THREE ESSAYS IN INDUSTRIAL ORGANIZATION: ALLIANCES, MERGERS, AND PRICING IN COMMERCIAL AVIATION

by

DAVID R. BROWN

B.A., Hastings College, 2005

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Economics
College of Arts and Sciences

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2010

Abstract

My research focuses primarily on industrial organization and applied microeconomics. Specifically, I have extensively studied the airline industry.

My first essay considers the effect of the Delta/Continental/Northwest codeshare alliance. Codeshare agreements can benefit airlines due to network expansion and benefit consumers by eliminating a double markup on flight itineraries with multiple operating carriers. However, policymakers have expressed concern that an alliance between airlines may facilitate price and service collusion in markets where codeshare partners' services overlap. I develop a structural econometric model that is able to separately identify supply and demand factors as sources of price-quantity changes caused by the creation of the alliance. The estimates from the model show both collusive and demand increasing effects associated with the codeshare alliance. However, the demand increasing effect is larger than the collusive effect.

My second essay considers the effects of the recent Delta/Northwest merger. This merger is of particular interest because the two airlines are codeshare partners. Using pre-merger data, a counterfactual simulation is performed in which Delta and Northwest are assumed to merge. The results indicate that codeshare products owned by the merging firms experience higher predicted price increases relative to pure online products. In addition, the mean predicted price increases are relatively small across most markets. I also examine pre-merger predictions with post-merger data and analysis and find that the pre-merger predictions roughly accord with "de-merger" simulated effects using post-merger data.

My third essay takes an extended look at airline mergers. When the Delta/Northwest merger was approved by the Department of Justice, consumer groups and policymakers were concerned that the merger and poor economic outlook would act as a catalyst for more mergers. This paper examines this possible scenario using simulations to model the effects of other codeshare partners merging in addition to Delta and Northwest. Results indicate that the predicted price increases for all mergers exhibit relatively small averages but large variances across markets. Further, the largest predicted price increases affect a small percent of products and an even smaller percent of passengers who choose products owned by a merging firm.

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Approved by:

Major Professor
Philip G. Gayle

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CHAPTER 1 - Airline Strategic Alliances in Overlapping Markets: Should Policymakers be Concerned?

1.1 INTRODUCTION

Policy analysts have expressed skepticism when reviewing airlines' applications to form a codeshare alliance in the event that such an alliance involves potential partners that have significant overlap in their route networks. The heart of the concern is that these potential partners are direct competitors in the segments of their networks that overlap, and an alliance between them, which often requires broad discussions between partners to make their interline[1] service seamless, could facilitate collusion (explicit or tacit) on prices and/or service levels in the partners' overlapping markets. Before ultimately approving the Delta/Continental/Northwest alliance, which was formed in June 2003, the U.S. Department of Transportation (DOT) expressed these concerns.[2] The DOT's review of this proposed alliance points out that the three airlines' service overlap in 3,214 markets accounting for approximately 58 million annual passengers, which is in contrast to the next largest alliance between United Airlines and US Airways with overlapping service in only 543 markets accounting for 15.1 million annual passengers. So unlike much of the earlier literature that focuses on international airline alliances [Brueckner (2003), Brueckner and Whalen (2000), Bilotkach (2007)], we focus on a U.S. domestic alliance [Bamberger, Carlton and Neumann (2004), Armantier and Richard (2006), Armantier and Richard (2008), Ito and Lee (2007)].

The central question that this paper sets out to answer is: Has the Delta/Continental/Northwest alliance reduced competition between these carriers in their overlapping markets? Using a reduced-form econometric model similar to that in Bamberger, Carlton and Neumann (2004), Gayle (2008) has shed some light on this question. In particular, Gayle (2008) found that the alliance is associated with a marginal price increase, which by itself points to possible collusive effects. But a marginal price increase is also consistent with increased demand, and there is good reason to believe that an alliance has a demand-increasing

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[1] Interline means that at some point in the trip when passengers change planes they also change airlines.
[2] See "Termination of review under 49U.S.C. § 41720 of Delta/Northwest/Continental Agreements," published by Office of the Secretary, Department of Transportation, January 2003.

effect associated with it. For example, passengers that are members of an airline's frequent-flyer program may cumulatively earn and redeem frequent-flyer miles across any partner in the alliance. The new opportunities for passengers to earn and redeem miles will likely increase demand for the alliance partners' products. In fact, Gayle (2008) also found that the alliance is associated with increased traffic (measured by number of passengers), a finding which casts doubt on the effectiveness of collusive behavior if at all present.

It is important to note however, that Gayle's (2008) conjecture about the possible absence of collusive effects is based on the estimated change in equilibrium price and quantity over the pre- and post-alliance periods. While the approach is an informative and suggestive first step, it is not definitive in regards to ruling out collusive effects unless we are able to disentangle the demand and supply sources of the equilibrium price-quantity changes. In other words, we cannot be certain that the price and quantity increases are solely driven by demand-increasing factors of the codeshare alliance. If collusive effects are also present, then the quantity increase is smaller and price increase larger than they would have been were it not for collusion. So the main contribution of our present paper is to derive and estimate a structural econometric model that allows us to disentangle the demand and supply sources of equilibrium price-quantity changes that are associated with a codeshare alliance. Second, the ability to do welfare analysis in a straightforward way is another advantage of the structural econometric model in this paper compared to the reduced-form econometric model in Gayle (2008). Third, since our econometric model can be applied to study the market effects of codeshare alliances other than the Delta/Continental/Northwest alliance, this paper contributes to the methodology of analyzing the competitive effects of codeshare alliances.

Our key findings are as follows: First, the econometric estimates for the air travel demand equation suggest that the Delta/Continental/Northwest alliance has a demand-increasing effect associated with it. Second, the econometric estimates for the air travel supply equation suggest that the alliance is associated with a softening of competition between the three airlines in their overlapping markets relative to competition between other competing airlines in these markets. To the best of our knowledge, this is the first paper to explicitly isolate and find evidence of a collusive effect associated with a domestic codeshare alliance.

We must point out that we are not the first to present a structural econometric model to examine codeshare alliances. Armantier and Richard (2008) also use a structural econometric model to examine a codeshare alliance. However, a fundamental difference between our model and the model in Armantier and Richard (2008) is that we model both demand and supply aspects of codesharing, while Armantier and Richard (2008) only model the demand side. This crucial methodological difference affords us the advantage of being able to separately identify demand and supply effects of codesharing, which further allows us to more meticulously examine short-run market effects within a market equilibrium framework.

For example, we use our model to perform counterfactual experiments by removing the demand-increasing and collusive effects of the alliance to see how the partners' equilibrium prices, number of passengers, and consumer surplus would be affected. These experiments reveal that the demand-increasing and collusive effects of codesharing reinforce each other in their influence of the partners' prices, with collusive effects accounting for a larger portion of the relatively small price increases in the case of the Delta/Continental/Northwest codeshare alliance. On the other hand, the demand-increasing and collusive effects of codesharing oppose each other in their influence on the partners' number of passengers, with the demand-increasing effect dominating and leading to increases in the partners' number of passengers. The experiments also reveal that the codeshare alliance seems to have improved consumer surplus owing to the domination of demand-increasing effects over collusive effects, which should be reassuring to policymakers who approved the alliance.

Armantier and Richard (2008) examine the effects on consumer surplus resulting from the earlier Continental/Northwest codeshare alliance implemented in 1999. They find that the Continental/Northwest alliance increased the welfare of passengers on connecting flights but decreased the welfare of passengers on nonstop flights, which resulted in no significant impact on overall consumer surplus. However, there is a fundamental difference in how we simulate and measure welfare effects versus how these effects are measured in Armantier and Richard (2008). Essentially, Armantier and Richard (2008) use their demand model to estimate and compare consumer surplus in the pre- and post-alliance periods in markets where the two airlines codeshare versus markets in which the two airlines do not codeshare. Thus, any temporal change in consumer surplus that is different across codeshare versus non-codeshare markets is attributed to the alliance. In our approach, we first econometrically identify both demand and supply effects of codesharing, which then gives us the advantage of performing well-controlled counterfactual welfare experiments. For example, in one counterfactual experiment we hold market conditions in the post-alliance period constant and simulate new market equilibria in the event that only the demand-increasing effect of codesharing is artificially removed. As such, for a given market at a given point in time, by comparing actual market equilibrium to simulated market equilibrium, we can assess how consumer surplus would change if only the demand-increasing effect of codesharing is removed.

The rest of the paper is organized as follows: In the next section we make some key definitions which build the foundation for important issues we subsequently model, analyze, and discuss. In Section 1.3 we present the structural econometric model, while the estimation strategy is discussed in Section 1.4. We discuss the characteristics of our data in Section 1.5 and results are shown and discussed in Section 1.6. Concluding remarks are offered in Section 1.7.

1.2. DEFINITIONS

A market is defined as directional round-trip air travel between an origin and a destination city during a particular period. The assumption that markets are directional implies that a round-trip air travel from Atlanta to Detroit is a distinct market compared to round-trip air travel from Detroit to Atlanta. Furthermore, this directional assumption allows for the possibility that origin city characteristics may influence market demand [see Gayle (2007a, 2007b, 2007c), Berry, Carnall and Spiller (2006)].

A flight itinerary is defined as a specific sequence of airport stops while traveling from the origin to destination city. An air travel product is defined as a unique combination of airline(s) and flight itinerary. Following Ito and Lee (2007), a pure online product means that the same airline markets and operates all segments of a round trip. For example, three separate pure online products are: (1) a non-stop round trip from Atlanta to Detroit marketed and operated by Delta Air Lines; (2) a round trip from Atlanta to Detroit with one stop in Minneapolis marketed and operated by Delta Air Lines; and (3) a non-stop round trip from Atlanta to Detroit marketed and operated by Northwest Air Lines. Note that all three products are in the same market.

A codeshare agreement effectively allows one carrier (called the "ticketing carrier" or "marketing carrier") to sell seats on its partners' planes as if these seats are owned by the carrier selling the seats. The carrier whose plane that actually transports the passenger is referred to as the "operating carrier". For example, Northwest may sell tickets for a subset of seats on the Delta operated flight between Atlanta and Detroit as if the plane were owned by Northwest. So a passenger that uses a codeshare itinerary may have purchased the round trip ticket from Northwest, but actually flies on a Delta plane.

The type of codeshare product we focus on in this research is referred to as "virtual" codeshare.[3] A passenger using a virtual codeshare itinerary remains on a single operating carrier's plane(s) for the entire round trip, but the ticket for the trip was marketed and sold by a partner ticketing carrier. We focus on virtual codeshare products because Gayle (2008) found that this was the only type of codeshare product that is strongly associated with price increases.

Figure 1.1 gives an example in which two airlines' route networks overlap, and they may virtual codeshare together in the origin-destination market. The figure shows that Northwest and Delta both operate non-stop flights in the Atlanta to Detroit market. If they virtual codeshare together in this market, then a subset of the passengers on the Delta plane would have bought their tickets from Northwest, while a subset of the passengers on the Northwest plane would have bought their tickets from Delta.

Figure 1.1 Route Network Diagram

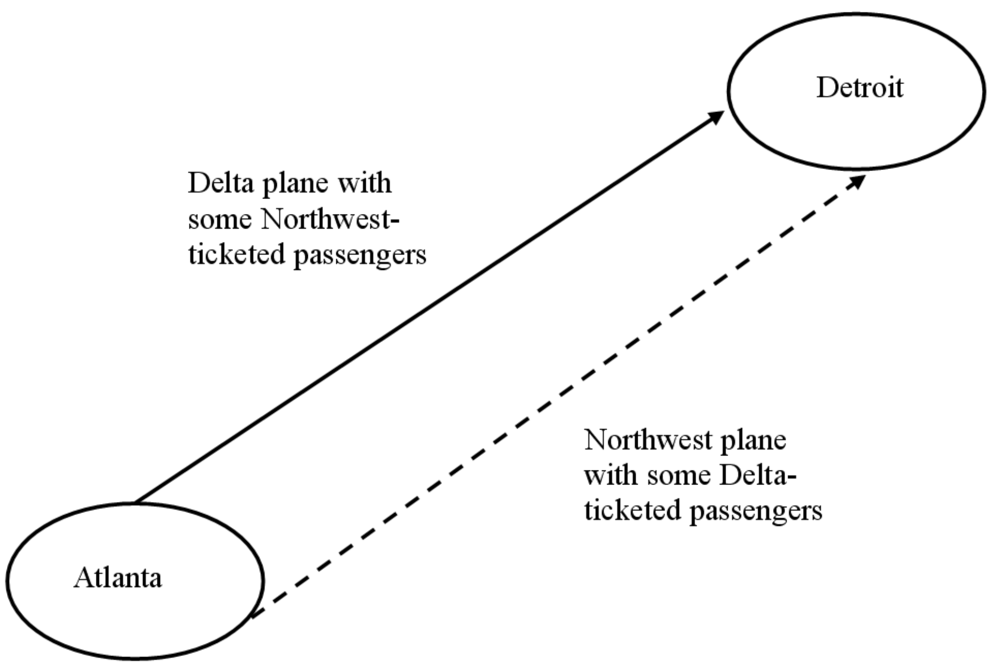
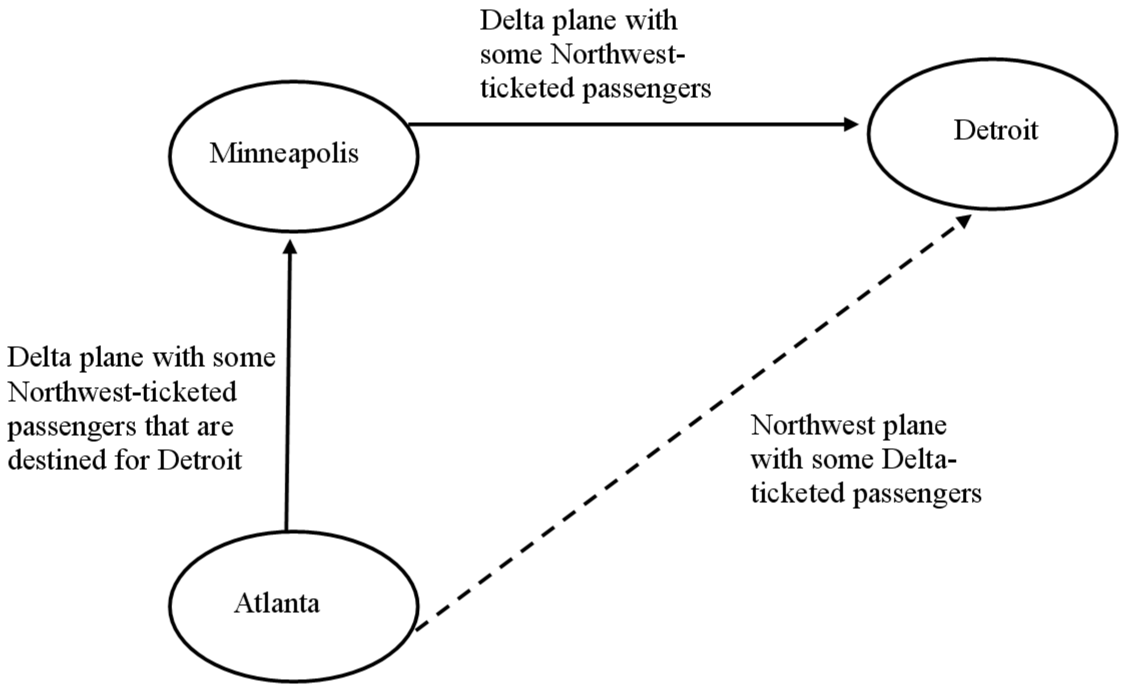


Figure 1.2 shows an alternate situation in which the airlines' route networks may overlap. In Figure 1.2, Northwest operates a non-stop flight in the Atlanta to Detroit market, while Delta operates a one-stop itinerary in the Atlanta to Detroit market, but unlike Figure 1.1, Delta does

[3] See Gayle (2008) and Ito and Lee (2007) for discussions of the main types of codeshare products in the U.S. domestic market.

not operate a non-stop flight in this market. Northwest and Delta's networks are still considered to be overlapping in Figure 1.2 even though Delta operates a one-stop itinerary while Northwest operates a non-stop itinerary. Both carriers may virtual codeshare together in Figure 1.2.

Figure 1.2 Modified Route Network Diagram



In Figure 1.2 it might seem counter-intuitive that a passenger would choose a one-stop itinerary even though a non-stop flight between the origin and destination is available. However, passengers often choose less convenient routes (flight itineraries that require intermediate stops) to get from their origin to destination when such alternate routing is competitively priced. In other words, within reasonable bounds, some passengers are willing to trade-off travel itinerary convenience for a lower price.

Figure 1.2 can also be used to illustrate a situation in which virtual codesharing is likely to have a demand-increasing effect associated with it. In the event that Northwest and Delta do not have a codeshare alliance, Northwest can only offer its Atlanta-based customers (some of whom may be members of Northwest's frequent-flyer program) a non-stop flight to Detroit. However, an alliance with Delta allows Northwest to offer its Atlanta-based customers both a non-stop flight on its own plane and a one-stop virtual codeshare itinerary operated solely by Delta. While passengers in Atlanta already had the option, prior to an alliance, to purchase either a pure online one-stop itinerary from Delta or a pure online non-stop flight from Northwest,

Northwest's frequent-flyers could not accumulate frequent-flyer miles on the Delta operated flights. Thus, the alliance created a new opportunity for Northwest frequent-flyers to accumulate miles on a Delta operated one-stop itinerary. Similarly, Delta frequent-flyers that would like to travel on the non-stop Northwest flight also have a new opportunity to accumulate frequent-flyer miles on the Northwest operated flight. The new opportunity for passengers to accumulate frequent-flyer miles across partner carriers is one reason we expect a demand-increasing effect to be associated with a codeshare alliance. Our econometric model is designed to isolate and test for this potential demand-increasing effect.

Figure 1.2 is also illustrates the main concern that the DOT expressed in its review of the proposed alliance between Delta, Continental, and Northwest. Since Delta and Northwest were competitors in the market shown in Figure 1.2, the DOT was concerned that forming an alliance could reduce how fiercely the two airlines compete with each other. The econometric model we present below is designed to isolate and test how competitive interactions between the three airlines differed in the post-alliance period compared to the pre-alliance period.

1.3. MODEL

We proceed by first describing the demand side of the model. The supply side is then laid out, which is where we model competitive interactions between airlines.

Demand

In the spirit of Peters (2006), Berry and Jia (2009), Berry, Carnall, and Spiller (2006), and Armantier and Richard (2008), air travel demand is modeled using a discrete choice framework. Specifically, we use a nested logit model.[4] Potential passenger *i* in market *l* during time period τ faces a choice between $J_{\tau l} + 1$ alternatives. There are $J_{\tau l} + 1$ alternatives because we allow passengers the option (*j* = 0, the outside good) not to choose either one of the $J_{\tau l}$ differentiated air travel products considered in the empirical model. Since the model focuses on pure online

[4] We concede that a nested logit model is not as flexible and therefore less desirable compared to a random coefficients logit model. However, it is well-known that the random coefficients model is more computationally demanding to estimate relative to the nested logit model. This estimation burden becomes particularly severe in our case since we have a large data set and plan to jointly estimate demand and supply parameters. As such, to make estimation feasible we had to choose the nested logit model over the random coefficients logit model. In addition, it is subsequently shown that the supply equation is highly nonlinear in its parameters, which also makes estimation computationally burdensome.

and virtual codeshare products, the outside good includes interline air travel products, and other means of getting from the origin to destination city besides air travel.

Products in a market are assumed to be organized into $G+1$ exhaustive mutually exclusive groups, $g = 0, 1, ..., G$, in which the outside good, $j = 0$, is assumed to be the only member of group 0. A group here refers to the set of products offered by an airline within a market.

A passenger solves the following optimization problem:

$$\underset{j \in \{0,...,J_{\tau l}\}}{Max} U_{ij\tau l} = \delta_{j\tau l} + \sigma\zeta_{i\tau l g} + (1-\sigma)\varepsilon_{ij\tau l} \qquad (1.1)$$

where $U_{ij\tau l}$ is the level of utility passenger *i* will obtain if product *j* is chosen, while $\delta_{j\tau l}$ is the mean level of utility across passengers that consume product *j*. $\delta_{j\tau l}$ is a function of the characteristics of product *j*, which we subsequently describe. $\zeta_{i\tau l g}$ is a random component of utility that is common to all products in group *g*, whereas the random term $\varepsilon_{ij\tau l}$ is specific to product *j* and is assumed to have an extreme value distribution. The parameter σ lies between 0 and 1, and measures the correlation of the consumers' utility across products belonging to the same group. Since products are grouped by airlines, σ can also be thought of as measuring the correlation of the consumers' utility across products offered by a given airline. As σ approaches 1, the correlation of preferences among products offered by the same airline within a market increases. Conversely, as σ decreases, the correlation of preferences for products offered by the same airline within a market decreases.

The rationale for the product grouping structure above is to capture the possibility that passengers view an airline's products as closer substitutes for each other compared to the substitutability of these products across airlines [Gayle (2007b)]. One reason why this could be the case is that a passenger may be heavily invested (accumulated miles flown) in a given airline's frequent-flyer program and therefore, on the margin, would prefer to choose among alternate flights offered by this airline in order to build up accumulated miles towards the required threshold necessary for a discounted trip. Second, some consumers may just have a strong brand loyalty to a given airline based on past experience. In any event, since σ is a parameter we estimate, the data will reveal whether or not a sufficient number of passengers are brand-loyal to render $\sigma > 0$.

The mean level of utility obtained across the population of consumers that consume product *j* is given by:

$$\delta_{j\tau l} = x_{j\tau l}\beta - \alpha p_{j\tau l} + a_r + \lambda_1 T + \lambda_2 T \times DCN + \lambda_3 T \times DCN \times Codeshare\_mkt + \xi_{j\tau l} \quad (1.2)$$

where $x_{j\tau l}$ is a vector of observed product characteristics (the number of intermediate stops used by an itinerary, an alternate measure of itinerary convenience, whether or not the origin is a hub for the carrier offering the product for sale, and whether or not the product is pure online or virtual codeshare), β is a vector of consumer taste parameters (marginal utilities) associated with the product characteristics in $x_{j\tau l}$, $p_{j\tau l}$ is the price of product *j*, α is a measure of the marginal utility of price, a_r are airline fixed effects where subscript *r* indexes ticketing carriers (ticketing carrier dummies), *T* is a zero-one time dummy equal to 1 if the itinerary occurred in the post-alliance period, *DCN* is a zero-one dummy equal to 1 if product *j* is being offered for sale by either Delta, Continental, or Northwest, *Codeshare_mkt* is a zero-one dummy equal to 1 if a virtual codeshare product between Delta, Continental, or Northwest was offered in the origin-destination market, and $\xi_{j\tau l}$ captures unobserved (by the econometricians but observed by passengers) product characteristics.

λ_1, λ_2, and λ_3 are taste parameters to be estimated. λ_1 captures the change in mean utility over the pre- and post-alliance periods for products offered by airlines other than Delta, Continental, or Northwest. $\lambda_1 + \lambda_2$ captures the change in mean utility over the pre- and post-alliance periods for products offered by Delta, Continental, or Northwest in markets where any two of the three airlines do not virtual codeshare together. Therefore, when we focus on markets in which Delta, Continental, and Northwest do not virtual codeshare together, λ_2 measures how the change in mean utility differs for products offered by Delta, Continental, or Northwest compared to products offered by other airlines.

$\lambda_1 + \lambda_2 + \lambda_3$ captures the change in mean utility over the pre- and post-alliance periods for products offered by Delta, Continental, or Northwest in markets where any two of the three airlines virtual codeshare together. Therefore, λ_3 measures how the change in mean utility for products offered by Delta, Continental, or Northwest differs in markets where any two of the three airlines virtual codeshare together compared to markets in which they do not virtual codeshare together. In other words, $\lambda_3 > 0$ implies that virtual codesharing has a demand-increasing effect associated with it, which is one of the main hypotheses we want to test.

