \nu_i(\lambda) + \lambda\varepsilon_{ij} \quad (1)$$

where p_j is the ticket price of connection j and x_j is a vector encompassing all observable characteristics; it includes features associated with the itinerary, the airline and the airport. A detailed description is given in Section 3.2. The scalar term ξ_j includes all characteristics that are unobserved by the analyst (but known to the passenger) such as in-advance ticket purchase, in-flight meal service quality, ticket restrictions etc, factors that give an important explanation for the deviation in ticket prices offered within given routes. The term $\nu_i(\lambda) + \lambda\cdot\varepsilon_{ij}$ is a stochastic term that captures the preferences of passenger i on airline connection j. $\nu_i(\lambda)$ is a random variable that is constant across airline connections (within the air nest) and differentiates them from the non-air alternative. ε_{ij} is an independent and identically distributed random variable across passengers and airline connections following the extreme value