NON-STOP VERSUS CONNECTING AIR SERVICES: AIRFARES, COSTS, AND CONSUMERS' WILLINGNESS TO PAY

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Discussion Paper

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Abstract

Airlines provide both non-stop and connecting services. The airfare for each service type is determined largely by the willingness to pay (WTP) of passengers and the costs for airlines. This paper estimates the impact of itinerary characteristics such as number of stopovers, detour, layover time, and aircraft size on airfares using a novel demand and supply model. This model allows us to calculate both costs and markups for non-stop and connecting itineraries in U.S. domestic markets. We find that, on average, passengers have a higher WTP for nonstop flights and the WTP for connecting flights is driven particularly by the number of stopovers, in-flight time, and transfer time. As a result, we identify significant heterogeneity with regard to costs and mark-ups between markets. While in most U.S. domestic markets airlines incur higher costs for operating connecting routings, the indirect routing via a hub achieves lower costs in some markets, as the economies associated with the use of larger aircraft offset the costs of the stopover. Finally, we show that the presence of connecting services reduces fares for nonstop flights, in particular for itineraries with a longer market distance as detours and the significance of fixed costs associated with a stopover decrease.

I. Introduction

Airfares in aviation markets, which can be defined by the points of origin and destination, are determined by passenger demand, airline costs, and market structure. In the United States, 56 percent of the markets with non-stop service are served non-stop by only one airline,[1] but competing airlines offer connecting flights in 80 percent of these markets. When deciding between non-stop and connecting services, airlines face trade-offs. On one hand, passengers tend to have a lower willingness to pay (WTP) for connecting itineraries since connecting services are associated with additional flight time as well as waiting time at transfer airports. Furthermore, airlines incur higher costs for connecting services, which result from additional flight distance and stopovers. On the other hand, connecting routings may enable cost savings through exploiting economies of traffic density on routes to and from a hub airport, particularly through using larger and more efficient aircraft and achieving higher load factors.

Many studies, particularly earlier ones, have analyzed demand and costs in airline markets separately, using either demand models with ticket data (e.g., Morrison and Clifford, 1989; Hsiao and Hansen, 2011) or cost models with accounting data (e.g., Caves, Christensen and Tretheway, 1984; Wei and Hansen, 2003). Earlier studies that estimate demand and supply simultaneously have treated flights in an origin and destination market as a homogenous product and/or assumed linear demand (e.g., Reiss and Spiller, 1989; Brueckner and Spiller, 1994).

A limited number of newer publications have modeled demand and supply simultaneously using a discrete choice model for the demand side, with the model estimated using ticket data (Berry, Carnall and Spiller, 2006; Berry and Jia, 2010; Gayle and Wu, 2015). Thereby, these studies avoid important shortcomings of older

[1] According to the DB1B ticket sample for the year 2011 provided by the US Department of Transportation.

analyses as they (i) avoid estimation bias through directly accounting for simultaneity of supply and demand; (ii) address potential problems associated with the use of cost accounting data (such as poor proxying for opportunity costs); and (iii) allow for more realistic substitution patterns by treating the different flight connections in a market as heterogeneous products. In such an approach, Berry, Carnall and Spiller (2006) analyzed heterogeneity in passenger preferences and cost advantages of hub-and-spoke networks. They found two groups of passengers with the typical characteristics of leisure and business travelers. Compared to the leisure traveler group, the business traveler group is less price-sensitive, has a stronger preference for non-stop flights, and values flight frequency more. The authors also found that hubs provide cost savings, thereby adding to the existing evidence on economies of traffic density in the airline industry (e.g., Caves, Christensen and Tretheway, 1984; Brueckner and Spiller, 1994). Using a similar approach, Berry and Jia (2010) analyzed changes in the profitability of non-stop and connecting services. They showed that the passenger preference for non-stop flights increased between 1999 and 2006, while the cost advantage of connecting services over the same time period vanished. Gayle and Wu (2015) studied the impact of the presence of connecting flights on the pricing of non-stop flights. Their results point toward limited substitutability between the two service types, with the presence of connecting flights having an impact of less than 1 percent on the prices of non-stop flights.

However, these existing studies account only for a reduced set of demand drivers with regard to the directness of a flight,[2] and model the supply side with cost functions that do not capture the heterogeneity of costs per passenger with respect to aircraft type or number of stops. As a result, the estimated WTP of consumers

[2] Demand drivers included: Berry, Carnall and Spiller (2006): Type of service (non-stop versus connecting services); Berry and Jia (2010): Number of stops of a service; Gayle and Wu (2015): Detour of connecting services (called "inconvenience") and number of stops of a service.

(on the demand side) and the estimated cost economies (on the supply side) might suffer from misspecification and omitted variable bias.

In this paper, we aim to explain the fare differences between non-stop and connecting flights by including in detail the route-specific drivers of passenger WTP and airline costs. For that purpose, we develop a structural demand-and-supply model, building on Berry and Jia (2010). We account for a comprehensive list of demand drivers, including the number of stopovers, in-flight time, transfer time, and flight frequency. To the best of our knowledge, previous studies have not considered these drivers simultaneously and have derived WTP values only for some drivers. On the supply side of our model, we describe costs through a cost function that accounts for the size of the actual aircraft used on a specific route and the number of stops on that route. Taken together, this allows us to more accurately describe route-specific supply costs and to explicitly account for the opposing cost effects of airline hubbing, which leads to more accurate estimates of the costs and markups on non-stop and connecting routes.

Furthermore, contrary to other recent studies (Berry, Carnall, and Spiller, 2006; Berry and Jia, 2010), we assume Cournot quantity competition between airlines, as both theory and empirical evidence favor the assumption of Cournot conduct (Brander and Zhang, 1990; Oum et al., 1993; Fischer and Kamerschen, 2003). As shown in Section VI.C, the results of the present study are sensitive to this assumption.

The remainder of this paper is structured as follows: Sections II and III outline our model and the estimation strategy. Section IV describes the data. Section V presents a descriptive analysis, while Section VI discusses the estimation results. These results are used in Section VII for detailed analyses of WTP, costs, and markups of non-stop and connecting services. Section VIII concludes.

II. The Model

A. Demand Side

We model the demand for individual air travel products through a discrete choice model. To be able to use data on air ticket purchases aggregated at the product level, we follow the discrete choice logit approach developed by Berry (1994), which does not require information on individual purchases or individual consumers.

We define an air travel market as the amount of air travel between two metropolitan areas in a quarter. All airports within a metropolitan area are considered as possible origins or destinations of air travel to or from that area. Since our data does not provide information on the exact flight that each traveler has taken, but only on airline and flight route, we define air travel products through a combination of airline, flight route, and quarter. Thus, an air travel product is a unique airline-route combination, where the route is the sequence of origin airport, potential connecting airport(s), and destination airport.

In each market, consumers are assumed to choose either one of the available air travel products or the outside good. The outside good represents the option (i) to use other modes of transport (such as a car), (ii) to travel to other destinations (most likely in the case of tourist travel), or (iii) to choose other non-travel alternatives. To allow for the outside good in the model, we follow Berry, Carnall and Spiller (2006) and define the potential market for air travel as the geometric mean of the population in the origin and destination metropolitan areas. The demand for product j in market t can then be expressed as a share of potential demand $s_{jt} = q_{jt}/M_t$, where q_{jt} denotes the absolute demand for the product and M_t is the size of market t.

The utility that a consumer obtains from an air travel product depends on market characteristics, non-price product characteristics, the airfare, and characteristics of the consumer. Market characteristics determine the utility of travel in the market and the utility of air travel relative to other modes of transport. Product characteristics include measures of the convenience of a particular air travel product and, in combination with the fare, define the utility of a specific product. Finally, consumer characteristics determine the utility of a particular consumer and include personal preferences and disposable income. We assume that the utility that an individual i obtains from consuming product j in market t can be described by Eq. (1):

$$u_{ijt} = \boldsymbol{x}_{jt}^{D}\boldsymbol{\beta}^{D} - (\alpha/y_t)\, p_{jt} + \xi_{jt}^{D} + \tau_{ijt}, \tag{1}$$

where $\boldsymbol{x}_{jt}^{D}$ is a vector of market and product characteristics, $\boldsymbol{\beta}^{D}$ is a vector of mean valuations for market and product characteristics, p_{jt} is the fare, α is the mean disutility from a marginal fare increase, y_t is the normalized average income of potential consumers, ξ_{jt}^{D} is the unobserved mean utility of the product, and τ_{ijt} is the unobserved utility specific to consumer i. From Eq. (1), mean utility of a product can be defined as shown in Eq. (2).

$$\delta_{jt} = \boldsymbol{x}_{jt}^{D}\boldsymbol{\beta}^{D} - (\alpha/y_t)\, p_{jt} + \xi_{jt}^{D}. \tag{2}$$

In Eq. (1), we further allow for correlation between the unobserved utility assigned to different air travel products by a consumer. For this purpose, we apply the nested-logit approach (McFadden, 1978) and rewrite consumer-specific utility as shown in Eq. (3):

$$\tau_{ijt} = \nu_{itg}(\sigma) + (1-\sigma)\varepsilon_{ijt}, \tag{3}$$

where $\nu_{itg}(\sigma)$ captures consumer-specific utility that is the same for all air travel products and is a function of the correlation parameter σ $(0 \leq \sigma < 1)$. The remaining consumer-specific utility of a particular air travel product $(1-\sigma)\varepsilon_{ijt}$ is then assumed to be identically and independently distributed.

