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The rebound effect in the aviation sector

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ABSTRACT

The rebound effect, i.e., the (partial) offset of the energy efficiency improvement potential due to a reduction in marginal usage costs and the associated increase in consumer demand, has been extensively studied for residential energy demand and automobile travel. This study presents a quantitative estimate of the rebound effect for an air traffic network including the 22 busiest airports, which serve 14 of the highest O–D cities within the domestic U.S. aviation sector. To satisfy this objective, passenger flows, aircraft operations, flight delays and the resulting energy use are simulated. Our model results indicate that the average rebound effect in this network is about 19%, for the range of aircraft fuel burn reductions considered. This is the net impact of an increase in air transportation supply to satisfy the rising passenger demand, airline operational effects that further increase supply, and the mitigating effects of an increase in flight delays. Although the magnitude of the rebound effect is small, it can be significant for a sector that has comparatively few options for reducing greenhouse gas emissions.

1. Introduction

When introducing more fuel efficient technology into consumer or producer markets, the full energy savings potential can often not be exploited, as the reduction in marginal costs generates extra demand for energy services. This "rebound" effect or "take back" effect, first quantified for household appliances by Khazzoom (1980), has mainly been studied for residential fuel demand, household space heating and cooling, and automobile travel (Greening et al., 2000). For automobile travel, the rebound effect, defined here as the percentage offset of the reduction in energy use as offered by the more fuel-efficient technology alone, was estimated to range from 10 to 30% (Greene et al., 1999; Greening et al., 2000).[2]

Understanding the magnitude of the rebound effect is especially important for aviation, given the rapid growth of this sector and the comparatively limited opportunities for reducing greenhouse gas emissions. Because of the constrained availability of synthetic low-carbon fuel substitutes (Schäfer et al., 2009), even a small rebound effect can significantly increase the costs for mitigating aviation greenhouse gas emissions. When introducing a fleet of more fuel-efficient aircraft, the marginal costs of operating these vehicles decline. Because of the competitive nature of the airline industry within the network we study, any decline in operating costs would lead to reduced fares. As a response to the reduction in fare, passengers would be expected to consume more air travel. Given already high average passenger load factors of over 80% (DOT, 2010), this consumer adjustment, which is determined by the price elasticity of air travel, is likely to be complemented by changes in airline behavior. The decline in operating costs and (associated)

Abbreviations: ATA, Air Transport Association; BADA, Base of Aircraft Data; DOT, U.S. Department of Transport; IATA, International Air Transport Association; ICAO, International Civil Aviation Organization; O–D, True origin–ultimate destination; RPK, Revenue Passenger Kilometers.

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[2] Greene et al. (1999) and Greening et al. (2000) define the rebound effect as a percentage increase in energy services, i.e., automobile driving, in response to a decrease in vehicle fuel consumption. Because kilometers driven are proportional to energy use for a given automobile, driving cycle, and ambient conditions, this energy service related rebound effect is identical to the energy use related rebound effect. The situation is different for space heating or cooling.

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increase in travel demand would cause the airline industry to undertake various adjustments, including a change in flight network, the use of differently sized (typically larger) aircraft, and—most importantly—an increase in flight frequency (Evans and Schäfer, 2011). Along competitive routes, airlines battle for market share on the basis of flight frequency (Belobaba, 2006)—an extra return flight a day gives passengers more flexibility at what time to leave from and return to the point of origin. Any of these operational changes translates into a change in energy use (the firm-related direct rebound effect). At the same time, the extent of operational changes is limited by a potential increase in airport congestion and thus flight delays, an outcome that increases airline operating costs and mitigates the increase in passenger demand and thus the rebound effect.

This paper estimates the direct rebound effect for the U.S. domestic aviation sector, by taking into account the above described adjustments on both the consumer and firm sides that lead to a new equilibrium. We define the rebound effect in terms of energy use, i.e., the offset in energy use from the technological potential due to a reduction in marginal costs leading to partial equilibrium adjustments. As with the vast majority of rebound effect studies, we focus on the *direct* rebound effect. Studying the indirect rebound effect, which results from the increase in consumer purchasing power due to the reduction in airfares and allows consumers to spend more on other goods or services (that also consume energy), and the resulting economy-wide adjustments would require the use of computable general equilibrium models and are thus not considered here.

We continue with a detailed description of our model, which simulates the various adjustment mechanisms described above. After validating the model, we estimate the magnitude of the rebound effect for a network of U.S. airports. We then continue with testing the sensitivity of the results before deriving conclusions.

