

Competition and Coordination in the U.S. Airline Hub-to-Hub Markets: An Industry Pre-Merger Case Study

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Abstract

Purpose: This paper investigates the nature of conduct that existed in the U.S. airline hub-to-hub markets prior to the recent merger wave of the legacy carriers. We explore the strategic importance of network carrier hubs in form of “spheres of influence” on airline market conduct. We also simultaneously recognize the overgrowing role played by Low Cost Carriers (LCC) over the years by estimating two conduct parameters - one in markets where LCCs directly compete head-to-head with legacy carriers and the other for markets which LCCs do not serve but has presence in the hub airports or adjacent airports comprising the market endpoints. Thus our supply side framework also sheds some light on the issue of perfect contestability in airline industry.

Design/methodology: We estimate a structural oligopoly model for differentiated products with competitive interactions using DB1B data for first quarter of 2004.

Findings: Our results imply that the nature of competition is more aggressive relative to Bertrand behavior in hub-to-hub markets and that these markets are less than perfectly contestable.

Originality/value: This paper adds to the empirical literature of airline competition by enabling estimation of the actual conduct parameter assuming firm price setting behavior in presence of product differentiation. Contrary to existing literature on airline competition, a structural model enables us to systematically separate out effects of demand, cost and strategic factors on observed airline prices.

Keywords: Structural oligopoly; product differentiation; hub-to-hub markets; conduct; airline competition; contestability; low cost carriers; spheres of influence.

1. Introduction

The U.S. airline industry has experienced substantial consolidation in the last decade following three mergers among the large network carriers namely Delta Airlines and Northwest Airlines in 2008, United Airlines and Continental Airlines in 2010 and finally American Airlines and U.S. Airways in 2013. Unlike the merger wave that followed deregulation in the 1980s, this recent consolidation of the industry is often attributed to financial struggle faced by the network carriers driven by high fixed costs, fluctuations in variable costs such as fuel and labor and intense price competition from low cost carriers (hereafter, LCCs). Given the extent of overlapping routes among the major network carriers this paper aims to evaluate the nature of conduct that existed in the industry prior to the merger wave of the 2000's.

Specifically our study focusses on a subset of airline markets namely hub-to-hub markets i.e. markets comprising of hubs of network carriers which are supposedly the vantage point of market power for these airlines. Several studies such as Borenstein (1989), Evans and Kessides (1993), Lee and Luengo-Prado (2005) have already documented how hubs can generate significant market power for the hub airline allowing it to charge supracompetitive prices for flights to and from hub airports. Further overlapping routes involving hub airports creates a strategic effect on an airline's pricing decision when these airlines meet at each other's hub airports. Gimeno (1999) observes that when airlines meet each other in their respective hub markets, they develop mutually recognized "spheres of influence" centered on their hub airports. Thus an airline refrains from initiating aggressive pricing actions in a competitor's hub market fearing similar retaliation of the competitor in their own hub markets. The idea is based on the fact that since an airline has more to lose in its hub airport in the event of a price war, carriers will refrain from undercutting one another when they meet each other in their respective hub markets. Evans and Kessides (1994) also voice their concern regarding how hubs can become important vantage points for airlines giving rise to development of spheres of influence centered in hub

airports, thus enhancing tacit collusion. In fact, Borenstein (2004) documents the Airline Tariff Publishing Case (ATPCO) of 1992 when eight legacy carriers were accused of price coordination by announcing future fare changes using fare codes and footnote designators through computer reservation systems. The U.S. Department of Justice (DOJ) also pointed out that such information sharing would have been most beneficial in routes where carriers had strong reciprocal relationships i.e. multiple carriers' overlapping markets characterized by presence of each other's hubs.

The objective of this paper is to analyze all tenets of competition in the U.S. airline industry within a comprehensive modeling framework. This is achieved by estimating market conduct parameters using a structural model of competitive behavior involving markets with endpoints which qualify as hubs of network carriers. Only a handful of studies such as Brander and Zhang (1990), Oum, Zhang and Zhang (1993), Fischer and Kamerschen (2003) have explicitly estimated the nature of conduct that exists in airline markets in general and more specifically those involving hubs of legacy carriers. Our present study adds to the empirical analysis of such market conduct in the U.S. airline industry in several ways. First of all, these existing studies have assumed airline products as homogeneous and thus ignored the presence of the widely accepted notion of product differentiation in the industry. Airline services have long been viewed as differentiated products (Berry, 1990). Demand models estimating consumer preferences for air travel products have accounted for product attributes such as stop v/s nonstop flights, number of connections, airline's presence in endpoint airports etc. which significantly affect consumers' choice of airlines and related itineraries. Building on the discrete choice empirical literature in the airline industry, in the spirit of Berry, Carnall and Spiller (1996) (hereafter, BCS), Gayle (2006), Aguirregabiria and Ho (2012), Berry and Jia (2010) and Brown and Gayle (2014), we consider an oligopolistic framework in which airlines, offering differentiated products and facing asymmetric costs, maximize profit by setting prices. Product differentiation is also an important determinant of market power in that airlines develop a wide range of products to create their market niches. Market structure is identified by the conduct parameters, which capture the interaction of price setting behaviors among airlines. Instances of either fierce price wars (Busse, 2002) or price coordination (Borenstein, 2004) common in the airline industry also justify a price setting oligopoly framework rather than quantity setting behavior. Bilotkach (2005) also discusses why a price setting oligopoly might be appropriate for the airline industry. A structural model of differentiated oligopoly also enables us to systematically separate out effects of demand, cost and strategic factors on observed airline prices. Further, in contrast to duopoly markets out of a single hub considered in the previous literature, we consider hub-to-hub markets where both market endpoints constitute a hub city of some network carrier. Our motivation in favor of such market selection is reinforced by the fact that the strategic effect of a hub airport on an

