

Measuring Merger Cost Effects: Evidence from a Dynamic Structural Econometric Model

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Abstract

Retrospective analyses of mergers disproportionately focus on assessing price rather than cost changes associated with mergers. Perhaps a reason for the disproportionate focus is that reliable price data are typically more readily available. In this paper we use a methodology that does not require data on cost to infer the effects of two recent airline mergers—Delta/Northwest and United/Continental—on merging firms' marginal costs, recurrent fixed costs, and sunk market entry costs. We find that both mergers are associated with marginal and fixed cost savings, but higher market entry costs. The magnitudes of the cost effects differ across the mergers.

Keywords: Airline Mergers; Merger Cost Efficiencies; Dynamic Entry/Exit Model

JEL Classification codes: L13, L93, C1, C25

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1. Introduction

As suggested in Whinston (2007, pp. 2435), most papers that conduct a retrospective empirical analysis of mergers focus on assessing price rather than cost changes associated with mergers.¹ Perhaps a reason for the disproportionate focus on price rather than cost is that reliable price data are more readily available. Despite the difficulty in obtaining cost data, researchers have sought to empirically assess whether cost efficiency gains associated with a merger outweigh the increased market power of the merged firm.² For example, Kim and Singal (1993) use pre-post merger relative changes in price and industry concentration to infer whether cost efficiency gains from a set of mergers outweigh increased market power of the merged firms. The idea is that if the merger causes both price and industry concentration to increase, then it can be inferred that market power increases outweigh cost efficiency gains. Even when price and cost data are not available, researchers have relied heavily on theory and market share data to empirically assess whether cost efficiency gains of a merger outweigh market power increases of the merged firm [Gugler and Siebert (2007)]. In this case the theoretical prediction relied on is that if the merged firm's market share increases relative to the pre-merger joint market share of the firms that merge, then it can be inferred that cost efficiency gains outweigh market power increases [see Gugler and Siebert (2007)].

It is clear from the literature that researchers are interested in measuring cost efficiency gains associated with mergers. Furthermore, merger cost efficiency gains may not just be restricted to marginal cost, even though this is the type of cost efficiency gain that most quickly puts downward pressure on short-run pricing. For example, a merger may eliminate duplication of some service departments of a firm, such as marketing and other administrative areas, which in turn is more likely to lower recurrent fixed cost rather than marginal cost. In addition, complementary characteristics/expertise across firms that merge may lower the merged firm's cost of entry into new markets. Lower recurrent fixed and sunk entry costs may allow the merged firm to enter new markets in the medium or long-run that the unmerged firms would not

¹ Examples of such merger analyses in the airline industry include: Werden, Joskow, and Johnson (1989); Borenstein (1990); Brown (2010); Luo (2011); Brueckner, Lee, and Singer (2012); Huschelrath, and Muller (2012).

² See Williamson (1968) and Farrell and Shapiro (1990) for theoretical treatments of the opposing effects of efficiency gains and increased market power that may result from a merger.

have individually entered without the merger [Benkard, Bodoh-Creed, and Lazarev (2010)].³ New entry potentially reduces price. So in the medium or long-run, recurrent fixed and sunk market entry cost efficiency gains could result in lower prices and higher welfare. We are unaware of papers in the literature that explicitly separate merger cost effects into these three main categories of cost – (1) marginal cost; (2) recurrent fixed cost; and (3) sunk market entry cost.

The main objective of our paper is to empirically estimate marginal, recurrent fixed and sunk entry cost effects associated with two recent airline mergers – Delta/Northwest (DL/NW) and United/Continental (UA/CO) mergers – using a methodology that does not require the researcher to have cost data. Before describing our methodology, it is useful to briefly discuss previous related work.

Werden, Joskow and Johnson (1989) investigated the price effects of two airline mergers: (1) Northwest (NW) and Republic (RC) airlines; and (2) Trans World Airline (TWA) and Ozark Airlines (OZ). Both mergers occurred in fall 1986. The authors find that the TWA-OZ merger caused a slight overall increase in fares in city pairs out of their major hub in St. Louis (1.5 percent). However, the merger between Northwest and Republic appears to have caused a more significant increase in fares. Overall fares went up by 5.6 percent on city pairs out of their major hub in Minneapolis-St. Paul.