Under utility-maximizing behavior, consumer i chooses product j in market t if $u_{ijt} \geq u_{ikt}$ for all k. Under the given assumptions, we can then derive the standard nested-logit formula giving the predicted share of product j in market t shown in Eq. (4).

$$(4)\ s_{jt} = s_{j|g} \cdot s_{g|t} = \frac{e^{\delta_{jt}/(1-\sigma)}}{D_{gt}} \cdot \frac{D_{gt}^{1-\sigma}}{\left(\sum_{gt} D_{gt}^{1-\sigma}\right)}, \quad where \quad D_{gt} = \sum_{j \in g} e^{\delta_{jt}/(1-\sigma)},$$

$s_{j|g}$ is the predicted share of product j in the group of air travel products, and $s_{g|t}$ is the predicted share of air travel products in the potential market. Following Berry (1994), we normalize the utility of the outside good to zero and invert the market share function. Substitution of the mean utility δ_{jt} then yields Eq. (5).

$$(5) \qquad ln(s_{jt}) - ln(s_{0t}) = \boldsymbol{x}_{jt}^{D}\boldsymbol{\beta}^{D} - (\alpha/y_t)\, p_{jt} + \sigma\, ln\,(s_{jt|g}) + \xi_{jt}^{D},$$

where $s_{jt} = q_{jt}/M_t$ is the observed share of product j, $s_{0t} = 1 - Q_t/M_t$ is the observed share of the outside good, and $s_{jt|g} = q_{jt}/Q_t$ is the observed share of product j in the group of air travel products.

B. Supply Side

The supply decision of airlines can be characterized as a two-stage process. In the first stage, airlines set flight schedules and choose the operating aircraft type, approximately 6−18 months before departure (Jacobs et al., 2012). In the second stage, airlines set airfares for given capacity choices and adjust these fares dynamically. Kreps and Scheinkman (1983) showed that if competing firms choose production capacity first and product price subsequently, market outcomes are under mild assumptions about demand equivalent to the outcome of a standard single-stage Cournot game. Consequently, we assume Cournot behavior in our model, which is consistent with prior empirical analyses on market conduct in the airline industry (Brander and Zhang, 1990; Oum et al., 1993; Fischer and Kamerschen, 2003). As such, the present study differs from previous discrete choice studies of air transport markets, which have largely assumed Bertrand-price competition. The sensitivity of our results with respect to the assumption of Bertrand competition is analyzed in Section VI.C.

To model the capacity decision of airlines, the profit of airline f in market t is assumed as shown in Eq. (6).

(6) $$\pi_{ft} = \sum_{j \in \mathcal{S}_{ft}} \left(p_{jt}(\boldsymbol{q}_t) - c_{jt}\right) q_{jt} l_{ft} - F_{ft},$$

where $\mathcal{S}_{ft}$ is a set of routes operated by airline f in market t, $\boldsymbol{q}_t$ is a vector of seat capacities supplied by the airlines in the market, q_{jt} is the seat capacity on route j, c_{jt} are marginal costs per passenger, l_{ft} is the average seat load factor, and F_{ft} are fixed costs of airline f in market t.

Rewriting capacity as a function of market share and market size $\left(q_{jt} = M_t s_{jt}\right)$ and maximizing profits with respect to product shares then yields the first-order conditions in Eq. (7).

(7) $$\frac{\partial \pi_{ft}}{\partial s_{jt}} = \sum_{k \in \mathcal{S}_{ft}} \left(\frac{\partial p_{kt}}{\partial s_{jt}} s_{kt}\right) + (p_{jt} - c_{jt}) = 0 \quad for\ all \quad j \in \mathcal{S}_{ft}$$

Defining markups as $b_{jt} = \sum_{j\in S_{ft}}(\partial \mathrm{p_{kt}}/\, \partial \mathrm{s_{jt}})\mathrm{s_{kt}}$ [3] and solving for p_{jt} gives Eq. (8).

$$p_{jt} = b_{jt} + c_{jt}. \quad (8)$$

Swan and Adler (2006) found that aircraft trip costs can be described by a linear function of aircraft and trip characteristics. Following this finding, we specify marginal costs per passenger as a linear function, as shown in Eq. (9).

$$c_{jt} = \boldsymbol{x}_{jt}^{C}\boldsymbol{\beta}^{C} + \xi_{jt}^{C} \quad (9)$$

where $\boldsymbol{x}_{jt}^{C}$ is a vector of cost characteristics, $\boldsymbol{\beta}^{C}$ is a vector of cost shifters, and ξ_{jt}^{C} is an unobserved cost component. Substituting Eq. (9) into Eq. (8) yields the airfare equation for product j in market t:

$$p_{jt} = b_{jt}(\boldsymbol{x}_{t}^{D}, \boldsymbol{p}_{t}, \boldsymbol{y}_{t}, \boldsymbol{\xi}_{t}^{D}, \boldsymbol{\theta}^{D}) + \boldsymbol{x}_{jt}^{C}\boldsymbol{\beta}^{C} + \xi_{jt}^{C} \quad (10)$$

where vector $\boldsymbol{\theta}^{D}$ contains the demand parameters to be estimated ($\boldsymbol{\beta}^{D}$, α, σ).

III. Estimation Method

To simultaneously estimate the demand-and-supply model in Eqs. (5) and (10), we follow Berry, Levinsohn and Pakes (1995) and use a Generalized Method of Moments (GMM) method based on demand- and supply-side moments. To obtain demand-side moments, we solve Eq. (5) for the unobservable mean utility ξ_{jt}^{D}:

$$\xi_{jt}^{D} = ln(s_{jt}) - ln(s_{0t}) - \left(\boldsymbol{x}_{jt}^{D}\boldsymbol{\beta}^{D} - (\alpha/y_t)\, p_{jt} + \sigma\, l\, n(s_{jt|g})\right) \quad (11)$$

[3] The marginal effects of an increase in quantity on prices ($\partial \mathrm{p_{kt}}/\, \partial \mathrm{s_{jt}}$) in the nested logit model can be found in Appendix I.

Let $\boldsymbol{\xi}^D$ describe a vector of all unobservable mean utilities. Assuming that vectors of demand instruments $\boldsymbol{z}_{jt}^D$ independent of ξ_{jt}^D exist, which together form the instrument matrix $\boldsymbol{Z}^D$, allows the construction of a vector of demand-side moments

$$\text{(12)} \qquad \boldsymbol{m}_D \equiv E\left(\boldsymbol{Z}^{D'}\boldsymbol{\xi}^D(\boldsymbol{X}^D, \boldsymbol{p}, \boldsymbol{y}, \boldsymbol{S}, \boldsymbol{\theta}^D)\right) = \boldsymbol{0},$$

where $\boldsymbol{\xi}^D$ depends on observed demand characteristics $\boldsymbol{X}^D$, observed fares $\boldsymbol{p}$, observed incomes $\boldsymbol{y}$, and observed product shares $\boldsymbol{S} = (\boldsymbol{s}, \boldsymbol{s_0}, \boldsymbol{s_g})$.

The construction of the supply-side moments is completed analogously by solving Eq. (10) for the unobserved cost component ξ_{jt}^C:

$$\text{(13)} \qquad \xi_{jt}^C = p_{jt} - b_{jt}(\boldsymbol{x}_t^D, \boldsymbol{p}_t, \boldsymbol{y}_t, \boldsymbol{\xi}_t^D, \boldsymbol{\theta}^D) - \boldsymbol{x}_{jt}^C\boldsymbol{\beta}^C.$$

Let $\boldsymbol{\xi}^C$ describe a vector of all unobserved costs. Assuming that vectors of cost instruments $\boldsymbol{z}_{jt}^C$ independent of ξ_{jt}^C exist, which together form the instrument matrix $\boldsymbol{Z}^C$, allows the construction of a vector of supply-side moments

$$\text{(14)} \qquad \boldsymbol{m}_S \equiv E\left(\boldsymbol{z}^{C'}\boldsymbol{\xi}^C(\boldsymbol{X}^C, \boldsymbol{p}, \boldsymbol{b}, \boldsymbol{\beta}^C)\right) = \boldsymbol{0},$$

where the unobserved cost component $\boldsymbol{\xi}^C$ depends on observed cost characteristics $\boldsymbol{X}^C$, predicted markups $\boldsymbol{b}(\boldsymbol{x}^D, \boldsymbol{p}, \boldsymbol{y}, \boldsymbol{\xi}^D, \boldsymbol{\theta}^D)$, and cost parameters to be estimated $\boldsymbol{\beta}^C$. We then combine the demand- and supply-side moments into a single vector of moments:

$$\text{(15)} \qquad \boldsymbol{m}(\boldsymbol{\theta}) \equiv \begin{pmatrix} \boldsymbol{m}_D(\boldsymbol{\theta}) \\ \boldsymbol{m}_S(\boldsymbol{\theta}) \end{pmatrix} = \boldsymbol{0},$$

where vector $\boldsymbol{\theta}$ contains the demand and cost parameters $(\boldsymbol{\theta}^D, \boldsymbol{\beta}^C)$. Estimates are obtained by applying the standard two-step GMM procedure, which chooses the parameters such that the sample analog of the moments vector in (15) is as close to zero as possible. The technical approach is detailed in Appendix II.