airline's pricing decision can be strengthened by realization of reciprocal territorial interests that are created by the overlap of such hub markets, an aspect not explored by previous studies on airline conduct. Finally our study also allows us to explore the strategic importance of network carrier hubs on airline market conduct simultaneously recognizing the overgrowing role played by LCCs in disciplining markets through intense competition. LCC competition in the U.S. airline industry has been extensively documented by Dresner and Windle (1999), Ito and Lee (2003), U.S. Department of Transportation (1993, 2001), Brueckner, Lee and Singer (2013) and others. Our model set up will allow us to jointly estimate two conduct parameters in hub-to-hub markets - one in markets where LCCs directly compete head-to-head with legacy carriers and the other for markets which LCCs do not serve but have presence in the hub airports or adjacent airports comprising the market endpoints. Thus this paper also sheds some light on the role of actual vs. potential competitive effect of LCCs on market conduct, a topic which has been the cornerstone of previous studies on airline market contestability like Dresner, Lin and Windle (1996), Morrison (2001) and Goolsbee and Syverson (2008).

The remainder of the paper is organized as follows. In the next section we outline the structural model of airline demand, supply and finally incorporate competitive interactions to enable estimation of conduct parameters. In Section 3 we overview the data and depict the estimation procedure with a focus on identification issues. Results are presented in Section 4. Section 5 concludes the paper.

2. The Model

We first discuss the structural specification of the demand model for airline products. Then we lay out the supply side and subsequently specify the marginal cost of production. Finally we augment the supply side in order to incorporate competitive interactions among airlines in equilibrium.

2.1. Demand Specification

A market is defined as a directional city-pair consisting of an origin city and a destination city. This allows the characteristics of origin and destination cities to affect demand. Further the market definition based on city pairs instead of airport pairs turns out to be an important aspect for this current study. This is because sometimes some LCCs typically avoid the congested hub airports and choose smaller secondary airports to serve markets based on these important hub cities e.g. instead of Dallas/Fort Worth International Airport (DFW) which is a hub airport for American Airlines, Southwest chooses the much smaller airport Dallas Love Field (DAL) to fly markets comprising of Dallas/Ft. Worth as an endpoint city. On the demand side this allows for substitution of airports and

airlines by passengers while on the supply side this enables an airline to potentially compete with a major hub airline without even physically serving the hub airport itself. Within each market a product is defined as a round-trip between the origin and the destination cities involving a unique combination of a ticketing carrier and flight itinerary. An itinerary consists of an origin, destination and intermediate airports that the passenger travels through. An example of three products in the Chicago-Washington D.C. market are:

- a non-stop ticket with itinerary ORD-DCA:DCA-ORD marketed by American Airlines,
- a two-stop itinerary MDW-CVG-DCA:DCA-CVG-MDW marketed by Delta Airlines and
- a non-stop itinerary ORD-IAD:IAD-ORD marketed by United Airlines.

It should be noted, however, that we do not further differentiate products of identical itinerary-airline combination but having different prices to avoid estimation problems that will arise with extremely small product market shares.

In the spirit of BCS (1996), Berry and Jia (2010) and Brown and Gayle (2014), we model air travel demand using a discrete choice framework. In particular, we assume that a potential passenger n in market t chooses between $J_{(t+1)}$ alternatives where $j=0$ is the outside good representing the passenger's option of not buying any of the J_t products. The outside option also represents alternative modes of transportation that the consumer might choose to travel between the origin and destination. Then the products in each market can be broadly partitioned into two mutually exclusive and exhaustive groups, $g \in \{0,1\}$, where the outside option is the only member of group 0. Following this specification, consumer n 's indirect utility from product j in market t can be represented as

$$u_{njt} = \delta_{jt} + \zeta_{ngt} + (1-\sigma) \varepsilon_{njt} \tag{1}$$

where δ_{jt} is the mean valuation of product j across passengers in market t . The term ζ_{ngt} captures the random component of utility that is common to all products in group g while ε_{njt} is a consumer and product specific idiosyncratic error term, the sum of which thus represents the deviation of an individual passenger's utility around the mean product valuation. The parameter σ lies between 0 and 1 and captures the correlation in consumers' utility among products belonging to the same group. Higher values of σ imply that the consumer views products in different nests, here flying or not flying, as poor substitutes. The mean utility δ_{jt} from product j is expressed as a function of price and non-price characteristics of the product as follows

$$\delta_{jt} = x_{jt}\beta - \alpha p_{jt} + \zeta_j + \Delta \xi_{jt} \tag{2}$$

where x_{jt} is a vector of observed product characteristics (number of stops in the itinerary, the airline's scale of operation in the origin and destination airports), β is a vector of marginal utilities of the different characteristics included in x_{jt} , p_{jt} is the ticket price and α measures marginal disutility of price. ξ_j are airline fixed effects controlling for carrier specific product characteristics which are common across markets while $\Delta\xi_{jt}$ accounts for any remaining product characteristics which are unobserved by the researcher and takes on a value that sets observed market shares equal to those predicted by the model. This differentiated product assumption is vital since the goal of the model is to analyze competition between carriers in hub-to-hub markets. Berry (1990) and BCS (1996) show that passengers value the size of a hub carrier's network and this superior product quality explains much of the hub premium, the premium a carrier is able to charge on itineraries originating or terminating at its hub airport.