Borenstein (1990) also examines market effects of the NW/RC and TWA/OZ airline mergers. He finds that the TWA/OZ merger had no systematic impact on these carriers price on routes originating at their St. Louis HUB since their price changes on these routes averaged almost exactly the same as the industry average price changes. In contrast, NW/RC merger seems to increase their price on routes out of their main hub in Minneapolis. Borenstein finds that both mergers are associated with increases in the merged firms' market share on routes originating from their main hub.

Kim and Singal (1993) examine price changes associated with 27 airline mergers during 1985 – 1988. The authors compute price changes of merging firms on sample routes (or treated routes) and compare them to price changes on control routes that do not have the merging firms. Using this same difference-in-differences methodology used for computing relative fare changes,

³ Benkard, Bodoh-Creed, and Lazarev (2010), study the potential medium and long-run dynamic effects of three airline mergers. They focus on predicting the “potential” medium and long-run effects of mergers on industry structure, rather than explicitly measuring the “actual” effects of mergers on firms' cost structure.

the authors compute relative changes in industry concentration (relative changes in Herfindahl-Hirschman Index (HHI)). The authors infer market power effects outweigh cost efficiency gains if a positive relationship between relative price changes and industry concentration is found. Alternatively, the authors infer that cost efficiency gains outweigh market power effects if a negative relationship between relative price changes and industry concentration is found. The authors find that for the full sample, cost efficiency gains are dominated by the exercise of market power because the relationship between relative price changes and relative changes in industry concentration is positive and statistically significant.

Peters (2006) investigates five mergers that occur in the 1980s. He first uses pre-merger data to estimate a model derived from the assumption that airlines set prices according to a static Bertrand-Nash game. The estimated model is then used to simulate predicted post-merger prices. He compares the simulation prediction of post-merger prices with observed post-merger prices and investigates the sources of deviations between these two sets of prices. He finds that there are significant differences between the average observed price changes and the average predicted price changes. He argues that these differences are mainly due to supply-side effects that may include changes in marginal costs, implying that mergers do influence marginal cost.

It is also useful to briefly describe findings of merger analyses in other industries. Gugler and Siebert (2007) find that mergers in the semiconductor industry raise the market share of participating firms. They argue on theoretical grounds that this is sufficient evidence to suggest that cost efficiency gains dominate market power effects for mergers in this industry.

Dranove and Lindrooth (2003) use actual cost data to empirically investigate whether hospital consolidation leads to cost savings. The authors, with cost data in hand, estimated a translog cost function at the hospital level over pre-post consolidation periods. The authors rely on a difference-in-differences identification methodology. Cost function estimates reveal that consolidations into systems (i.e. common ownership but operations and financial reporting remain separate for the entities that consolidated, therefore limited corporation post-consolidation) does not generate cost savings, even after 4 years. However, mergers in which hospitals consolidate financial reporting and licenses generate saving of approximately 14%.

Harrison (2011) examines cost savings due to scale economies associated with hospital mergers. Using actual cost data, she non-parametrically estimate costs for each individual reporting entity before and after the merger. Her findings suggest that economies of scale exist

for the merging hospitals and that they take advantage of these cost savings immediately following a merger. The findings also indicate that cost savings are higher one year after the merger than in subsequent years.

In the set of papers cited above we can see that some were able to use actual cost data to measure merger efficiencies, while others relied on theoretical predictions to exploit more readily available data on price and/or market share to infer whether merger cost efficiency gains outweigh increases in market power. One of the key distinction between our paper and previous work that we are aware of is that, without the need for actual cost data, we use a methodology that allows for separate identification of marginal; recurrent fixed; and sunk entry cost effects associated with a merger. The following is a brief summary description of our methodology.

We begin by specifying and estimating a static differentiated products Bertrand-Nash game. The static model incorporates both demand and short-run supply. We first estimate a discrete choice model of air travel demand. For the short-run supply aspect of the model, we assume that prices are set according to a static Bertrand-Nash equilibrium with multiproduct firms. The static Bertrand-Nash assumption allows us to derive product-specific markups and recover product-level marginal cost. With marginal cost estimates in hand, along with data on variables that should shift marginal cost, we then specify and estimate a marginal cost function. For a given merger of interest, we specify the marginal cost function in a way that allows all firms' (both non-merging firms and firms that merge) marginal cost to change in the post-merger period relative to the pre-merger period. Consistent with a difference-in-differences methodology, we identify marginal cost effects of a merger by comparing the pre-post merger change in merging firms' marginal cost relative to the change in non-merging firms' marginal cost.