We note that the moment conditions require the specification of the instrument vectors $\boldsymbol{z}_{jt}^{D}$ and $\boldsymbol{z}_{jt}^{C}$. While these vectors generally include all regressors, endogenous demand and cost characteristics are excluded since they are correlated with unobservable mean utility ξ_{jt}^{D} and unobserved costs ξ_{jt}^{C}. Such endogenous variables are identified in Section IV alongside additional exogenous instrumental variables, which are correlated with the respective endogenous variable, but uncorrelated with unobserved utility or cost. These exogenous instrument variables are added to the instrument vectors to replace the endogenous variables.

IV. Data and Variables

The main data source for this analysis is the 2011 Airline Origin and Destination Survey (DB1B), which is a 10 percent sample of all US domestic airline tickets provided by the US Department of Transportation (US DOT).

After processing the data (see Appendix III), the ticket data is aggregated to the product level to obtain the number of passengers (q) for each product. We then assign products to origin and destination markets, whereby origin and destination regions are defined using the metropolitan area definition of the US Office of Management and Budget. Since small metropolitan areas can be substantially smaller in size than the core catchment areas of airports, we limit our analysis to air travel between metropolitan areas with a population of at least 500,000 people.

Table 1 summarizes all variables and their data sources, and provides summary statistics. A detailed description of variable selection is presented in the following subsections.

TABLE 1—VARIABLES AND SUMMARY STATISTICS

Variable		Description	Data source	Mean	Std. dev.
q	Passengers	(in thousands)	US DOT (DB1B)	0.12	0.50
Q	Market passengers	(in thousands)	US DOT (DB1B)	2.78	7.19
M	Market size	Geometric mean of the populations of the origin and destination regions (in millions)	US DOT (DB1B)	2.95	2.22
Demand variable					
p	Fare	Fare (in $100)	US DOT (DB1B)	2.63	1.11
y	Income	Average annual per capita income in the origin and destination regions (normalized to the national mean)	US BEA	1.07	0.15
$\boldsymbol{x}^D$					
	Constant	-	-	1.00	0.00
	Market distance	Great circle distance between the centers of the origin and destination region (in 100 miles)	US DOT (DB1B)	12.92	6.56
	(Market distance)^2	Square of market distance	-	210.06	191.07
	Tourist orientation	Share of the annual income in the origin and destination region in the accommodation sector	US BEA	0.01	0.02
	Ground distance	Sum of the great circle distance from the center of the origin region to the origin airport, and the great circle distance from the destination airport to the center of the destination region (in 100 miles)	-	0.20	0.12
	Flight time	Total flight time (in hours)	US DOT (T-100)	4.25	1.52
	Connecting time	Total connecting time (in hours)	OAG	0.86	0.69
	Stops	Number of stopovers	US DOT (DB1B)	0.91	0.33
	1/(Flight frequency)	Inverse of the number of flights per week	US DOT (T-100)	0.08	0.43
	Airline presence	Share of flights departing from the origin and destination regions that are marketed by the airline	US DOT (T-100)	0.17	0.14
	Slot airports	Number of takeoffs and landings at slot-controlled airports	US DOT (DB1B)	0.20	0.53
	Demand carrier dummies	-	US DOT (DB1B)	-	-
Cost variable					
$\boldsymbol{x}^C$					
	Constant	-	-	1.00	0.00
	Flight legs	Number of flight legs	US DOT (DB1B)	1.91	0.33
	Σ1/Seats	Inverse of the average aircraft seat capacity summed over all flight legs	US DOT (T-100)	0.02	0.01
	Flight distance	Total flight distance (in 100 miles)	US DOT (DB1B)	15.07	7.13
	Σ (Leg distance)/Seats	Flight leg distance (in 100 miles) divided by the average aircraft seat capacity summed over all flight legs	US DOT (DB1B, T-100)	0.13	0.06
	Cost carrier dummies	-	US DOT (DB1B)	-	-

A. Demand variables

Parameterization of the demand-side of the model requires identification of the market and product characteristics.

Market characteristics ($\boldsymbol{x}^D$ (1))

Market characteristics are drivers of travel demand and of air travel relative to other modes of transport. These characteristics generally include measures of origin and destination attractiveness as well as general travel impedance measures.

The effect of the population size of the origin and destination regions on the travel attractiveness is captured through the definition of market size (see Section II). As an additional driver of travel attractiveness, we consider tourist attractiveness, which is parameterized following Borenstein (1989) as the average share of income earned in the accommodation sector.

As a market-specific measure of travel impedance, we include linear market distance, for which the sign of the impact is a priori undetermined. On one hand, the fixed time investment associated with air travel (for activities such as security and boarding) makes air transportation less desirable than ground transportation for shorter market distances. On the other hand, regions that are further away from each other may have fewer social and economic links, which might lower travel demand. As these trade-offs can cause non-linearities, we model the impact of market distance as a second-order polynomial.

Product characteristics ($\boldsymbol{x}^D$ (2))

Product characteristics describe the convenience of a flight connection and determine product demand. These include drivers of the generalized travel costs of a specific routing, including schedule delay and delay costs, and convenience attributes of the onboard product.

Besides airfares, time costs constitute one of the most significant drivers of generalized travel costs. As such, we consider flight times, measured as gate-to-gate ('block') time, as a product characteristic. For connecting itineraries, we calculate flight time as the sum of the non-stop flight times of all flight legs. Furthermore, connecting time − computed from OAG flight schedules as the quarterly average of the minimum connecting time of each day for each airline-routing combination − is included in the model. We also introduce the number of stopovers to model the fixed inconvenience effects of transfers. To account for the impact of airport access costs on passengers' routing choice, we add the total distance between the origin/destination airports and the centers of the origin/destination regions to the vector of product characteristics.

Finally, schedule delay, which is defined as the difference between the actual flight departure time and the preferred flight departure time of the traveler, is included as a product characteristic. It is approximated through the average time span between two consecutive flights measured by the inverse of flight frequency. For indirect flight routes, we assume flight frequency to be determined by the flight leg with the lowest frequency. To account for the costs associated with flight delays, we include the number of takeoffs and landings at slot-controlled airports.[4]

Quality attributes of airlines (such as seat pitch and inflight service) are captured through carrier dummy variables. We also expect airline presence in a region to increase the perceived convenience of a flight product, such as through increasing the value of the frequent flyer program. As such, we add each airline's share of flights departing from the origin and destination regions to the model.

Airfare (p)

The airfare is the average ticket fare that passengers paid for an air travel product.

[4] The slot-controlled airports are John F. Kennedy International (JFK), LaGuardia (LGA), Newark Liberty International (EWR), and Ronald Reagan Washington National (DCA).

Consumer characteristics (y)

The average disposable income of consumers in a market is calculated as the average annual per capita income in the origin and destination regions normalized to the national mean.

B. Cost variables

Cost characteristics ($\boldsymbol{x}^C$)

The cost variables are derived from the aircraft trip cost function identified by Swan and Adler (2006). They include the number of flight legs, total flight distance, and two interaction terms that capture the influence of average aircraft size (measured in seats) on leg- and distance-related costs. The derivation and computation of these variables is detailed in Appendix IV. In addition, carrier-specific cost differences, such as those between a low-cost carrier like Southwest and a full-service carrier like United, are captured through carrier dummy variables.

C. Instruments

As discussed in Section III, drivers of demand and costs, which are correlated with unobservable mean utility and unobserved costs and are therefore endogenous, must be excluded from the instrument vectors. While we do not identify potential endogeneity in the set of cost drivers, some drivers of demand are potentially endogenous. In particular, we consider airfares, the share of air travel products, flight frequency, and airline presence to be endogenous since they are likely affected by unobserved product utility. Therefore, we exclude these variables from the demand-side instrument vector and include additional exogenous instruments.

Following Berry, Carnall and Spiller (2006) we treat the route networks of airlines as exogenous and use network characteristics to construct instrumental variables. To instrument for airfares and market volumes, we consider two types of instruments. First, we include measures of competition with products of other airlines in the market, particularly the number of competing products, the number of competitors, the difference between flight distance and average flight distance of competitors, and the difference between number of stops and average number of stops of competitors. These instruments are relevant because higher levels of competition with products with similar characteristics are expected to lower markups and fares and increase the number of air travelers. Second, we determine the number of alternative products offered by the airline in each market and add the resulting variable to the instrument vector. This variable is relevant as an increase in seat capacity on one route in a market results not only in lower prices on that route, but also on other routes that the airline operates. Therefore, the more routes an airline operates in a market, the lower the incentive to supply additional seat capacity, which would result in higher prices and a lower number of air travelers.