The discussion above reveals that a key component of our demand specification that allows us to identify demand effects associated with the Delta/Continental/Northwest codeshare alliance (λ_3), is that equation (2) effectively compares consumers' choice behavior before and after implementation of the alliance in markets where the three airlines virtual codeshare together ("treatment" markets) versus markets in which they do not virtual codeshare together ("control" markets). A reasonable criticism to raise at this point is that *Codeshare_mkt* in equation (2) is not strictly exogenous since airlines choose which markets to codeshare in and which markets not to codeshare in. However, one argument in support of using *Codeshare_mkt* as is in equation (2), is that airlines' decisions about whether or not to codeshare in a market is likely predetermined at the time when a typical consumer decides on their utility maximizing product. In other words, it may be reasonable to assume that *Codeshare_mkt* is a predetermined variable in equation (2) and therefore estimates of λ_3 will not be biased.

We now complete the derivation of our demand equation. In what follows we drop the market and time subscripts (l and τ) only to avoid a clutter of notation.

Let there be G_g products in group *g*. If product *j* is in group *g*, the well-known formula for product *j*'s predicted group share or equivalently, the conditional probability of choosing product *j* given that group *g* is chosen is given by

$$s_{j/g} = \frac{e^{\frac{\delta_j}{(1-\sigma)}}}{D_g}$$

where, $D_g = \sum_{j \in G_g} e^{\frac{\delta_j}{(1-\sigma)}}$. The probability of choosing group *g* or equivalently, group *g*'s predicted share is

$$s_g = \frac{D_g^{1-\sigma}}{D_0^{1-\sigma} + \sum_{g=1}^{G} D_g^{1-\sigma}} \qquad (1.3)$$

Recall that the outside good is the only good in group 0, therefore, $D_0^{1-\sigma} = e^{\delta_0}$. As usual, we normalize the mean utility of the outside good to zero, i.e. $\delta_0 = 0$. This implies that $D_0^{1-\sigma} = 1$ and equation (1.3) can be written as

$$s_g = \frac{D_g^{1-\sigma}}{1 + \sum_{g=1}^{G} D_g^{1-\sigma}}$$

The unconditional probability of choosing product *j*, or equivalently, the predicted market share of product *j* is given by

$$s_j = s_{j/g} \times s_g = \frac{e^{\frac{\delta_j}{(1-\sigma)}}}{D_g} \times \frac{D_g^{1-\sigma}}{1 + \sum_{g=1}^{G} D_g^{1-\sigma}}$$

or

$$s_j = \frac{e^{\frac{\delta_j}{(1-\sigma)}}}{D_g^{\sigma}\left[1 + \sum_{g=1}^{G} D_g^{1-\sigma}\right]} \qquad (1.4)$$

Equation (1.4) is the well-known nested logit formula.

Finally, the demand for product *j* is given by

$$d_j = M \times s_j(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}, \theta_d)$$

where *M* is a measure of market size, which we assume to be the size of the population in the origin city, $s_j(\cdot)$ is the predicted product share function described in equation (1.4), **x** and **p** are vectors of observed non-price product characteristics and price, respectively, $\boldsymbol{\xi}$ is a vector of unobserved (by the researchers) product characteristics, and $\theta_d = (\beta, \alpha, \lambda, \sigma)$ is the vector of demand parameters to be estimated.

Supply

What is commonly known about how a codeshare agreement works is that the ticketing carrier markets and sets the final price for the round-trip ticket and compensates the operating carrier for operating services provided. Details on compensation mechanisms actually used by partner airlines are not usually made known to the public and may even vary across partnerships.

Therefore, we face the challenge of coming up with a modeling approach that captures our basic understanding of what is commonly known about a codeshare agreement without imposing too much structure on a contracting process about which we have few facts. We concede that the following is possibly a simplistic approximation of the actual contracting used by partners to compensate each other for services needed to provide a codeshare product.

One way to proceed, as pointed out in Gayle (2007c), is to think of a codeshare agreement as a privately negotiated pricing contract between partners (w, Γ), where w is a per-passenger price the ticketing carrier pays over to an operating carrier for transporting the passenger, while Γ represents a potential lump sum transfer between partners that determines how the joint surplus is distributed. As we develop the supply side of the model further, it will become clear that only the level of w affects equilibrium final product prices. Since for the purposes of this paper we are not concerned how the surplus is distributed between partners through the lump sum transfer Γ, we do not attempt to derive an equilibrium value of Γ.[5]

We assume that the final price of a codeshare product is determined within a sequential price-setting game. In the first stage of the sequential process, the operating carrier sets the price for transporting a passenger, w, and privately makes it known to its partner ticketing carrier. In the second stage, conditional on the agreed upon price w for services supplied by the operating carrier, the ticketing carrier sets the final round-trip price p for the codeshare product. The final subgame in this sequential price-setting game is played between ticketing carriers.

Let $r = 1, ..., R$ index competing ticketing carriers in a market and let $f = 1, ..., \mathcal{F}$ index the corresponding operating carriers. Further, let F_r be a subset of the J products that are offered for sale by ticketing carrier r in the origin-destination market.[6] Carrier r solves the following profit maximization problem for each $j \in F_r$:

$$\underset{p_j}{Max} \sum_{j \in F_r} (p_j - w_j^f) q_j \qquad (1.5)$$

where $q_j = d_j(\mathbf{p})$ in equilibrium, q_j is the quantity of product j offered for sale on the market, $d_j(\mathbf{p})$ is market demand for product j, $\mathbf{p}$ represents a $J \times 1$ vector of final prices, and as defined

[5] See Chen and Gayle (2007) for a similar theoretical modeling approach of an airline codeshare agreement.

[6] For most of the subsequent equations, we intentionally omit a market subscript for variables and equations only to avoid notational clutter. Notwithstanding our omission of market subscripts, the reader should continue to interpret equations in a market-specific way.

previously w_j^f is the price the ticketing carrier pays to operating carrier *f* for its transportation services. So w_j^f is the effective marginal cost that ticketing carrier *r* incurs by offering codeshare product *j* for sale.[7] Since in the first stage of the sequential price-setting game operating carriers each optimally choose w_j^f, we know that the equilibrium level of w_j^f depends on the marginal cost of the operating carrier that offers transportation services for codeshare product *j*. Therefore, we can specify w_j^f as a function of factors that shift the marginal cost of the operating carrier. Specifically, we posit that

$$w_j^f = \exp(W_j\gamma + a_f + \eta_j)$$

where W_j is a vector of variables that shift marginal cost of the operating carrier (itinerary distance, itinerary distance squared, time fixed effect) and γ is the associated vector of parameters, a_f captures the operating carrier-specific portion of marginal cost, and η_j is a mean-zero, random error term that captures unobserved determinants of marginal cost.

In the event that product *j* is a pure online product instead of a virtual codeshare product, we replace w_j^f in profit function (1.5) with c_j^r, where c_j^r is the marginal cost that carrier *r* incurs by offering product *j*. Note that in such a case carrier *r* is the sole ticketing and operating carrier of product *j*. The marginal cost function is therefore

$$\exp(W_j\gamma + a_f + \eta_j) = \begin{cases} w_j^f & \text{if } j \text{ is virtual codeshare} \\ c_j^r & \text{if } j \text{ is pure online} \end{cases} \qquad (1.6)$$

Competitive Interactions

In the spirit of Sudhir (2001), we measure cooperative or aggressive behavior by the degree to which equilibrium prices may deviate from Bertrand-Nash prices. We now augment the profit function (1.5) above to allow for such analysis.

Let A_r be a subset of the *J* products that are offered for sale by the alliance partners of carrier *r*, while B_r is a subset of the *J* products that are offered for sale by carriers that are not partners of carrier *r*. Note that sets F_r, A_r, and B_r do not have any elements in common but

[7] We implicitly assume here that the ticketing carrier of a virtual codeshare product only incurs fixed expenses in marketing the product to potential passengers.

together they contain all the products in the market. We can now specify the augmented profit function for carrier *r*:

$$\Pi_r = \sum_{j \in F_r} (p_j - w_j^f) q_j + \phi_a \times \sum_{j \in A_r} (p_j - w_j^f) q_j + \phi_{-a} \times \sum_{j \in B_r} (p_j - w_j^f) q_j \qquad (1.7)$$

where ϕ_a is the weight an airline puts on its partners' profits, while ϕ_{-a} is the weight an airline puts on non-partners' profits. Note that $\phi = 0$ in the augmented profit function (1.7) yields the profit function in (1.5), which would generate Bertrand Nash prices. Therefore, $\phi > 0$ implies cooperative behavior relative to Bertrand Nash, while $\phi < 0$ implies more aggressive competitive behavior relative to Bertrand Nash.

A pure strategy Nash equilibrium in final prices requires that p_j of any product *j* offered by carrier *r* must satisfy the first-order condition:

$$\frac{\partial \Pi_r}{\partial p_j} = d_j(\mathbf{p}) + \sum_{k \in F_r} (p_j - w_k^f) \frac{\partial d_k(\mathbf{p})}{\partial p_j} + \phi_a \times \sum_{k \in A_r} (p_j - w_k^f) \frac{\partial d_k(\mathbf{p})}{\partial p_j} + \phi_{-a} \times \sum_{k \in B_r} (p_j - w_k^f) \frac{\partial d_k(\mathbf{p})}{\partial p_j} = 0$$

The first-order conditions are a set of *J* equations, one for each product. A few additional definitions allow for a more convenient representation of the first-order conditions using matrix notation.

First, let Ω^{own} be a $J \times J$ matrix which describes the ticketing carriers' ownership structure of the *J* products. Let $\Omega^{own}(k, j)$ denote an element in Ω^{own}, where

$$\Omega^{own}(k, j) = \begin{cases} 1 & \text{if distinct products } k \text{ and } j \text{ are offered by the same carrier} \\ 0 & \text{otherwise} \end{cases}$$

Second, let Ω_a be a $J \times J$ matrix which contains zeros and ϕ_a, which is the parameter describing the degree of competition between partner carriers. Let $\Omega_a(k, j)$ denote an element in Ω_a, where

$$\Omega_a(k, j) = \begin{cases} \phi_a & \text{if distinct products } k \text{ and } j \text{ are offered by partner carriers} \\ 0 & \text{otherwise} \end{cases}$$

Third, let Ω_{-a} be a $J \times J$ matrix which contains zeros and ϕ_{-a}, which is the parameter describing the degree of competition between carriers that do not belong to the same alliance. Let $\Omega_{-a}(k, j)$ denote an element in Ω_{-a}, where

$$\Omega_{-a}(k,j) = \begin{cases} \phi_{\text{-a}} & \text{if distinct products } k \text{ and } j \text{ are offered by carriers} \\ & \text{that do not belong to the same alliance} \\ 0 & \text{otherwise} \end{cases}$$

Fourth, let Δ be a $J \times J$ matrix of first-order derivatives of product market shares with respect to final prices, where element $\Delta(k,j) = -\frac{\partial d_j}{\partial p_k}$. In vector notation, the system of J first-order conditions for the ticketing carriers can now conveniently be expressed as

$$\mathbf{p} = \mathbf{w} + [(\Omega^{own} + \Omega_a + \Omega_{-a}).*\Delta]^{-1} \times \mathbf{d}(\mathbf{p}) \tag{1.8}$$

where $\mathbf{d}(\cdot)$, **p**, and **w** are $J \times 1$ vectors of product demands, final prices, and ticketing carriers' effective marginal costs, respectively, while .* means element-by-element multiplication of two matrices. Equation (1.8) says the set of prices **p** that satisfy a pure strategy Nash equilibrium is a function of effective marginal costs, **w**, and product markups, $[(\Omega^{own} + \Omega_a + \Omega_{-a}).*\Delta]^{-1} \times \mathbf{d}(\mathbf{p})$.

Specializing the Supply Equation

We now specialize equation (1.8) to facilitate analyzing the competitive effects of virtual codesharing between Delta, Continental, and Northwest in markets where at least two of them are direct competitors both before and subsequent to forming the alliance. Appendix A provides a simple three-airline single market example of the supply model laid out below.

As we discuss further in the data section, our sample is restricted to markets in which at least two of the three airlines (Delta, Continental, and Northwest) offer their own competing pure online products. Furthermore, the time span of the sample is deliberately chosen to include pre-alliance and post-alliance periods.

Let ϕ_{dcn}^{pre} be the weight Delta, Continental, and Northwest put on each others' profits in the pre-alliance period, while ϕ_{-dcn}^{pre} is the weight competing airlines put on each others' profits assuming that at least one airline in the pair of competitors is neither Delta, Continental, or Northwest. For example, Delta's profit function in a market during the pre-alliance period is:

$$\Pi_{Delta} = \sum_{j \in F_{Delta}} (p_j - w_j^f) q_j + \phi_{dcn}^{pre} \times \sum_{j \in A_{Delta}} (p_j - w_j^f) q_j + \phi_{-dcn}^{pre} \sum_{j \in B_{Delta}} (p_j - w_j^f) q_j \tag{1.9}$$

where F_{Delta} is the set of products offered for sale by Delta airlines in the specific origin-destination market during the pre-alliance period, A_{Delta} is the set of products offered either by

Northwest or Continental airlines in the said market during the pre-alliance period, and B_{Delta} is the set of products offered by other competing airlines in the said market during the pre-alliance period.

Based on our matrix notation convention described above, this market would have the following matrices associated with it during the pre-alliance period: $\Omega^{pre-own}$, $\Omega_{dcn}^{pre-comp}$, and $\Omega_{-dcn}^{pre-comp}$, where $\Omega^{pre-own}$ is a $J \times J$ matrix of zeros and ones that describes the ticketing carriers' ownership structure of the *J* products in the pre-alliance period, $\Omega_{dcn}^{pre-comp}$ is a matrix of zeros and ϕ_{dcn}^{pre}, while $\Omega_{-dcn}^{pre-comp}$ is a matrix of zeros and ϕ_{-dcn}^{pre}. The system of product markup equations during the pre-alliance period for a market is:

$$\mathbf{m}^{pre} = \left[\left(\Omega^{pre-own} + \Omega_{dcn}^{pre-comp} + \Omega_{-dcn}^{pre-comp}\right).*\Delta^{pre}\right]^{-1} \times \mathbf{d}(\mathbf{p})^{pre}$$

During the post-alliance period, Delta, Continental, and Northwest only virtual codeshare together in a subset of the markets in our sample. So in our sample some markets play the role of a treatment group ($\nu = 1$, markets in which the three airlines directly compete and virtual codeshare together), while the other markets play the role of a control group ($\nu = 0$, markets in which the three airlines directly compete but do not virtual codeshare together).

In markets where Delta, Continental, and Northwest do codeshare together in the post-alliance period, let $\phi_{dcn,\ \nu=1}^{post}$ be the weight that each of the three airlines put on each others' profit, while $\phi_{-dcn,\ \nu=1}^{post}$ is the weight competing airlines put on each others' profits assuming that at least one airline in the pair of competitors is neither Delta, Continental, or Northwest. In the case of markets in which Delta, Continental, and Northwest do not codeshare together in the post-alliance period, let $\phi_{dcn,\ \nu=0}^{post}$ be the weight that each of the three airlines put on each others profit, while $\phi_{-dcn,\ \nu=0}^{post}$ is the weight competing airlines put on each others profits assuming that at least one airline in the pair of competitors is neither Delta, Continental, or Northwest. For a given market in the post-alliance period, the markup equation is:

$$\begin{aligned}\mathbf{m}^{post} &= \left\{V.*\left[\left(\Omega^{post-own} + \Omega_{dcn,\ \nu=1}^{post-comp} + \Omega_{-dcn,\ \nu=1}^{post-comp}\right).*\Delta^{post}\right]^{-1}\right\}\times \mathbf{d}(\mathbf{p})^{post} \\ &+ \left\{(\mathrm{Y}-V).*\left[\left(\Omega^{post-own} + \Omega_{dcn,\ \nu=0}^{post-comp} + \Omega_{-dcn,\ \nu=0}^{post-comp}\right).*\Delta^{post}\right]^{-1}\right\}\times \mathbf{d}(\mathbf{p})^{post},\end{aligned}$$

where *V* is a $J \times J$ indicator matrix whose elements are all ones if $\nu = 1$ for this market, but if $\nu = 0$ for the market, then all elements in *V* are zeros. *Y* is a $J \times J$ matrix of ones. To complete our description of $\mathbf{m}^{post}$, note that $\Omega^{post-comp}_{dcn,\ v=1}$ is a $J \times J$ matrix that contains zeros and $\phi^{post}_{dcn,\ v=1}$, $\Omega^{post-comp}_{-dcn,\ v=1}$ is a $J \times J$ matrix that contains zeros and $\phi^{post}_{-dcn,\ v=1}$, $\Omega^{post-comp}_{dcn,\ v=0}$ is a $J \times J$ matrix that contains zeros and $\phi^{post}_{dcn,\ v=0}$, and $\Omega^{post-comp}_{-dcn,\ v=0}$ is a $J \times J$ matrix that contains zeros and $\phi^{post}_{-dcn,\ v=0}$. See Appendix A for an illustration of what the matrices in $\mathbf{m}^{pre}$ and $\mathbf{m}^{post}$ look like in the case of a three-airline single market example.

The supply equation used to evaluate the competitive effects of virtual codesharing between Delta, Continental, and Northwest is given by:

$$\mathbf{p}_{\tau,l} = \mathbf{w}_{\tau,l} + \mathbf{m}_{\tau,l} \qquad (1.10)$$

where τ indexes time period, l indexes market, and $\mathbf{m}_{\tau,l}$ is the product markup term for market l during period τ. From above we know that $\mathbf{m}_{\tau,l}$ is determined by the expression for either $\mathbf{m}^{pre}$ or $\mathbf{m}^{post}$.

Our task is to use equation (1.10) along with our demand equation to obtain econometric estimates of ϕ^{pre}_{dcn}, ϕ^{pre}_{-dcn}, $\phi^{post}_{dcn,\ v=1}$, $\phi^{post}_{-dcn,\ v=1}$, $\phi^{post}_{dcn,\ v=0}$ and $\phi^{post}_{-dcn,\ v=0}$. We can then do pairwise comparisons of these parameters. For example, if $\phi^{post}_{dcn,\ v=1} \neq \phi^{post}_{dcn,\ v=0}$, then the degree of competitiveness between Delta, Continental, and Northwest differs in markets where they directly compete and virtual codeshare together compared to markets in which they directly compete but do not virtual codeshare together. Second, if $\phi^{post}_{dcn,\ v=1} \neq \phi^{pre}_{dcn}$, then the degree of competitiveness between Delta, Continental, and Northwest differs in the post-alliance period relative to the pre-alliance period. Most important, the pairwise comparisons of ϕ^{pre}_{-dcn}, $\phi^{post}_{-dcn,\ v=1}$, and $\phi^{post}_{-dcn,\ v=0}$ can help us determine whether pairwise comparisons of ϕ^{pre}_{dcn}, $\phi^{post}_{dcn,\ v=1}$, and $\phi^{post}_{dcn,\ v=0}$ are identifying the competitive effects of virtual codesharing between Delta, Continental, and Northwest or just reflecting market wide trends in competitive behavior.

Implicit in our discussion above is that a key component of our strategy to identify (anti-) competitive effects associated with the Delta/Continental/Northwest codeshare alliance is to compare Delta, Continental, Northwest, and other airlines' pricing behavior before and after implementation of the alliance in markets where the three carriers virtual codeshare together ("treatment" markets) versus markets in which they compete but do not virtual codeshare together ("control" markets). Again, we acknowledge that the airlines also choose which markets to codeshare in, but we presume that such codeshare choices would have been decided prior to making optimal pricing decisions for the menu of products the airlines already planned to offer passengers. Our analysis is therefore focused on short-run pricing behavior conditional on the airlines' predetermined menu of product offerings.

In summary, the vector of supply parameters are, $\theta_s = (\gamma, \phi)$.

1.4. Estimation

The parameters to be estimated are $\theta_d = (\beta, \alpha, \lambda, \sigma)$ for demand and $\theta_s = (\gamma, \phi)$ for supply. Following Berry (1994), the estimation strategy for demand parameters involves choosing parameter values such that observed product shares, S_j, are equal to predicted product shares, s_j, that is,

$$S_j = s_j(\delta, \sigma), \quad \forall\, j \tag{1.11}$$

We compute observed product shares based on $S_j = \frac{q_j}{M}$, where *M* is the size of the population in the origin city and q_j is the actual number of travel tickets sold for a particular itinerary-airline(s) combination called product *j*. As Berry (1994) shows, in the case of the nested logit model, we can analytically solve for the mean levels of utility (δ) that satisfy equation (1.11). The analytical solution is:

$$\delta_j = \ln(S_j) - \ln(S_0) - \sigma \ln(S_{j/g}) \tag{1.12}$$

where S_0 is the observed share of the outside option, and $S_{j/g}$ is the observed within group share of product *j*.[8] Using equation (1.2) to substitute for δ_j in equation (1.12) and rearranging terms yields:

$$\begin{aligned} \ln(S_j) - \ln(S_0) = x_j\beta - \alpha p_j + \sigma \ln(S_{j/g}) + a_r + \lambda_1 T + \lambda_2 T \times DCN \\ + \lambda_3 T \times DCN \times Codeshare\_mkt + \xi_j \end{aligned} \tag{1.13}$$

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[8] The observed share of the outside option is computed by $S_0 = 1 - \sum_{g=1}^{G} S_g$, where $S_g = \sum_{j \in G_g} S_j$. The observed within group share of product j is computed by $S_{j/g} = \frac{S_j}{S_g}$.

where ξ_j is the structural demand error term.

Provided we have valid instruments for p_j and $S_{j/g}$, equation (1.13) is straightforward to estimate using a linear instrumental variables technique such as two-stage least squares (2SLS). However, we are also interested in estimating supply parameters, and there is some efficiency benefit in estimating demand and supply parameters jointly. Since both demand and supply parameters enter the supply equation in a nonlinear way, we need a nonlinear system estimation technique to estimate the parameters jointly. We use system Generalized Methods of Moments (GMM) for joint estimation of the parameters.

Using the marginal cost function in equation (1.6) to substitute for **w** in equation (1.10) yields the following econometric specification of the supply equation:

$$p_j = \exp(W_j\gamma + a_f + \eta_j) + m_j(\theta_d, \phi)$$

or equivalently,

$$\ln\left[p_j - m_j(\theta_d, \phi)\right] = W_j\gamma + a_f + \eta_j \qquad (1.14)$$

where η_j is the structural supply error term, and $m_j(\theta_d, \phi)$ is the product markup function that depends on demand and competition parameters, θ_d and ϕ.

The GMM estimates of the parameters are obtained by solving the following problem,

$$\underset{\theta_d, \theta_s}{Min}\ \psi' Z\Phi^{-1}Z'\psi$$

where ψ is a vector of the demand and supply structural error terms, $\psi = \begin{pmatrix} \xi_j \\ \eta_j \end{pmatrix}$, Φ^{-1} is a positive definite weight matrix, while *Z* is a block diagonal matrix of instruments for the demand and supply equations that are assumed orthogonal to the error vector ψ.[9]

Instruments

First focusing on demand equation (1.13), we recognize that a product's price and its within group share (p_j and $S_{j/g}$ respectively) are likely to be correlated with the portion of the

[9] In particular, $Z = \begin{bmatrix} Z_d & \mathbf{0} \\ \mathbf{0} & Z_s \end{bmatrix}$ where Z_d is an $N \times L_d$ matrix of demand instruments and Z_s is an $N \times L_s$ matrix of supply instruments. *N* is the sample size, L_d is the number of demand instruments, while L_s is the number of supply instruments.

product's quality captured in ξ_j (where ξ_j is unobserved to the researchers but observed to passengers). As such, we need to find instruments for p_j and $S_{j/g}$. We make the well-known identifying assumption found in the literature on discrete choice models of demand that observed non-price product characteristics are uncorrelated with the unobserved product quality, ξ_j. This allows us to use various combinations of non-price product characteristics to form valid instruments for p_j and $S_{j/g}$.