2. Modeling approach

To estimate the rebound effect in the aviation sector, passenger and airline behavior are simulated in response to the introduction of low fuel burn technology. An integrated framework that captures the interactions between the airline and passenger responses, ensuring that the simulation model accounts for demand effects, changes in airline operations, and the impact of airport capacity constraints, is presented in Fig. 1. Each component of the model is described in detail below.

Introducing lower fuel burn technology into the air transport system will in most cases reduce airline operating costs. The latter, which include direct and indirect operating costs, are calculated by *Operating Cost Calculators* for each airline. Direct operating costs, per flight hour,

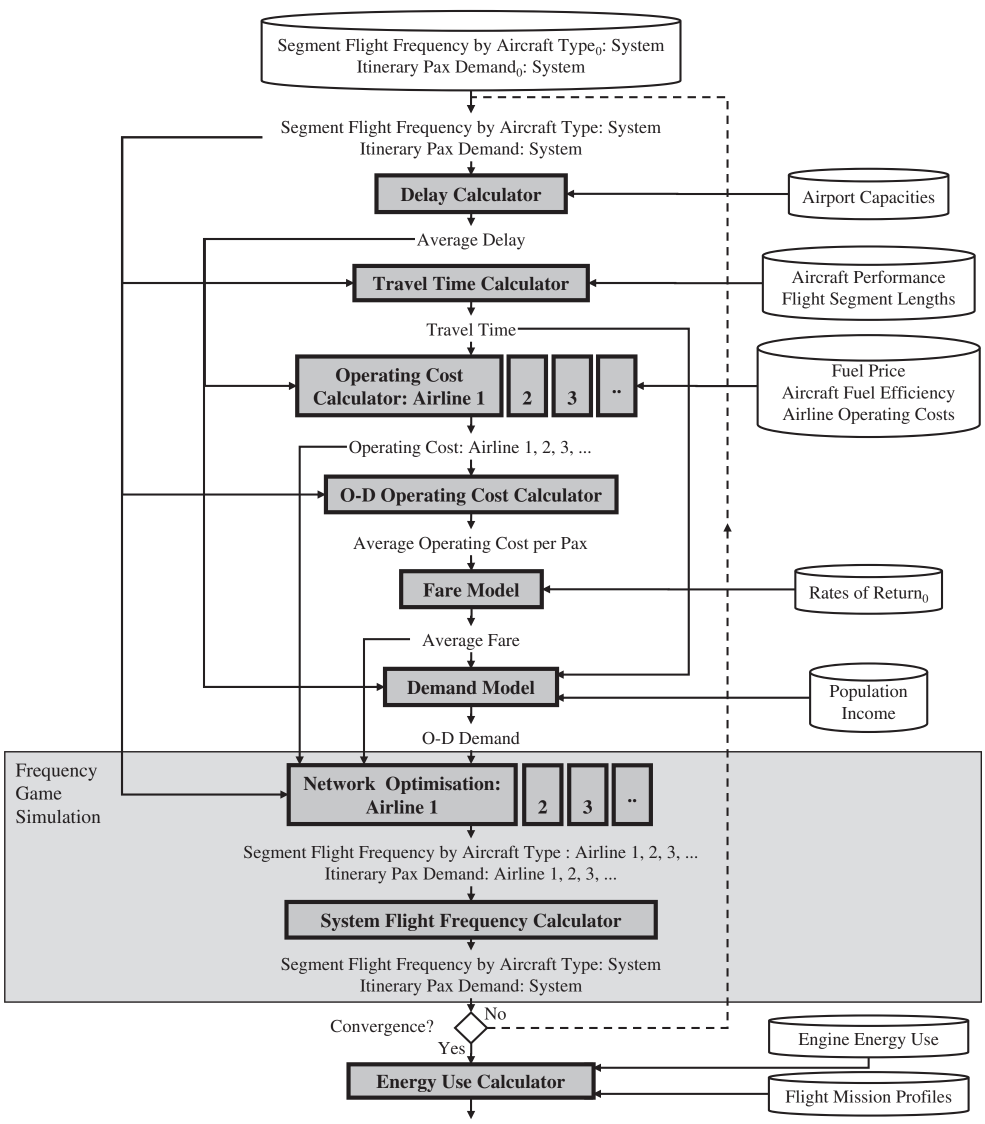

Fig. 1. Modeling framework for simulating airline and passenger responses to lower fuel burn technology.