Assuming both ε_{ijt} and $\varsigma_{ngt} + (1-\sigma)\varepsilon_{ijt}$ are type I extreme value random variables, the respective product market shares can be transformed following Berry (1994) to yield the following linear estimation equation

$$\ln(s_{jt}) - \ln(s_{0t}) = x_{jt}\beta - \alpha p_{jt} + \sigma \ln(\bar{s}_{j/gt}) + \xi_j + \Delta\xi_{jt} \quad (3)$$

where s_{jt} represents product j 's market share, s_{0t} , the share of the outside good, and $\bar{s}_{j/gt}$ the group share of product j . The demand for product j in market t is given by

$$q_{jt}(\mathbf{x}_t, \mathbf{p}_t, \Delta\xi_{jt}; \theta_d) = M_t s_{jt}(\mathbf{x}_t, \mathbf{p}_t, \Delta\xi_{jt}; \theta_d) \quad (4)$$

where \mathbf{x}_t and \mathbf{p}_t are respectively the vectors of observed non-price product characteristics and price, $\Delta\xi_{jt}$ is a vector of unobserved product characteristics, M_t the market size and $\theta_d = (\beta, \alpha, \sigma)$ is the vector of demand parameters to be estimated.

2.2. Supply and Marginal Cost Specification

There are F multiproduct firms in T markets. In each market t a firm f sells a subset J_{ft} of the total set of J_t products sold in market t . Assuming price-setting behavior, the variable profit of firm f in a market is given by

$$\pi_f = \sum_{i \in J_f \cap V_g} (p_i - c_i) M s_i(\mathbf{x}, \mathbf{p}, \Delta\xi; \theta_d) \quad (5)$$

where c_i is the marginal cost of product i , which is assumed to be constant with respect to the quantity sold and V_g is the set of products in nest g . It is to be noted that we drop the market subscript t in order to avoid notational clutter; hence all subsequent equations are to be treated as if they are indexed by t .

We do not have data for marginal cost, so they need to be estimated in order to make identification of the conduct parameters possible. We specify marginal cost of product j using the functional form below following the linear marginal cost specification outlined by Aguirregabiria and Ho (2012) and Berry and Jia (2010).

$$c_j = W_j \gamma + \eta_j + \omega_j \tag{6}$$

where W_j is a vector of observed variables that shift cost (number of stops in the itinerary, itinerary distance and hub status of origin and destination airports), η_j are product fixed effects (airline dummies) capturing market invariant components of airline's products' marginal cost, ω_j is a random error term capturing unobserved (to the researcher) idiosyncratic factors affecting costs and γ is a vector of unknown cost parameters to be estimated.

2.3. Competitive Interactions

In the spirit of Sudhir (2001) and Verboven (1996), the degree of competition or market conduct is measured by the extent to which equilibrium prices deviate from Bertrand-Nash prices. We implement this by augmenting the profit function in equation 5 as follows

$$\pi_j = \sum_{i \in J_j \cap V_s} (p_i - c_i) Ms_i + \varphi_k \sum_{i \notin J_j \cap V_s} (p_i - c_i) Ms_i \tag{7}$$

where φ_k is the weight that an airline puts on its competitors' profits. A similar exposition is also presented in Bresnahan (1987). This specification has the convenient property of nesting both Bertrand and collusive outcomes as special cases when φ_k takes values of zero and one respectively. At the same time, $\varphi_k > 0$ will imply more cooperative behavior relative to Bertrand as the firm puts positive weights on its competitors' profits whereas $\varphi_k < 0$ will imply more aggressive behavior relative to Bertrand. Since we are interested in exploring conduct in the presence and absence of LCCs in the market, we allow the conduct parameter to capture different weights in these different scenarios by indexing it with k . Thus k refers to two market groups namely markets with LCCs and markets without LCCs.