The instruments we use for the demand equation include: (1) itinerary distance; (2) the squared deviation of a product's itinerary distance from the average itinerary distance of competing products offered by other airlines; (3) the number of competing products offered by other airlines with equivalent number of intermediate stops; (4) the number of competitor products in the market; (5) the number of other products offered by an airline in a market; and (6) the mean number of intermediate stops across products offered by an airline in a market.[10] As described in Gayle (2007a and 2007c), instruments (1) to (5) are motivated by supply theory, which predicts that the equilibrium price and within group product share are affected by changes in marginal cost and changes in product markup. For example, itinerary distance (instrument (1)) is a marginal cost shifting variable, instruments (2) to (4) proxy for the degree of competition facing a product, which in turn affects the size of a product's markup, and instrument (5) recognizes the fact that the more substitute products an airline offers in a market, ceteris paribus, the airline is better able to charge a higher markup on each of these products. Last, instrument (6) is possibly associated with reasons why passengers may prefer the set of products offered by one airline over the set of products offered by other airlines.

As mentioned above, the structural error term in supply equation (1.14), η_j, captures the unobserved portion of marginal cost, which is correlated with price. Due to the nonlinearity of the predicted product share function with respect to price, the product markup term, m_j, is a function of price. Therefore, m_j is likely to be correlated with η_j in the supply equation. We assume that observed non-price product characteristics are uncorrelated with η_j. Based on the

[10] We also include interactions of these variables as instruments.

discussion of the validity of instruments used in the demand equation, instruments (2) to (6) above are also valid for the supply equation.

1.5. Data

Data are drawn from the Origin and Destination Survey (DB1B), which is a 10% random sample of airline tickets from reporting carriers. DB1B is a database that is maintained and published by the U.S. Bureau of Transportation Statistics. Among other things the database includes: (1) number of passengers that choose a given flight itinerary; (2) the fares of these itineraries; (3) the specific sequence of airport stops that each itinerary uses in getting passengers from the origin to destination city; (4) the carrier(s) that marketed and sold the travel ticket (ticketing carriers), and the carrier(s) that passengers actually fly on for their trip (operating carriers); and (5) the distance flown on each itinerary in a directional market. The distance associated with each itinerary in a market may differ since each itinerary may use different connecting airports in transporting passengers from the origin to destination city. The data we use link each product to a directional market rather than a mere non-stop route or segment of a market. For this research, we focus on U.S. domestic flights offered and operated by U.S. carriers in the fourth quarters of 2002 (pre-alliance) and 2003 (post-alliance).[11]

We arrive at the final sample used for estimation by applying a few filters to the original data set. First, itineraries with price less than $100 are excluded due to the high probability that these may be coding errors or passengers redeeming frequent flyer miles to obtain a discounted fare. Second, itineraries with an inordinate number (more than three) of intermediate stops were dropped. Third, we focus on pure online and virtual codeshare products as defined previously. Fourth, following the standard practice for empirical analyses of airline codesharing, we recode regional feeder carriers to have their major carrier codes. In the absence of such recoding of feeder carriers, products that only include a major carrier and its associated regional feeder carrier(s) may mistakenly be counted as codeshare products since the operating and ticketing carrier codes would differ.[12] Fifth, based on our previously stated research objectives, we focus on origin-destination markets in which at least two of the three airlines (Delta, Continental, and Northwest) offered competing pure online products both in the pre and post-alliance periods. In

[11] Collecting data from the same quarter in both years will eliminate potential seasonal effects in demand.
[12] We identify codeshare products as products where the ticketing and operating carriers differ.

other words, the three carriers' networks overlap in all of the markets that remained in our final sample.

After applying the above restrictions, we follow Gayle (2007a) and collapse the data by averaging the price and aggregating the number of passengers purchasing products as defined by unique itinerary-airline(s) combination. In other words, before the data are collapsed, there are several observations of a given itinerary-airline(s) combination that are distinguished by prices paid and number of passengers paying each of those prices.[13] The final sample has 124,965 products contained in 4,300 origin-destination markets that span the pre and post-alliance periods.

Variables that we gathered and constructed from the database that have not yet been described are "Price", "Hub", "Stops", "Convenient", and "Virtual". These variables are the observable product characteristics contained in vector $x_{j\tau l}$ in equation (1.2). "Price" is the average price paid by passengers who chose the specific itinerary-airline(s) combination. "Hub" is a zero-one dummy variable that takes the value one if the origin airport is a hub for the ticketing carrier. "Stops" is a variable that counts the number of intermediate stops associated with each product. For example, in the case of products that use non-stop flight itineraries, "Stops" takes the value zero. "Convenient" is the ratio of itinerary distance to the non-stop distance between origin and destination airports. The presumption is that an itinerary is less convenient the further its "Convenient" measure is from 1. "Virtual" is a zero-one dummy that takes the value one if the product is virtual codeshared. We leave discussing the rationale for using each of these variables until the results section since the main task now is to provide descriptive information on the data.

Table 1.1 provides a list of the airlines in the sample according to type of products the airlines are involved in. Table 1.2 reports sample summary statistics broken down by time period and market type, where market type is based on whether or not Delta, Continental, and Northwest virtual codeshare together in the market.

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[13] Based on how products are defined in this paper, which follows product definition in Gayle (2007a), the demand model is only intended to explain choices between itinerary-airline(s) combinations rather than more narrowly defined products that may differ within a given itinerary-airline(s) combination.

Table 1.1 List of Airlines in the Dataset

Airlines Involved in Virtual Codeshare Products		Airlines Involved in Pure Online Products	
Airline Name	**Code**	**Airline Name**	**Code**
American Airlines Inc.	AA	American Airlines Inc.	AA
Alaska Airlines Inc.	AS	Alaska Airlines Inc.	AS
Continental Air Lines Inc.	CO	JetBlue Airways	B6
Delta Air Lines Inc.	DL	Continental Air Lines Inc.	CO
Hawaiian Airlines	HA	Delta Air Lines Inc.	DL
America West Airlines	HP	Frontier Airlines	F9
Northwest Airlines Inc.	NW	AirTran Airways	FL
United Air Lines Inc.	UA	America West Airlines	HP
US Airways Inc.	US	National Airlines	N7
		Spirit Air Lines	NK
		Northwest Airlines Inc.	NW
		Chautauqua Airlines	RP
		Expressjet Airlines	RU
		Sun Country Airlines	SY
		ATA Airlines	TZ
		United Air Lines Inc.	UA
		US Airways Inc.	US
		Mesaba Airlines	XJ
		Midwest Airlines	YX

Notes: Note that feeder carriers such as Chautauqua Airlines and Expressjet Airlines are not listed as involved in codeshare products. This is because we assign these carriers their major carrier codes (effectively not making a distinction between feeder and major carriers) for products where feeder carriers operate segment(s) of the trip but the ticketing carrier is the major carrier. However, the feeder carriers do offer pure online products, which is why they show up in the column labeled "Airlines involved in Pure Online Products". In the data section of the text we provide discussion on the rationale for assigning feeder carriers their major carrier code prior to identifying codeshare products.

Table 1.2 Summary statistics broken down by time period and market type, where market type is based on whether or not DL, CO, and NW virtual codeshare together in the market

	Origin-destination markets in which DL, CO and NW virtual codeshare together during the post-alliance period (2262 markets).							
	Pre-alliance period (2002)				Post-alliance period (2003)			
Variable	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Price	251.84	184.72	100.06	4227.03	241.03	162.81	100	4227.03
HUB	0.16	0.37	0	1	0.15	0.36	0	1
Stops	1.23	0.70	0	3	1.15	0.64	0	3
Convenient	1.25	0.30	1	3.66	1.24	0.29	1	3.64
Virtual	0.07	0.25	0	1	0.16	0.37	0	1
	Number of products = 38171				Number of products = 41219			
	Origin-destination markets in which DL, CO and NW did not virtual codeshare together during the post-alliance period (2038 markets).							
	Pre-alliance period (2002)				Post-alliance period (2003)			
Variable	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Price	263.51	202.88	100	5810.01	251.85	171.03	100.02	3274.82
HUB	0.19	0.39	0	1	0.18	0.38	0	1
Stops	1.22	0.70	0	3	1.14	0.66	0	3
Convenient	1.30	0.35	1	3.53	1.27	0.34	1	3.49
Virtual	0.02	0.14	0	1	0.07	0.26	0	1
	Number of products = 22512				Number of products = 23063			

First, Table 1.2 reveals that during the post-alliance period the three airlines virtual codeshare together in 2,262 of the origin-destination markets in our sample, while they did not virtual codeshare together in 2,038 of the origin-destination markets. In all these 4,300 origin-destination markets, at least two of the three airlines offered their own substitute pure online products both in the pre and post-alliance periods. Second, markets in which the three airlines virtual codeshare together tend to have more competing products compared to markets in which the three airlines do not virtual codeshare together. Third, the mean level of each product characteristic does not seem to have drastic changes between pre and post-alliance periods. However, it is noticeable that mean prices are slightly higher in markets where the three airlines do not virtual codeshare together compared to markets in which they do virtual codeshare together. Furthermore, there is a slight decline in mean price over the pre- and post-alliance periods.

Table 1.3 provides similar statistics as in Table 1.2 with the exception that Table 1.3 focuses on products offered by Delta, Continental, or Northwest. The market trends we identified in Table 1.2 appear to follow through to Table 1.3. For example, the three airlines' mean prices seem to be lower and they offer more substitute products in markets that they virtual codeshare together compared to markets that they do not virtual codeshare together. In summary, the trends of simple descriptive statistics across Tables 1.2 and 1.3 suggest that competition may be stiffer in markets where the three airlines virtual codeshare together compared to markets in which they do not virtual codeshare together. But these descriptive statistics do not disentangle the effects of consumer behavior from the effects of strategic interactions between competing airlines, which is why we now turn to analyzing results from our formal econometric model.

Table 1.3 Summary statistics for products offered by DL, CO or NW. These statistics are broken down by time period and market type, where market type is based on whether or not DL, CO, and NW virtual codeshare together in the market.

	Origin-destination markets in which DL, CO and NW virtual codeshare together during the post-alliance period (2262 markets).							
	Pre-alliance period (2002)				Post-alliance period (2003)			
Variable	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Price	244.46	176.08	100.06	2330.08	237.02	154.70	100.01	3287.9
HUB	0.13	0.34	0	1	0.13	0.33	0	1
Stops	1.23	0.67	0	3	1.15	0.62	0	3
Convenient	1.26	0.30	1	3.13	1.25	0.29	1	3.05
Virtual	0.13	0.34	0	1	0.18	0.38	0	1
	Number of products = 19675				Number of products = 20492			
	Origin-destination markets in which DL, CO and NW did not virtual codeshare together during the post-alliance period (2038 markets).							
	Pre-alliance period (2002)				Post-alliance period (2003)			
Variable	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Price	256.84	190.23	100	3611.51	248.46	155.62	100.17	2449.14
HUB	0.11	0.31	0	1	0.11	0.31	0	1
Stops	1.22	0.67	0	3	1.14	0.64	0	3
Convenient	1.31	0.35	1	3.53	1.30	0.34	1	3.49
Virtual	0.04	0.19	0	1	0.001	0.03	0	1
	Number of products = 11517				Number of products = 10896			

1.6. Results

We begin by estimating demand equation (1.13) by itself using straightforward linear estimation techniques such as ordinary least squares (OLS) and two-stage least squares (2SLS). Results from the single equation demand estimation are reported in Table 1.4.

Table 1.4 Demand Parameter Estimates from Single Equation Estimation

	Ordinary Least Squares (OLS)		**Two-Stage Least Squares (2SLS)**	
Variable	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**
Constant	-11.657*	0.135	-10.952*	0.146
Price	-0.012*	0.003	-0.251*	0.016
Stops	-1.013*	0.015	-1.031*	0.020
Convenient	-0.458*	0.009	-0.722*	0.011
Hub	1.028*	0.023	0.805*	0.026
Hub × Stops	-0.426*	0.016	-0.612*	0.017
Virtual	-0.940*	0.016	-1.127*	0.019
σ	0.441*	0.002	0.175*	0.006
T	λ_1 = -0.033*	0.012	λ_1 = -0.048*	0.013
T × DCN	λ_2 = -0.319*	0.021	λ_2 = -0.241*	0.023
T × DCN × Codeshare_mkt	λ_3 = 0.439*	0.018	λ_3 = 0.315*	0.020
R^2	0.4655		0.3835	
Exogeniety Test: Hausman statistic = 3227.91 Critical $\chi^2(0.95, 2) = 5.99$				

Notes: Models are estimated with ticketing carrier dummies even though these dummy coefficients are not reported in the table. * indicates statistical significance at the 1% level.

The first two data columns in Table 1.4 report OLS estimates. The OLS estimation ignore that price and within group product share (p_j and $S_{j/g}$ respectively) are likely endogenous variables, and therefore the estimates of the price coefficient and σ are most likely biased. To confirm the endogeneity of price and within group product share we re-estimate the demand equation using 2SLS and perform a Hausman exogeneity test. Based on the Hausman test we easily reject at conventional levels of statistical significance that price and within group product share are exogenous variables in the demand equation. As such, the following discussion of results in Table 1.4 is based on the 2SLS estimates.

All coefficient estimates are statistically different from zero at conventional levels of significance. So the following discussion focuses on the signs of the estimated coefficients.

First, as expected, an air travel product's price has a negative effect on the utility obtained from choosing the product, ceteris paribus. Second, the more intermediate stops an air travel product has, the lower the utility obtained from choosing that product, ceteris paribus. The number of intermediate stops that an air travel product has is one measure of the inherent convenience of the travel itinerary - the negative coefficient for "Stops" is consistent with our expectation.[14]

Gayle (2007a) points out that number of intermediate stops may only capture a portion of the inherent convenience of an itinerary. For example, two itineraries may each have one intermediate stop, but depending on where the intermediate stop is located in relation to the origin and destination cities, the two one-stop itineraries may have very different travel distances and travel time associated with them. As such, passengers could view these two itineraries as having very different levels of convenience even though the itineraries have the same number of intermediate stops. Our "Convenient" variable, which measures the ratio of itinerary distance to non-stop distance between the origin and destination cities, is supposed to capture aspects of itinerary convenience that are not picked up by number of intermediate stops.[15] We therefore expect the coefficient on "Convenient" to be negative, which is indeed the estimated sign in Table 1.4.

It has been argued that passengers are more likely to choose itineraries offered by hub airlines for the following reasons: (1) flight schedules offered by hub airlines may be more convenient; (2) it is more likely that passengers have frequent-flyer membership with a hub airline.[16] We also include the interaction variable "Hub × Stops", to capture the possibility that an advantage of hub products[17] over non-hub products may not be absolute. In other words, if a hub product happens to have sufficiently unattractive features (such as large number of intermediate stops) relative to a non-hub product, then consumers are likely to choose the non-hub product over the hub product. Consistent with these arguments, the coefficient on "Hub" is positive while the coefficient on "Hub × Stops" is negative. The negative coefficient on "Hub ×

[14] The coefficient on "Hub × Stops" is also negative which implies that intermediate stops are viewed negatively by consumers whether or not the product is a hub product. This interaction variable is discussed further in a subsequent paragraph.
[15] The minimum value that the "Convenient" variable can take on is 1. As such, the further an itinerary's "Convenient" measure is from 1, the less convenient is the itinerary.
[16] See Proussaloglou and Koppelman (1995), Berry (1990), Schumann (1986).
[17] As described earlier, a hub product means that the origin airport on the itinerary is a hub for the airline that offers the product for sale.

Stops" also suggests that intermediate stops are viewed more negatively for hub products compared to non-hub products.[18]

Ito and Lee (2007) argue that passengers that are members of an airline's frequent-flyer program may view the airline's virtual codeshare product as an inferior substitute to its pure online product since virtual tickets often do not allow the frequent-flyer to upgrade to first class even though the flights on the two itineraries (pure online and virtual) are the same. This argument leads us to expect the negative sign of the coefficient on the "Virtual" dummy variable in Table 1.4. In other words, the negative sign suggests that passengers perceive virtual codeshare products as inferior substitutes to pure online products.

The estimate of σ is statistically greater than zero, but its value is closer to zero than one. As such, there is statistical (but weak economic) evidence that passengers perceive the set of products offered by an airline as closer substitutes for each other compared to the substitutability of these products with products offered by other airlines [Gayle (2007b)]. In other words, passengers' choice behavior does have some element of airline brand-loyalty associated with it, even though this brand-loyalty does not seem to be very strong.

The results in Table 1.4 indicate that $\lambda_1 < 0$, $\lambda_2 < 0$, and $\lambda_3 > 0$. First, $\lambda_1 < 0$ implies that the mean level of utility declines over the pre and post-alliance periods for products offered by airlines other than Delta, Continental, or Northwest. Second, $\lambda_2 < 0$ implies that the mean utility for products offered by Delta, Continental, or Northwest in markets where the three airlines do not virtual codeshare together falls by more compared to the fall in mean utility for products offered by other airlines in the said markets. Third, $\lambda_3 > 0$ suggests that virtual codesharing between Delta, Continental, and Northwest has a demand-increasing effect associated with it, which is the main demand effect of virtual codesharing we set out to test.

We also tested the null hypothesis that $\lambda_1 + \lambda_2 + \lambda_3 = 0$, and could not reject this null hypothesis at conventional levels of statistical significance. In other words, the statistical evidence suggests that the mean utility is unchanged over the pre and post-alliance periods for products offered by Delta, Continental, and Northwest in markets where the three airlines virtual codeshare together. However, note that this is in contrast to the decrease in mean utility ($\lambda_1 + \lambda_2 < 0$) for Delta, Continental, and Northwest's products in markets where the three

[18] See Gayle (2007a) for some intuition on this result.

airlines do not virtual codeshare together. In summary, the apparent demand-increasing effect of virtual codesharing serves to halt the decline in mean utility obtained from products offered by Delta, Continental, and Northwest.

Results from the System GMM Estimation

We now discuss results from joint estimation of parameters in the demand and supply equations, which are reported in Table 1.5. Given the nonlinearity in how both demand and supply parameters enter the supply equation, the system GMM estimation algorithm was overwhelmed by the large number of matrices (which is determined by the large number of markets in the sample)[19] that have to be computed with each iteration in searching for the set of parameters that minimizes the GMM objective function.[20] So we proceeded by using a random number generator to randomly select a manageable subsample of markets from the full data set on which we ran the system GMM estimation algorithm. The random subsample has a total of 495 origin-destination markets (approximately 12% of full sample origin-destination markets) and 14,431 products that span the pre and post-alliance periods.[21] Delta, Continental, and Northwest virtual codeshare together in 256 (or 51.7%) of the 495 subsample origin-destination markets during the post-alliance period. In the full sample the three airlines virtual codeshare together in 52.6 % of the origin-destination markets during the post-alliance period. This is an encouraging sign that our randomly drawn subsample is representative of the full sample. Furthermore, the qualitative demand results are consistent across Tables 1.4 and 1.5, which gives us additional reassurance that our random subsample used for Table 1.5 is fairly representative of market conditions in the full sample. As such, we go straight to discussing the supply results in Table 1.5.

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[19] Please revisit the supply side of the econometric model outlined previously to see the structure of the matrices that must be computed for each market.
[20] When we ran the GMM estimation algorithm on the full sample using a very powerful computer (Intel Core2 quad, 8GB random access memory, 64 bit operating system), the computer code ran continuously for over two and a half months (more than 80 days) without convergence. The significant number of markets in the full sample caused a single iteration in the GMM algorithm to take more than one minute.
[21] Recall that in the data section we report that the full sample has 124,965 products contained in 4,300 origin-destination markets.

Table 1.5 Demand and Supply Parameter Estimates

Variable	**Coefficient**	**Standard Error**
Demand Equation:		
Constant	-10.318*	0.003
Price	-1.000*	0.001
Stops	-0.612*	0.001
Convenient	-0.544*	0.000
Hub	0.915*	0.005
Hub × Stops	-0.753*	0.001
Virtual	-1.627*	0.001
σ	0.001*	0.0002
T	λ_1 = -0.039*	0.0005
T × DCN	λ_2 = -0.086*	0.001
T × DCN × Codeshare_mkt	λ_3 = 0.083*	0.001
Supply Equation:		
Marginal Cost Shifters		
Constant	-0.520	0.419
Distance	0.280	0.263
Distance^2	-0.000004	0.0003
T	0.006*	0.001
Competitive Interaction Parameters		
ϕ_{dcn}^{pre}	0.453	0.776
ϕ_{-dcn}^{pre}	0.032	0.359
$\phi_{dcn,v=0}^{post}$	14.630	24.208
$\phi_{-dcn,v=0}^{post}$	2.981	2.148
$\phi_{dcn,v=1}^{post}$	-0.101*	0.002
$\phi_{-dcn,v=1}^{post}$	-0.410†	0.163
GMM objective = 3574.25		

Notes: The demand equation includes a set of ticketing carrier dummies while the supply equation includes a set of operating carrier dummies even though the estimated dummy coefficients are not reported in the table. * and † indicate statistical significance at the 1% and 5% levels respectively.

First, consistent with previous empirical findings [see Berry, Carnal, and Spiller (1997) and Gayle (2007a)], the sign pattern of the coefficients on distance and distance squared suggests that marginal cost increases with itinerary distance up to some distance threshold and declines in distance thereafter. However, the distance coefficients are not statistically significant at conventional levels of significance.

Second, recall that T is a zero-one time dummy that equals one for the post-alliance period. The positive coefficient associated with T in the marginal cost function suggests that marginal cost increased over the time period of our sample. This result is not surprising given increases in fuel cost over the period.

Our most important result from the supply equation lies in the estimated competitive interaction parameters. The competitive interaction parameters for the pre-alliance period (ϕ_{dcn}^{pre} and ϕ_{-dcn}^{pre}) and for the markets in which Delta, Continental, and Northwest compete but do not virtual codeshare together in the post-alliance period ($\phi_{dcn,\ v=0}^{post}$ and $\phi_{-dcn,\ v=0}^{post}$), are statistically indistinguishable from zero at conventional levels of significance. In other words, the degree of market competitiveness characterized by differentiated products Bertrand Nash equilibrium ($\phi = 0$) cannot be rejected in these markets. However, $\phi_{dcn,\ v=1}^{post}$ and $\phi_{-dcn,\ v=1}^{post}$ are both statistically less than zero at conventional levels of significance, which implies that competition is more aggressive than Bertrand Nash in markets where Delta, Continental, and Northwest compete and virtual codeshare together in the post-alliance period.

Even though we find that competition is more aggressive in markets where the three airlines compete and virtual codeshare together, it is interesting to know whether such heightened competition is uniform across all airlines in these markets. In other words, is there a difference in the level of competition between Delta, Continental, and Northwest versus the level of competition between the other airlines in these markets? To get at this question we formally test whether $\phi_{dcn,\ v=1}^{post}$ is statistically equal to $\phi_{-dcn,\ v=1}^{post}$ and find that we reject this equality in favor of $\phi_{dcn,\ v=1}^{post} > \phi_{-dcn,\ v=1}^{post}$ at conventional levels of significance.[22] We may interpret this finding as suggesting that Delta, Continental, and Northwest managed to soften competition between themselves relative to other competitors in markets where the three virtual codeshare together in the post-alliance period. Thus, there is evidence of a collusive effect in these markets.

This subtle effect on competition cannot be picked up by the reduced-form econometric approach in Gayle (2008), which basically estimates changes in price and quantity over the pre

[22] We use a simple standard normal z-test in which the null hypothesis is, H_0: $\phi_{dcn,\ v=1}^{post} = \phi_{-dcn,\ v=1}^{post}$, while the alternative hypothesis is, H_a: $\phi_{dcn,\ v=1}^{post} > \phi_{-dcn,\ v=1}^{post}$. The computed z score is 1.896, while the critical z for a one tail test at 5% level of significance is 1.64. So we reject H_0 in favor of H_a.

and post-alliance periods that are associated with the codeshare alliance. The reason is that equilibrium price and quantity changes nest both demand and supply effects. As such, a structural econometric model is needed to properly disentangle these effects, which is what we have shown in this paper.

Counterfactual Simulations

We now use our model to perform counterfactual simulations that reveal how virtual codesharing between Delta, Continental, and Northwest in their overlapping markets influenced their equilibrium prices, number of passengers, and consumer surplus. The three counterfactual questions we address are:

1. How would the three airline's equilibrium prices, number of passengers, and consumer surplus change if only the demand-increasing effect associated with virtual codesharing was removed ($\lambda_3 = 0$)?