Besides competition factors, we follow Berry and Jia (2010) and add cost-drivers as instruments for airfares. In particular, we use total flight distance as a demand-side instrument, since this variable drives many costs, including those of fuel, crew, and capital.

To instrument for the flight frequency variable, we follow Peters (2006) and use the fact that each flight leg is usually also a leg of other routes. The flight frequency on a leg, which is part of other routes serving other markets, tends to increase with the total potential demand in these markets. Market demand, in turn, depends positively on the populations of the origin and destination regions. To construct the instrument, we calculate for each flight leg the sum of the populations at the origins and destinations of the routes that include that flight leg. The inverse of the population sum of the flight leg with the minimum flight frequency is then used as an instrument for the frequency variable.

As an instrument for the airline presence variable, we also follow Peters (2006). Analogously to the instrument for flight frequency, we use the fact that market demand should increase with the population at origin and destination. The instrument for airline presence is the total population that the carrier serves non-stop from the origin and destination airports, divided by the total population that all carriers serve non-stop from the origin and destination airports.

V. Descriptive Analysis

Using the fare data described in Section IV, we compute average fares for non-stop and connecting services. The resulting data is shown for different market distances in Figure 1. In regional and short-haul markets with distances less than 1500 miles, fares are, on average, approximately 20 percent higher for connecting services than for non-stop services. However, with increasing distance, this gap decreases and fares for connecting services are almost identical to non-stop fares in medium-haul markets.

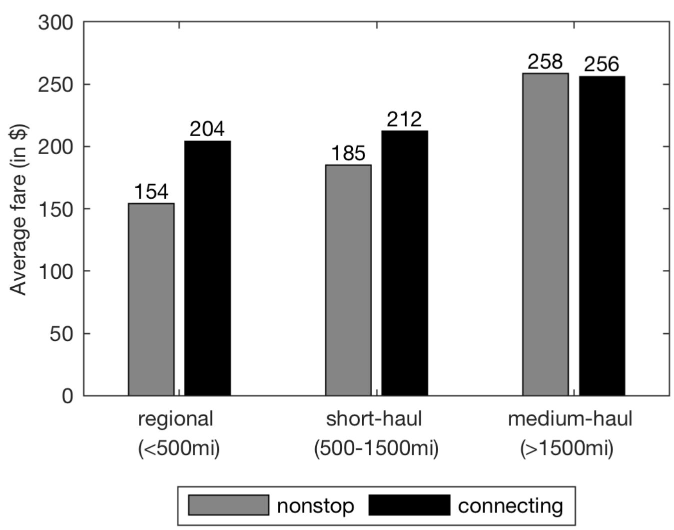

FIGURE 1. AVERAGE FARES FOR NON-STOP AND CONNECTING FLIGHTS

To further understand the fare differences between non-stop and connecting services, we compute the differences in average fares for all markets. The resulting distribution of fare differences is shown in Figure 2. In 75 percent of the markets, average fares are lower for non-stop services than for connecting services, with a mean difference in average fares over all markets of -14 percent. However, in 25 percent of the markets, fares are higher for non-stop services. Using the modeling approach described above, the following analyses aim to explore the drivers of these differences.

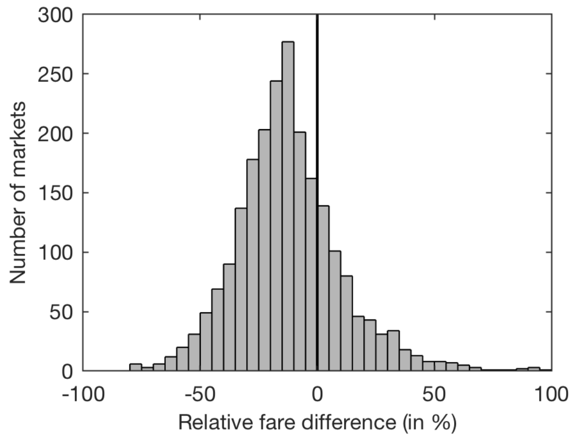

FIGURE 2. RELATIVE FARE DIFFERENCE BETWEEN NON-STOP AND CONNECTING FLIGHTS

VI. Results

A. Validity check

The model described in Eqs. (5) and (10) is estimated using the estimation method outlined in Section III and the data described in Section IV. The results are reported in Table 2. Before discussing these results, we assess the validity of our approach through a three-step approach.

First, we compare observed average fares with the predicted fares from the model. For that purpose, we compute a passenger-weighted R^2 that measures the share of the passenger-weighted fare variance, which is explained by the model. We obtain an R^2 of 0.78, which suggests a reasonable explanatory power of the model.

Second, we compute the average price elasticity of market demand obtained from our estimation results and compare it to previous findings from the literature. From our results, we obtain an average price elasticity of market demand of -2.66, which is in line with Berry and Jia (2010), who reported an average elasticity of -2.01 for U.S. domestic markets in 2006.[5] We note that our price elasticity estimates differ between markets. For example, we estimate a significantly lower average market demand elasticity of -1.89 for the 1000 largest US domestic markets; this is consistent with the average demand elasticity of -1.46 reported by InterVISTAS (2007) for the 1000 largest US domestic markets.

Finally, we compare the average marginal costs per passenger mile obtained from the model with average operating expenses derived from DOT Form 41 financial reports. We find the marginal costs per passenger mile estimated by our model to be 12.8 cents per passenger mile, which is 3.5 cents (22 percent) lower than the average reported operating expenses of 16.2 cents per passenger mile on domestic routes.[6] However, we note that the reported operating expenses include carrier- and route-fixed costs such as advertising and administrative expenses. If we consider reported variable costs only, average expenses are 14.5 cents per passenger mile, which is within 13 percent of our cost estimate.[7]

[5] Berry and Jia (2010) reported this average price elasticity for an alternative model specification, in which they defined markets based on groups of geographically close airports, which is similar to our approach.

[6] Operating expenses are calculated as direct operating expenses plus indirect operating expenses (excludes transport-related expenses).

[7] Variable expenses are calculated as direct operating expenses plus the following indirect operating expenses: passenger service expenses, aircraft servicing expenses, and reservation and sales expenses.

TABLE 2—PARAMETER ESTIMATES

Demand parameter		Coeff.	Std. err.	Willingness to pay
α	Fare/Income	1.115**	(0.023)	
$\boldsymbol{\beta}^D$				
	Constant	-7.231**	(0.035)	-
	Market distance	0.156**	(0.003)	-
	(Market distance)^2	-0.003**	(0.000)	-
	Tourist orientation	3.911**	(0.196)	-
	Ground distance	-0.708**	(0.027)	-0.64 $ per mile
	Flight time	-0.169**	(0.008)	-15.2 $ per hour
	Connecting time	-0.266**	(0.005)	-23.8 $ per hour
	Stops	-1.562**	(0.023)	-140.1 $
	1/(Flight frequency)	-0.650**	(0.045)	-58.3 $
	Airline presence	1.013**	(0.048)	90.8 $
	Slot airports	-0.333**	(0.007)	-29.9 $
	Demand carrier dummies (baseline = Delta Airlines)			
	AirTran	0.380**	(0.020)	34.1 $
	Alaska Airlines	-0.056	(0.032)	-5.0 $
	Allegiant	-0.076	(0.044)	-6.8 $
	American	0.126**	(0.010)	11.3 $
	Continental	0.218**	(0.016)	19.6 $
	Frontier	-0.095**	(0.020)	-8.5 $
	Jet Blue	0.568**	(0.021)	51.0 $
	Southwest	0.108**	(0.011)	9.7 $
	Spirit	0.074	(0.043)	6.6 $
	Sun Country	0.193**	(0.073)	17.3 $
	United	0.078**	(0.016)	7.0 $
	US Airways	0.500**	(0.011)	44.9 $
	USA 3000	0.662	(0.462)	59.4 $
	Virgin	0.504**	(0.048)	45.2 $
σ	Nested logit parameter	0.333**	(0.004)	-
Cost parameter				Cost
$\boldsymbol{\beta}^C$				
	Constant	0.653**	(0.023)	65.3 $
	Flight legs	0.225**	(0.009)	22.5 $
	Σ1/Seats	9.577**	(0.671)	-
	Flight distance	0.032**	(0.001)	0.032 $ per mile
	Σ (Leg distance)/Seats	1.518**	(0.123)	-
	Cost carrier dummies (baseline = Delta Airlines)			
	AirTran	-0.664**	(0.008)	-66.4 $
	Alaska Airlines	-0.282**	(0.023)	-28.2 $
	Allegiant	-1.054**	(0.015)	-105.4 $
	American	-0.164**	(0.008)	-16.4 $
	Continental	0.067**	(0.012)	6.7 $
	Frontier	-0.679**	(0.009)	-67.9 $
	Jet Blue	-0.500**	(0.012)	-50.0 $
	Southwest	-0.316**	(0.006)	-31.6 $
	Spirit	-1.090**	(0.013)	-109.0 $
	Sun Country	-0.503**	(0.029)	-50.3 $
	United	0.353**	(0.010)	35.3 $
	US Airways	0.156**	(0.007)	15.6 $
	USA 3000	-0.456**	(0.052)	-45.6 $
	Virgin	-0.685**	(0.035)	-68.5 $

** Significant at the 1 percent level.

B. Parameter Estimates

The parameter estimates for the baseline model are presented in Table 2, with most parameters being significantly different from zero and having the expected signs.