Assuming a pure strategy Nash equilibrium exists at strictly positive prices, we can express the first-order profit maximizing conditions as

$$\frac{\partial \pi_j}{\partial p_j} = s_j + \sum_{i \in J_j \cap V_s} (p_i - c_i) \frac{\partial s_i}{\partial p_j} + \varphi_k \sum_{i \notin J_j \cap V_s} (p_i - c_i) \frac{\partial s_i}{\partial p_j} = 0, \quad \forall j \in J_j \cap V_g \tag{8}$$

If there are a total of J products taken all markets together, then we have J first order conditions which can be summarized in vector form as follows

$$\mathbf{p} = \mathbf{c} + \underbrace{[\Delta(\mathbf{p}) * (\Theta^{\text{own}} + \sum_k \Psi_k^{\text{comp}})]^{-1}}_{\text{Markup}} \mathbf{s}(\mathbf{p}) \tag{9}$$

where $\Delta(\mathbf{p})$ is a $J \times J$ matrix of first-order derivatives of product market shares with respect to prices, * implies Hadamard product of two matrices, Θ^{own} and Ψ_k^{comp} are $J \times J$ ownership matrices defined as

$$\Theta^{\text{own}}(i, j) = \begin{cases} 1 & \text{if } i \text{ and } j \text{ belong to the same airline} \\ 0 & \text{otherwise} \end{cases}$$

and

$$\Psi_k^{\text{comp}}(i, j) = \begin{cases} \varphi_k & \text{if } i \text{ and } j \text{ are distinct products offered by different} \\ & \text{airlines and belong to the same market group } k \\ 0 & \text{otherwise} \end{cases}$$

We follow Goldberg (1995) and Verboven(1996) in assuming that a pure strategy Nash equilibrium exists and proceed below to derive the pricing equation.

For the nested logit model, the supply side pricing equation has a closed form which can be brought into data for estimation. The pricing equation for product j belonging to firm f in a market is given by

$$p_j = c_j + \frac{1}{\alpha \left[\frac{1}{1-\sigma} - L_g \left(\sum_{i \in J_j \cap V_g} q_i + \varphi_k \left(1 - (1-\varphi_k)(1-\sigma) L_g \sum_{i \in J_j \cap V_g} q_i \right) Y_g \right) \right]} \tag{10}$$

where $L_g = \frac{1}{M} + \frac{\sigma}{(1-\sigma) Q_g}$ and $Y_g = \sum_{\substack{c \in F \\ c \neq f}} \frac{Q_c}{1 - (1-\varphi_k)(1-\sigma) L_g Q_c}$ such that Q_g and Q_c are the sums of quantities of all products in nest g and products belonging to firm c in nest g respectively. Substituting equation 6 in equation 10 yields the following estimable equation

$$\omega_j = p_j - \frac{1}{\alpha \left[\frac{1}{1-\sigma} - L_g \left(\sum_{i \in J_j \cap V_g} q_i + \varphi_k \left(1 - (1-\varphi_k)(1-\sigma) L_g \sum_{i \in J_j \cap V_g} q_i \right) Y_g \right) \right]} - W_j \gamma - \eta_j \tag{11}$$

Specifically, $\theta_s = (\gamma, \Phi_{LCCMkt}, \Phi_{Non-LCCMkt})$ is the vector of parameters we estimate on the supply side where Φ_{LCCMkt} and $\Phi_{Non-LCCMkt}$ are the conduct parameters for markets with and without LCCs respectively.

3. Data and Estimation Procedure

3.1. Data

Data employed in this analysis is drawn from the DB1B market survey which is a quarterly 10% random sample of all itineraries published by the U.S. Department of Transportation. Three separate databases of DB1B namely DB1B-Coupon, DB1B-Market and DB1B-Ticket were used for this paper. DB1B-Coupon provides information at the coupon or boarding pass level, DB1B-Market reports one directional origin-destination itinerary specific data while DB1B-Ticket consists of summary information for the entire trip of the passenger. Altogether these datasets provide information, among other things, on operating and ticketing carriers, origin and destination airports, sequence of intermediate airports, number of passengers transported, distance flown and fare paid. Data was collected for the first quarter of 2004 and the three databases were merged using the unique Itinerary ID common in all these datasets.

Since our paper is about competition in hub-to-hub markets, we confine the dataset to observations where origin and destination cities qualify as U.S. hub cities for the major network carriers. In case of stop flights, we consider only those itineraries which involve intermediate airports in the 48 U.S. contiguous states. We drop observations where either the operating or the ticketing carrier is a foreign airline. Following Berry and Jia (2010) and Gayle (2006), firm assignments are done according to the ticketing carrier. We use the fare screen in the DB1B data set to eliminate tickets with possible coding errors. We also drop itineraries with extremely high or low fares and those which cannot be correctly identified as round trips. We keep tickets with a maximum of five coupons. Finally we only consider tickets where the ticketing carrier is the same for the different segments of the itinerary. Our final set of ticketing carriers is presented in Table 1 where we group them according to their type i.e. legacy carrier or LCC.

Legacy Carriers	
Carrier Name	Carrier Code
American	AA
Alaska	AS
Continental	CO
Delta	DL
Northwest	NW
United	UA
US Airways	US
Midwest	YX
LCCs	
Carrier Name	Carrier Code
JetBlue	B6
Frontier	F9
Airtran	FL
America West	HP
Spirit	NK
Sun Country	SY
ATA	TZ
Southwest	WN

Table 1. List of Legacy and Low Cost Carriers

Table 2 provides a list of hubs of the legacy carriers. In the same table we also report the hub cities in which these hub airports are located and whose combinations make up the markets in our sample. In this paper we consider markets comprised of hubs of only airlines classified as major carriers by the U.S. Department of Transportation i.e. those with annual operating revenues of more than \$1 billion. Since Midwest Airlines does not fall under this category we do not explicitly consider hubs of Midwest, although we keep the carrier in our analysis. On the other hand, Alaska Airlines concentrates most of its business in Seattle, Portland, Los Angeles and Anchorage with 68% of its total in and outbound traffic being generated in Seattle (2004 Annual Report). Thus, in spite of being a major carrier, Alaska gets underrepresented in our sample which prevents us from using hubs of Alaska as part of our market consideration. For our paper we restrict ourselves to markets formed by hubs of the six largest major carriers following Lee and Luengo-Prado (2005).