2. How would the three airline's equilibrium prices, number of passengers, and consumer surplus change if competition between all airlines remained uniform ($\phi^{post}_{dcn,\ v=1} = \phi^{post}_{-dcn,\ v=1}$, which effectively removes collusive effects of virtual codesharing) in markets where the three airlines virtual codeshare together in the post-alliance period?

3. How would the three airline's equilibrium prices, number of passengers, and consumer surplus change if the demand-increasing and collusive effects associated with virtual codesharing between these airlines were removed?

The counterfactual experiments hold market conditions in the post-alliance period constant and simulate new market equilibria in each of the three cases described above. So actual post-alliance prices, number of passengers, and consumer surplus serve as benchmarks in each of the experiments. Note however that the experiments presume that all competing airlines would make the same product characteristic choices in the absence of demand-increasing and/or collusive effects associated with virtual codesharing, which might not necessarily be the case. To account for endogenous product characteristic choice we would have to significantly modify the model to incorporate elements of empirical entry models [Aguirregabiria and Ho (2008), Ciliberto and Tamer (2009)], which is beyond the scope of this paper.

We only outline how the model is used to perform counterfactual experiment (3), after which it is straightforward to see how counterfactual experiments (1) and (2) are implemented.

Similar in spirit to simulation techniques in Nevo (2000), we first use our supply equation to recover marginal costs ($\hat{\mathbf{w}}$) as follows:

$$\hat{\mathbf{w}} = \mathbf{p} - \mathbf{m}^{post}\left(\mathbf{p}, \lambda_3, \phi^{post}_{dcn,\ v=1}, \phi^{post}_{-dcn,\ v=1}\right)$$

where $\mathbf{p}$ is the vector of actual post-alliance prices. All demand and supply parameters are set equal to their estimated values in Table 1.5. With $\hat{\mathbf{w}}$ in hand, we can then use the supply equation again to solve for the price vector $\mathbf{p}^*$ that satisfy:

$$\mathbf{p}^* = \hat{\mathbf{w}} + \mathbf{m}^{post}\left(\mathbf{p}^*, \lambda_3 = 0, \phi^{post}_{dcn,\ v=1} = \phi^{post}_{-dcn,\ v=1} = -0.410\right) \quad (1.15)$$

where λ_3 is counterfactually set equal to 0, and $\phi^{post}_{dcn,\ v=1}$ is counterfactually set equal to -0.410. Recall that λ_3 captures the demand-increasing effect of virtual codesharing between the three airlines.[23] A comparison of $\mathbf{p}$ with $\mathbf{p}^*$ reveals how equilibrium prices change as a result of counterfactually setting $\lambda_3 = 0$ and $\phi^{post}_{dcn,\ v=1} = -0.410$. The equilibrium quantity effect associated with virtual codesharing between the three airlines is computed by $\Delta s_j = s_j\left(\mathbf{p}, \lambda_3 = \hat{\lambda}_3\right) - s_j\left(\mathbf{p}^*, \lambda_3 = 0\right)$, where $\hat{\lambda}_3 = 0.083$ from Table 1.5, s_j is the predicted product share function in equation (1.4), and product *j* is offered for sale by either Delta, Continental, or Northwest airlines.

The well-known expression for consumer surplus in the case of the nested logit demand model is:

$$CS = \frac{1}{\alpha}\ln\left(1 + \sum_{g=1}^{G} D_g^{(1-\sigma)}\right) \quad (1.16)$$

Among other things, *CS* is a function of equilibrium prices and λ_3. To compute the status quo consumer surplus ($CS_{\mathbf{p},\lambda_3=\hat{\lambda}_3}$), we evaluate equation (1.16) at actual post-alliance market prices and the estimated parameter value of λ_3 in Table 1.5. On the other hand, the counterfactual consumer surplus is computed at the new simulated market equilibrium prices when λ_3 is set equal to 0 and $\phi^{post}_{dcn,\ v=1}$ is set equal to -0.410, that is $CS_{\mathbf{p}^*,\lambda_3=0}$, where $\mathbf{p}^*$ is the predicted equilibrium price vector in the absence of demand-increasing and collusive effects of

[23] See equation (2) and Table 5.

virtual codesharing. We then compute the change in consumer surplus attributed to these effects of virtual codesharing by $\Delta CS = CS_{\mathbf{p},\lambda_3=\hat{\lambda}_3} - CS_{\mathbf{p}^*,\lambda_3=0}$.

By only removing the demand-increasing effect of virtual codesharing between the three airlines in their overlapping markets (counterfactual experiment (1)), we find that the partners' equilibrium prices would fall by a mean 0.0003 percent, while their equilibrium number of passengers would fall by a mean 7.95 percent. On the other hand, by only removing the collusive effect (counterfactual experiment (2)), we find that the partners' prices would fall by a mean 0.002 percent, while their equilibrium number of passengers would rise by a mean 0.004 percent. While the price changes are small, the mean price reduction is larger when we remove the collusive effects compared to removing the demand-increasing effects of virtual codesharing. On the other hand, the expected opposing quantity (number of passengers) changes attributed to demand-increasing versus collusive effects seem to be dominated by the demand-increasing effects.

Next we run counterfactual experiment (3) in which we simultaneously remove demand-increasing and collusive effects of virtual codesharing between the three airlines. In this case we find that the partners' equilibrium prices would fall by a mean 0.002 percent, while their equilibrium number of passengers would fall by a mean 7.95 percent. In summary, the demand-increasing and collusive effects of virtual codesharing reinforce each other in their influence of the partners' prices, with collusive effects accounting for a larger portion of the relatively small price increases in the case of the Delta/Continental/Northwest codeshare alliance. On the other hand, the demand-increasing and collusive effects of virtual codesharing oppose each other in their influence on the partners' number of passengers, with the demand-increasing effect dominating in the case of the Delta/Continental/Northwest codeshare alliance.

For rough comparative purposes, parameter estimates from the reduced-form econometric model in Gayle (2008)[24] suggest that virtual codesharing between the three airlines is associated with an approximate 1 percent increase in the partners' price[25] and an approximate 23 percent

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[24] See Table 7 in Gayle (2008).

[25] Since price increases depend on the pre-alliance level of city pair concentration (HHI_{pre} in Gayle's (2008) reduced-form econometric model), we evaluate the percent price increase at his sample mean pre-alliance city pair concentration ($HHI_{pre} = 0.532$).

increase in the partners' traffic (number of passengers). Therefore, the price-quantity effects generated from our structural econometric model seem to be a little more conservative.

As described above, our structural econometric model can be used for consumer surplus analysis in a straightforward way. This is another advantage of the econometric model in this paper compared to the reduced-form model in Gayle (2008). By counterfactually removing only the demand-increasing effect of virtual codesharing between the three airlines in their overlapping markets, we find that consumer surplus falls by a mean 4.12 percent. Second, by only removing the collusive effects we find that consumer surplus increases by a mean 0.002 percent. Last, by removing both collusive and demand-increasing effects we find that consumer surplus falls by a mean 4.12 percent. So on net, consumers seem to be better off as a result of the virtual codesharing between the three airlines. These results also reveal that even though virtual codesharing is associated with price increases, this type of codesharing nonetheless increases consumer surplus owing to its demand-increasing aspects.

1.7. Conclusions

The central question that this paper sets out to answer is: Has the Delta/Continental/Northwest codeshare alliance reduced competition between these carriers in their overlapping markets? Specifically, we focused on the market effects of virtual codesharing in the three airlines' overlapping markets since this is the only type of codesharing that was found to be associated with price increases in previous work [see Gayle (2008)]. To achieve our objective, we put together a structural econometric model of air travel demand and supply that is tailored to disentangle the demand and supply sources of equilibrium price-quantity changes associated with virtual codesharing. So in addition to answering the specific question we pose, we also believe that this paper contributes to the methodology of analyzing the competitive effects of codeshare alliances.

Our two major findings are as follows: (1) econometric estimates for the air travel demand equation suggest that virtual codesharing between Delta, Continental, and Northwest has a demand-increasing effect associated with it; (2) econometric estimates for the air travel supply equation suggest that virtual codesharing between the three airlines in their overlapping markets is associated with a softening of competition between them relative to competition between other competing airlines. The demand-increasing effect is consistent with our expectations since passengers that are members of an airline's frequent-flyer program may cumulatively earn and redeem frequent-flyer miles across any partner in the alliance. So the demand-increasing effect likely stems from the new opportunities for passengers to earn and redeem frequent-flyer miles across alliance partners. In the case of our collusive effect result, even though we find that overall competition is more aggressive in markets where the three airlines compete and virtual codeshare together during the post-alliance period, Delta, Continental, and Northwest managed to soften competition between themselves relative to other competitors in these markets.

We use our model to perform counterfactual experiments by simulating new market equilibria in the post-alliance period when the demand-increasing and collusive effects of virtual codesharing are removed. These experiments show that the demand-increasing and collusive effects of virtual codesharing reinforce each other in their influence of the partners' prices, with collusive effects accounting for a larger portion of the relatively small price increases in the case of the Delta/Continental/Northwest codeshare alliance. On the other hand, the demand-increasing and collusive effects of virtual codesharing oppose each other in their influence on the partners' number of passengers, with the demand-increasing effect dominating in the case of the Delta/Continental/Northwest codeshare alliance.

Using post-alliance market prices, number of passengers, and consumer surplus as benchmarks, removing the demand-increasing and collusive effects resulted in the partners' prices falling by a mean 0.002 percent, their number of passengers falling by a mean 7.95 percent, and consumer surplus falling by a mean 4.12 percent. On net, this codeshare alliance seems to have improved consumer surplus owing to the domination of demand-increasing effects over collusive effects, which should be reassuring to policymakers who approved the alliance. However, now that we have evidence that a codeshare alliance can be associated with collusive effects, policymakers should exercise caution in approving future alliances since collusive effects may not always be dominated by demand-increasing effects.

Last, we should point out that a caveat of our counterfactual experiments is that they presume that all competing airlines would make the same product characteristic choices in the absence of demand-increasing and/or collusive effects of virtual codesharing between the three airlines, which might not necessarily be the case. A fruitful area for future research is to endogenize product characteristic choices of airlines when evaluating the market effects of an alliance. The empirical industrial organization literature on entry models may prove useful in developing such a framework.[26]

[26] See Berry and Reiss (2007) and Doraszelski and Pakes (2007) for reviews of this literature.

CHAPTER 2 - Analyzing the Effect of a Merger between Airline Codeshare Partners

2.1. Introduction

Market power is often studied in the microeconomic literature for various reasons. Industries with high concentration ratios sometimes have higher markups and profits due to the firms' ability to set higher prices. Mergers are of particular interest in the industrial organization literature. When a merger occurs, the market will become more concentrated, but the net effects aren't always the same – a merger could be harmful by greatly decreasing competition, increasing prices, and heightening entry barriers. A merger may also be beneficial by creating cost efficiencies (leading to lower prices), which can be conducive to competition.

Although there was speculation as far back as February 2008 about a possible merger between Delta Airlines and Northwest Airlines,[27] Delta announced its plans to acquire Northwest on April 14, 2008.[28] The combined carrier will operate under the Delta name, be headquartered in Atlanta, and operate the nine hubs of both airlines in the U.S., Europe, and Asia.

Critics believe the merger will cause significant price increases and may even initiate other large airline mergers, eventually leading to an industry with less than 5 main competitors. If true, this could lead to higher markups and prices if market power could be exercised.

Proponents, specifically the airlines, argue that the merger will have positive effects, and that the positive effects will outweigh any negative effects such as price increases. If two firms wanting to merge can show the benefits of the merger – such as cost efficiencies and increased quality of service – the merger has a greater chance of getting approved by the U.S. Department of Justice (DoJ).[29]

On August 6th, 2008, the European Commission gave unconditional clearance for the Delta/Northwest merger. The Commission stated that the merger would not impede effective competition in Europe or the trans-Atlantic. Further, a new development occurred less than two

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[27] Atlanta Journal-Constitution.
http://www.ajc.com/business/content/business/delta/stories/2008/02/16/delta_0217.html
[28] CNN Money.
http://money.cnn.com/2008/04/14/news/companies/delta_northwest/index.htm
[29] DoJ Horizontal Merger Guidelines. http://www.usdoj.gov/atr/public/guidelines/horiz_book/4.html

months later on September 25th when the stockholders of the two companies "overwhelmingly approved" the merger. [30] After the shareholders approved, the legal processes continued, and it was up to the DoJ to examine the situation to see if the merger would be permitted.

On October 29th, 2008, the DoJ approved the Delta/Northwest merger, stating that "the Division has determined that the proposed merger between Delta and Northwest is likely to produce substantial and credible efficiencies that will benefit U.S. consumers and is not likely to substantially lessen competition".[31] The integration process will take approximately 2 years to complete, and began in January 2009.[32]

This merger is of particular interest because Delta and Northwest are codeshare partners. With codesharing, a trip is ticketed by a single carrier, even though some (or all) of the flights on the passenger itinerary are operated by a different carrier, which is the codeshare partner. This is different from a pure online flight itinerary, in which the trip is ticketed and operated by the same carrier. [33]

There is a growing body of literature that analyzes airline mergers and the effects they have on market power and airline fares. Beutel and McBride (1992) illustrate a direct econometric method to estimate the change in market power caused by a merger. Their results indicate that the quantitative effects of a merger are directly related to the pre-merger market power of the merging firms. Singal (1996) studies the pricing behavior of airlines following mergers that occurred in the 1980's, and finds that changes in market concentration as well as changes in multimarket contact can significantly affect fares. Morrison (1996) uses a unique dataset to analyze long-term trends and effects of mergers by looking 7 years before and after a merger occurs, paying special attention to routes that were served by both carriers before the merger. For the three mergers studied, fares for the newly merged firm increased immediately after the merger, but fell over time to levels at or below competitors' fares. Clougherty (2006) studies domestic mergers, but argues that these mergers are driven by international competition incentives as well as domestic competition incentives. He finds that domestic mergers lead to an

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[30] Delta Press Release
http://news.delta.com/article_display.cfm?article_id=11162
[31] Department of Justice Press Release
http://www.usdoj.gov/atr/public/press_releases/2008/238849.htm
[32] Delta Press Release
http://news.delta.com/article_display.cfm?article_id=11176
[33] Formal definitions of codeshare and pure online products are given in Section 2.

increased international competitive performance due to network enhancement and network consolidation effects. Peters (2006) uses a counterfactual simulation method in order to predict price increases resulting from five airline mergers that occurred in the 1980s, and compares the predicted price increases to actual price increases. The post-merger data allowed differences in predicted price changes and actual price changes to be decomposed. He finds that unobservable supply-side factors, namely changes in marginal costs and deviations from the assumed model of firm conduct, play a large role in post-merger price increases. Adler and Smilowitz (2007) demonstrate a basic framework assuming competitive markets and minimal regulation that allows airlines to choose both international network structure and alliances. They find that both alliances and mergers have a positive effect for partners involved but damaging effects for an airline that fails to find an alliance or merger partner.

Other literature has studied the effects of frequent flyer alliances, but with the exception of Ito and Lee (2007), Gayle (2008), and Bilotkach (2007), these studies do not address the different types of products associated with codesharing with frequent flyer alliances. Bilotkach (2007) examines airline consolidation (defined as forming an alliance and codesharing) using transatlantic markets to determine if codesharing with and without antitrust immunity decreases fares for interline trips equally. The results show that codesharing and alliance-forming both have fare-decreasing effects, but the codesharing effect is more than twice the magnitude of the alliance effect. As noted in Brueckner and Whalen (2000) and Brueckner (2003), codesharing allows airlines to eliminate a double markup on itineraries with multiple operators, resulting in lower fares. Ito and Lee (2007) also show codesharing to be associated with lower fares.

This paper analyzes potential market effects of the Delta/Northwest merger with a particular focus on comparing predicted price changes across different product types (codeshare vs. pure online). To estimate the potential effects of the merger, we use a well-known structural econometric framework[34] to examine markets in which Delta and Northwest both offer products prior to the merger. Specifically, we use pre-merger data to estimate demand, then use the demand parameter estimates along with an assumed price-setting behavior (Bertrand-Nash) of airlines to recover product-level marginal costs. With the product-level marginal costs and demand estimates in hand, we use the multiproduct firm Bertrand-Nash pricing framework to conduct counterfactual experiments. One counterfactual experiment we ran is to compute the

[34] For examples, see Nevo (2000) and Ivaldi and Verboven (2005).

extent to which Delta and Northwest product prices might increase in the worst case scenario in which the merger does not produce any efficiency gains. To the best of our knowledge, our paper is the first to examine the potential market effects across different product types of an airline merger between codeshare alliance partners.

The data reveal that Delta and Northwest products are substitutable (competing) in a significant number of markets in which they offer products. Delta offers products in over half of the markets in which Northwest offers products, and Northwest offers products in almost half of the markets in which Delta offers products. Thus, antitrust authorities clearly should not grant approval of the merger on the grounds that these carriers rarely compete. Deeper analysis is required to assess the extent to which: (1) these two carriers constrain each other's pricing decisions when they compete; (2) other competing carriers would constrain the joint pricing behavior of Delta and Northwest. To examine these issues we use our econometric model to predict the extent to which Delta and Northwest's product prices will increase if these products are jointly priced in the worst case scenario where the merger is not associated with cost efficiency gains.

In our sample, Delta and Northwest have a combined 27.1% passenger share in the U.S. domestic industry, varying between 0.42% to 100% in different markets. Based on our econometric estimates, the average predicted change in price due to the merger is only an increase of 0.62%, hardly big enough to concern consumers. However, the maximum predicted increase in price was over 6%.

To better understand predicted percent price increases for Delta and Northwest products (which varied across markets and product types), we ran auxiliary regressions with predicted percent price increases as the dependent variable and various product and market characteristics as regressors. The results reveal a significant positive relationship between the share of Delta/Northwest passengers in a market and the predicted increase in prices attributed to the merger. We also find that Delta/Northwest codeshare products have higher predicted price increases relative to their pure online products.

We then analyzed market level (rather than product level) factors that influence the predicted price increases. Our estimates suggest that longer-distance markets are expected to experience lower price increases, and that the presence of other airlines offering competing products is crucial in keeping the predicted price increases of Delta/Northwest products low.

Finally, we were fortunate that the limited amount of post-merger data available (second and third quarters of 2009) at the time when this paper was been written had Delta and Northwest products still separately identified, even though the merger was long approved by antitrust authorities and therefore the two airlines were likely to have started jointly pricing their products. We exploit this window of opportunity and re-estimate our econometric model and perform counterfactual "de-merger" simulations with this unique 2009 post-merger data. Assuming that these post-merger data are characterized by Delta and Northwest jointly pricing their products, our counterfactual "de-merger" analysis suggests that the two airlines' product prices would fall by a mean 0.748% if they separately priced their products, with the maximum predicted price reduction being 7.2%. We found it encouraging that these counterfactual "de-merger" predicted price changes are consistent with our predicted price changes when pre-merger data were used to perform counterfactual "merger" simulations.

The rest of the paper is as follows: Section 2.2 outlines the demand model while Section 2.3 details the estimation. Section 2.4 is devoted to explaining the merger analysis. Section 2.5 discusses the data, the results are covered in Section 2.6, and Section 2.7 offers concluding remarks.

2.2. The Model

Definitions

Some definitions are worth mentioning before illustrating the model. These definitions follow from Gayle (2007a and 2008). A *market* is defined as an origin-destination combination. Markets are directional, meaning that a trip from Los Angeles to New York is a different market than a trip from New York to Los Angeles. This allows us to consider origin city characteristics such as population and whether or not the airport is a hub for the carrier offering the air travel product for sale. Directional markets also allow for the use of origin and destination fixed effects.

An *itinerary* contains the origin and destination of the journey, as well as all of the intermediate stops. Thus, a non-stop flight from Chicago to Seattle is a different itinerary than a passenger who flies from Chicago to Seattle with a layover in Denver. A *product* is defined as a combination of airline(s) and itinerary. Each flight has a *ticketing carrier* and an *operating carrier*. The ticketing carrier is the airline that actually sells the flight ticket to the passenger and is the 'owner' of the product. The operating carrier is the airline that operates the plane that the passenger is traveling on for the flight.

Further, we want to study the effects of a merger on codeshared products relative to pure online products. While all flights have both an operating carrier and ticketing carrier, the ticketing carrier and operating carrier could be the same or different for any flight on the itinerary. A *pure online* product has a single ticketing carrier and operating carrier for the whole itinerary and the two carriers are the same. For example, a passenger buys a single ticket from United and flies on two United planes for his itinerary. A *traditional codeshare* product has a single ticketing carrier for the trip, but multiple operating carriers, one of which is the same as the ticketing carrier. For example, a single ticket is purchased from Delta for a two-flight itinerary where one of the planes is operated by Delta and the other is operated by Continental. A *virtual codeshare* product has a single ticketing carrier and operating carrier for the itinerary, but the operating and ticketing carriers are different. For example, a single-flight itinerary is ticketed through Northwest, but the flight is operated by Continental.[35]

Demand

We start by describing our discrete choice demand model in which a consumer chooses one product among many alternatives with the objective of utility maximization. The consumer also has the option to choose an outside alternative (driving, taking a train, or not traveling at all).

Following Berry and Jia (2009) and Berry, Carnall, and Spiller (2007), we use a random coefficients logit demand model. The utility function specification allows for two types of travelers, leisure (L) or business (B) travelers. Traveler *i* who is type $t \in \{L, B\}$, obtains the following utility if product *j* in market *m* is chosen:

$$u_{ijm} = x_{jm}\beta_t - \alpha_t p_{jm} + \xi_{jm} + \sigma\zeta_{igm} + (1-\sigma)\varepsilon_{ijm} \qquad (2.1)$$

where x_{jm} is a vector of non-price observed product characteristics, β_t is a random traveler-type-specific vector of parameters that measures the marginal utility of respective non-price product characteristics, p_{jm} is the price of the product, α_t is a measure of the traveler-type-specific marginal utility of price, ξ_{jm} captures product characteristics that are unobserved by

[35] For a more detailed analysis of codesharing, see Gayle (2008), and Ito and Lee (2007).

researchers but observed by travelers, and $\sigma\zeta_{igm} + (1-\sigma)\varepsilon_{ijm}$ is a random component of utility that is assumed to follow a distribution that yields the "nested logit" choice probability for type *t* travelers.

Let g = 1, 2,…, G index distinct product groups (nests) within a market, and one additional group (g = 0) for the outside good. Products within the same group are closer substitutes than products from different groups. Products in a market-quarter are grouped by non-stop versus products requiring intermediate stop(s) to complete the origin-destination trip. ζ_{igm} in equation (2.1) is a random component of utility that is common to all products in group g, while σ is a parameter that measures the correlation of the consumers' utility across products belonging to the same group. If σ = 1, there is a perfect correlation of preferences for products within the same group and the products are perfect substitutes. If σ = 0, there is no correlation of preferences. For all values of σ between 0 and 1 inclusive, the model is consistent with utility maximization, and each consumer *i* chooses the product *j* that maximizes his utility.

In what follows, we drop the market index *m* only to avoid a clutter of notation. As such, the reader should continue to interpret each equation in a market-specific way. The "within group" share of product *j* among type *t* consumers is

$$s_{j|g}^{t}(\mathbf{x},\mathbf{p},\boldsymbol{\xi},\theta) = \frac{\exp\left[\left(x_j\beta_t - \alpha_t p_j + \xi_j\right)/(1-\sigma)\right]}{D_{gt}} \tag{2.2}$$

where

$$D_{gt} = \sum_{k\in K_g}\exp\left[\left(x_k\beta_t - \alpha_t p_k + \xi_k\right)/(1-\sigma)\right].$$

The share of group g among type t consumers is

$$s_{g}^{t}(\mathbf{x},\mathbf{p},\boldsymbol{\xi},\theta) = \frac{D_{gt}^{1-\sigma}}{1+\sum_{g=1}^{G} D_{gt}^{1-\sigma}} \tag{2.3}$$

Let λ_t be the percentage of type *t* consumers in the population, where $t \in \{L, B\}$. The overall market share of product *j* in any given market is

$$s_j(\mathbf{x},\mathbf{p},\boldsymbol{\xi},\theta) = \lambda_L \times s_{j|g}^{L} \times s_g^{L} + \lambda_B \times s_{j|g}^{B} \times s_g^{B} \tag{2.4}$$

where $\lambda_L + \lambda_B = 1$, p and x are vectors of observed price and non-price product characteristics respectively, while $\boldsymbol{\xi}$ is a vector of unobserved (by researchers) product characteristics. Since

$\lambda_B = 1 - \lambda_L$, we only need to estimate λ_L. The vector of demand parameters to be estimated is, $\theta = (\alpha_L, \beta_L, \alpha_B, \beta_B, \sigma, \lambda_L)$.