With the product-specific markups in hand, we are able to compute firm-level variable profits. Estimates of firm-level variable profits are subsequently used in a dynamic entry/exit game, which is the long-run part of our model used for identifying recurrent fixed and sunk entry cost. In the dynamic entry/exit game, each airline chooses which markets to be active in during specific time periods in order to maximize its expected discounted stream of profit, where per-period profit comprises variable profit less per-period fixed cost and a one-time entry cost if the airline was not in the relevant market in the previous period. The dynamic entry/exit game allows us to estimate fixed and entry costs by exploiting observed data on airlines' decisions to

enter and exit certain markets. For a given merger of interest, we allow all firms' (both non-merging and the firms that merge) fixed and entry cost functions to change in the post-merger period relative to the pre-merger period. Consistent with a difference-in-differences methodology, we identify fixed and entry cost effects of a merger by comparing the pre-post merger change in merging firms' fixed and entry cost functions relative to the change in non-merging firms' fixed and entry cost functions.

Our empirical results reveal that for the merging firms: (1) Marginal cost efficiency gains are associated with both DL/NW and UA/CO mergers; (2) Fixed cost efficiency gains are associated with both DL/NW and UA/CO mergers; (3) Both mergers however are associated with increased market entry costs; and (4) The magnitudes of these effects differ across the two mergers. The magnitude of marginal cost savings associated with the DL/NW merger is smaller than that of the UA/CO merger. In contrast, the magnitude of fixed cost savings associated with the DL/NW merger is greater than that of the UA/CO merger. The magnitude of the increase in market entry costs associated with the UA/CO merger is greater than that of the DL/NW merger. In the case of non-merging airlines, we find that their recurrent fixed costs are unchanged throughout the entire evaluation periods for both mergers. However, non-merging airlines' market entry costs increase after the DL/NW merger, but decrease after the UA/CO merger.

We also estimate a regression in which a variable of product markups generated from the structural model is regressed on several determinants of markup. Results from this product markup regression reveal that both mergers led to only small increases in markups, suggesting that market power effects of these mergers were negligible.

Results from our structural model are consistent with results from a reduced-form price regression we estimate. The reduced-form price regression reveals evidence that each merger is associated with price decreases, which suggests the marginal cost efficiencies outweigh market power increases. However, the reduced-form price regression is not able to separately measure the magnitudes of marginal cost efficiencies and markup increases associated with the mergers, hence the need for our structural model analysis.

The rest of the paper is organized as follows: The next section presents some details of the two mergers. Section 3 describes the working sample. Sections 4 and 5 present the static and dynamic models, respectively. Section 6 describes the estimation procedure of the static model. A brief discussion of those estimation results follows in section 7. Section 8 describes

the estimation method for the dynamic model, as well as discussions of those results. Section 9 provides additional discussion of some results and section 10 concludes.

2. Details of the DL/NW and UA/CO mergers

Delta and Northwest announced their plan to merge on April 14, 2008. At the time, it would create the largest U.S. commercial airline measured by available seat miles. Delta's headquarters and primary hub are based in Atlanta, Georgia while Northwest was headquartered in Eagan, Minnesota and has a primary hub in Minneapolis, Minnesota. They were the third and fifth largest airlines in the United States, respectively. On October 29, 2008, the United States Department of Justice (DoJ) approved the merger after a six months investigation. The DoJ's approval release statement suggests that the two airlines networks overlapped in some origin-destination markets, which normally triggers antitrust concerns with a proposed merger. However, the DoJ did not challenge the merger in these markets because the DoJ is satisfied that either: (1) sufficient competition from other airlines was present; or (2) cost efficiency gains would be sufficient to mitigate anti-competitive effects. The DoJ stated the following in its approval release statement:⁴

*“The two airlines currently compete with a number of other legacy and low cost airlines in the provision of scheduled air passenger service on the vast majority of nonstop and connecting routes where they compete with each other. In addition, the merger likely will result in **efficiencies such as cost savings** in airport operations, information technology, supply chain economics, and fleet optimization that will benefit consumers.”*

From the perspective of the merging airlines' executives, they believe that Delta and Northwest are a good fit on many levels. They assert that the combination will benefit customers, employees, shareholders, and the communities they serve. Moreover, it will help create a more resilient airline for long-term success and financial stability. In terms of possible efficiency gains from the merger, they anticipate that by 2012, major revenue and cost synergies

