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On the impact of jet fuel cost on airlines' capacity choice: Evidence from the U.S. domestic markets

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ABSTRACT

Using publicly available datasets, we analyze three capacity decisions (flight frequency, aircraft size, and load factor) of seven major airlines and address their relationship with the level and fluctuations of three exogenous factors (fuel cost, total passenger demand, and unemployment rate). Our results show that increased passenger demand is associated with smaller aircraft and more frequent flights, while higher fuel costs are associated with larger aircraft and less frequent flights. Overall, our results indicate that airlines adjust both flight frequency and aircraft sizes to manage capacity and maintain load factors in response to fluctuations in passenger demand and fuel cost.

1. Introduction

In the past fifteen years, U.S. airlines have experienced periods of significant fluctuations in fuel costs and passenger demand, along with an economic expansion, Great Recession and recovery. How does an airline respond to these fluctuations and disruptions? One option is utilizing sophisticated pricing tools, known as revenue management. Revenue management may lead to some passenger discontent, but these tools have been universally successful for the airlines. A second option most airlines have employed is to hedge fuel costs, locking in a fixed price for some portion of their fuel needs for a period of time. Unfortunately, hedging has had a mixed impact. Some airlines have increased profits substantially by hedging, while others have experienced significant losses. Indeed, some airlines have abandoned fuel hedging entirely.

A third option, which is the focus of this research, is to adjust capacity.[1] "Capacity" is defined in this paper by aircraft size and the frequency of flights on a given origin-destination route. In other words, capacity is the number of seats available on a given route. A key measure of capacity utilization is the load factor, which is the ratio of passenger-miles travelled to seat-miles available.

Capacity decisions are extremely important for the airlines. Carey and Nicas (2015) point out, for instance, that airlines increased capacity as the economy recovered from the Great Recession. They added seats to existing planes and replaced smaller planes with larger ones. Load factors generally increased, which clearly is beneficial for the airlines. However, increased numbers of seats can reduce legroom and decrease available overhead bin space, leading to significant customer dissatisfaction. Furthermore, these capacity decisions may increase route cancellations (especially for smaller cities), flight delays, and airport congestion (Stock, 2013; Wei and Hansen, 2006; Carey and Nicas, 2015). The airlines must account for these effects as they manage capacity and load factors.

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[1] It is instructive to note that airlines appear to make decisions on capacity, hedging and airfares in different silos, rather than in an integrated way. The authors have direct information from three airlines regarding these decision silos.

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In our model, we incorporate all three capacity measures (flight frequency, aircraft size, and load factor) to enhance our understanding of how the airlines adjust each of them in response to three exogenous factors – passenger demand, fuel cost, and unemployment rate. We study seven U.S. domestic carriers, including both low-cost and legacy airlines, over the 2003–2015 period.

Few papers on the airline industry explicitly account for fuel cost as an exogenous factor in capacity decisions. In this research, not only do we incorporate fuel cost along with two other exogenous factors, but we also examine actual cost per gallon data, which includes market price and hedging policies. Our empirical results reveal, among other things, that flight frequency and aircraft size move in opposite directions in response to changes in fuel cost and overall passenger demand. In addition, we go beyond regression analysis, by employing methods due to Sobol (1993), to study the impact of *fluctuations* in the exogenous factors on capacity decisions. As such, our model extends prior research, and our results both confirm and counter findings from prior literature.

This paper is organized as follows: Section 2 reviews the current literature on air travel demand estimation, airlines' capacity choices, and the impact of fuel costs on demand and capacity. Section 3 presents an overview of the dataset employed in our empirical research. We also report relevant data about the current airline industry to support our research agenda. In Section 4, we develop an empirical model to estimate the effect of the three exogenous factors on the airlines' capacity decisions. Specifically, we employ a two-stage least squares model in order to (1) estimate passenger demand, and (2) understand the effects of fuel cost, passenger demand, and unemployment rate on flight frequency, aircraft size, and load factor. The two-stage model effectively controls for demand endogeneity with respect to available capacity. In Section 5, we apply Sobol ANOVA-based indices to quantify the contribution of the variability of the exogenous factors on the variability of the capacity decisions. Section 6 concludes the paper.