The demand for product *j* is obtained by:

$$d_j = M \times s_j(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}, \theta), \qquad (2.5)$$

where *M* is a measure of the market size, which we assume to be the size of the population in the origin city.

Product Pricing and Marginal Cost

Each carrier *f* offers a set F_f of products for sale. Firm *f* has a variable profit of

$$\pi_f = \sum_{j \in F_f} (p_j - c_j) q_j, \qquad (2.6)$$

where $q_j = d_j(\mathbf{p})$ in equilibrium, q_j is the quantity of tickets for product *j* sold in the market, $d_j(\mathbf{p})$ is the market demand for product *j* specified in equation (2.5), p is a $J \times 1$ vector of product prices, and c_j is the marginal cost incurred from offering product *j*.

We assume carriers pricing behavior can be approximated by a simultaneous-move Nash game. Consistent with this assumption, carriers simultaneously choose prices to maximize profit, and multiproduct firms take into account that lost sales on one product may be partly offset by increased sales on another product. A multiproduct Nash equilibrium is given by the following system of *J* first order conditions:

$$\sum_{k \in F_f} (p_k - c_k) \frac{\partial s_k}{\partial p_j} + s_j = 0 \qquad \text{for all } j = 1, \ldots, J. \qquad (2.7)$$

Equation (2.7) can be re-written in the following way:

$$c_j = p_j - markup_j(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}, \theta), \qquad (2.8)$$

where $markup_j(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}, \theta)$ is a product markup function, which we subsequently discuss in the methodology for merger analysis section.

We use the following specification for the marginal cost function:

$$\ln c_j = w_j \gamma + \eta_j \qquad (2.9)$$

where w_j is a vector of observed marginal cost-shifting variables, γ is a vector of cost parameters to be estimated, and η_j captures shocks to marginal cost that are unobserved by researchers.

2.3. Estimation

We estimate the demand and marginal cost parameters jointly using Generalized Method of Moments (GMM). The structural demand and marginal cost error terms needed to construct moment conditions are ξ_j and η_j respectively. Constructing moment conditions using η_j is straightforward since it enters equation (2.9) linearly. However, constructing moments using ξ_j is more challenging since it enters equation (2.4) nonlinearly.

Our estimation strategy involves choosing demand parameters such that observed product share, S_j,[36] are equal to shares predicted by the demand model, that is,

$$S_j = s_j(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}; \theta) \text{ for all } j = 1, \ldots, J \tag{2.10}$$

To construct moment conditions using the structural demand error term, we first invert the system of equations characterized by equation (2.10) to solve for the vector of non-price unobserved product characteristics, $\boldsymbol{\xi}$, as a function of demand parameters, observed product shares, prices, and product characteristics,

$$\boldsymbol{\xi} = \mathbf{s}^{-1}(\mathbf{x}, \mathbf{p}, \mathbf{S}; \theta). \tag{2.11}$$

Following Berry and Jia (2009) and Berry, Carnall, and Spiller (2006), we use the following "contraction mapping" method to solve for $\boldsymbol{\xi}$:

$$\boldsymbol{\xi}^{r} = \boldsymbol{\xi}^{r\text{-}1} + (1-\sigma)\left[\ln \mathbf{S} - \ln \mathbf{s}(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}^{r\text{-}1}; \theta)\right], \tag{2.12}$$

where iterations are indexed by r, $\mathbf{s}(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}; \theta)$ is a vector of predicted product share functions based on equation (2.4), and S is a vector of observed product shares.

The preceding discussion results in the following moment conditions:

$$m_d = \frac{1}{n} Z_d' \boldsymbol{\xi}(\mathbf{x}, \mathbf{p}, \mathbf{S}; \theta) = \mathbf{0}, \tag{2.13}$$

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[36] Observed product shares are computed by $S_j = \frac{q_j}{M}$, where q_j is the quantity of tickets for product j sold in the market and M is the size of the population in the origin city.

where n is the number of observations in the sample, Z_d is a $n \times L_d$ matrix of instruments, and **0** is a $L_d \times 1$ vector of zeros. Moment conditions using the structural error term from the marginal cost equation is

$$m_s = \frac{1}{n} Z_s' \boldsymbol{\eta}(\mathbf{w}, \mathbf{p}, markups; \gamma) = \mathbf{0}\,, \tag{2.14}$$

where $\boldsymbol{\eta} = \ln[\mathbf{p} - markups(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}, \theta)] - \mathbf{w}\gamma$. Note that the moment conditions in (2.14) also help when estimating demand parameters since demand parameters enter these moment conditions through the markup function, $markups(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}, \theta)$.

The GMM optimization problem is

$$\underset{\hat{\theta},\hat{\gamma}}{Min}\left[m(\hat{\theta},\hat{\gamma})' W m(\hat{\theta},\hat{\gamma}) \right] \tag{2.15}$$

where $m(\hat{\theta},\hat{\gamma}) = \begin{pmatrix} m_d \\ m_s \end{pmatrix}$, and block diagonal weight matrix

$$W = \begin{pmatrix} \left[\frac{1}{n} Z_d' \boldsymbol{\xi}\boldsymbol{\xi}' Z_d \right]^{-1} & \mathbf{0} \\ \mathbf{0} & \left[\frac{1}{n} Z_s' \boldsymbol{\eta}\boldsymbol{\eta}' Z_s \right]^{-1} \end{pmatrix}.$$

The instruments in matrices Z_d and Z_s are subsequently discussed.

Instruments

For a valid set of demand instruments in Z_d, variables are needed that are associated with the price of the product but not the error term, ξ_j. Without using instruments, the estimated price coefficient will be inconsistent. Our demand instruments include the number of competitors in the market, the number of other products offered by the airline, characteristics of competing products offered by competitors, itinerary distance, and interactions of these variables. Each instrument has an intuitive explanation for their inclusion. For the competitors, supply theory predicts that a product's price will be influenced by the number and closeness of competitors in the market. Next, if an airline offers multiple products in the same market, the airline will jointly set the prices for these products. When considering other products, we examine competing products with the same number of intermediate stops and similar levels of convenience. The more similarities there are between competing products, the less discrepancy we expect between prices of these products. The inclusion of itinerary distance is based on the idea that distance is correlated with marginal cost and therefore influences price.[37]

For the supply side, we set $Z_s = \mathbf{w}$. In the marginal cost equation, the cost-shifting variables in $\mathbf{w}$ are assumed exogenous, and therefore estimates of γ will not be inconsistent.

2.4. Methodology used for Merger Analysis

Following the general procedure described in Nevo (2000), marginal costs are recovered by using the estimated demand elasticities and assuming a model of pre-merger pricing conduct. The new price equilibrium is computed by using estimated demand elasticities, pre-merger marginal costs, and assuming a model of post-merger pricing conduct. Finally, the predicted post-merger equilibrium prices are compared to actual pre-merger prices.

The first order conditions that characterize optimal price-setting behavior can be written using matrix notation as follows:

$$(\mathbf{p} - \mathbf{c}) \times (\Omega .* \Delta) + \mathbf{s} = 0, \qquad (2.16)$$

where p, c, and s are $J \times 1$ vectors of product prices, marginal costs, and predicted product shares respectively, Ω is a $J \times J$ matrix which captures airline ownership structure of the products, .* is the operator for element-by-element matrix multiplication, and Δ is a $J \times J$ matrix of own and cross price effects ($\frac{\partial s_j}{\partial p_j}$ and $\frac{\partial s_k}{\partial p_j}$ respectively) for all products with the own-price effects on the main diagonal.

The ownership structure matrix, Ω, consists of zeroes and ones and shows which products have the same owner. Let Ω_{ij} denote the element in the i^{th} row and j^{th} column of matrix Ω, where *i* and *j* also index products. If products *i* and *j* are owned by the same firm, then $\Omega_{ij} = 1$, otherwise, $\Omega_{ij} = 0$. For example, suppose there is a four-product market where there are three airlines, A, B, and C. Suppose A owns products 1 and 3, B owns product 2, and C owns product 4. The ownership structure would be defined as follows:

[37] See Gayle (2007a) for similar types of instruments.

$$\Omega = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

If one airline owns all the products in a market, the ownership structure would be a $J \times J$ matrix of ones, with J being the number of products in the market.

Product markups are determined separately for each market. The markups for products in any given market are:

$$\textit{markups} = \mathbf{p} - \mathbf{c} = -(\Omega .* \Delta)^{-1} \times \mathbf{s}. \tag{2.17}$$

The counterfactual experiment involves specifying both a pre-merger and a post-merger product ownership structure. First, marginal costs are recovered using the pre-merger product ownership structure as follows:

$$\hat{\mathbf{c}} = \mathbf{p} + (\Omega^{pre} .* \Delta)^{-1} \times \mathbf{s}, \tag{2.18}$$

where $\hat{\mathbf{c}}$ is the vector of estimated marginal costs for all products and Ω^{pre} is the pre-merger product ownership structure. Now, assuming a post-merger product ownership structure of Ω^{post} and using pre-merger marginal costs, we can compute post-merger equilibrium prices by searching for the new price vector $\mathbf{p}^*$ that satisfies

$$\mathbf{p}^* = \hat{\mathbf{c}} - \left[\Omega^{post} .* \Delta(\mathbf{p}^*)\right]^{-1} \times \mathbf{s}. \tag{2.19}$$

Having solved for post-merger equilibrium prices $\mathbf{p}^*$, we can compare $\mathbf{p}^*$ to $\mathbf{p}$ to predict how the merger would affect prices.[38]

Based on the ownership matrix Ω^{pre}, Delta and Northwest separately and independently set the price of their products within a market for which each of them are a ticketing carrier. This is true for all their product types – pure online, traditional codeshare, and virtual codeshare. In the case of the Ω^{post} ownership matrix, these Delta/Northwest products in the market are all jointly priced by the new ticketing carrier formed by the merger of Delta and Northwest.

2.5. Data

[38] Ivaldi and Verboven (2005) provide another application of this model by studying horizontal mergers approved by the European Commission.

Data are gathered from the DB1B market survey, published by the U.S. Department of Transportation. This dataset is a quarterly 10% sample of all flight itineraries in the U.S. Each observation in the dataset is a flight itinerary and includes information on operating and ticketing carriers, fares, passengers, intermediate stops, total itinerary distance, and the number of airports in the origin and destination city. Data was collected for four quarters: 2007:2, 2007:3, 2007:4, and 2008:1. Only markets that appear in all four quarters and include both Delta and Northwest itineraries are used for analysis. The data are further restricted to include only itineraries in the contiguous U.S., and foreign operating carriers such as Air France and Iberia are eliminated. Further, observations were dropped that listed market fares less than $25 – this helps us avoid discounted fares that may be due to employee travel or passengers using frequent-flyer miles.[39]

Collapsing the Data

Each quarter of data originally had over 5 million observations, making the data extremely large and unmanageable. Due to the airlines being very effective at using yield management, there are many identical itineraries that have different observed fares. This leads to the dataset containing many repeat itineraries each listed as having passengers paying different fares. To render our data more manageable, the dataset was collapsed by product – for each quarter, passengers were aggregated over a given itinerary-airline(s) combination (this created the *quantity* variable) and the average market fare was found, creating the *price* variable. In the collapsed data set, each airline(s)-itinerary-quarter combination appears only once, with its aggregated passenger quantity and average market fare. Following Berry (1992), we then eliminate itineraries that have less than 50 passengers for the quarter.[40]

Creation of Other Variables

From this collapsed dataset, observed product market shares S_j are created. For the purpose of properly identifying codeshare products in the data, feeder/regional operating carriers are recoded to match their major company.[41] For example, Comair Delta Connection (OH) was recoded as Delta (DL). Airline dummies are created, as well as indicators for whether the

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[39] See Ito and Lee (2007) and Brueckner (2003).
[40] Berry eliminated itineraries that had less than 90 passengers for the quarter.
[41] If we did not recode operating feeder carriers to have their major carrier code, then products that have the major carrier as the ticketing carrier and associated regional feeder carrier(s) as operating carrier(s) will mistakenly be counted as codeshare products since the operating and ticketing carrier codes would differ.

itinerary was pure online, traditional codeshared, or virtual codeshared. Ticketing carriers that appeared less than 50 times were dropped – this eliminated 6 smaller ticketing carriers that combined to make up only 135 observations. The final set of ticketing carriers is presented in Table 2.1. A dummy variable *hub_origin* was created indicating whether the origin airport is a hub for the ticketing carrier.

A measure of product convenience is created as well, and is defined as itinerary distance divided by *nonstop_miles*, where *nonstop_miles* is the direct flight distance between origin and destination. Thus, the most *convenient* itinerary for a given market would be a direct flight from origin to destination. Because of how the variable is defined, the minimum value for *convenient* is equal to 1.

Table 2.1 Airlines represented in the dataset

Code	Airline
AA	American Airlines
AS	Alaskan Airlines
B6	JetBlue Airways
CO	Continental Airlines
DL	Delta Airlines
F9	Frontier Airlines
FL	Airtran Airways
NW	Northwest Airlines
UA	United Airlines
US	US Airways
WN	Southwest Airlines
YX	Midwest Airlines

For our purposes, each itinerary needs to have an 'owner', so itineraries that were listed as having multiple ticketing carriers were discarded from the sample. After each product is listed as having a single owner, product types are created and are denoted as *pure online*, *traditional codeshare*, and *virtual codeshare*.

Quarter dummies and fixed effects for the origin and destination are added to the dataset as well. Thus, observed product characteristics (x_j) include the following variables: convenience, a dummy indicating whether or not the flight is nonstop, hub origin indicator, codeshare type, quarter, airline indicator, and the origin and destination fixed effects. After cleaning and collapsing the data, the combined four quarters contain 10,217 observations across 1,936 markets.

In order to assess the degree of substitutability across Delta and Northwest products, we analyzed the original dataset before performing any of the data cleaning described above. For each quarter, we examine the number of markets and the presence of Delta/Northwest in the markets. Table 2.2 shows the results.

We can clearly see that Delta offers products in over half of the markets in which Northwest offers products, and Northwest offers products in almost half of the markets in which Delta offers products. This implies Delta and Northwest products are substitutes for each other in almost half of the markets where either firm offers products. Summary statistics of the samples used for estimation are presented in Table 2.3.

Table 2.2 Dual Presence of Delta and Northwest in Markets

	Markets			
Quarter	Total	With DL	With NW	With Both
2007:2	56514	28131	22766	12549
2007:3	57314	28810	22329	12425
2007:4	56024	27566	22416	12293
2008:1	53228	25994	21591	11840

Table 2.3 Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Itinerary Distance	1684.165	651.854	229	3407
Nonstop Distance	1579.626	620.780	229	2625
Quantity	283.822	627.665	50	8510
Price	2.036	0.515	0.805	4.511
Convenient	1.074	0.118	1	2.399
Nonstop	0.215	0.411	0	1
Pure Online	0.951	0.216	0	1
Traditional Codeshare	0.008	0.086	0	1
Virtual Codeshare	0.042	0.200	0	1
Hub Origin	0.129	0.335	0	1
Spring	0.269	0.444	0	1
Summer	0.266	0.442	0	1
Autumn	0.245	0.430	0	1
Winter	0.220	0.414	0	1
Observations	10217			

2.6. Results

Variable signs and significance

The demand results are shown in Table 2.4. We start by estimating a simple nested logit demand specification that does not allow for different consumer types.[42] Results for this simple demand model specification are reported in the panels labeled OLS and 2SLS. An important difference between the OLS and 2SLS regressions is noticeable in the price coefficient. In the OLS regression, the price coefficient is biased (and has the wrong sign), once again illustrating the need to instruments for this endogenous variable. The large variation in estimates between the OLS and 2SLS regressions once again illustrates the importance of using instruments for endogenous variables. Estimates of σ are between 0 and 1 with significance, implying that the model is consistent with utility maximization.

[42] In the case of the simple nested logit demand specification, the linear equation we estimate is given by: $\ln(S_j) - \ln(S_0) = x_j\beta - \alpha p_j + \sigma \ln(S_{j/g}) + \xi_j$.

Table 2.4 Demand Regression Results

Variable	OLS		2SLS		GMM	
"Leisure" Type						
Price (hundreds)	0.009	(0.015)	-0.307**	(0.038)	-6.099**	(0.550)
Convenient	-0.189**	(0.053)	-0.420**	(0.061)	-0.458**	(0.126)
Nonstop	1.316**	(0.018)	1.657**	(0.027)	1.113**	(0.333)
Constant	-7.552**	(0.190)	-6.103**	(0.235)	-3.805	(2.305)
"Business" Type						
Price (hundreds)					-1.206**	(0.014)
Convenient					-0.778**	(0.092)
Nonstop					1.838**	(0.040)
Constant					-2.499**	(0.284)
Hub Origin	0.204**	(0.020)	0.339**	(0.024)	0.563**	(0.020)
Virtual Codeshare	-0.376**	(0.031)	-0.810**	(0.045)	-0.888**	(0.019)
Traditional Codeshare	-0.094	(0.063)	-0.279**	(0.072)	-0.228**	(0.003)
Spring	0.105**	(0.015)	0.044*	(0.018)	0.032**	(0.000)
Summer	0.099**	(0.016)	0.049**	(0.018)	0.035**	(0.004)
Autumn	0.040**	(0.016)	0.001	(0.018)	-0.009**	(0.000)
σ	0.492**	(0.008)	0.131**	(0.024)	0.041**	(0.000)
λ_L					0.697**	(0.100)
Marginal Cost Parameters						
Itinerary Distance					0.543**	(0.021)
Itinerary Distance^2					-0.072**	(0.005)
Spring					-0.056**	(0.002)
Summer					-0.050**	(0.001)
Autumn					-0.031**	(0.000)
Constant					-0.485**	(0.018)
R-squared	0.850		0.810			
Wu-Hausman F test:	252.612**	F(2,10030)				
Durbin-Wu-Hausman chi-sq test	489.977**	Chi-sq(2)				

The regressions include fixed effects for airlines, origin, and destination, even though the coefficients are not reported.
Standard errors are shown in parentheses
* Statistically significant at the 5% level
** Statistically significant at the 1% level

To test the validity of the instruments, we regressed both endogenous variables against the instruments using OLS and also performed a Hausman test. The results show that each instrument is strongly correlated with the endogenous variables. These results are shown in

Appendix B. Each instrument used is correlated with significance to at least one of the endogenous variables. Hausman tests shown in Table 2.4 also reject the exogeneity of *price* and $\ln(S_{j/g})$, implying that instruments are needed.[43]

The coefficient on *nonstop* is positive and significant in all regressions, as expected. Passengers prefer direct flights from origin to destination –intermediate stops during the itinerary lead to lower levels of utility. The *convenient* coefficient also has the expected negative sign for all regressions, and is significant in each case. Recall that this variable is defined as itinerary miles flown divided by nonstop miles, and would thus have a higher value for flights that are more "out of the way". Thus, the negative coefficient suggests intuitively that passengers prefer the most direct route to the destination. The *hub_origin* coefficient is positive, indicating that consumers prefer flying out of an airline's hub, perhaps due to more convenient gate locations and departure times. The seasonal dummy coefficient estimates suggest that demand is subject to seasonal effects.

The *traditional codeshare* variable has a negative and significant coefficient – note that the "left out" product type category is pure online, so this indicates that a traditional codeshare product has a lower demand relative to a pure online product. Recall that there are multiple operating carriers on this type of codeshare itinerary. The negative sign may be capturing some unobserved handiness effects of traditional codeshare relative to pure online itineraries. A pure online itinerary is very streamlined, and a company can better organize its own planes and schedules to minimize layover time and efficiently organize gates at airports. With a traditional codeshare flight, a passenger may be more likely to experience longer layovers or longer journeys through the airport to find a different gate. Even though codeshare partners try to coordinate their efforts in this manner, the negative coefficient on traditional codeshare suggests that these coordination efforts are not perfect. The coefficient on *virtual* is negative and significant. Moreover, it is greater in magnitude than the coefficient on *traditional*. As previously noted in Ito and Lee (2007), this negative coefficient could be due to the fact that virtual codeshare itineraries are a relatively inferior product – frequent flyer miles may often not be used, and first-class upgrades are usually unavailable on this type of itinerary.

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[43] The Hausman test presents a null hypothesis of *price* and $\ln(S_{j/g})$ being exogenous. The Durbin-Wu-Hausman chi-square test with two degrees of freedom rejects the null hypothesis with over 99.99% confidence.

We now discuss results from our full model that includes cost parameters and allows for different consumer types. These results are reported in the panel of Table 2.4 labeled GMM. The coefficients associated with, *price*, *constant*, *convenient*, and *nonstop* are allowed to differ by consumer type. These consumer type-specific coefficients all have the correct sign. More importantly, the "business" type coefficients have the correct magnitude relative to the "leisure" type coefficients. The business type traveler's demand is affected less by higher prices, perhaps because his travel will be reimbursed by his employer. Further, the business traveler will most likely have a tighter time constraint than the leisure traveler, and thus has a stronger preference toward convenient, nonstop flights. The constant term for the business traveler is greater (less negative) than the constant term for the leisure traveler, indicating that business travelers have a greater preference for airline travel as opposed to the outside good relative to the leisure travelers.

The main cost parameters of interest in the GMM model give the expected signs. Cost increases with distance, but the negative coefficient on the distance squared variable shows this relationship is not linear.

Demand Elasticities

Along with the demand parameter estimates reported in Table 2.4, we computed the average own- and cross-price elasticity of Delta and Northwest products. The average own-price elasticity of Delta / Northwest products is -2.44 and the average cross-price elasticity of Delta / Northwest products is 0.06. As argued by Oum, Gillen and Noble (1986) and Brander and Zhang (1990), a reasonable range for own price elasticity in the airline industry is from -1.2 to -2.0. Peters (2006) found own price elasticity estimates ranging from -3.2 to -3.6. Thus, we feel comfortable that the elasticity estimates generated from our model are reasonable and accord with evidence in the existing literature.

Merger Analysis

Since our main objective is to analyze the merger, recall that our dataset includes only markets that contain both Delta and Northwest products before the merger.[44] This will allow us to isolate the merger effects in markets where the two firms' services overlap. Summary

[44] Markets that include neither firm or just one of the two firms will not experience a price increase according to our model since the ownership structure of products will be the same before and after the merger.

statistics for variables of interest in the subsample are displayed in Table 2.5. The average pre-merger markup is approximately $80.96. The average predicted change in price is only an increase of 0.62%, hardly big enough to concern consumers, let alone antitrust authorities. However, the maximum predicted increase in price is over 6%.