Demand parameters

The coefficient estimates for the market characteristic variables have the expected signs. In particular, we find that the tourist orientation of origin and destination regions and linear market distance have positive effects on utility. However, the utility impact of market distance is found to be nonlinear. While the generally positive impact of market distance reflects the increasing relative utility of air transportation compared to ground transportation with distance, the marginal impact decreases with market distance. The latter can be explained by a weakening of socio-economic links with increasing distance between origin and destination.
As expected, utility of air travel products is found to decrease with drivers of generalized travel costs, including airfares, distance to and from the airport, total flight time, number of intermediate stops, and connecting time. Our results also provide evidence that passengers prefer air travel products with higher flight frequency and air travel products offered by airlines with higher presence in the origin and destination regions. Lastly, passengers appear to derive lower utility from flight connections that include congested slot-controlled airports, potentially because of higher flight delays.

From these parameter estimates we compute the average WTP of passengers for the individual flight characteristics. The average WTP for characteristic k is calculated as $WTP_k = \beta_k^D/\alpha$. Here, we calculate WTPs for an average consumer with a national mean income. The resulting WTPs are reported in Table 2 alongside the regression results and explained in the following:

- Our results indicate a WTP of potential travelers at $15.20 per hour of flight time reduction. This is largely in line with the guidance on the value of travel time savings by the US Department of Transportation (2011). For the year 2011, the USDOT recommends a value of $22.90 per hour for intercity business travel and $16.40 per hour for intercity personal travel.[8]
- In contrast, our results imply a WTP for reducing connecting time at $23.80 per hour, which is 57 percent higher than the WTP for flight time reductions. This is consistent with prior evidence on disutility of interchange waiting time in public transport; such studies suggest that the value of interchange waiting time in public transport is 50 percent higher than the value of in-vehicle travel time (Wardman, Chintakayala and de Jong, 2016).
- After controlling for additional flight time and connecting time, the estimated WTP for avoiding a stopover is $140. This WTP can be explained by the additional inconvenience of transferring to another flight as well as the risks associated with (i) missing a connecting flight or (ii) waiting for a delayed flight. To compare our estimate with the results of Armantier and Richard (2008) and Berry and Jia (2010), we determine WTPs for stopover avoidance based on their parameter estimates. The results of Armantier and Richard (2008) imply a WTP for a non-stop connection of $84 in 1999. This value would need to be adjusted for inflation and income growth in order to compare it to our results.

[8] The USDOT recommends these values for evaluating travel time savings in intercity ground transport. It calculates the value for intercity personal travel as 70 percent of the hourly median household income, and the value for intercity business travel as the hourly median gross wage. For time savings in air transport, the DOT recommends higher values of time because the median household income and the median gross wage of air travelers exceed the national medians. However, our results refer to the potential air traveler in the US population and not the actual air traveler. Therefore, we compare our results to the values for ground transport.

Furthermore, the results of Berry and Jia (2010) imply a WTP for avoiding a connection of $92 in 1999 and $112 in 2006.[9] However, these values include disutility of connecting time, so they are not directly comparable.

*Cost parameter*s

The estimates of the cost parameters show that costs increase with the number of flight legs and additional flight distance. These factors, in turn, increase the cost for indirect connections. In contrast, costs per flight leg and flight mile decrease with aircraft size. Figure 3 shows the resulting cost economies of aircraft size and the impact of flight distance on these economies. Similarly to Wei and Hansen (2003), our results indicate that the economies of aircraft size increase with distance and the cost economies diminish with increasing aircraft size.

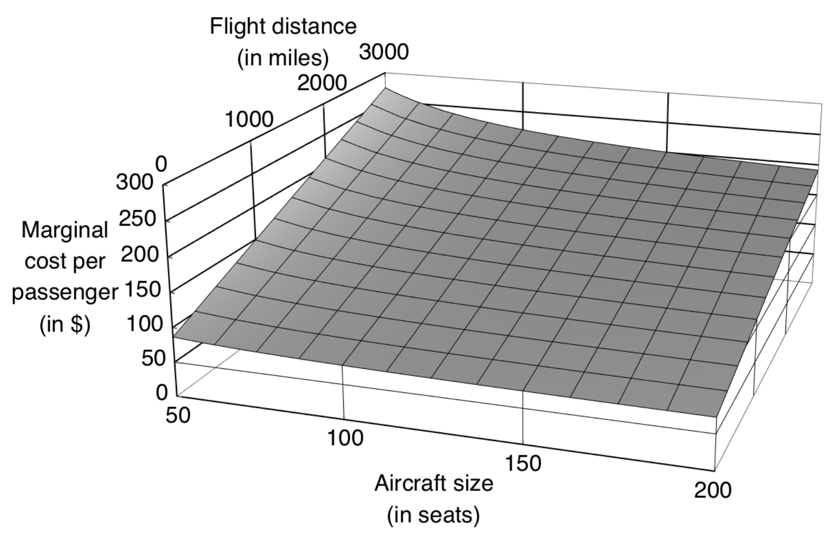

FIGURE 3. MARGINAL COST PER PASSENGER FOR DIFFERENT AIRCRAFT SIZES AND FLIGHT DISTANCES

9 Berry and Jia (2010) obtained valuations of product characteristics for a tourist-type and a business-type consumer. The calculated WTPs are weighted averages of the two consumer types using their estimated share in the population.

C. Sensitivity Analysis

Before discussing the implications of our results, we analyze the sensitivity of our estimation results. In particular, we conduct sensitivity analysis with respect to five modeling assumptions: (i) the Cournot competition between airlines; (ii) the market definition based on metropolitan areas; (iii) the choice to consider markets between metropolitan areas with at least 0.5 million inhabitants; (iv) the definition of market potentials; and (v) the choice of instruments. While Table 3 reveals some differences in estimation results, these differences are expected and the results generally align with our base specification, as discussed below:

First, we study the sensitivity of our results with respect to the assumed competitive behavior of airlines, by comparing the results for Cournot competition in the baseline model to the results for Bertrand competition. The results are shown in Column 2. While most parameter estimates are unchanged, we find that the constant marginal cost component increases under Bertrand competition. This result is consistent with Vives (1985), who showed that markups are strictly lower under Bertrand competition than under Cournot competition, when products are substitutes. Therefore, by assuming Bertrand competition, markups decrease and marginal cost estimates increase.

Second, to assess the impact of market definition, we define markets based on airport pairs instead of metro region pairs. The results are shown in Column 3. Overall, the results are consistent with the baseline specification. However, the impact of price on demand increases so that demand becomes more elastic. This result is expected, since the model now assumes that travelers disregard flights at nearby airports as possible alternatives, so that the observed substitution patterns are captured through a higher price elasticity of demand. As a result, markups decrease and marginal cost increase, which is evident in the significantly higher cost constant.