2. Literature review

2.1. Estimating passenger demand

An extensive literature estimating airline passenger demand has developed in the last three decades. Most of the research articles either study the impact of different parameters on air travel demand or measure the impact of the economic environment on the quality of airlines' services. Early studies of air transportation demand modeling, dating from the 1970s, identified the impact of various factors on air travel demand (e.g. Douglas and Miller, 1974; Fridstorom and Thune-Larsen, 1989; Jorge-Calderón, 1997; Ito and Lee, 2005; Junwook and Jungho, 2013). Jorge-Calderón (1997) summarized prior research by categorizing the parameters affecting flight demand into two main groups of drivers. The first group, geo-economic factors, fall outside of the airlines' control. The second group of drivers, known as service-related factors, encompasses airfares and the quality of service. The quality of service is categorized into three main variables: flight frequency, aircraft size, and load factor, the three capacity decisions we investigate in this paper. Wei and Hansen (2006) developed an aggregate demand model for air passenger traffic in a hub-and-spoke network. Their model examined the influence of airline service quality such as flight frequency, aircraft size and ticket price, in addition to other variables such as flight distance and socio-economic conditions. Wei and Hansen (2005) examined airlines' market share and total demand in non-stop duopoly markets. They studied aircraft size, flight frequency, airfares, and seat availability, and they conclude that airlines gain more market share by increasing flight frequency than by increasing aircraft size. In the first stage of our two-stage least squares (2SLS) model we draw on these papers to estimate overall passenger demand.

2.2. Exogenous factors and capacity decisions

Recent articles evaluate the impact of other groups of parameters on the demand-supply equilibrium (see Ito and Lee, 2005; Franke and John, 2011; Pearce, 2012; Chi and Baek, 2013; Barrett, 2004; Pels et al., 2009). The second stage of our 2SLS model builds on these papers by incorporating several of their exogenous factors, including passenger demand and economic conditions, to determine their effect on airlines' capacity decisions.

As noted in the introduction, a common tradeoff in the airline industry is the balance between profit maximization and quality of service. Higher flight frequencies, lower load factors, and sufficiently large aircraft sizes are all linked to higher customer satisfaction, but they induce higher costs and lower profits. Consequently, many studies address the airlines' network configurations, determination of flight frequency, and choice of aircraft size with respect to the demand–supply equilibrium (see Swan, 1979; Teodorovic and Krcmar-Nozic, 1989; Givoni and Rietveld, 2010; Pitfield et al., 2010; Takebayashi, 2011; Zou and Hansen, 2012). In order to find the optimal flight frequency on an airline network, Hsu and Wen (2003) integrated two sub-models – a passenger airline flight choice model and an airline flight frequency model. Pitfield et al. (2010) developed a three-stage least squares approach to simultaneously evaluate the interaction between three variables: flight frequency, aircraft size, and the total number of passengers travelled in a market, using pooled time series cross sectional data on the North Atlantic routes. The goal was to understand the airlines' response to changes in demand so that airports can predict the load on their facilities. They found that increases in demand are associated with increased flight frequency and larger aircraft. See also Pitfield et al. (2012). Wei and Hansen (2003) developed a model of aircraft cost and size, and discovered that economies of scale exist in both aircraft size and stage length. Our research adds to this literature by including fuel cost as an exogenous factor. As well, our more robust model reveals that flight frequency and aircraft size move in opposite directions in response to passenger demand and fuel cost. Thus, our results are consistent with Wei and Hansen, but are partially counter to Pitfield et al. (2010). Furthermore, we examine fluctuations in the exogenous variables, and their effects on the capacity decisions.

An important parameter that combines all three capacity dimensions is Available-Seat-Miles (ASM), which counts the total available seats in one mile of a flight operation. The literature reveals that both the demand and supply side of air traffic impact ASM.