Airline	Hub City (State)	Hub Airport (Code)
AA	Dallas/Ft. Worth (TX)	Dallas/Ft. Worth Int'l (DFW)
	Chicago (IL)	O'Hare Int'l (ORD)
	Miami (FL)	Miami Int'l (MIA)
	St. Louis (MO)	Lambert-Louis Int'l (STL)
CO	New York/Newark (N.Y./N.J.)	Newark Liberty Int'l (EWR)
	Houston (TX)	GeorgeBush Intercontinental (IAH)
	Cleveland (OH)	Cleveland-Hopkins Int'l (CLE)
DL	Atlanta (GA)	Hartsfield Jackson Int'l (ATL)
	Cincinnati (OH)	Cincinnati-N. Kentucky Int'l (CVG)
	Salt Lake City (UT)	Salt Lake City Int'l (SLC)
NW	Detroit (MI)	Detroit Metro (DTW)
	Minneapolis/St. Paul (MN)	Minneapolis/St.Paul Int'l (MSP)
	Memphis (TN)	Memphis Int'l (MEM)
UA	Chicago (IL)	O'Hare Int'l (ORD)
	Denver (CO)	Denver Int'l (DEN)
	San Francisco (CA)	San Francisco Int'l (SFO)
	Washington D.C. (DC)	Dulles Int'l (IAD)
	Los Angeles (CA)	Los Angeles Int'l (LAX)
US	Philadelphia (PA)	Philadelphia Int'l (PHL)
	Charlotte (NC)	Charlotte Douglas Int'l (CLT)
	Pittsburgh (PA)	Pittsburgh Int'l (PIT)

Source: Form 10-K and Annual Reports of the different airlines for 2004

Table 2. Hubs of Legacy Carriers (2004)

After our initial filtering of the data, we still find similar airline-itinerary observations with different fares. This reflects the commonly practiced yield management techniques by the airlines. Since we do not have information on such ticket specific restrictions and further to make estimation manageable, we collapse the data by aggregating passengers to the level of unique airline and itinerary combination. Thus our product is a unique combination of the origin airport, the intermediate connecting airports, the destination airport, the ticketing carrier and the passenger weighted average ticket *Price* for the airline-itinerary combination. Our final sample has 15,828 products offered across 372 directional hub-to-hub markets.

The variables which we construct to be included on the demand side in the vector of observed product characteristics are - *Stops* which is the total number of stops in the itinerary, and *AirlinePresenceOrigin* and *AirlinePresenceDest* based on the number of cities that a ticketing carriers connects to from the origin and destination airports respectively by non-stop flights. Population figures from the U.S. Census Bureau is used to calculate the potential market size *M* which we assume to be the geometric mean of the population of the origin and destination cities that comprise the market. To control for the fact that appeal of the outside option can be different for different markets originating from the same city, we use controls for vacation oriented markets. *Vacation* is a dummy variable which takes a value of 1 for tourist oriented destinations. Variables which we include in the marginal cost specification other than

Stops are - *ItinDistance* i.e. roundtrip distance traveled by the passenger and a *Hub* dummy capturing whether the origin or destination airport is a hub for the airline.

Summary statistics of our sample is presented in Table 3. We notice substantial heterogeneity in the airlines' scale of operation in origin and destination airports as well as in the hub variable thus showing the dominant positions held by some carriers in their hub airports.

Variable	Mean	Std. Dev.	Min	Max
Price (\$100)	4.81	3.37	0.50	45.18
Stops	1.72	0.73	0	3
AirlinePresenceOrigin (100 cities)	0.44	0.41	0	1.44
AirlinePresenceDest (100 cities)	0.46	0.42	0	1.44
Vacation	0.27	0.44	0	1
ItinDistance ('000 miles)	3.21	1.38	0.19	7.82
Hub	0.59	0.49	0	1
Product market share (%)	0.34e ⁻²	0.02	0.18e ⁻⁴	0.53
Firm market share (%)	16.38	24.42	0.02	99.60
Market size (100K)	10.34	8.36	2.38	56.97

No. of Observations: 15,828

Source: Author's calculations.

Table 3. Summary Statistics

The firm market share also reveals some important information about the nature of hub-to-hub markets. The high standard deviation of this variable reveals the fact that some hub carriers manage to disproportionately attract more passengers departing from or arriving at their hub airports. In order to gain some insight regarding the exposure of hub network carriers to LCCs in their hub airports (or adjacent airports in case of multi-airport cities), we take a look at Table 4.

It is evident from the table that LCCs have established their presence in all hub cities of network carriers with the exception of Cincinnati. This has been achieved through either directly offering service from the hub airport or in some cases adjacent airports in the same city. Table 5 further illustrates the extent of LCC penetration in hub-to-hub markets that originate from or terminate into different hub cities of network carriers. Both Tables 4 and 5 clearly reveal the nature of actual and potential competition that network carriers face in their hub airports.