TABLE 3—PARAMETER ESTIMATES FROM ALTERNATIVE SPECIFICATIONS

Demand parameter		1 Base spec.	2 Bertrand comp.	3 Airport-pair markets	4 Metro pop. >100,000	5 Alternative market size	6 Alternative instruments
α	Fare/Income	1.115**	1.115**	1.706**	1.153**	1.247**	0.811**
		(0.023)	(0.030)	(0.040)	(0.024)	(0.021)	(0.029)
$\boldsymbol{\beta}^D$							
	Constant	-7.231**	-7.231**	-6.257**	-7.934**	-6.909**	-7.722**
		(0.035)	(0.045)	(0.059)	(0.037)	(0.038)	(0.041)
	Market distance	0.156**	0.156**	0.195**	0.153**	0.164**	0.156**
		(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.002)
	(Market distance)^2	-0.003**	-0.003**	-0.004**	-0.003**	-0.003**	-0.003**
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Tourist destination	3.911**	3.911**	2.725**	0.881**	0.318**	3.804**
		(0.196)	(0.184)	(0.277)	(0.223)	(0.090)	(0.168)
	Ground distance	-0.708**	-0.708**	-2.580**	-0.873**	-0.866**	-0.567**
		(0.027)	(0.027)	(0.047)	(0.029)	(0.028)	(0.025)
	Flight time	-0.169**	-0.169**	-0.173**	-0.171**	-0.200**	-0.218**
		(0.008)	(0.009)	(0.012)	(0.008)	(0.007)	(0.008)
	Connecting time	-0.266**	-0.266**	-0.225**	-0.259**	-0.222**	-0.276**
		(0.005)	(0.005)	(0.007)	(0.005)	(0.005)	(0.004)
	Stops	-1.562**	-1.562**	-1.402**	-1.548**	-1.086**	-1.655**
		(0.023)	(0.024)	(0.035)	(0.024)	(0.023)	(0.023)
	1/(Flight frequency)	-0.650**	-0.650**	-0.558**	-0.624**	-0.302**	-0.707**
		(0.045)	(0.045)	(0.044)	(0.045)	(0.039)	(0.048)
	Airline presence	1.013**	1.013**	1.464**	0.868**	0.544**	0.637**
		(0.048)	(0.061)	(0.064)	(0.051)	(0.040)	(0.049)
	Slot airports	-0.333**	-0.333**	-0.616**	-0.435**	-0.390**	-0.277**
		(0.007)	(0.007)	(0.012)	(0.008)	(0.007)	(0.007)
σ	Nested logit parameter	0.333**	0.333**	0.261**	0.325**	0.380**	0.323**
		(0.004)	(0.003)	(0.005)	(0.004)	(0.004)	(0.004)
Cost parameter							
$\boldsymbol{\beta}^C$							
	Constant	0.653**	0.681**	0.922**	0.680**	0.743**	0.314**
		(0.004)	(0.027)	(0.020)	(0.023)	(0.019)	(0.046)
	Flight legs	0.225**	0.215**	0.194**	0.220**	0.243**	0.261**
		(0.009)	(0.010)	(0.009)	(0.009)	(0.008)	(0.010)
	Σ1/Seats	9.577**	9.584**	9.999**	9.647**	16.545**	8.977**
		(0.009)	(0.672)	(0.673)	(0.671)	(0.503)	(0.676)
	Flight distance	0.032**	0.032**	0.033**	0.032**	0.036**	0.031**
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	Σ (Leg distance)/Seats	1.518**	1.509**	1.374**	1.498**	0.759**	1.697**
		(0.123)	(0.124)	(0.124)	(0.123)	(0.094)	(0.125)

Notes: Standard errors are in parentheses. Demand and cost carrier dummies omitted.
** Significant at the 1 percent level.

Third, our analysis focuses on studying large metropolitan areas with more than 500,000 inhabitants. This cut-off may induce selection bias. Therefore, we analyze model sensitivity to this cut-off assumption by including all metropolitan areas with a population of more than 100,000 people in the dataset. According to the results in Column 4, our results are not found to be sensitive to this assumption.

Fourth, we study the sensitivity of our results with respect to the definition of market potential. In our base specification, we use the geometric mean of the population in the origin and destination metropolitan areas. A standard approach in non-transport applications is to assume that potential demand is linear to the population or the number of households in a market (see, e.g., Berry, Levinsohn, and Pakes, 1995; Nevo, 2001). Thus, in an alternative specification, we use the sum of the population of the origin and destination region as a measure of market size. Again, the results are generally in line with our baseline specification.

Finally, we study the impact of instrument choice. For the alternative specification, we follow Berry, Levinsohn, and Pakes (1995) and use different instruments for the airfare variable. These instruments include the sum of the number of stops of other products of the same airline, the sum of the flight distances of other products of the same airline, the sum of the number of stops of competing products, and the sum of the flight distances of competing products. In addition, as in the base specification, flight distance is used as an instrument for airfare. As shown in Column 6 of Table 3, our estimation results are robust to this alternative specification.

VII. Analysis of Non-stop and Connecting Service

We now analyze the differences in willingness-to-pay and costs for non-stop and connecting services as well as the impacts of connecting services on markups for non-stop services. For this purpose, we limit the scope of our analysis to markets where both non-stop flights and connecting services exist.

A. Willingness to Pay Differences

We calculate WTP differences based on differences in service characteristics, specifically differences in flight time, number of stops, connecting time, and flight frequency. For each market, we consider the most convenient non-stop service and the most convenient indirect service. The most convenient services are itineraries for which we compute the highest WTP on the basis of flight characteristics and our estimation results.

We find that the WTP for the most convenient non-stop service is, on average, $168 higher than for the most convenient indirect service. Table 4 shows the contribution of the individual flight characteristics to the WTP difference. The main driver is the existence of the stop, which causes additional inconvenience for travelers. The effects of longer flight time and connecting time are less important than this WTP impact. We note that while indirect connections are served with higher frequency, the associated increase in WTP for connecting flights cannot offset the disutility associated with the indirect routing.

TABLE 4—WILLINGNESS TO PAY DIFFERENCE OF NON-STOP VS. CONNECTING SERVICES

Flight characteristic	Average difference	Avg. WTP difference
Flight time	-52 minutes	+$13.8
Stops	-1 stop	+$148.5
Connecting time	-30 minutes	+$12.6
Flight frequency	-12 flights per week	-$7.0
Total		+$167.5

Beyond analyzing mean variation, we analyze the WTP differences in all markets. As shown in Figure 4, the results reveal significant heterogeneity in the WTP differences between non-stop and connecting services. While the WTP difference between the service types points towards a strict dominance of the disutility effects over frequency impacts, the WTP differences range from 136 USD (5^{th} percentile) to 214 USD (95^{th} percentile). In line with Table 4, a significant driver of this variation is the additional travel time of the most convenient indirect connection. From Figure 5, we conclude that this additional travel time decreases with increasing market distance. This finding suggests an increasing competitiveness of connecting services compared to non-stop flights for longer market distances, thereby providing an initial explanation for the closing gap between airfares for non-stop flights and connecting services (Figure 1).

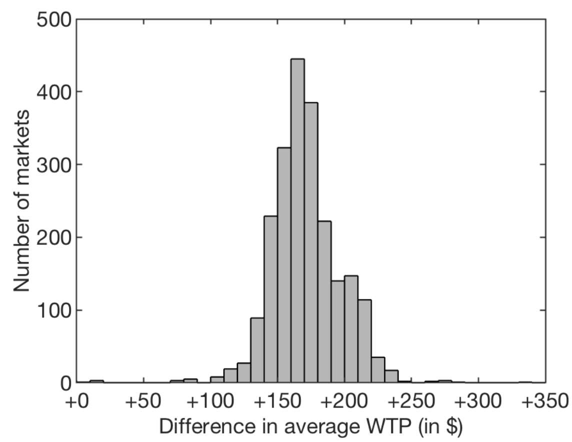

FIGURE 4: WTP DIFFERENCE BETWEEN NON-STOP AND CONNECTING ROUTINGS

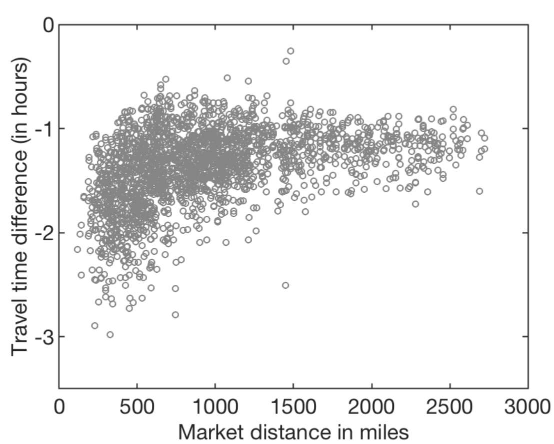

FIGURE 5: TRAVEL TIME DIFFERENCE BETWEEN NON-STOP AND CONNECTING FLIGHTS

B. Cost Differences

We calculate marginal cost differences per passenger based on differences in flight characteristics; specifically, differences in the number of flight legs, total flight distance, and average aircraft size. We run this analysis for all origin and destination markets under investigation and include for each market the least costly non-stop service as well as the least costly indirect service.

We find that the least costly non-stop service is, on average, $31 less costly than the least costly connecting service. Table 5 shows that the main driver of this average cost difference is the additional flight leg, which is likely driven by additional landing fees and the fuel costs of extra take-offs and landings. In contrast, the additional costs of extra flight distance result in a much smaller cost difference. Although economies of scale from using larger aircraft are present, they cannot offset these cost disadvantages.

TABLE 5—COST DIFFERENCES PER PASSENGER BETWEEN NON-STOP AND CONNECTING ROUTINGS

Flight characteristic	Average difference	Avg. cost difference
Flight distance	-98 miles	-$4.4
Flight legs	-1 leg	-$30.4
Aircraft size	-15 seats	+$3.9
Total		-$30.9

Beyond analyzing mean variation, we analyze the cost differences in all markets. Figure 6 reveals significant heterogeneity in these cost differences. While connecting services are associated with higher costs in almost all markets, economies of scale over-compensate the additional costs of additional flight distance and additional flight legs in approximately one percent of markets. One example is the air travel market between Dallas (TX) and Charleston (SC), where American Airlines incurs higher costs per seat through offering non-stop service with 50-seat Embraer ERJ-145 than Delta Airlines offering connecting services via Atlanta using predominantly McDonnell Douglas MD-88 with 142 seats. We note that there is almost no additional flight distance for flying through Atlanta, which results in minimal cost disadvantage.