⁴ Department of Justice. “Statement of the Department of Justice's Antitrust Division on Its Decision to Close Its Investigation of the Merger of Delta Air Lines Inc. and Northwest Airlines Corporation.” 19 October 2008. <http://www.justice.gov/atr/public/press_releases/2008/238849.htm>

in excess of \$1 billion a year will be achieved.⁵ Approximately \$700-\$800 million of benefits is anticipated to come from combining and improving the airlines' complementary network structure, where effective fleet optimization will account for more than half of those network benefits. Cost synergies are anticipated to come from the combining of sales agreements, vendor contracts, and more efficient operation of airport facilities. They will also streamline overhead structures, redundant facilities, and technology integration. While the airlines anticipate that much of these costs savings will be offset by higher wages and benefits for employees of the combined carrier, they estimate these gains to be in the \$300-\$400 million range.

Approximately two years following the DL/NW merger, on May 3, 2010 United (UA) and Continental (CO) made public their plan to merge. Even though the formal announcement did not take place until two years later, United and Continental merger negotiations were underway at the time of the DL/NW merger. The unification of distinct cultures and groups of workers who were represented by different unions slowed progress of the merger. Nonetheless, the merger was approved by the DoJ on August 27, 2010 creating the largest U.S. passenger airline based on capacity, as measured by year 2009 available seat miles, surpassing DL/NW.

Although it only took three months for the DoJ to approve the UA/CO merger—much shorter than the DL/NW approval—there was a major concern. The number of overlapping routes between United's hub airports and Continental's hub at Newark Liberty Airport was large. Continental had a high share of service at this hub, and new entry into markets connected to this hub was difficult because of the limited number of available slots. Therefore, Continental and United had to agree to give up some take-off and landing slots at Newark Liberty Airport to Southwest Airlines in order to gain DoJ's approval.⁶ Continental would lease 18 pairs of take-off and landing slots during peak and off-peak travel times to Southwest. Although the number is relatively small, Southwest did not have any presence there previously and it only had limited service at neighboring La Guardia Airport. The slot-transfer agreement therefore was enough to ease DoJ's anticompetitive concerns.

⁵ See seeking Alpha. "Delta Air Lines, Northwest Airlines Merger Call Transcript." 16 April 2008. <<http://seekingalpha.com/article/72537-delta-air-lines-northwest-airlines-merger-call-transcript>>

⁶ See Department of Justice. "United Airlines and Continental Airlines Transfer Assets to Southwest Airlines in Response to Department of Justice's Antitrust Concerns." 27 August 2010. <http://www.justice.gov/opa/pr/2010/August/10-at-974.html>

Unlike the Delta and Northwest executives, United and Continental did not provide numerical projections of the possible efficiency gains from the merger. They however believe that UA and CO are compatible partners in many ways. For example, both have similar fleets and operate in different geographic markets that complement each other. Flying mainly Boeing aircrafts helps reduce costs associated with multiple orders. Operating in distinct geographical markets enables them to link and expand their networks as United's strength is mainly in the western part of the United States while Continental has a larger presence in the east coast.⁷ In sum, efficiency gains are anticipated from both mergers. However, by providing numerical projections, Delta and Northwest seems to be more confident in achieving of those gains compare to United and Continental.

3. Data Construction, Descriptive Statistics and Definitions

The dataset comes from the Origin and Destination Survey (DB1BMarket) collected by the Bureau of Transportation Statistics. It is quarterly data that constitute a 10 percent sample of airline tickets from reporting carriers. Each observation is a flight itinerary that includes information such as the identity of the airline, airfare, number of passengers that purchase the specific itinerary, market miles flown on the trip itinerary, origin and destination airports, as well as intermediate airport stops. Unfortunately, the DB1B data do not contain passenger-specific information, or information on ticket restrictions such as advance-purchase and length-of-stay requirements.