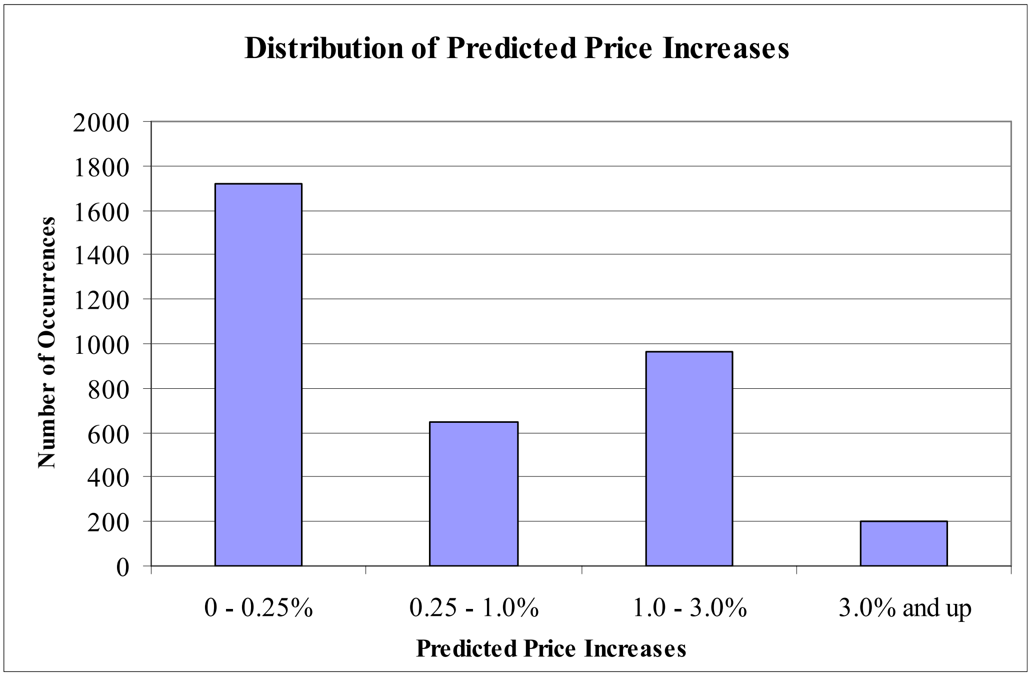
Table 2.5 Summary Statistics for Merger Analysis

Variable	Mean	Std. Dev.	Min	Max
Pre-merger marginal costs	122.291	50.571	0.235	367.870
Pre-merger markup	80.955	3.039	77.263	91.678
Post-merger predicted price	199.418	49.583	82.117	427.969
Predicted Price Increases (percent)	0.622	1.019	1.56E-06	6.258
Delta/Northwest pre-merger combined market product share	42.704	31.729	0.418	100
Delta/Northwest pre-merger combined market passenger share	45.445	25.146	7.692	100

To obtain a more detailed analysis of Delta/Northwest dominance in different markets, we calculated the combined passenger share that Delta and Northwest had in each market. For example, if 1,000 passengers flew from Minneapolis to Atlanta and 400 of them flew on Delta or Northwest tickets, then the Delta/Northwest share for this market is 40%. Note that this share is calculated by passengers, and not by the number of flights. This is displayed in the last row in Table 2.5. On average, Delta and Northwest combined own 45.445% of the passenger share in markets where both firms competed before the merger.

Summary statistics (not reported in Table 2.5) suggest a positive relationship between pre-merger Delta/Northwest combined market passenger share and predicted price increases. As shown in Table 2.5, all products and markets considered, the average predicted percent increase in price is 0.62% and the average pre-merger Delta/Northwest combined passenger share in markets is 45.44. However, for products with a predicted price increase between 1% and 3%, the average Delta/Northwest combined passenger share in the market is 48.14%, and for predicted price increases of 3% or more, the average Delta/Northwest combined passenger share in the market is 71.09%. Figure 2.1 shows the distribution of predicted price increases.

Figure 2.1 Distribution of Predicted Price Increases



To fully examine the association between Delta/Northwest pre-merger combined passenger share and predicted price increases, we regress the predicted percent change in prices as a function of the Delta/Northwest combined passenger share (*Quantshare_DLNW*) as well as some other control variables. We also regress the pre-merger price as a function of these same variables. The estimates are displayed in Table 2.6.

Table 2.6 Decomposition of Predicted Price Increases

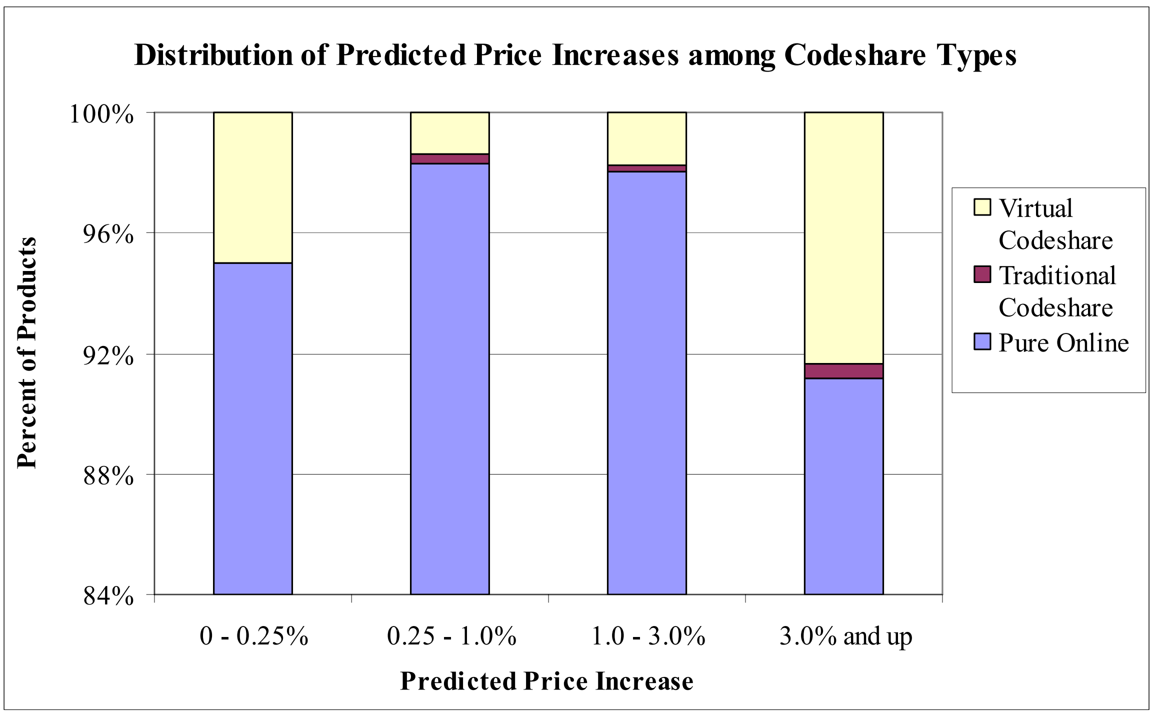
	Predicted Price Increase		Pre-Merger Price	
Quantshare_DLNW	0.015***	(0.001)	0.001	(0.000)
Convenient	0.781***	(0.167)	-0.534***	(0.062)
Nonstop	-0.835***	(0.063)	0.277***	(0.023)
Itin Distance / 1000	-0.359***	(0.059)	0.466***	(0.022)
Virtual Codeshare	0.607***	(0.102)	0.056	(0.038)
Traditional Codeshare	0.707*	(0.419)	-0.331**	(0.155)
Spring	0.157***	(0.045)	-0.027	(0.017)
Summer	0.101**	(0.046)	-0.067***	(0.017)
Autumn	0.135***	(0.046)	-0.080***	(0.017)
Delta Dummy	-0.233***	(0.033)	0.106***	(0.012)
Constant	-1.341***	(0.421)	2.878***	(0.156)

The regressions include fixed effects for airlines, origin, and destination, even though the coefficients are not reported.
Standard errors are shown in parentheses
* Statistically significant at the 10% level
** Statistically significant at the 5% level
*** Statistically significant at the 1% level

These results allow us to see what factors determine the predicted post-merger price increases. The regressions show that prices are predicted to increase by larger amounts when Delta/Northwest combine for a larger pre-merger passenger share in a market. However, while these results are statistically significant, they are not economically significant. The positive coefficient on *convenient* and negative coefficient on *nonstop* suggest that the airlines may not raise prices on the most desirable itineraries. The coefficients on *traditional codeshare* and *virtual codeshare* are positive, implying that these types of products will experience higher price increases (in terms of percentages) relative to pure online products. To examine this further, we regressed the pre-merger price against market and product characteristics and found a statistically insignificant coefficient on virtual codeshare but a statistically significant negative coefficient on the traditional codeshare variable. Thus, the price regression in the right panel of Table 2.6 suggests that, on average, Delta and Northwest virtual codeshare products are priced relatively similar to their pure online products in the pre-merger period, but the predicted price increase regression in the left panel suggests that Delta and Northwest virtual codeshare products' prices will increase by more than their prices for pure online products. In the case of the two airlines' traditional codeshare products, we see that these products are priced lower than the two airlines pure online products, but these codeshare products are predicted to experience marginally higher price increases compared to their pure online products.

Although the results in Table 2.6 suggest that both types of codeshare products on average have higher predicted price increases compared to pure online products, it is useful to see the distribution of price increases among codeshare products. To see the distribution pattern a little more clearly, we created a 100% stacked column chart in Figure 2.2 to show the percent of each product type in each price increase range.[45] The figure reveals that codeshare products tend to be slightly weighted toward the largest price increases.

Figure 2.2 Distribution of Predicted Price Increases among Codeshare Types



Figures 2.1 and 2.2 use only information about product types before the merger. However, products may change type classification after Delta and Northwest merge because the ownership structure of the products changes. Specifically, one of three things could happen to Delta/Northwest's products after the merger:

1. A pure online product remains a pure online product
2. A codeshare product remains a codeshare product
3. A codeshare product becomes a pure online product

[45] A 100% stacked column chart is used instead of a regular column chart to account for the large difference in the absolute number of pure online products compared to codeshare products.

For ease of analysis, we sort these products into three groups according to the number of cases above. The reason why product groups two and three arise is that Delta, Northwest, and Continental are codeshare alliance partners prior to the Delta/Northwest merger. As such, many of Delta and Northwest's codeshare products involve Continental as an operating carrier, and therefore these products retain their classification as codeshare products after our simulated Delta/Northwest merger. However, the codeshare products that only involve Delta and Northwest as either operating or ticketing carriers, will become pure online products with the simulated Delta/Northwest merger.

It is of particular interest to see if these three scenarios differ in terms of predicted price increases. We examine this in the left panel of Table 2.7, which includes only Delta/Northwest products. Using OLS, we regress the predicted price increase against a set of product group dummy variables and other control variables to gain information about cases two and three described above. On the right panel of Table 2.7, we use pre-merger price as the dependent variable instead of predicted price increase.

We observe some interesting effects for the groups. Note that group 1 is the excluded category, which are products that were pure online before the merger. We see positive and statistically significant coefficients on the Group 2 and Group 3 dummies, with a particularly large coefficient on Group 3, indicating that pre-merger codeshare products which become pure online products after the simulated merger experience higher predicted price increases. Further, the right side of Table 2.7 shows that there is not a significant difference in pre-merger prices across product groups 1, 2, and 3. Thus, it is not simply a difference in pre-merger price levels that is causing the significant difference in predicted percent price increases.

Table 2.7 Determinants of Predicted Price Increases and Pre-merger Prices when Delta/Northwest Codeshare Products are Decomposed into Groups

Regressors	Predicted Price Increase		Pre-merger Price	
	Dependent Variable			
Group 2	0.335*	(0.138)	-0.009	(0.058)
Group 3	1.572**	(0.211)	-0.091	(0.088)
Quantshare_DLNW	0.013**	(0.001)	0.006**	(0.000)
Convenient	1.500**	(0.197)	-0.556**	(0.083)
Nonstop	-1.063**	(0.070)	0.354**	(0.030)
Pop (100K)	0.020**	(0.005)	-0.012**	(0.002)
Spring	-0.001	(0.063)	0.031	(0.026)
Summer	-0.074	(0.065)	0.048	(0.027)
Autumn	-0.003	(0.065)	-0.034	(0.027)
Itin. Distance / 1000	-0.463**	(0.037)	0.389**	(0.015)
Constant	-0.063	(0.239)	1.630**	(0.100)

Standard errors are shown in parentheses

* Statistically significant at the 5% level

** Statistically significant at the 1% level

Finally, we examine competition at the market level. To do this, dummy variables are created to indicate the presence of competitors in the market. Next, we calculated the 25th, 50th, and 75th percentile of predicted price increases in each market so as to capture what is happening at contrasting points of the predicted price increase distribution. The predicted price increases are regressed against the Delta/Northwest combined passenger share, competitors, and market characteristics including nonstop distance, origin city population, and the number of itineraries in the market. Each observation in the regressions represents a market rather than a product. The results are shown in Table 2.8.

The coefficient on Delta/Northwest combined passenger share is positive, but economically insignificant, implying that Delta and Northwest product prices are predicted to increase by a marginally greater amount when their combined pre-merger passenger share in the market is larger. The origin city population coefficient is positive in two of the regressions implying that larger cities are predicted to experience higher price increases relative to smaller cities. The coefficients on nonstop miles are negative in all regressions, illustrating that longer-distance markets are expected to have lower price increases. The number of itineraries in the market seems to have no effect on predicted price increases; a larger effect can be seen with the actual competitors that offer products in the market, shown by airline dummies. The market airline dummy coefficients show that American, Frontier, Airtran, and Southwest tend to have the greatest effect in keeping predicted post-merger prices lower for Delta/Northwest products.

Table 2.8 Percent Predicted Price Increases at Various Market Percentiles

	Market Percentile					
Variable	25		50		75	
Quantshare_DLNW	-0.001	(0.001)	0.004*	(0.002)	0.009**	(0.002)
Origin Population (100K)	0.015*	(0.007)	0.012	(0.008)	0.022*	(0.010)
Nonstop Miles (1,000)	-0.160**	(0.061)	-0.228**	(0.069)	-0.324**	(0.087)
Itineraries in Market	-0.008	(0.020)	-0.016	(0.022)	0.041	(0.028)
American Airlines	-0.359**	(0.071)	-0.383**	(0.080)	-0.476**	(0.102)
Alaskan Airlines	-0.296	(0.151)	-0.264	(0.170)	-0.551*	(0.216)
JetBlue Airways	-0.293	(0.193)	-0.364	(0.218)	-0.450	(0.275)
Continental Airlines	-0.056	(0.079)	-0.054	(0.089)	-0.162	(0.112)
Frontier Airlines	-0.633**	(0.079)	-0.682**	(0.089)	-0.847**	(0.112)
Airtran Airways	-0.443**	(0.072)	-0.457**	(0.081)	-0.403**	(0.103)
United Airlines	-0.031	(0.079)	-0.044	(0.089)	-0.058	(0.112)
US Airways	-0.141*	(0.069)	-0.034	(0.078)	-0.059	(0.098)
Southwest	-0.206**	(0.075)	-0.190*	(0.085)	-0.332**	(0.107)
Midwest	0.090	(0.123)	0.138	(0.138)	0.147	(0.174)
constant	1.813**	(0.132)	2.072**	(0.149)	2.310**	(0.188)

Standard errors are shown in parentheses

* Statistically significant at the 5% level

** Statistically significant at the 1% level

Post-Merger Data Analysis

So far, we have done a merger analysis using pre-merger data to estimate predicted price increases as a result of the merger in the worst-case scenario in which the firms realize zero cost efficiencies from merging. However, as of this writing of our paper, a small amount of post-merger data is available. In this dataset, Delta and Northwest products are still separately identified, but we assume that the products are jointly priced since the data are from quarters after the firms began to integrate.

We estimate demand and perform a counterfactual "de-merger" analysis on this post-merger data similar to the analyses done on the pre-merger data. However, a key difference is that instead of doing a merger simulation with this data, the counterfactual simulation involves assuming that Delta and Northwest separately price their products. Demand parameter estimates for the post-merger data are reported in Appendix B. The summary statistics from the counterfactual simulation are shown in Table 2.9.

Table 2.9 Summary Statistics for Post Merger Data

Variable	Mean	Std. Dev.	Min	Max
Jointly-priced Delta/Northwest Price	183.134	45.698	65.920	522.549
Jointly-priced marginal costs	109.132	44.059	0.099	438.578
Jointly-priced markup	74.001	3.080	65.370	85.456
Separate ownership predicted price	178.431	46.101	75.524	500.772
Predicted Price Changes (percent)	-0.748	1.254	-7.227	-1.10E-06
Delta/Northwest combined market product share	50.503	31.682	0.658	100
Delta/Northwest combined market passenger share	44.658	24.180	8.333	100

First, notice that the combined product and passenger share for Delta and Northwest is similar to the pre-merger data. As expected, when products are priced separately by Delta and Northwest, these products are predicted to have lower prices compared to when they are jointly priced. Specifically, the simulation shows that the average Delta / Northwest price will decrease by 0.748% when the products are priced separately relative to jointly, with the largest predicted price decrease being 7.227%. The predicted price changes in Table 2.9 roughly coincide with our predictions from pre-merger data in Table 2.5.

2.7. Conclusions

Using a structural econometric model and pre-merger data, this paper studied the potential effects of the Delta/Northwest merger. Our findings suggest that, on average, the merger will not cause significant price increases. However, we predict larger price increases in markets that are dominated by Delta and Northwest, and that certain products are expected to have price increases much greater than the average. To prevent market power abuse in concentrated markets, the DoJ may want to carefully monitor prices and behavior in markets that have the largest combined Delta/Northwest passenger shares. The presence of competing airlines, particularly Southwest and American, also helps keep predicted price increases lower.

Delta and Northwest codeshare products, both traditional and virtual, have larger predicted price increases in terms of percentages relative to their pure online products. In addition, Delta/Northwest codeshare products that become pure online products in the post-merger scenario experience higher predicted price increases than pre-merger pure online products and products that remain codeshared with other airlines.

Finally, using post-merger data, a counterfactual "de-merger" simulation gives price changes of similar magnitude to that of the pre-merger data merger simulation.

This paper adds to the relatively sparse literature studying the pricing of pure online versus codeshare product types. To our knowledge, it is the only paper that examines changes in prices of different product types as the result of a merger.

Future work may involve studying international markets rather than just US markets. A major selling-point of the merger on a worldwide scale is that the only non-stop overlap market for Delta and Northwest is New York-Amsterdam. Delta and Northwest have antitrust immunity on this route to coordinate services even if the merger had failed.[46] Thus, significant international price effects are unlikely.

[46] Hearing on: Impact of Consolidation on the Aviation Industry, with a Focus on the Proposed Merger between Delta Air Lines and Northwest Airlines

CHAPTER 3 - Mergers Triggering Mergers: A Simulation Analysis of Merging Airline Codeshare Partners

3.1. Introduction and Background

The airline industry has experienced many changes over the years, including deregulation in 1978, many mergers (with some large mergers in the 1980's), bankruptcies, and bailouts. In October 2008, another notable event occurred; the Antitrust Division of the U.S. Department of Justice (DoJ) approved a merger between Delta and Northwest, two of the largest firms in the industry. The DoJ stated that "the Division has determined that the proposed merger between Delta and Northwest is likely to produce substantial and credible efficiencies that will benefit U.S. consumers and is not likely to substantially lessen competition".[47] However, like many mergers, the union of Delta and Northwest was not without critics. James Oberstar, Minnesota Democratic Congressman and chairman of the Committee on Transportation and Infrastructure, stated that "This should not be and must not be considered a standalone, individual transaction but rather as the trigger of what will surely be a cascade of subsequent mergers that will consolidate aviation in the United States and around the world into global, mega carriers."[48]

This paper subjects Congressman Oberstar's statement to an econometric analysis. Three major mergers in the 1980's occurred within a period of less than two years.[49] Thus, it may seem that airline mergers may indeed not be standalone incidents, but could have the potential to occur in clusters. More mergers may be discussed, and are more likely to be approved if firms show they are no longer viable by themselves, possibly due to economic recession.

Keeping a possible scenario of multiple mergers in mind, I perform simulations in which more mergers occur after the Delta / Northwest merger. Specifically, the firms in these additional mergers, like the Delta / Northwest merger, will be codeshare partners. I consider five additional merger scenarios beyond the original Delta / Northwest merger:

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[47] Department of Justice Press Release
http://www.usdoj.gov/atr/public/press_releases/2008/238849.htm
[48] CNN Money.
http://money.cnn.com/2008/05/14/news/companies/airline_merge/index.htm?postversion=2008051418
[49] Northwest and Republic in July 1986, Transworld and Ozark in September 1986, and USAir and Piedmont Aviation in October 1987. Singal (1996) studies the pricing behavior of airlines following the mergers that occurred in the 1980's.

1. American Airlines merges with Alaska Airlines
2. United Airlines merges with Continental Airlines
3. United, Continental, and US Airways merge
4. All of the above mergers happen
5. The airline industry becomes an unregulated monopoly

This paper aims to expand upon the work of Brown and Gayle (2009), who studied the Delta/Northwest merger using a counterfactual simulation. This work provides insight in predicting a "double" worst-case scenario: First, a "rough" economy and an already-approved Delta/Northwest merger act as a catalyst for a string of other mergers, and second, each merger has zero cost efficiencies. A discrete choice nested logit demand model is used in which demand parameters are utilized in conjunction with a multiproduct Bertrand-Nash supply side assumption to estimate firms' marginal costs. A counterfactual simulation involves modeling a "worst-case" scenario in which the estimated marginal costs remain constant after a merger, allowing only prices to change.

The data reveal that the Delta/Northwest merger by itself has average price increases of 0.30%, close to the previous estimate of 0.54% found by Brown and Gayle (2009). However, the variance in predicted price increases is large, ranging from 0% to 13.1%, suggesting that if any (or all) of the mergers were to occur, the DoJ may need to monitor markets in which the highest price increases are expected. The results also reveal a general preference for pure online, nonstop products as well as itineraries departing from a hub airport.

The rest of the paper is organized as follows: Section 3.2 outlines the model and some common airline definitions while Section 3.3 details the estimation technique. The data are discussed in Section 3.4, and results are discussed in Section 3.5. Section 3.6 ends with some concluding notes.

3.2. The Model

Definitions

The model follows from Brown and Gayle (2009), and some definitions are useful prior to describing the model in detail.[50] A *market* is an origin-destination combination. Markets are

[50] The definitions follow from Ito and Lee (2007) and Gayle (2007 and 2008).

directional, meaning that a trip from Miami to Seattle is a different market than a trip from Seattle to Miami. Defining markets as directional allows the model to account for origin characteristics such as city population and whether the origin airport is a hub for the carrier offering the product. An *itinerary* consists of the origin, destination, and all intermediate stops. In the Miami-Seattle market, an itinerary with a layover in Chicago would be a different itinerary than a non-stop flight. A *product* is a unique grouping of airline(s) and itinerary.

In terms of ownership and flight service, each flight has a *ticketing carrier* and an *operating carrier*. The ticketing carrier sells the ticket and is the "owner" of the product. The operating carrier is the airline that operates the plane the passenger is seated on for the flight(s). The ticketing carrier and operating carrier could be the same or different for any flight on the itinerary, resulting in a different type of product. A *pure online* product has a single ticketing and operating carrier for the itinerary, and the two carriers are the same. For instance, a passenger purchases a single ticket from Delta and flies on two Delta-operated planes for his itinerary. A *traditional codeshare* product has a single ticketing carrier but multiple operating carriers, one of which is the same as the ticketing carrier. For example, a single Delta ticket is purchased for a two-flight itinerary where one of the planes is operated by Delta and the other by Northwest. Finally, a *virtual codeshare* product has a single ticketing carrier and operating carrier for the itinerary, but the carriers are different. For example, an itinerary is ticketed through Northwest, but the passenger flies on a plane operated by Continental.

Demand

A discrete choice nested logit demand model is estimated in which a consumer chooses one product among many alternatives with the goal of utility maximization. The consumer also has the choice of an "outside" alternative (driving, taking a train, or not traveling at all). The model defines *G* groups of products with one additional group for the outside good, where products within a group are closer substitutes than products from across groups. In this paper, a group of products has the same market, number of intermediate stops, and codeshare type. Nesting by market is an obvious first step; itineraries that have the same origin and destination will be closer substitutes than products with different starting and ending points. Further nesting by the number of intermediate stops implies that consumers will view nonstop itineraries within the market differently than itineraries with a layover. Finally, previous literature suggests that nesting further by codeshare type may also reflect consumer preferences. Ito and Lee (2007) state that codeshare itineraries are relatively inferior because frequent flyer miles may be unredeemable and first-class upgrades are usually unavailable. Armantier and Richard (2008) state that consumers may dislike codeshare itineraries because the flight is operated by a firm that they didn't buy the ticket from, and there may be unknown responsibilities in case of delays, refunds, or lost luggage. In sum, it is reasonable to believe that codeshare products are viewed differently than pure online products, and are thus nested accordingly.