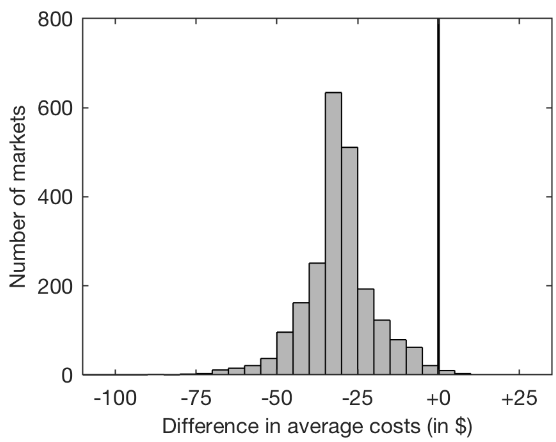

FIGURE 6. COST DIFFERENCE BETWEEN NON-STOP AND CONNECTING ROUTINGS

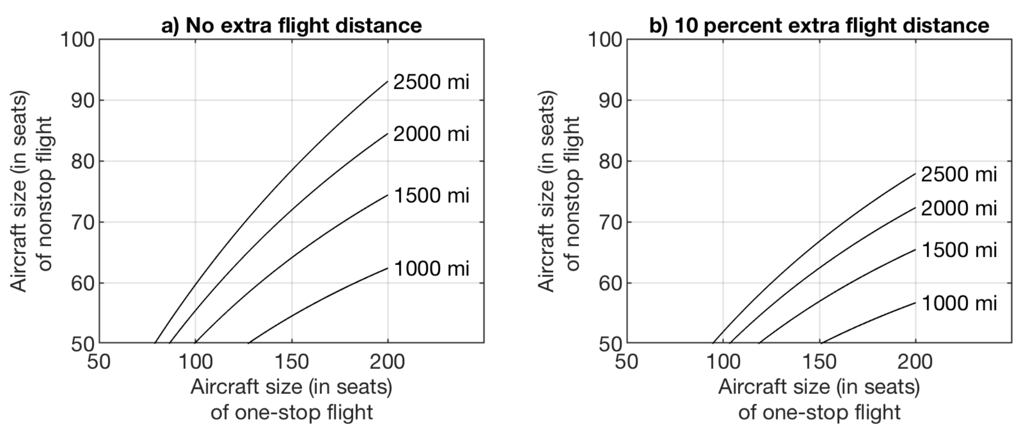

FIGURE 7. REQUIRED AIRCRAFT SIZE ON CONNECTING FLIGHTS TO ACHIEVE COST PARITY WITH A NON-STOP FLIGHT BY MARKET DISTANCE

Figure 7 further illustrates the required economies of scale for connecting services to offset the additional costs associated with detours and the stopover. We find that substantial aircraft size differentials are required in order for economies of scale to dominate. We note that shorter flights require even larger aircraft on connecting services because the high fixed costs associated with a connecting service dominate operating costs on short routes.

Apart from the differences in aircraft size, another driver of the heterogeneity in cost differences is additional flight distance. As shown in Figure 8, the additional flight distance associated with indirect connections decreases with increasing market distance as more direct connecting itineraries can be designed with longer market distance. This finding provides further evidence of a reduction in airfare differences between non-stop flights and connecting flights.

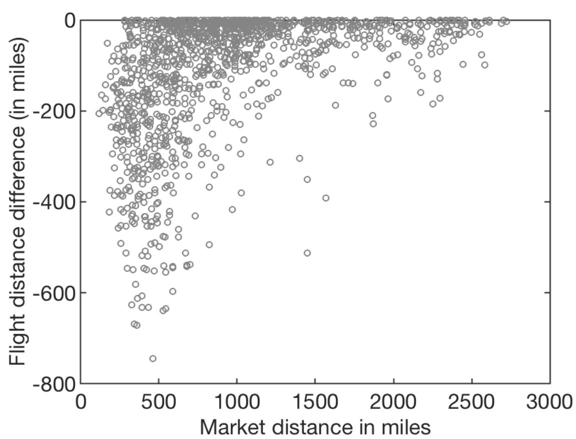

FIGURE 8. FLIGHT DISTANCE DIFFERENCE BETWEEN NON-STOP AND CONNECTING FLIGHTS

C. Markups and Fares

To analyze market outcomes and competitive pressures, we analyze airfares and markups for non-stop flights and compare them to airfares and markups for connecting services. In contrast to the cost and WTP analyses, we consider all flight connections in markets with non-stop and connecting services for this analysis. We then calculate average costs, markups, and predicted fares[10] for non-stop flights and connecting services and average them for three market distance groups.

In line with our analysis in Figure 8, we find that the cost advantage of non-stop flights decreases with market distance. Furthermore, our results indicate that markups are, on average, higher for non-stop flights than for connecting services, which points towards limited substitutability of non-stop services through connecting services. Given the declining WTP and cost differences between non-stop and one-stop services (Sections VI. A and B), our results indicate that declining markup differences between non-stop and connecting services exist with increasing market distance. As such, indirect connections become more competitive, on average, for longer market distances.

Summing the cost and markup estimates yields the fare estimates shown in Table 6. The substantially lower cost of non-stop flights leads to lower fares for non-stop connections, even though markups are higher. However, the (negative) fare difference between non-stop and indirect flights decreases with increasing market distance because the (negative) cost difference declines more strongly than the (positive) markup difference. The fare composition is visualized in Figure 9, which reveals significant reductions in the fare gap with increasing market distance. As such, our model can explain our findings from the observational data presented in Figure 1.

[10] Passenger-weighted means are used in order to correctly account for market volumes.

TABLE 6—COSTS, MARKUPS AND FARES FOR NON-STOP AND CONNECTING FLIGHTS

	regional (<500 mi)	short-haul (500-1500 mi)	medium-haul (>1500 mi)
	Average cost (passenger-weighted)		
Non-stop flights	$91	$113	$163
Connecting flights	$146	$160	$205
Difference	-$55	-$47	-$43
	Average markup (passenger-weighted)		
Non-stop flights	$85 (76 pct.)	$81 (60 pct.)	$82 (45 pct.)
Connecting flights	$71 (45 pct.)	$69 (39 pct.)	$71 (33 pct.)
Difference	+$15	+$12	+$10
	Average fare estimate (passenger-weighted)		
Non-stop flights	$177	$194	$244
Connecting flights	$217	$229	$277
Difference	-$40	-$35	-$33

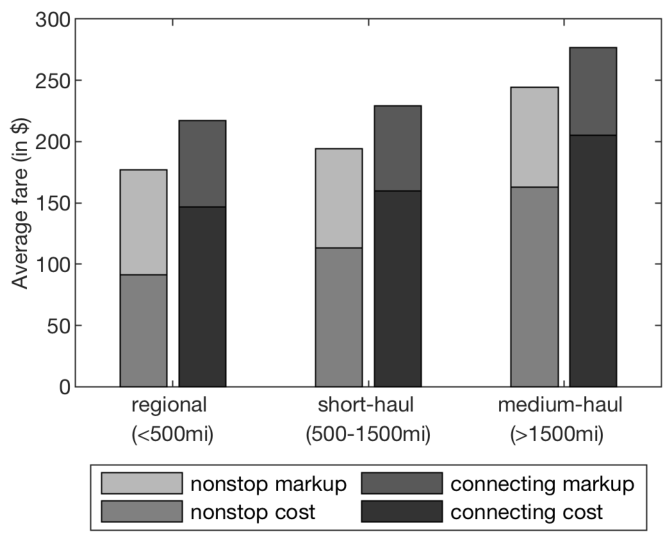

FIGURE 9. FARE ESTIMATES FOR NON-STOP AND CONNECTING FLIGHTS

D. Fare Effect of competing Connecting Service

To assess the competitive impact of connecting flights on fares for non-stop flights, we follow Gayle and Wu (2015) and simulate fares for non-stop flights in the absence of connecting flights. In contrast to Gayle and Wu (2015), however, we do not remove all connecting services. Instead, we simulate for each airline a scenario in which only the connecting services of competing airlines are removed, and determine the impact on the non-stop fares that the airline is able to charge. Thereby, we focus solely on the fare decreases associated with increasing competition. Also removing the connecting flights of the airline under consideration would introduce additional fare effects, because the airline then ignores the potential cannibalization of connecting traffic in its choice of non-stop capacity.

As shown in Table 7, we find that competing connecting services reduce fares for non-stop flights by an average of 1 percent, which is consistent with the limited substitutability and cost disadvantages of indirect flight services. In line with our earlier findings, the results point towards increasing competitive pressures of connecting services with increasing market distance.

TABLE 7— IMPACT OF CONNECTING FLIGHTS ON FARES OF NON-STOP FLIGHTS

	Average fare change		
	regional (<500 mi)	short-haul (500−1500 mi)	medium-haul (>1500 mi)
Average fare change	-$0.8 (-0.4 pct.)	-$2.8 (-1.2 pct.)	-$3.9 (-1.5 pct.)
Fare change > 5 pct.	1.3 pct.	5.2 pct.	7.8 pct.