We use data that span from the first quarter of 2005 to the third quarter of 2011. The raw dataset contains millions of observations each quarter. For example, there are 9,681,258 observations in the third quarter of 2011. We define and construct our estimation sample in the following manner:

- i. *City selection*: Following Aguirregabiria and Ho (2012) among others, we focus on air travel between the 64 largest US cities based on the Census Bureau's Population Estimates Program (PEP) which produces estimates of the population for the United

⁷ Alukos, Basili. "How Long Has a Continental-United Merger Been in the Works?" Seeking Alpha. 30 April 2010. <<http://seekingalpha.com/article/202056-how-long-has-a-continental-united-merger-been-in-the-works>>

States. We use data from the category “Cities and Towns”. We group cities that belong to the same metropolitan areas and share the same airport. Table 1 provides a list of the cities, corresponding airport groupings and population estimate in 2009. We use population of the origin city as a measure of the market size. Our sample has a total of 55 metropolitan areas (“cities”) and 63 airports.

- ii. *Market definition:* A market is defined as directional origin-destination-time period combination. Directional means that Dallas to Atlanta is a different market than Atlanta to Dallas.
- iii. *Product definition:* A product is defined as an itinerary-operating carrier combination. For example, a direct flight from Dallas to Atlanta operated by American Airline.
- iv. *Airlines:* There are three types of carriers in the data—ticketing carrier, operating carrier, and reporting carrier. The ticketing carrier is the airline that issues the flight reservation or ticket to consumers. The operating carrier is the airline that engages directly in the operation of the aircraft, i.e., the airline that actually transports the passengers. The reporting carrier submits the ticket information to the Office of Airline Information. We focus on products that use a single operating carrier for all segments of the trip itinerary and designate the operating carrier as the “owner” of the product. Table 2 lists the names and associated code of the 41 carriers in our sample.
- v. *Itinerary selection:* We drop all itineraries with market fares less than \$50 or greater than \$2,000. Eliminating fares that are too low helps avoid discounted fares that may be due to passengers using their frequent-flyer miles to offset the full price of the trip. We also drop all itineraries with the following characteristics: (1) outside the 48 mainland US states; (2) one-way tickets; and (3) more than two intermediate stops.
- vi. *Price and quantity:* An observation in the data may contain more than one passenger buying the same product at different fares. Thus, the dataset has many repeated

- products due to passengers paying different fares. We construct the price and quantity variables by averaging the market fare and aggregating number of passengers by defined products respectively. During a given time period, a product appears only once in the collapsed data. Last, a product survives deletion from our sample if it is purchased by at least 9 consumers during a quarter, which helps in eliminating products that are not part of the regular offerings by an airline.
- vii. *Observed Product Shares*: From the collapsed dataset, *Observed Product Shares* (subsequently denoted by upper case S_j) are constructed by dividing quantity of product j purchased (subsequently denoted by q_j) by origin city population (subsequently denoted by POP), i.e. $S_j = q_j / POP$.
- viii. *Origin and destination presence*: We create two variables that capture the magnitudes of an airline's "presence" at the market endpoint cities. The *Origin presence* variable is calculated by aggregating the number of destinations that an airline connects with the origin city using non-stop flights. Similarly, the *Destination presence* variable is calculated by aggregating the total number of destinations that an airline connects with the destination city using non-stop flights. The greater the number of different cities that an airline provides service to using non-stop flights from a given airport, the greater the "presence" the airline has at that airport.
- ix. *Creation of other variables*: *Interstop* is a variable that captures one measure of travel itinerary convenience, and is measured by the number of intermediate stops in a product's itinerary. *Inconvenience* is another variable that captures the relative convenience to the consumer of a product's flight itinerary. It is calculated by dividing the itinerary distance flown from the origin to destination by the nonstop flight distance between the origin and destination. If a product uses a nonstop itinerary, its *Inconvenience* measure takes the minimum value, which is 1.

Table 3 shows summary statistics of variables used in estimation. The average market fare is approximately \$166. Origin and destination presence variables measure an airline's scale of operation at an airport. On average, airlines service approximately 29 different cities from the

relevant market's origin and destination cities respectively. The average distance flown across all products is about 1,500 miles.