If product *j* is in group *g*, the utility of consumer *i* from choosing product *j* is given by

$$u_{ij} = \delta_j + \sigma\zeta_{ig} + (1-\sigma)\varepsilon_{ij}, \tag{3.1}$$

where δ_j is the mean valuation across consumers of product *j*, ζ_{ig} is a random component of utility that is common to all products in group *g*, σ measures the correlation of the consumers' utility among products in same group, and ε_{ij} is an idiosyncratic error term. If $\sigma = 1$ there is a perfect correlation of preferences for products within a group and the products are perfect substitutes. If $\sigma = 0$ there is no correlation of preferences, and the model becomes equivalent to the standard logit. The model is consistent with consumer utility maximization for all values of σ between 0 and 1 inclusive. The mean valuation δ_j is determined by the price of the product (p_j), observed product characteristics (x_j), and unobserved product characteristics (ξ_j):

$$\delta_j = x_j\beta - \alpha p_j + \xi_j, \tag{3.2}$$

where α is a measure of the marginal utility of price and β is a vector of parameters that measures the marginal utility of non-price product characteristics.

Supply

The supply methodology follows Nevo (2000) in which marginal costs are recovered using the estimated demand elasticities and assuming the pre-merger pricing conduct. The new price equilibria are computed using the estimated demand, pre-merger marginal costs, and assuming the post-merger pricing conduct. The post-merger equilibrium prices are compared to pre-merger prices to obtain estimates of predicted price increases as a result of the merger.

Each firm *f* produces a set F_f of products. Firm *f* has a variable profit of

$$\pi_f = \sum_{j \in F_f} (p_j - c_j) q_j, \tag{3.3}$$

where q_j is the quantity of tickets for product *j* sold in the market (equal to the market demand for product *j* in equilibrium), and c_j is the marginal cost incurred from offering product *j*.

Firms choose prices to maximize profit, and multiproduct firms realize that lost sales on one product may be partly countered by higher sales on a substitute product. The multiproduct Nash equilibrium is specified by the following system of *J* first order conditions:

$$\sum_{k \in F_f} (p_k - c_k) \frac{\partial s_k}{\partial p_j} + s_j = 0 \qquad \text{for all } j = 1, \ldots, J. \tag{3.4}$$

In matrix notation, the first order conditions are as follows:

$$(\mathbf{p} - \mathbf{c}) \times (\Omega .* \Delta) + \mathbf{s} = 0, \tag{3.5}$$

where p, c, and s are $J \times 1$ vectors of product prices, marginal costs, and predicted product shares respectively, Ω is a $J \times J$ matrix which captures airline ownership structure of the products, .* is the operator for element-by-element matrix multiplication, and Δ is a $J \times J$ matrix of own and cross price effects ($\frac{\partial s_j}{\partial p_j}$ and $\frac{\partial s_k}{\partial p_j}$ respectively) for all products with the own-price effects on the main diagonal.

The ownership structure Ω is a matrix of zeroes and ones that describes which products are owned by the same firm. Specifically, $\Omega_{jk} = 0$ means that product *j* and product *k* are owned by different firms while $\Omega_{jk} = 1$ means the two products are owned by the same firm.

Product markups are separately estimated for each market and are defined as

$$markups = \mathbf{p} - \mathbf{c} = -(\Omega .* \Delta)^{-1} \times \mathbf{s}. \tag{3.6}$$

The counterfactual simulation begins by specifying both a pre- and post-merger product ownership structure. First, estimated marginal costs are recovered using the pre-merger product ownership structure as follows:

$$\hat{\mathbf{c}} = \mathbf{p} + (\Omega^{pre} .* \Delta)^{-1} \times \mathbf{s}, \tag{3.7}$$

where Ω^{pre} is the pre-merger product ownership structure. Next, using pre-merger marginal costs and assuming a post-merger ownership structure of Ω^{post}, the post-merger equilibrium prices can be calculated by searching for the new price vector $\mathbf{p}^*$ that satisfies

$$\mathbf{p}^* = \hat{\mathbf{c}} - \left[\Omega^{post} .* \Delta(\mathbf{p}^*)\right]^{-1} \times \mathbf{s}. \tag{3.8}$$

The estimated post-merger equilibrium prices $\mathbf{p}^*$ are then compared to $\mathbf{p}$ to examine how the merger would affect prices according to the simulation.

Based on the ownership matrix Ω^{pre}, different firms will separately and independently set prices for all product types within markets in which they offer products. In the case of the Ω^{post} ownership matrix, the products in a market owned by the firms involved in a merger are all jointly priced by the new ticketing carrier formed by the simulated merger. [51]

3.3. Estimation

Observed product shares are computed by $S_j = \frac{q_j}{M}$, where *M* is the size of the market, defined as the population of the origin city. It is well known in empirical industrial organization that the nested logit demand model results in the following estimating equation: [52]

$$\ln(S_j) - \ln(S_0) = x_j\beta - \alpha\, p_j + \sigma \ln(S_{j/g}) + \xi_j,$$

where S_0 is the observed share of the outside good and $S_{j/g}$ is the observable share of product *j* in group *g*. The error term ξ_j represents product characteristics such as brand quality and promotional activities observed by consumers and firms but not by researchers. The demand parameters of interest are $\theta = (\alpha, \beta, \sigma)$.

Airlines consider non-price product characteristics when setting the price. Thus, instruments are needed because the product price will be correlated with the error term (ξ_j). Error term components, such as advertising, promotions, and consumer opinions of quality are market-specific and will likely have an effect on the price, but are unobservable to the econometrician. For legitimate instruments, variables are needed that are associated with the price of the product but not the error term. Without instruments, the price coefficient estimated will be inconsistent. Further, non-price product characteristics in ξ_j that affect the price may also affect the within-group share of the product, meaning that $S_{j/g}$ is also endogenous.

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[51] Ivaldi and Verboven (2005) provide another application of this model by studying horizontal mergers approved by the European Commission.
[52] For a more detailed analysis of the nested logit demand model, see Berry (1994).

Instruments

Instruments used include the number of competitors in the market, the number of other products offered by the airline, characteristics of products offered by competitors, and itinerary distance. Each instrument has an intuitive explanation for inclusion. Supply theory predicts that the price of a product will be affected by the number and closeness of competitors in the market. For multiproduct firms, the Bertrand-Nash model assumes the airline will jointly set the prices of its products in that market. Competing products with the same number of intermediate stops and similar levels of convenience are examined – the more similarities there are between competing products, less deviation is expected between prices of these products. Itinerary distance is included since it is correlated with marginal cost and therefore influences price.[53]

The parameter estimates imply a negative marginal cost for some products when Two-Stage Least Squares (2SLS) is used to estimate the demand equation. To correct for this unrealistic outcome, demand is also estimated using constrained Generalized Methods of Moments (GMM), where the constraint is to impose non-negative marginal costs. The constrained GMM estimation produces demand parameters that are consistent with utility maximization and static profit maximization. The demand estimation procedure requires solving the following constrained optimization problem:

$$\underset{\theta}{Min}\left[(\xi' Z)(Z' Z)^{-1}(Z' \xi)\right]$$

$$\text{such that } \min(\mathrm{p} - markup) \geq 0, \quad \text{and} \quad 0 < \sigma < 1$$

where Z is the matrix of the control variables and instruments. The procedure minimizes the objective function by choosing the set of parameters in θ. The 2SLS estimates are used as a starting point for the GMM minimization procedure.

3.4. Data

Data are gathered from the DB1B market survey, a quarterly 10% sample of all flight itineraries in the U.S. published by the U.S. Department of Transportation. In this dataset, each observation is a flight itinerary including information on operating and ticketing carriers, fares, passengers, intermediate stops, origin and destination airport, and total itinerary distance. The U.S. Census Bureau was also used to collect population data. Data was collected for the third

[53] See Gayle (2007) and Brown and Gayle (2009) for similar types of instruments.

quarter of 2008. The data are restricted to include only itineraries in the contiguous 48 states, and foreign operating carriers such as Lufthansa and Royal Jordanian are eliminated. Observations that listed market fares of less than $25 were dropped – this helps avoid discounted fares that may be due to passengers using frequent-flyer miles. Itineraries that had a price of more than 4 standard deviations above the market mean were also dropped from the sample.[54]

Because the objective of this paper is to explicitly analyze the effects of a number of mega-mergers, the dataset is restricted to contain only markets that are affected by at least one of the merger scenarios that are examined. For example, a market that will be affected by the Alaskan/American merger is a market in which both Alaskan and American both offer products.

Airlines effectively use yield management, leading to a dataset containing many repeat itineraries each listed as having passengers paying different fares. To make the estimation more manageable, the data was collapsed by product – the *quantity* variable was found by aggregating passengers over a given itinerary-airline(s) combination, and price was found by taking the average fare paid by passengers on the aggregated itinerary. In the collapsed data set, each itinerary-airline(s) combination appears only once. Following Berry (1992), a product is only included if it was purchased by at least 20 passengers in the quarter.[55] Ticketing carriers that made up less than 0.1% of the collapsed dataset were discarded, eliminating small carriers such as Allegiant Air and Virgin America. The final set of ticketing carriers is presented in Table 3.1.

Table 3.1 Airlines represented in the dataset

Code	Airline
AA	American Airlines
AS	Alaska Airlines
B6	JetBlue Airways
CO	Continental Airlines
DL	Delta Airlines
F9	Frontier Airlines
FL	Airtran Airways
NW	Northwest Airlines
UA	United Airlines
US	US Airways
WN	Southwest Airlines
YX	Midwest Airlines

[54] This eliminated unusually high prices in the sample that may have been due to the use of private charter jets or data entry error. One observation in the dataset had a market fare of more than $89,000.

[55] Berry (1992) used the more restrictive quantity of 90 passengers per quarter.

Product *convenience* is defined as itinerary distance divided by the direct flight distance between origin and destination. Thus, the most convenient itinerary for a market would be a direct flight from origin to destination. The *hub_origin* variable indicates whether the origin airport acts as a hub for the ticketing carrier. A list of hubs is given in Table C.2 in Appendix C.

Itineraries that were listed as having multiple ticketing carriers were dropped from the sample since each itinerary needed to have a single "owner" for the merger analysis. The remaining single ticketing carrier products are then assigned a product type of *pure online*, *traditional codeshare*, or *virtual codeshare*. [56]

Thus, observed non-price product characteristics (x_j) include the following: convenience, a *nonstop* dummy equal to 1 if the flight is nonstop and equal to 0 otherwise,[57] nonstop miles between origin and destination, hub origin indicator, codeshare type, airline indicator, and fixed effects for origin and destination. After cleaning and collapsing the original sample, the dataset used for analysis contains 16,934 observations across 2,173 markets. There are 132 origin airports and 131 destination airports. Summary statistics are presented in Table 3.2.

[56] To properly identify codeshare product types in the data, regional carriers are recoded to match their major carrier. If regional carriers were not recoded to their major carrier code, then products that have the major carrier as the ticketing carrier and associated regional carrier as operating carrier would mistakenly be counted as codeshare products since the operating and ticketing carrier codes would differ.

[57] The dataset itself contains the actual number of intermediate stops. However, after the quantity and airline restrictions were imposed, only nonstop and one-stop itineraries remained. Thus, *nonstop* = 0 means the itinerary has exactly one intermediate stop.

Table 3.2 Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Itinerary Distance	1747.23	681.7396	213	3567
Nonstop Distance	1592.607	646.977	213	2724
Nonstop Flight	0.123775	0.329334	0	1
Quantity	145.2241	447.359	20	10704
Price	224.3834	58.81689	81.27238	702.4503
Hub origin	0.156549	0.363386	0	1
Convenient	1.118138	0.170473	1	2.66004
Pure Online	0.959549	0.197021	0	1
Traditional Codeshare	0.013346	0.114755	0	1
Virtual Codeshare	0.027105	0.162395	0	1
ln(Sj) – ln(S0)	-9.14022	1.300923	-13.7725	-4.63598
ln(Sj/g)	-2.02293	1.019073	-6.54302	0

3.5. Results

Demand Parameters

The demand regression results are presented in Table 3.3. Immediately noticed is a non-significant positive price coefficient in the OLS regression. This illustrates the endogeneity of this variable and the need for instruments. In the 2SLS and GMM regressions, the coefficient has the appropriate negative sign, implying that higher prices are associated with lower levels of utility, ceteris paribus.

The coefficient on $\ln(S_{j/g})$ is the estimate for σ. All estimates of σ are between 0 and 1 with significance, implying the model is consistent with utility maximization. However, the magnitude differences (the OLS estimate is four times the magnitude of the 2SLS estimate) again illustrates the need to use instruments with this endogenous variable. To test the validity of the instruments, both endogenous variables were regressed against the instruments using Ordinary Least Squares (OLS), and a Hausman test was performed. The results, shown in Appendix C, confirm that each instrument is strongly correlated with both endogenous variables, with one exception. Hausman tests shown in Table 3.3 also reject the exogeneity of *price* and $\ln(S_{j/g})$, implying that instruments are needed.[58]

Table 3.3 Demand Regression Results

Variable	OLS		2SLS		GMM	
Price (100s)	0.0075	(0.0110)	-2.3012**	(0.6413)	-1.6905**	(0.0003)
ln(Sj/g)	0.6491**	(0.0062)	0.1616*	(0.0658)	0.1486**	(0.0002)
Convenient	-0.5151**	(0.0310)	-0.7294**	(0.0906)	-1.2372**	(0.0004)
Nonstop	0.8180**	(0.0179)	1.7840**	(0.0591)	1.6203**	(0.0005)
Nonstop miles (1,000s)	-0.1192**	(0.0144)	0.9983**	(0.3553)	0.7239**	(0.0003)
Hub_origin	0.1283**	(0.0152)	0.6048**	(0.1169)	0.4413**	(0.0003)
Traditional Codeshare	-1.7016**	(0.0422)	-1.4838**	(0.3141)	-1.1106**	(0.0007)
Virtual Codeshare	-1.6530**	(0.0310)	-1.3548**	(0.1159)	-1.2569**	(0.0006)
Constant	-6.7737**	(0.2150)	-1.8545	(1.3471)	-2.0974**	(0.0025)
R-squared		0.8021		0.1694		
Wu-Hausman F test:	2240**	F(2,16651)				
Durbin-Wu-Hausman chi-sq test	3590**	Chi-sq(2)				

The regressions include a full set of fixed effects for airline, origin, and destination even though the coefficients are not reported.
Standard errors are shown in parentheses
* Statistically significant at the 5% level
** Statistically significant at the 1% level

The coefficient on *nonstop* is positive and significant in all regressions. Passengers prefer direct flights from origin to destination – any stop during the itinerary leads to lower levels of utility. The *convenient* variable has the expected negative coefficient in all regressions. Flights that fly any path other than directly to the destination are expected to be associated with disutility. The *nonstop_miles* coefficient is positive, and this makes sense when viewed in relationship to the outside good substitute. The longer the distance is between origin and destination, the more desirable flying becomes relative to another form of transportation.[59]

The *hub_origin* dummy is positive, indicating a preference for flying an airline out of its hub airport. An airline may be able to organize more convenient gates and departure times when flying out of its hub, therefore making the itinerary more desirable. Borenstein (2005) and Berry

[58] The Hausman test presents a null hypothesis of *price* and $\ln(S_{j/g})$ being exogenous. The Durbin-Wu-Hausman chi-square test with two degrees of freedom rejects the null hypothesis with over 99.99% confidence.
[59] Berry and Jia (2009) state that airline demand is hill-shaped in distance. Demand increases with distance of travel as other substitutes become infeasible, but only up to a point where extremely long flights become unpleasant.

and Jia (2009) find evidence of a decreasing "hub premium". Consumers may realize advantages to choosing a hub airline, but those benefits could be disappearing in recent years. Service gaps between hub and non-hub products may have narrowed, or perhaps loyalty programs have become less valued.

Consistent with the results in Brown and Gayle (2009), the *traditional codeshare* variable has a negative and significant coefficient. Note that the "left out" product type category is pure online, indicating a traditional codeshare product has a lower demand relative to a pure online product. While there are multiple operating carriers on a traditional codeshare itinerary, the double markup may be eliminated because of a single ticketing carrier. Thus, the negative sign may be capturing some other unobserved handiness effects of this type of product. The itinerary for a pure online product is relatively streamlined; an airline can organize its own planes and schedules to minimize layover time and efficiently organize gates at airports. With a traditional codeshare flight, a passenger may be more likely to experience longer layovers or long journeys through the airport to find a different gate. Even though codeshare partners try to coordinate their efforts in this manner, the negative coefficient on *traditional codeshare* suggests that these coordination efforts are not as efficient relative to pure online products. The coefficient on *virtual codeshare* is negative and significant in all regressions. This is supported by the previous literature of Ito and Lee (2007) and Armantier and Richard (2008) summarized earlier.

Merger Analysis

The main objective of the merger analysis is to study the effects of the Delta / Northwest merger as well as other potential mergers. Summary statistics for variables of interest are displayed in Table 3.4.

Table 3.4 Summary Statistics for Merger Variables

Variable	Observations	Mean	Std. Dev.	Min	Max
Pre-merger variables					
Price	16934	224.3834	58.8169	81.2724	702.4503
Recovered marginal costs	16934	171.6423	58.7982	22.1166	651.0165
Markups	16934	52.7411	2.3352	50.3699	59.7315
Post-merger estimated product prices*					
Delta / Northwest	16934	224.7467	58.7298	81.3303	702.4503
American / Alaska	16934	224.7581	58.7353	81.3303	702.4503
United / Continental	16934	225.0405	58.8564	81.3303	702.4507
United / Continental / US Airways	16934	225.4365	58.9388	81.3303	702.4507
All mergers occur	16934	225.4479	58.9442	81.3303	702.4507
Monopoly	16934	230.9215	58.7919	81.3361	710.2069
Post-merger estimated product price increases (%)**					
Delta / Northwest	4833	0.6522	0.8526	0	6.0726
American / Alaska	2316	0.0377	0.2503	0	3.9000
United / Continental	4776	0.4423	0.5675	0	6.5327
United / Continental / US Airways	6320	0.8035	0.7280	0	6.5518
All mergers occur	13469	0.6209	0.7698	0	6.5518
Monopoly	16934	3.1103	1.3949	0.0001	10.6844

* Note that the AA / AS, the UA / CO, and the UA / CO / US merger simulations are performed assuming that Delta and Northwest have already merged.
** The predicted percentage price increases are only summarized over products in which the particular merger had a direct effect. For example, mean AA / AS predicted price increase only includes AA and AS products. The predicted price increases for the "monopoly" row were calculated using the full dataset.

The average itinerary price before the merger is $224.38, and it appears that the average prices increase only negligibly. However, there is a large range of price increases for each simulated merger. The predicted price increases show the Delta / Northwest merger alone causes an average predicted price increase of just 0.30% which is close to the result of 0.54% found by Brown and Gayle (2009). Interestingly, the situation outlined by Congressman Oberstar in which the industry is dominated by four or five mega-carriers (all mergers occur) doesn't give mean predicted price increases much different than any single merger combined with DL/NW. As expected, the monopoly simulation gives the largest predicted price increases. Overall, the summary statistics alone are not sufficient to make conclusions about any merger, and it is important to examine the markets directly affected by each merger and look at specific factors that may cause larger price increases in certain markets compared to others, rather than just comparing means across the whole dataset. In addition, it is useful to examine the distribution of predicted price increases rather than just the means.

To get a further detailed analysis of the possible effects of the merger, the predicted price increases are regressed as a function of product characteristics to examine what may account for varying predicted price increases among different products. The results are shown in Table 3.5.

The share of passengers owned in a market by the merging firms has a positive effect on the predicted price increase, although the values are economically insignificant. In all simulations, the coefficients on *nonstop* and *hub_origin* are negative and significant. Firms could be reluctant to raise prices on their most desirable itineraries in a given market due to fear that a consumer may choose a competitor's product. Another possible reason to keep hub prices lower would be to gain market shares in a given region.

Nonstop flight distance is negatively correlated with predicted price increases. Airlines may be more reluctant to raise prices on longer flights, possibly because of an increased likelihood of competing carriers being able to offer itineraries with similar convenience.[60] The *convenience* variable by itself seems to be merger-specific in terms of its effect on predicted price increases. The three largest merger scenarios on the right side of Table 3.5 give a positive coefficient, implying that inconvenient itineraries experience higher predicted price increases. Inconvenient itineraries are often relatively cheaper to begin with, and an airline that has gained market power via a merger might find it more profitable to raise the price of the relatively cheaper products by more (in terms of percent).

[60] I thank an anonymous referee for this insight.

Table 3.5 Decomposition of Predicted Price Increases Among Merger Products

	DL/NW	DL/NW + AA/AS	DL/NW + UA/CO	DL/NW + UA/CO/US	All mergers	Monopoly
Passenger % Share of Merging Firms	0.0126**	0.0049**	0.0061**	0.0048**	0.0017**	
	(0.0007)	(0.0005)	(0.0004)	(0.0004)	(0.0003)	
Convenient	0.0328	-0.0904	-0.1670**	0.2843**	0.2746**	0.5635**
	(0.0584)	(0.0469)	(0.0443)	(0.0452)	(0.0409)	(0.0567)
Nonstop	-0.3635**	-0.2149**	-0.3787**	-0.3912**	-0.3025**	-1.7035**
	(0.0399)	(0.0267)	(0.0281)	(0.0267)	(0.0225)	(0.0289)
Nonstop Miles (thousands)	-0.1545**	-0.1076**	-0.2428**	-0.1924**	-0.1242**	-0.7914**
	(0.0368)	(0.0226)	(0.0236)	(0.0234)	(0.0193)	(0.0255)
Hub Origin	-0.3760**	-0.2853**	-0.0833**	-0.0903**	-0.1498**	-0.5263**
	(0.0606)	(0.0295)	(0.0297)	(0.0260)	(0.0214)	(0.0270)
# of Pre-Merger Competitors in Market	-0.0389**	-0.0805**	-0.0586**	-0.0460**	-0.0490**	0.2137**
	(0.0117)	(0.0088)	(0.0080)	(0.0081)	(0.0074)	(0.0101)
Constant	-0.1259	0.1030	0.5554	-0.0109	-0.2238	1.7284**
	(0.4022)	(0.2917)	(0.2841)	(0.2962)	(0.2576)	(0.3920)
# Observations	4833	7149	8736	11153	13469	16934
R-squared	0.4776	0.4157	0.3404	0.1952	0.1877	0.3894

Regressions include a full set of origin and destination fixed effects, although these coefficients are not reported
Standard errors are shown in parentheses
* Statistically significant at the 5% level
** Statistically significant at the 1% level

The number of competitors in a pre-merger market has a negative effect on predicted price increases caused by the mergers. A larger number of non-merging competitors would help keep prices lower even while rivalry is decreasing. The exception is the monopoly simulation – here, prices are actually predicted to increase *more* when there is a larger number of competitors in the pre-merger market. This makes sense intuitively – if a market was noncompetitive in the sense that prices were already high and there were very few pre-merger competitors in the market, prices would not be expected to increase as much (in terms of percent) relative to a more competitive market if both markets were to become monopolized. The constant term also increases greatly in size when the monopoly is simulated, showing once again the larger predicted price changes caused by extreme changes in product ownership and market power. The monopoly simulation is the only scenario in which the constant term is significant and positive.

Finally, I examined the distribution of the price increases. Specifically, I analyzed ranges of predicted price increases for products directly affected by each merger. In addition, the products are then weighted by passenger quantities to find the percentage of passengers who experience various predicted price increases. The distributions appear below in Table 3.6.

The distribution of predicted price increases and the percentage of passengers experiencing these increases gives a much clearer picture compared to just examining mean predicted price increases across all products. The mean predicted price increase for each merger is small because of the skewed distribution toward prices that are expected to increase less than one percent. However, there are still some products which experience noticeable price changes; in the "all mergers" scenario, 6.18% of the products are expected to have a price increase of greater than 2%. When the predicted price increases are weighted by quantity, the skew toward the smallest price increases becomes even larger. For the "all mergers" scenario, even though 6.18% of the products are expected to have price increases greater than 2%, these products only represent 2.48% of the passengers that choose a product affected by any of the mergers.