Since our results enable us to analyze the competitive pressures from connecting services as a function of the characteristics of the connecting flight, we can analyze the heterogeneity of the competitive pressures among different markets. The distribution of the fare impact is shown in Figure 10. Competition authorities often consider a price increase of more than 5 percent as a critical threshold; for example, when deciding on merger proposals. We find that the fare impact is larger than 5 percent for 4.4 percent of the non-stop connections. In addition, as Table 7 shows, fare impacts larger than 5 percent are more present in short- and medium-haul markets.

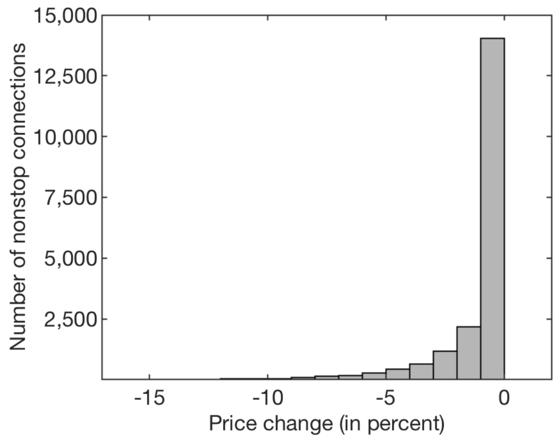

FIGURE 10. IMPACT OF CONNECTING FLIGHTS ON FARES OF NON-STOP FLIGHTS

VIII. Conclusions

We have considered US domestic air travel markets with non-stop and connecting services and find that, in all markets, consumers have, on average, the highest WTP for non-stop routings. Furthermore, the additional operating costs from a stopover cannot be offset by cost economies from larger aircrafts for most connecting air services. As such, we find that most connecting services are imperfect substitutes for non-stop flights, which allows airlines to charge higher markups for non-stop flights, while remaining able to set lower fares for non-stop flights as compared to connecting services due to substantially lower costs. Our data provides substantial evidence that airlines can, in some cases, create connecting services that have substantial competitive impacts on non-stop flights. This is particularly true for longer market distances, when routes can be designed to minimize detours and economies of scale are substantial.

These findings contribute to the existing literature in explaining, in detail, the drivers of competitiveness of non-stop services compared to connecting services. In contrast to Berry, Carnall and Spiller (2006), Berry and Jia (2010), and Gayle and Wu (2015), our approach allows us to explore the advantages and disadvantages of indirect connections in more detail, specifically considering, simultaneously, flight detours, the number of stops, connecting time, and potential economies of scale from aircraft size. Therefore, contrary to previous analyses, we can estimate the WTP, costs, and markups of non-stop and connecting flights at the route level. While our results lend support to the outcomes of existing studies with regard to the sign and order of magnitude for an average connection, we find significant heterogeneity of WTP, costs, and, consequently, competitive pressure from connecting on non-stop connections between different routes. In this regard, this study not only provides additional insight into the drivers of the competitive impacts of connecting services, but also provides support for a highly disaggregated approach to anti-trust analyses.

Our study is limited to an analysis of the average WTP only. Modeling heterogeneous travelers, such as business and leisure travelers, could acquire further insights into the variability of the competitive impacts of connecting services between passenger groups. For example, one could argue that the WTP of business travelers for non-stop flights versus connecting services could more heavily depend on the trade-off between flight frequency and detour as higher values of time would result both in a higher utility of the increased flight frequencies associated with indirect services and in higher disutility of detours. Such an analysis is left for future research.

APPENDIX

I. Marginal Effects in the Nested-Logit Model

Consider a nested logit model with one level of nests, where the inside goods are in one nest and the outside good is in another. As shown by Irwin and Pavcnik (2004), the marginal effects of a quantity increase on price are then given by:

(A1)
$$\frac{\partial p_k}{\partial s_j} = \begin{cases} \frac{1}{\alpha}\left(\frac{1}{s_k} - \frac{\sigma}{s_k} + \frac{\sigma}{s_g} + \frac{1}{s_0}\right), \ for\ j = k \\ \frac{1}{\alpha}\left(\frac{1}{s_j} - \frac{\sigma}{s_j} + \frac{\sigma}{s_g} + \frac{1}{s_0}\right)\left(\frac{s_k\left(\frac{\sigma}{(1-\sigma)s_g}+1\right)}{\frac{1}{(1-\sigma)} - s_j\left(\frac{\sigma}{(1-\sigma)s_g}+1\right)}\right), \ for\ j \neq k \end{cases}$$

where s_g is the share of the group of inside goods in the potential market, and s_0 is the share of the outside good in the potential market.

II. Estimation Method

Replacing the theoretical demand- and supply-side moments with their sample analogs gives:

(A2)
$$\boldsymbol{m}(\boldsymbol{\theta}) = \begin{pmatrix} \frac{1}{n}\boldsymbol{Z}^{D\prime}\xi^{D} \\ \frac{1}{n}\boldsymbol{Z}^{C\prime}\xi^{C} \end{pmatrix}$$

The GMM estimator is then:

(A3)
$$\widehat{\boldsymbol{\theta}} = arg\, min_{\boldsymbol{\theta}}\, [\boldsymbol{m}(\boldsymbol{\theta})'\boldsymbol{W}\boldsymbol{m}(\boldsymbol{\theta})]$$

where $\boldsymbol{W}$ is a symmetric positive definite weight matrix. To obtain a consistent and efficient estimate of $\boldsymbol{\theta}$, we use the two-step GMM procedure. As a first step, an initially consistent but inefficient estimate of $\boldsymbol{\theta}$ is obtained by using the following initial weight matrix:

(A4)
$$\boldsymbol{W} = \begin{pmatrix} \frac{1}{n}\boldsymbol{Z}^{D\prime}\boldsymbol{Z}^{D} & 0 \\ 0 & \frac{1}{n}\boldsymbol{Z}^{C\prime}\boldsymbol{Z}^{C} \end{pmatrix}$$

As a second step, we use the initial estimate of $\boldsymbol{\theta}$ to calculate unobservable mean utilities $\boldsymbol{\xi}^D$ and unobservable costs $\boldsymbol{\xi}^C$. A consistent and efficient estimate of $\boldsymbol{\theta}$ is then obtained using the following weight matrix:

(A5)
$$\boldsymbol{W} = \begin{pmatrix} \frac{1}{n}(\boldsymbol{Z}^{D}\boldsymbol{\xi}^{D})'(\boldsymbol{Z}^{D}\boldsymbol{\xi}^{D}) & 0 \\ 0 & \frac{1}{n}(\boldsymbol{Z}^{C}\boldsymbol{\xi}^{C})'(\boldsymbol{Z}^{C}\boldsymbol{\xi}^{C}) \end{pmatrix}$$

III. Processing of the dataset

We remove tickets with the origin or destination outside the contiguous United States, tickets with a fare of less than $10 (likely tickets purchased with frequent-flyer miles), ticket with business or first-class segments, tickets with more than two stops (the stop at an intermediate airport is more likely to be a destination of a circular trip), and tickets with segments of ground transport. In addition, we keep only one-way tickets and return tickets that we can break down into two one-way tickets. Finally, we require that at least two passengers booked a route-airline combination in a quarter for the associated air travel product to be considered for our analysis.

IV. Cost function

Swan and Adler (2006) found that aircraft costs per flight leg increase linearly with flight distance and linearly with aircraft seat capacity. They identified the following planar function for operating costs per flight leg:

(A6)
$$Cl = k(legdist + a)(seats + b)$$

where $legdist$ is the flight distance of the leg, $seats$ is the aircraft seat capacity, and a, b, and k are estimated parameters. Expanding the product and dividing by $seats$ gives the following linear function for cost per seat and flight leg:

(A7) $$cl = k\ a + k \cdot legdist + k\ a\ b \frac{1}{seats} + k\ b \cdot \frac{legdist}{seats}$$

Costs per seat for a flight consisting of $l = 1, \ldots, L$ flight legs are subsequently given by:

(A8) $$c = \sum_{l=1}^{L} (k\ a \cdot + k \cdot legdist_l + k\ a\ b \frac{1}{seats_l} + k\ b \cdot \frac{legdist_l}{seats_l})$$

Defining $fltlegs$ as the number of flight legs and $fltdist$ as the total flight distance allows us to rewrite the equation as:

(A9) $$c = k\ a \cdot fltlegs + k \cdot fltdist + k\ a\ b \cdot \sum_{l=1}^{L} \frac{1}{seats_l} + k\ b \cdot \sum_{l=1}^{L} \frac{legdist_l}{seats_l}$$

Estimating this linear equation with non-linear constraints on the coefficients would require non-linear estimation methods. Since linear functions are significantly less demanding to estimate, we rewrite the equation as a function of four parameters instead of three:

(A10) $$c = \beta_2^C \cdot fltlegs + \beta_3^C \cdot fltdist + \beta_4^C \cdot \sum_{l=1}^{L} \frac{1}{seats_l} + \beta_5^C \cdot \sum_{l=1}^{L} \frac{legdist_l}{seats_l}$$

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