City, State	Airports	2009 Population	City, State	Airports	2009 Population
New York City, NY and Newark, NJ	LGA, JFK, EWR	8,912,538	Las Vegas, NV	LAS	567,641
Los Angeles, CA	LAX, BUR	3,831,868	Louisville, KY	SDF	566,503
Chicago, IL	ORD, MDW	2,851,268	Portland, OR	PDX	566,143
Dallas, Arlington, Fort Worth and Plano, TX	DAL, DFW	2,680,817	Oklahoma City, OK	OKC	560,333
Houston, TX	HOU, IAH, EFD	2,257,926	Tucson, AZ	TUS	543,910
Phoenix-Tempe-Mesa, AZ	PHX	2,239,335	Atlanta, GA	ATL	540,922
Philadelphia, PA	PHL	1,547,297	Albuquerque, NM	ABQ	529,219
San Antonio, TX	SAT	1,373,668	Kansas City, MO	MCI	482,299
San Diego, CA	SAN	1,306,300	Sacramento, CA	SMF	466,676
San Jose, CA	SJC	964,695	Long Beach, CA	LGB	462,604
Denver-Aurora, CO	DEN	933,693	Omaha, NE	OMA	454,731
Detroit, MI	DTW	910,921	Miami, FL	MIA	433,136
San Francisco, CA	SFO	815,358	Cleveland, OH	CLE	431,369
Jacksonville, FL	JAX	813,518	Oakland, CA	OAK	409,189
Indianapolis, IN	IND	807,584	Colorado Spr., CO	COS	399,827
Austin, TX	AUS	786,386	Tula, OK	TUL	389,625
Columbus, OH	CMH	769,332	Wichita, KS	ICT	372,186
Charlotte, NC	CLT	704,422	St. Louis, MO	STL	356,587
Memphis, TN	MEM	676,640	New Orleans, LA	MSY	354,850
Minneapolis-St. Paul, MN	MSP	666,631	Tampa, FL	TPA	343,890
Boston, MA	BOS	645,169	Santa Ana, CA	SNA	340,338
Baltimore, MD	BWI	637,418	Cincinnati, OH	CVG	333,012
Raleigh-Durham, NC	RDU	634,783	Pittsburg, PA	PIT	311,647
El Paso, TX	ELP	620,456	Lexington, KY	LEX	296,545
Seattle, WA	SEA	616,627	Buffalo, NY	BUF	270,240
Nashville, TN	BNA	605,473	Norfolk, VA	ORF	233,333
Milwaukee, WI	MKE	605,013	Ontario, CA	ONT	171,603
Washington, DC	DCA, IAD	599,657			

Airline Code	Airline Name	Airline Code	Airline Name
16	PSA Airlines	L3	Lynx Aviation
17	Piedmont Airlines	NK	Spirit
3C	Regions Air	NW	Northwest ⁴
3M	Gulfstream	OO	SkyWest
9E	Pinnacle	QX	Horizon Air
9L	Colgan Air	RP	Chautauqua
AA	American ¹	RW	Republic
AL	Skyway	S5	Shuttle America Corp.
AQ	Aloha Air Cargo	SX	Skybus
AS	Alaska	SY	Sun Country
AX	Trans States	TZ	ATA
B6	JetBlue	U5	USA 3000
C5	Commutair	UA	United ⁵
C8	Chicago Express	US	US Airways ⁶
CO	Continental ²	VX	Virgin America
CP	Compass	WN	Southwest
DH	Independence Air	XE	ExpressJet
DL	Delta ³	YV	Mesa ⁷
F9	Frontier	YX	Midwest
FL	AirTran		
G4	Allegiant Air		
G7	GoJet		

¹ American (AA) + American Eagle (MQ) + Executive (OW)

² Continental (CO) + Expressjet (RU)

³ Delta (DL) + Comair (OH) + Atlantic Southwest (EV)

⁴ Northwest (NW) + Mesaba (XJ)

⁵ United (UA) + Air Wisconsin (ZW)

⁶ US Airways (US) + America West (HP)

⁷ Mesa (YV) + Freedom (F8)

Variable	Mean	Std. Dev.	Min	Max
Price ^a	165.8974	50.6787	38.5115	1,522.46
Quantity	213.8515	604.0482	9	11,643
Inconvenience	1.1453	0.2199	1	3.0928
Interstop	0.7917	0.4491	0	2
Origin presence	29.0576	25.8611	0	177
Destination presence	28.9186	25.5970	0	176
Itinerary distance flown (miles) ^b	1,544.255	720.9628	36	4,099
Nonstop flight distance (miles)	1,377.951	667.414	36	2,724
Observed Product Shares (S_j)	0.0003	0.00096	1.01e-06	0.0458
Number of Products	647,167			
Number of markets ^c	75,774			

^a Inflation-adjusted.

^b In DB1B database this variables is reported as “Market miles flown”.

^c Recall that a market is defined as a origin-destination-time period combination.