Table 3.6 Distribution of Predicted Price Increases

Predicted Price Increases	DL / NW	AA /AS	UA / CO	UA / CO / US	All Mergers	Monopoly
	Number of Products					
Less than 1%	3696	2289	4218	4298	10278	1507
1% - 2%	721	10	442	1625	2359	1312
2% - 3%	294	14	84	312	622	4384
3% - 4%	90	3	21	59	152	5931
Greater than 4%	32	0	11	26	58	3800
	Percent of Products					
Less than 1%	76.47	98.83	88.32	68.01	76.31	8.90
1% - 2%	14.92	0.43	9.25	25.71	17.51	7.75
2% - 3%	6.08	0.60	1.76	4.94	4.62	25.89
3% - 4%	1.86	0.13	0.44	0.93	1.13	35.02
Greater than 4%	0.66	0.00	0.23	0.41	0.43	22.44
	Percent of Passengers					
Less than 1%	88.78	98.74	92.32	82.74	88.86	30.94
1% - 2%	7.92	0.61	6.99	14.16	8.66	17.06
2% - 3%	2.08	0.64	0.49	2.49	1.87	19.79
3% - 4%	1.01	0.02	0.13	0.42	0.47	20.39
Greater than 4%	0.20	0.00	0.07	0.19	0.14	11.82

Further breaking down the predicted price increases yields results showing a large passenger share owned by the merging firms in markets where prices are expected to increase the most. In the Delta/Northwest merger, 25 of the 32 products which are expected to have a price increase of greater than 4% are in markets where Delta and Northwest have a combined 50% or greater pre-merger passenger share, with 17 of the 25 products having a combined 100% passenger share. In the American / Alaska merger simulation, 15 of the 17 products with a predicted price increase of more than 2% are in markets where the combined American / Alaska passenger share is over 75%. Finally, in the United / Continental / US Airways merger simulation, 22 of the 26 products that are predicted to have the largest price increases are in markets where the three firms combine for over 75% of the pre-merger passenger share. Analogously, lower pre-merger passenger shares are associated with lower predicted price increases. The average pre-merger combined market share for Delta / Northwest products that are expected to have price increases of less than 1% is only 6.3%. For American / Alaska, this combined share is 6.5%. Overall, it is clear to see that higher pre-merger passenger shares among merging firms are associated with higher predicted price increases.

3.6. Conclusions

This paper estimates a structural demand model for airline products and studies the potential effects of the Delta/Northwest merger in conjunction with other possible merger scenarios. Consistent with previous literature, the demand results show that passengers prefer low-priced, pure online, nonstop itineraries. In addition, passengers prefer products that are offered from an airline's hub airport, perhaps to due to higher convenience in gate locations and departure times.

The merger results suggest that, on average, the Delta / Northwest merger will not cause significant price increases on average, even when the scenario is modeled with zero cost efficiencies. Similar results hold when other codeshare partner mergers are simulated concurrently with the DL/NW merger. Only when the simulation models a monopoly merger do the predicted price increases become larger on average, with particularly large maximum values. However, the distribution of the predicted price increases associated with any of the mergers is large, with a small number of products experiencing noticeable price increases. When the products are weighted by passenger quantities, I find that a very small number of passengers are expected to be affected by the largest predicted price increases. Finally, the largest price increases tend to be associated with products that are in products in which the merging firms have a large pre-merger passenger share.

Weaknesses of the model

Some weaknesses of the results can arise from the model. First, when the estimate of σ is relatively close to zero, approximately yielding the standard logit demand model, this type of simulation is a way to translate market share data into predicted price increases.[61] As a result, larger predicted price increases are often predicted when both firms involved in a merger have a relatively large market share, independent of the degree of substitutability between the products.[62] However, using higher-ordered nests (nesting by number of intermediate stops and codeshare type) may help correct for this problem. Second, even though fixed effects for origin and destination are included in the demand model, it may be useful to model separate demand functions for various regions and markets rather than a single model for the entire industry. Third, an exclusive reliance on the discrete choice nested logit demand model comes with a cost. For example, Peters (2006) used merger simulation techniques with the benefit of having actual post merger data at hand, and found large differences in some cases between predicted prices and actual post-merger prices. He theorized that the difference could be caused by unobservable supply-side factors such as changes in firm conduct or marginal costs. Armantier and Richard (2006 and 2008) theorize that using a random coefficients logit demand model may yield more precise estimates, but it is much more tedious to estimate. However, using a random coefficients model, or perhaps dealing with the large airline fare variations in a different way (rather than averaging) may eliminate the need for using a constrained GMM which forces positive marginal costs. Fourth, while this paper provides an exercise in simulating a merger and estimating price increases, it cannot give any information about the likelihood of any of the mergers actually occurring. The mergers simulated in this paper were chosen to follow the same precedent as Delta / Northwest; firms that are already in a codeshare alliance together form a new single firm due to a merger.

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[61] See Ivaldi and Verboven (2005)

[62] I thank an anonymous referee for this critique.

Policy Implications & Future Research

While the predicted price increases are relatively small on average, the distribution is large, and the maximum price increases are much larger than the average. If any of the simulated mergers were actually to occur, the DoJ may want to monitor markets of interest, such as markets with a smaller number of competitors, a smaller number of products offered, and markets where the merging firms have a relatively large pre-merger passenger and product share.

Future research will be focused mainly with dealing with the aforementioned weaknesses of the model. Specifically, it may be of interest to estimate multiple demand equations for various markets and use a random coefficients logit model.

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Appendix A - Three Airline Single Market Example

Assume that in the pre-alliance period there are only three pure online substitute differentiated products (1, 2, and 3), and only three non-allied competing airlines in the market: Delta, Northwest, and American, where Delta offers product 1, Northwest offers product 2, and American offers product 3. In the post-alliance period, Delta and Northwest are alliance partners and may offer virtual codeshare products, while American is non-allied.

Strategic Interaction in the Pre-Alliance Period

$$\Pi_{Delta} = (p_1 - c_1)q_1 + \phi_{dcn}^{pre}(p_2 - c_2)q_2 + \phi_{-dcn}^{pre}(p_3 - c_3)q_3$$

$$\Pi_{Northwest} = \phi_{dcn}^{pre}(p_1 - c_1)q_1 + (p_2 - c_2)q_2 + \phi_{-dcn}^{pre}(p_3 - c_3)q_3$$

$$\Pi_{American} = (p_3 - c_3)q_3 + \phi_{-dcn}^{pre}(p_1 - c_1)q_1 + \phi_{-dcn}^{pre}(p_2 - c_2)q_2$$

First-order conditions:

$$q_1 + (p_1 - c_1)\frac{\partial q_1}{\partial p_1} + \phi_{dcn}^{pre}(p_2 - c_2)\frac{\partial q_2}{\partial p_1} + \phi_{-dcn}^{pre}(p_3 - c_3)\frac{\partial q_3}{\partial p_1} = 0$$

$$q_2 + \phi_{dcn}^{pre}(p_1 - c_1)\frac{\partial q_1}{\partial p_2} + (p_2 - c_2)\frac{\partial q_2}{\partial p_2} + \phi_{-dcn}^{pre}(p_3 - c_3)\frac{\partial q_3}{\partial p_2} = 0$$

$$q_3 + \phi_{-dcn}^{pre}(p_1 - c_1)\frac{\partial q_1}{\partial p_3} + \phi_{-dcn}^{pre}(p_2 - c_2)\frac{\partial q_2}{\partial p_3} + (p_3 - c_3)\frac{\partial q_3}{\partial p_3} = 0$$

Therefore:

$$\Omega^{pre-own} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}; \ \Omega_{dcn}^{pre-comp} = \begin{pmatrix} 0 & \phi_{dcn}^{pre} & 0 \\ \phi_{dcn}^{pre} & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}; \text{ and}$$

$$\Omega_{-dcn}^{pre-comp} = \begin{pmatrix} 0 & 0 & \phi_{-dcn}^{pre} \\ 0 & 0 & \phi_{-dcn}^{pre} \\ \phi_{-dcn}^{pre} & \phi_{-dcn}^{pre} & 0 \end{pmatrix}$$

Furthermore, product markups are given by:

$$\mathbf{m}^{pre} = \left[\left(\Omega^{pre-own} + \Omega_{dcn}^{pre-comp} + \Omega_{-dcn}^{pre-comp}\right).* \Delta^{pre}\right]^{-1} \times \mathbf{d}(\mathbf{p})^{pre}$$

$$= \left[\begin{pmatrix} 1 & \phi_{dcn}^{pre} & \phi_{-dcn}^{pre} \\ \phi_{dcn}^{pre} & 1 & \phi_{-dcn}^{pre} \\ \phi_{-dcn}^{pre} & \phi_{-dcn}^{pre} & 1 \end{pmatrix} .* \begin{pmatrix} \frac{\partial q_1}{\partial p_1} & \frac{\partial q_2}{\partial p_1} & \frac{\partial q_3}{\partial p_1} \\ \frac{\partial q_1}{\partial p_2} & \frac{\partial q_2}{\partial p_2} & \frac{\partial q_3}{\partial p_2} \\ \frac{\partial q_1}{\partial p_3} & \frac{\partial q_2}{\partial p_3} & \frac{\partial q_3}{\partial p_3} \end{pmatrix} \right]^{-1} \times \begin{pmatrix} q_1 \\ q_2 \\ q_3 \end{pmatrix}$$

Strategic Interaction in the Post-Alliance Period

The post-alliance period for any given market can take on one of two distinct scenarios: (1) a post-alliance market in which Delta and Northwest compete and virtual codeshare together ($v = 1$); (2) a post-alliance market in which Delta and Northwest compete but do not virtual codeshare together ($v = 0$). For simplicity, suppose that product 7 is the only virtual codeshare product that is introduced in the market in the event that Delta and Northwest codeshare together, where Delta is the ticketing carrier and Northwest the operating carrier.

Strategic interaction in market when v = 1:

$$\Pi_{Delta} = (p_4 - c_4)q_4 + (p_7 - c_7)q_7 + \phi_{dcn,\ v=1}^{post}(p_5 - c_5)q_5 + \phi_{-dcn,\ v=1}^{post}(p_6 - c_6)q_6$$

$$\Pi_{Northwest} = (p_5 - c_5)q_5 + \phi_{dcn,\ v=1}^{post}(p_7 - c_7)q_7 + \phi_{dcn,\ v=1}^{post}(p_4 - c_4)q_4 + \phi_{-dcn,\ v=1}^{post}(p_6 - c_6)q_6$$

$$\Pi_{American} = (p_6 - c_6)q_6 + \phi_{-dcn,\ v=1}^{post}(p_4 - c_4)q_4 + \phi_{-dcn,\ v=1}^{post}(p_5 - c_5)q_5 + \phi_{-dcn,\ v=1}^{post}(p_7 - c_7)q_7$$

First-order conditions:

$$q_4 + (p_4 - c_4)\frac{\partial q_4}{\partial p_4} + \phi_{dcn,\ v=1}^{post}(p_5 - c_5)\frac{\partial q_5}{\partial p_4} + \phi_{-dcn,\ v=1}^{post}(p_6 - c_6)\frac{\partial q_6}{\partial p_4} + (p_7 - c_7)\frac{\partial q_7}{\partial p_4} = 0$$

$$q_5 + \phi_{dcn,\ v=1}^{post}(p_4 - c_4)\frac{\partial q_4}{\partial p_5} + (p_5 - c_5)\frac{\partial q_5}{\partial p_5} + \phi_{-dcn,\ v=1}^{post}(p_6 - c_6)\frac{\partial q_6}{\partial p_5} + \phi_{dcn,\ v=1}^{post}(p_7 - c_7)\frac{\partial q_7}{\partial p_5} = 0$$

$$q_6 + \phi_{-dcn,\ v=1}^{post}(p_4 - c_4)\frac{\partial q_4}{\partial p_6} + \phi_{-dcn,\ v=1}^{post}(p_5 - c_5)\frac{\partial q_5}{\partial p_6} + (p_6 - c_6)\frac{\partial q_6}{\partial p_6} + \phi_{-dcn,\ v=1}^{post}(p_7 - c_7)\frac{\partial q_7}{\partial p_6} = 0$$

$$q_7 + (p_4 - c_4)\frac{\partial q_4}{\partial p_7} + \phi_{dcn,\ v=1}^{post}(p_5 - c_5)\frac{\partial q_5}{\partial p_7} + \phi_{-dcn,\ v=1}^{post}(p_6 - c_6)\frac{\partial q_6}{\partial p_7} + (p_7 - c_7)\frac{\partial q_7}{\partial p_7} = 0$$

Therefore:

$$\Omega^{post-own} = \begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 \end{pmatrix}; \quad \Omega^{post-comp}_{dcn,\ v=1} = \begin{pmatrix} 0 & \phi^{post}_{dcn,\ v=1} & 0 & 0 \\ \phi^{post}_{dcn,\ v=1} & 0 & 0 & \phi^{post}_{dcn,\ v=1} \\ 0 & 0 & 0 & 0 \\ 0 & \phi^{post}_{dcn,\ v=1} & 0 & 0 \end{pmatrix}; \text{ and}$$

$$\Omega^{post-comp}_{-dcn,\ v=1} = \begin{pmatrix} 0 & 0 & \phi^{post}_{-dcn,\ v=1} & 0 \\ 0 & 0 & \phi^{post}_{-dcn,\ v=1} & 0 \\ \phi^{post}_{-dcn,\ v=1} & \phi^{post}_{-dcn,\ v=1} & 0 & \phi^{post}_{-dcn,\ v=1} \\ 0 & 0 & \phi^{post}_{-dcn,\ v=1} & 0 \end{pmatrix}$$

Furthermore, product markups are given by:

$$\mathbf{m}^{post} = \left[\left(\Omega^{post-own} + \Omega^{post-comp}_{dcn,\ v=1} + \Omega^{post-comp}_{-dcn,\ v=1}\right).*\Delta^{post}\right]^{-1} \times \mathbf{d}(\mathbf{p})^{post}$$

$$= \left[\begin{pmatrix} 1 & \phi^{post}_{dcn,\ v=1} & \phi^{post}_{-dcn,\ v=1} & 1 \\ \phi^{post}_{dcn,\ v=1} & 1 & \phi^{post}_{-dcn,\ v=1} & \phi^{post}_{dcn,\ v=1} \\ \phi^{post}_{-dcn,\ v=1} & \phi^{post}_{-dcn,\ v=1} & 1 & \phi^{post}_{-dcn,\ v=1} \\ 1 & \phi^{post}_{dcn,\ v=1} & \phi^{post}_{-dcn,\ v=1} & 1 \end{pmatrix} .* \begin{pmatrix} \frac{\partial q_4}{\partial p_4} & \frac{\partial q_5}{\partial p_4} & \frac{\partial q_6}{\partial p_4} & \frac{\partial q_7}{\partial p_4} \\ \frac{\partial q_4}{\partial p_5} & \frac{\partial q_5}{\partial p_5} & \frac{\partial q_6}{\partial p_5} & \frac{\partial q_7}{\partial p_5} \\ \frac{\partial q_4}{\partial p_6} & \frac{\partial q_5}{\partial p_6} & \frac{\partial q_6}{\partial p_6} & \frac{\partial q_7}{\partial p_6} \\ \frac{\partial q_4}{\partial p_7} & \frac{\partial q_5}{\partial p_7} & \frac{\partial q_6}{\partial p_7} & \frac{\partial q_7}{\partial p_7} \end{pmatrix}\right]^{-1} \times \begin{pmatrix} q_4 \\ q_5 \\ q_6 \\ q_7 \end{pmatrix}$$

Strategic interaction in market when v = 0:

$$\Pi_{Delta} = (p_4 - c_4)q_4 + \phi^{post}_{dcn,\ v=0}(p_5 - c_5)q_5 + \phi^{post}_{-dcn,\ v=0}(p_6 - c_6)q_6$$

$$\Pi_{Northwest} = (p_5 - c_5)q_5 + \phi^{post}_{dcn,\ v=0}(p_4 - c_4)q_4 + \phi^{post}_{-dcn,\ v=0}(p_6 - c_6)q_6$$

$$\Pi_{American} = (p_6 - c_6)q_6 + \phi^{post}_{-dcn,\ v=0}(p_4 - c_4)q_4 + \phi^{post}_{-dcn,\ v=0}(p_5 - c_5)q_5$$

First-order conditions:

$$q_4 + (p_4 - c_4)\frac{\partial q_4}{\partial p_4} + \phi^{post}_{dcn,\ v=0}(p_5 - c_5)\frac{\partial q_5}{\partial p_4} + \phi^{post}_{-dcn,\ v=0}(p_6 - c_6)\frac{\partial q_6}{\partial p_4} = 0$$

$$q_5 + \phi^{post}_{dcn,\ v=0}(p_4 - c_4)\frac{\partial q_4}{\partial p_5} + (p_5 - c_5)\frac{\partial q_5}{\partial p_5} + \phi^{post}_{-dcn,\ v=0}(p_6 - c_6)\frac{\partial q_6}{\partial p_5} = 0$$

$$q_6 + \phi^{post}_{-dcn,\ v=0}(p_4 - c_4)\frac{\partial q_4}{\partial p_6} + \phi^{post}_{-dcn,\ v=0}(p_5 - c_5)\frac{\partial q_5}{\partial p_6} + (p_6 - c_6)\frac{\partial q_6}{\partial p_6} = 0$$

Therefore:

$$\Omega^{post-own} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}; \ \Omega^{post-comp}_{dcn,\ \nu=0} = \begin{pmatrix} 0 & \phi^{post}_{dcn,\ \nu=0} & 0 \\ \phi^{post}_{dcn,\ \nu=0} & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}; \text{ and}$$

$$\Omega^{post-comp}_{-dcn,\ \nu=0} = \begin{pmatrix} 0 & 0 & \phi^{post}_{-dcn,\ \nu=0} \\ 0 & 0 & \phi^{post}_{-dcn,\ \nu=0} \\ \phi^{post}_{-dcn,\ \nu=0} & \phi^{post}_{-dcn,\ \nu=0} & 0 \end{pmatrix}$$

Furthermore, product markups are given by:

$$\mathbf{m}^{post} = \left[\left(\Omega^{post-own} + \Omega^{post-comp}_{dcn,\ \nu=0} + \Omega^{post-comp}_{-dcn,\ \nu=0} \right) .* \Delta^{post} \right]^{-1} \times \mathbf{d}(\mathbf{p})^{post}$$

$$= \left[\begin{pmatrix} 1 & \phi^{post}_{dcn,\ \nu=0} & \phi^{post}_{-dcn,\ \nu=0} \\ \phi^{post}_{dcn,\ \nu=0} & 1 & \phi^{post}_{-dcn,\ \nu=0} \\ \phi^{post}_{-dcn,\ \nu=0} & \phi^{post}_{-dcn,\ \nu=0} & 1 \end{pmatrix} .* \begin{pmatrix} \frac{\partial q_4}{\partial p_4} & \frac{\partial q_5}{\partial p_4} & \frac{\partial q_6}{\partial p_4} \\ \frac{\partial q_4}{\partial p_5} & \frac{\partial q_5}{\partial p_5} & \frac{\partial q_6}{\partial p_5} \\ \frac{\partial q_4}{\partial p_6} & \frac{\partial q_5}{\partial p_6} & \frac{\partial q_6}{\partial p_6} \end{pmatrix} \right]^{-1} \times \begin{pmatrix} q_4 \\ q_5 \\ q_6 \end{pmatrix}$$

Appendix B - Additional Chapter 2 Tables

Table B.1 Instrument Validity Test

	Dependent Variable			
	Price (hundreds)		ln(Sj_g)	
Variable				
Nest_sum_convenient	-0.103	(0.081)	1.498**	(0.106)
Nest_sum_interstop	-0.531**	(0.026)	-1.015**	(0.034)
Nest_convenient	-0.061**	(0.011)	-0.421**	(0.015)
Nest_interstop	0.082**	(0.007)	0.352**	(0.009)
N_comp	-0.028**	(0.003)	-0.008*	(0.004)
N_multi	-0.052**	(0.010)	-0.069**	(0.012)
comp_distance	0.684**	(0.103)	0.885**	(0.135)
close_comp	-0.005	(0.012)	-0.061**	(0.015)
Itinerary distance / 1000	0.412**	(0.009)	-0.109**	(0.012)
constant	2.022**	(0.078)	-1.169**	(0.102)
R-squared	0.275		0.579	

Standard errors are shown in parentheses
* Statistically significant at the 5% level
** Statistically significant at the 1% level

Table B.2 Post-Merger Data Demand Results

"Leisure" Type		
Price (hundreds)	-0.946**	(0.003)
Convenient	-0.546**	(0.049)
Nonstop	1.606**	(0.032)
Constant	-0.946**	(0.003)
"Business" Type		
Price (hundreds)	-1.454**	(0.024)
Convenient	-0.790**	(0.039)
Nonstop	2.124**	(0.021)
Constant	-0.866**	(0.038)
Hub Origin	0.412**	(0.001)
Virtual Codeshare	-1.261**	(0.002)
Traditional Codeshare	-0.373**	(0.004)
Spring	0.041**	(0.001)
Summer	-2.780**	(0.083)
σ	0.120**	(0.001)
λ_L	0.601**	(0.020)

Standard errors are shown in parentheses
* Statistically significant at the 5% level
** Statistically significant at the 1% level

Appendix C - Additional Chapter 3 Tables

Table C.1 Instrument Validity Test

	Dependent Variable			
	Price		ln(Sj_g)	
Variable				
Nest_sum_convenient	0.2486**	(0.0603)	2.6086**	(0.0798)
Nest_sum_interstop	-0.3967**	(0.0288)	-1.4823**	(0.0381)
Nest_convenient	-0.0879**	(0.0079)	-0.5073**	(0.0105)
Nest_interstop	0.1055**	(0.0086)	0.3782**	(0.0114)
N_comp	-0.0092**	(0.0023)	-0.0122**	(0.0030)
N_multi	-0.0218**	(0.0045)	0.0066	(0.0060)
comp_distance	0.4780**	(0.0393)	0.2384**	(0.0520)
close_comp	-0.0262**	(0.0039)	0.0799**	(0.0051)
Itin Distance / 1000	0.4271**	(0.0077)	-0.1303**	(0.0102)
constant	1.7805**	(0.0572)	-2.2756**	(0.0756)
R-squared	0.2353		0.5547	

Standard errors are shown in parentheses

* Statistically significant at the 5% level

** Statistically significant at the 1% level

Table C.2 List of Hubs for each Airline

Airline	Hubs
American Airlines	BOS - Logan International, Boston DFW - Dallas/Fort Worth International JFK - John F Kennedy International, New York LAX - Los Angeles International MIA - Miami International ORD - Chicago O'Hare International RDU - Raleigh-Durham International STL - Lambert St. Louis International
Alaska Airlines	BOI - Boise Air Terminal/Gowen Field SEA - Seattle/Tacoma International
JetBlue Airways	JFK - John F Kennedy International, New York
Continental Airlines	CLE - Hopkins International, Cleveland EWR - Newark Liberty International IAH - George Bush Intercontinental, Houston
Delta Airlines	ATL - Hartsfield-Jackson Atlanta International CVG - Cincinnati/ Northern Kentucky DFW - Dallas/Fort Worth International SLC - Salt Lake City International
Frontier Airlines	DEN - Denver International
Airtran Airways	ATL - Hartsfield Jackson Atlanta International MCO - Orlando International
Northwest Airlines	DTW - Detroit Metropolitan MEM - Memphis International MSP - Minneapolis/St. Paul International
United Airlines	DEN - Denver International IAD - Washington Dulles International LAX - Los Angeles International ORD - Chicago O'Hare International SFO - San Francisco International

Airline	Hubs
US Airways	BWI - Baltimore/Washington International CLT - Charlotte Douglas IND - Indianapolis International LAX - Los Angeles International PHL - Philadelphia International PIT - Pittsburgh International SFO - San Francisco International SYR - Syracuse Hancock International
Southwest Airlines	BNA - Nashville International BWI - Baltimore/Washington International DAL - Dallas Love Field DEN - Denver International HOU - William P Hobby, Houston LAS - McCarran International, Las Vegas LAX - Los Angeles International MCO - Orlando International MDW - Chicago Midway OAK - Oakland International PHL - Philadelphia International PHX - Sky Harbor International, Phoenix SAN - San Diego TPA - Tampa International
Midwest Airlines	MKE - General Mitchell International, Milwaukee