Hub City	Hub Airport	LCC in Hub Airport	Other Airport in City	LCC in Other Airport
Atlanta	ATL	F9, FL, HP	None	None
Charlotte	CLT	TZ	None	None
Chicago	ORD	HP, NK	MDW	F9, FL, TZ, WN
Cincinnati	CVG	None	None	None
Cleveland	CLE	HP, WN	None	None
Dallas/Ft. Worth	DFW	F9, FL, HP, SY, TZ	DAL	WN
Denver	DEN	B6, F9, FL, HP, NK, SY, TZ	None	None
Detroit	DTW	HP, NK, WN	None	None
Houston	IAH	F9, HP, WN	HOU	FL, WN
Los Angeles	LAX	F9, FL, HP, NK, SY, TZ, WN	None	None
Memphis	MEM	FL, HP	None	None
Miami	MIA	FL, HP, SY, TZ	None	None
Minneapolis/St. Paul	MSP	F9, FL, HP, SY, TZ	None	None
New York/Newark	EWR	FL, HP, TZ	JFK	B6, HP, SY
			LGA	F9, FL, NK, TZ
Philadelphia	PHL	FL, HP, TZ	None	None
Pittsburg	PIT	FL, HP, TZ	None	None
Salt Lake City	SLC	B6, F9, HP, WN	None	None
San Francisco	SFO	F9, FL, HP, TZ	None	None
St. Louis	STL	F9, HP, WN	None	None
Washington D.C.	IAD	FL, HP	DCA	F9, FL, HP, TZ

Table 4. LCC Presence in Hub Cities of Network Carriers (2004)

Hub City	% of O&D H-H markets served by LCCs	Number of LCCs in Hub City
Atlanta	73.68	3
Charlotte	31.58	1
Chicago	94.74	6
Cincinnati	0	0
Cleveland	36.84	2
Dallas/Ft. Worth	78.95	6
Denver	94.74	7
Detroit	42.11	3
Houston	89.47	4
Los Angeles	94.74	7
Memphis	68.42	2
Miami	73.68	4
Minneapolis/St. Paul	78.95	5
New York/Newark	63.16	7
Philadelphia	57.89	3
Pittsburg	55.26	3
Salt Lake City	84.21	4
San Francisco	92.11	4
St. Louis	47.37	3
Washington D.C.	57.89	4

Note: O&D H-H markets represent all hub-to-hub markets formed with the hub city as either origin or destination of a roundtrip travel.

Source: Author's calculation from DB1B sample.

Table 5. Hub-to-Hub Market Coverage of LCCs from each Hub City (2004)

3.2. Identification

On the demand side, equilibrium prices and market shares will depend on both observed and unobserved product characteristics. Thus although unobserved to the researcher, the contemporaneous demand shock $\Delta\xi_j$ will be observed by market participants. As a result price and within group market shares will be correlated with the error term and thus OLS estimates of both α and σ will be biased. To overcome this problem we use an instrumental variable technique to estimate the parameters of the model. The best candidates for instruments in the differentiated products case are the product characteristics themselves, which are usually treated to be exogenous, based on the assumption that in the short run they cannot be quickly adjusted by a firm. Our choice of the second set of instruments is based on the proposition by Berry, Levinsohn and Pakes (1995) (hereafter, BLP). They suggest functions of the exogenous characteristics of competitors can qualify as instruments since they affect the competitive environment in the market and thus pricing decision of the firm while being uncorrelated with the carrier's demand shock. In this spirit we include the means and sums of rival carriers' origin and destination airport presences as well as number of competitors and total number of competitor products in the market with equivalent number of intermediate stops as instruments. Another identification strategy relies on variables that shift marginal cost but does not affect demand. Based on this argument itinerary distance qualifies as a valid candidate for the instrumental vector. Motivated by supply theory of multiproduct pricing, we also include total number of products with equivalent number of stops offered by the firm in the market as valid instruments. To enhance identification we also use dummies for vacation-oriented destinations. Finally in addition to the exogenous product characteristics, all the exogenous variables appearing in the share equation are included in the instrument vector Z_d since they are correlated with themselves but uncorrelated with the error term $\Delta\xi_j$.

On the supply side in the pricing equation, the structural error term ω_j which captures the unobserved components of marginal cost is expected to be correlated with price. Moreover the markup term in the pricing equation is a function of shares which themselves are functions of prices. Hence the markup term is also likely to be endogenous. Our supply side instrument vector Z_s includes all the excluded instruments that we use on the demand side other than itinerary distance based on a similar logic. Additionally all exogenous variables in the pricing equation also form a part of Z_s .

Based on equation 11, it can be seen that assessment of market power and hence choice of the appropriate oligopoly pricing model fundamentally rests on the substitution patterns generated by the demand model under consideration. Our choice of a nested logit demand specification is supported by the fact that it generates flexible substitution patterns necessary for reliable estimation of the supply

side. On the other hand, absence of publicly available marginal cost data imposes a further challenge in distinguishing between alternative models of oligopoly competition (Bresnahan, 1982). Specifically, an identification problem arises in discerning whether higher marginal costs or higher values of conduct parameter rationalize higher observed prices. Based on the intuition of Bresnahan (1982) and recent work by Berry and Haile (2014), changes in the “market environment” can be used to distinguish between competing models of oligopoly conduct based on changes in firms' incentive to collude. We believe that our current distinction of hub-to-hub markets with and without LCCs provides such an opportunity to enable identification of conduct parameters on the supply side.