We estimate the static parts of our model (demand and marginal cost equations) on the full sample of data (2005:Q1 to 2011:Q3) since estimating these parts of the model are not computationally intensive. However, due to significant computational intensity required to estimate the dynamic part of the model, we had to treat each merger separately when examining fixed and entry cost effects, which allows us to use more manageable pre-post merger periods data subsamples for each merger. In case of the DL/NW merger, we use 2007:Q1 and 2007:Q2 for the pre-merger period data, and 2011:Q1 and 2011Q:2 for the post-merger period data. In case of the UA/CO merger, we use 2009:Q1 and 2009:Q2 for the pre-merger period data, and 2011:Q1 and 2011:Q2 for the post-merger period data.

Similar to Aguirregabiria and Ho (2012), we use a number of passengers’ threshold to determine whether or not an airline is actively servicing an origin-destination market. We define an airline to be active in a directional origin-destination market during a quarter if the airline transports at least 130 passengers in this market during the quarter.⁸ Table 4 indicates that in the post-merger period, UA/CO has entered into 65 new markets—markets where neither operated before merging. Likewise, the table shows that DL/NW has entered into as many as 123 new

⁸ The 130 passenger threshold we use for a directional market is equivalent to the 260 for non-directional market used by Aguirregabiria and Ho (2012).

markets—markets where neither operated before they merged. Perhaps these markets are the high cost-to-enter markets where if it were not for the merger, they would not have entered.

Table 4		
Number of Unique Markets Entered and Exited Post-merger		
	United/Continental	Delta/Northwest
Number of Entries	65	123
Number of Exits	187	267

3.1 Reduced-form Price Regression

To help motivate the need for our subsequent structural model, we start by examining how each merger affects price via a reduced-form price regression. Identification of the merger price effects in the reduced-form price regression relies on a difference-in-differences methodology. This identification strategy is in keeping with how many studies, some of which we discussed in the introduction, conduct retrospective analyses of mergers.

Table 5 shows estimation results from a simple reduced-form price equation. T_t^{dn} and T_t^{cu} are zero-one time period dummy variables that take the value 1 only in the post-merger period for each merger respectively. T_t^{dn} is for the DL/NW merger, while T_t^{cu} is for the UA/CO merger. DN_{jmt} is a zero-one airline-product dummy variable that equals 1 for all products that are associated with either Delta or Northwest. Similarly, CU_{jmt} is a zero-one airline-product dummy variable that equals 1 for all products that are associated with either Continental or United. The coefficients on the interaction variables, $T_t^{dn} \times DN_{jmt}$ and $T_t^{cu} \times CU_{jmt}$, therefore measure how DL/NW and UA/CO's prices change over the respective pre and post-merger periods, while the coefficients on T_t^{dn} and T_t^{cu} measure how non-merging airlines' price change over the respective pre-post merger periods.

The coefficient estimate on T_t^{dn} is not statistically significant at conventional levels of statistical significance, suggesting that non-merging airlines' price, on average, did not change over the pre-post DL/NW merger periods. However, the negative and statistically significant coefficient estimate on $T_t^{dn} \times DN_{jmt}$ indicates that the prices of products offered by Delta and Northwest, on average, declined by \$7.22 (a 4% decline from pre-merger mean price level) over the pre-post DL/NW merger periods.

Table 5		
Estimation Results for Reduced-form Price Regression		
647,167 observations: 2005-Q1 to 2011-Q3		
Variable	Coefficient Estimate	Robust Standard Errors
T_t^{dn}	-0.2180924	0.3340149
$T_t^{dn} \times DN_{jmt}$	-7.224441***	0.3130204
T_t^{cu}	1.134174***	0.297489
$T_t^{cu} \times CU_{jmt}$	-14.67186***	0.541704
Itinerary distance flown (miles)	0.0357345***	0.0001105
Interstop	-0.1187226	0.1554094
Origin presence	0.4998494***	0.0086043
(Origin presence) ²	-0.0002731***	0.0000752
Dest. Presence	0.533465***	0.0087129
(Dest. presence) ²	-0.0004711***	0.0000777
Constant	113.1979***	1.203644
Operating carrier effects	YES	
Origin city effects	YES	
Destination city effects	YES	
Quarter and Year effects	YES	

*** Statistical significance at the 1% level. The equation is estimated using ordinary least squares.

The coefficient estimate on T_t^{cu} is positive and statistically significant, and suggests that non-merging airline prices increase, on average, by \$1.13 (a 0.7% increase over pre-merger mean price level) over the pre-post UA/CO merger periods. In contrast to non-merging airlines, the negative and statistically significant coefficient estimate on $T_t^{cu} \times CU_{jmt}$ suggests that the prices of products offered by United and Continental declined, on average, by \$14.67 (a 8% decline from pre-merger mean price level) over the pre-post UA/CO merger periods.