3.3. Estimation

Our estimation of both demand and supply side parameters rests on the critical assumption that the structural error terms are orthogonal to the vector of instruments i.e. $E[\Delta\xi_j | Z_d] = 0$ and $E[\Delta\omega_j | Z_s] = 0$. There is some efficiency gain if demand and supply are estimated jointly (BLP 1995). But on the other hand a step-by-step estimation reduces the computational burden of the estimation. At the same time the demand side identification in such a procedure becomes independent of the specification of the supply side functional form. Lastly it also reduces the need for a vast set of instruments that is demanded in the joint estimation of the parameters of the system. This is because identification of the model parameters requires the rank of the instrumental variables matrix to be at least as large as the number of parameters to be estimated. Following Nevo (2001) and Goldberg and Verboven (2001), we first estimate the demand system and use the estimated demand parameters to construct the matrix $\mathbf{\Delta}(\mathbf{p})$ of own and cross price derivatives. Then we substitute this matrix into the pricing equation to estimate the supply side parameters subsequently.

Since the share equation is linear in parameters, the demand side is estimated using a two stage least squares (2SLS) procedure. On the other hand the supply parameters enter the pricing equation in a highly nonlinear fashion. As a result we use a nonlinear Generalized Method of Moments (GMM) procedure to estimate the pricing equation. We exploit the orthogonality condition of the error term ω_j to form moment conditions whereby the GMM routine estimates the vector of parameters which sets the sample analogue of the covariance of the errors and the instruments as close as possible to zero. In particular, the GMM estimate is given by

$$\hat{\theta}_s = \underset{\theta_s}{\operatorname{argmin}} \omega(\theta_s)' Z_s \Omega^{-1} Z_s' \omega(\theta_s) \quad (12)$$

where Z_i is a $N \times L$ matrix of supply side instruments such that N is the sample size, L is the number of instruments and Ω^{-1} is a positive definite optimal weight matrix.

4. Results

4.1. Demand Estimates

Results from the demand estimation are shown in Table 6. The noticeable difference in the magnitude of OLS and 2SLS estimates of *Price* and $\ln(\bar{s}_{igt})$ illustrates the endogeneity of these variables. All coefficient estimates are statistically different from zero at 1% level of significance. As expected, *Price* has a negative impact on consumers' mean valuation of airline products. Estimate of σ lies between 0 and 1, implying that our model is consistent with the principles of random utility maximization. This indicates that air travel products within a market are viewed as better substitutes than the outside option. The negative coefficient on *Stops* depicts the inherent inconvenience associated with itineraries with connecting flights. Both *AirlinePresenceOrigin* and *AirlinePresenceDest* affect consumers' utility positively thus indicating consumers' preference of flying with an airline having larger scales of operation at origin and destination airports. Such preference is likely to be based on convenient flight schedules, airport facilities and loyalty programs associated with the airline. Finally, the positive *Vacation* coefficient shows that tourist oriented cities attract more consumers.

Our nested logit model yields a median elasticity of 1.91 which is slightly higher than found by earlier studies estimating random utility models of airline products like Berry and Jia (2010). Such a difference is likely to arise because Berry and Jia (2010) estimates a more flexible random coefficient model allowing for two types of passengers with different price sensitivities. On the other hand our current analysis is based on only a subset of markets namely hub-to-hub markets instead of a larger set of markets as considered in the other studies. However our elasticity value lies within the reasonable range of 0.181 to 2.01 as reported by a survey of air travel demand elasticities conducted by Gillen, Morrison and Stewart (2008).

Variable	OLS		2SLS	
	Est.	S.E.	Est.	S.E.
Price	-0.035	0.002	-0.200	0.012
$\ln(s_{igt})$	0.774	0.003	0.614	0.007
Stops	-0.245	0.009	-0.354	0.015
AirlinePresenceOrigin	0.264	0.014	0.568	0.033
AirlinePresenceDest	0.098	0.014	0.168	0.023
Vacation	0.350	0.013	0.259	0.018
Constant	-7.650	0.117	-7.992	0.157
R-squared:	0.847		0.736	
Observations:15,828				

Note: All estimations include airline dummy variables although the coefficient estimates of the dummy variables are not reported for brevity. All estimates are significant at 1% level.

Table 6. Demand Parameter Estimates

4.2. Estimates of Marginal Cost and Conduct Parameters

We report our GMM estimates from the pricing equation in Table 7. All coefficients of our marginal cost specification have the expected signs and are significant at conventional levels of statistical significance. In fact the signs of our marginal cost parameters are in accord with earlier studies such as Berry and Jia (2010).

Variable	Est.	S.E.
Marginal Cost Shifters		
Stops	0.367	0.041
ItinDistance	0.298	0.031
Hub	-0.370†	0.176
Constant	1.026	0.267
Conduct Parameters		
$\Phi_{Non-LCCMkt}$	-0.736	0.188
Φ_{LCCMkt}	-1.308	0.150
Observations: 15,828		

Note: Estimation includes airline dummy variables. All estimates are significant at 1% level except † which indicates statistical significance at 5% level.

Table 7. GMM Estimates from Pricing Equation

The positive coefficient on *Stops* implies that connecting flies are more expensive to operate than non-stop flights. Berry and Jia (2010) argues that there are two countervailing factors which affect the marginal cost of connecting flights. On one hand load consolidation by pooling passengers with different destinations through the connecting airport can lead to economies of density thus resulting in lower marginal costs. But on the other hand more connections imply more takeoffs and landings which can lead to higher costs due to increased fuel consumption. Our results indicate that the net effect of these two factors is positive which might be a consequence of higher fuel prices during the sample

period offsetting any efficiency gain from economies of traffic density resulting from connecting flights. The coefficient on the *Hub* dummy is negative indicating marginal cost is lower for airlines flying into and out of their hub airports. Thus in spite of presence of congestion and delays in hub airports, airlines seem to exploit economies of scale in these airports by flying larger fuel efficient aircrafts. Finally, as expected, longer routes have higher marginal costs.

Next we look at the estimated conduct parameters from the pricing equation which is the focus of our current paper. Both the competitive interaction parameters $\Phi_{Non-LCCMkt}$ and Φ_{LCCMkt} are negative and statistically significant. This implies that competition is more aggressive than the Bertrand benchmark in hub-to-hub markets with and without LCC presence, with the degree of aggressiveness heightened in markets served by LCCs. Our results corroborate the critical role played by LCCs in disciplining airline markets, both in form of actual and potential competition. We further check whether the nature of such aggressive competition is uniform across all hub-to-hub markets i.e. formally we test whether $\Phi_{Non-LCCMkt}$ is statistically equal to Φ_{LCCMkt} . We test the null hypothesis $H_0: \Phi_{Non-LCCMkt} = \Phi_{LCCMkt}$ against the alternative hypothesis $H_1: \Phi_{Non-LCCMkt} > \Phi_{LCCMkt}$. The z score calculated is found to be 2.527 which is higher than the critical z value at 1% level of significance, thus leading to the rejection of H_0 in favor of H_1 . Our test results indicate that the two conduct parameters are not statistically equivalent to each other thus implying that extent of aggressive competition is softened in the absence of LCCs. This further lends support to the idea that potential competition by LCCs is not a perfect substitute for actual competition.

5. Conclusion

This paper explicitly estimates conduct parameters in hub-to-hub airline markets i.e. markets characterized by presence of network carrier hub airports at both market endpoints prior to the onset of the merger wave of the network carriers in the 2000s. In order to highlight the growing importance of LCCs in shaping market conduct, we further distinguish between conduct in markets with and without LCC service. In doing so this paper acknowledges the prevalence of product differentiation and price setting behavior in the airline industry by utilizing a structural econometric framework for differentiated products with competitive interactions. The empirical results indicate that the nature of competition is more aggressive relative to Bertrand behavior in hub-to-hub markets. The competitive intensity is also found to be higher in markets actually served by LCCs compared to those where LCCs are potential entrants thus implying that airline markets are less than perfectly contestable. Given the sample period of this study, our results shed light on the strategic importance of hubs during an era of

changing landscape of airline competition and raises questions regarding the impact of such intense competition on the economic sustainability and organizational structure of the industry in the future.

Deregulation of the airline industry has resulted in substantial consumer benefits but the extensive growth of legacy carrier hubs had raised the concern that industry competition is less than perfect. But since 2000 industry conditions have changed dramatically which have led to acute financial distress for the legacy carriers. Intense competition coupled with high fixed costs and increasing burden of labor and fuel expenses in the face of declining industry demand attributed to the declining margins of network carriers. In fact legacy carriers also started to lose their strong foothold in their respective hub airports. Borenstein (2005) reports a 12% decline in hub premium in the 10 most expensive airports in the nation between 1995 and 2004. In fact many of these hubs which were long believed to insulate network carriers from aggressive competitors and further provide cost efficiency turned out to be unprofitable and costly to operate. Consequently some legacy carriers were forced to de-hub some of the least efficient hub airports e.g. U.S. Airways dismantled its hub status in Pittsburg later during 2004 while Delta de-hubbed from Cincinnati-N. Kentucky in 2006. On the other hand the LCCs responded to the new market opportunities and emerged as a stronger player in the marketplace.

Our results indicate that the U.S. airline industry in the 2000s has been most competitive like never before. Based on the ever growing role played by LCCs in disciplining the industry, Alfred Kahn (1988), the chief advocate of airline deregulation, quoted this trend as “an illustration of competition doing exactly what we hoped and expected it to do”. But the financial distress of network carriers amidst this competitive environment raises important questions regarding the organizational structure and long-run equilibrium in the industry. Although the proponents of deregulation envisioned that deregulation may pave the path of convergence towards a long run competitive equilibrium, it is unclear whether such a market structure is sustainable in the airline industry. As Borenstein and Rose (2008) argue that although a case of “destructive competition” is not warranted, it is apparent only time will tell what market structure evolves in the long run as the industry reorganizes and stabilizes from this current wave of massive consolidation.

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