The reduced-form evidence suggests that both mergers are associated with lowering the merging firms' prices. However, the UA/CO merger seems to be associated with a larger decline in prices, both in terms of dollars and percentage, compared to the DL/NW merger. Since the mergers are associated with falling prices, we can infer that marginal cost savings outweigh market power increases associated with the mergers. However, a structural model is needed to disentangle and separately measure the magnitudes of marginal cost savings and markup increases (a measure of market power) associated with the mergers.

All other control variables in the reduced-form price regression have the expected sign. Itinerary distance positively affect price, likely via its influence on marginal cost. Prices are lower for products with intermediate stops, perhaps because passengers prefer nonstop products. The size of an airlines' presence at the endpoint airports of a market is initially positively related to price, but becomes negatively related to price as size of airport presence increases beyond a certain threshold. This relationship between price and size of airport presence could in part be driven by economies of traffic density, i.e., lowering of marginal cost as airlines channel large number of passengers through their major hub airports.

4. Model

4.1 Demand

We model air travel demand using a discrete choice framework. A passenger c chooses among a set of $J_{mt} + 1$ alternatives in market m during period t , that is, the passenger either chooses one of the J_{mt} differentiated air travel products in the market or the outside option/good ($j = 0$). The outside option includes other modes of transportation besides air travel. Products are organized into $G + 1$ mutually exclusive groups, $g = 0, 1, \dots, G$ where the outside good is the only member of group 0. A group is a set of products offered by an airline within a market.

Potential passenger c solves the following utility maximization problem:

$$\underset{j \in \{0, 1, \dots, J_{mt}\}}{\text{Max}} \{U_{cjmt} = \mu_{jmt} + \delta \zeta_{cgmt} + (1 - \delta) \varepsilon_{cjmt}^d\}, \quad (1)$$

where U_{cjmt} is passenger c 's indirect utility from choosing product j ; μ_{jmt} is the mean level of utility across passengers that choose product j ; ζ_{cgmt} is a random component of utility common across all products within the same group; and ε_{cjmt}^d is an independently and identically distributed (across products, consumers, markets and time) random error term assumed to have type 1 extreme value distribution. The parameter δ lies between 0 and 1 and measures the correlation of consumer utility across products belonging to the same group/airline. The correlation of preferences increases as δ approaches 1. In the case where δ is 0, the model collapses to the standard logit model where products compete symmetrically.

The mean utility, μ_{jmt} , is specified as:

$$\mu_{jmt} = x_{jmt}\phi^x + \phi^p p_{jmt} + \eta_j + v_t + origin_m + dest_m + \xi_{jmt}, \quad (2)$$

where x_{jmt} is a vector of observed non-price product characteristics. The variables in x_{jmt} were briefly defined in the previous section, they include: (1) the number of intermediate stops in a product (*Interstop*); (2) an alternate measure of itinerary convenience (*Inconvenience*); and (3) a measure of the size of an airline's presence at the origin city (*Origin presence*). The vector of parameters, ϕ^x , measures passengers' marginal utilities associated with the measured non-price product characteristics. The price is p_{jmt} , and associated parameter, ϕ^p , captures the marginal utility of price. Airline fixed effects, η_j , are captured by airline dummy variables. Time period effects, v_t , are captured by quarter and year dummy variables. $origin_m$ and $dest_m$ are origin and destination city fixed effects. ξ_{jmt} is the unobserved (by researchers) component of product characteristics that affect consumer utility. For notational convenience, we drop the market and time subscripts in some subsequent equations.

The specifications above result in the nested logit model. The nested logit model has the following well-known predicted product share function:

$$s_j = \frac{\exp\left(\frac{\mu_j}{1-\delta}\right)}{D_g} \times \frac{D_g^{1-\delta}}{[1 + \sum_{g=1}^G D_g^{1-\delta}]}, \quad (3)$$

where $D_g = \sum_{j \in G_g} \exp\left(\frac{\mu_j}{1-\delta}\right)$ and G_g is the set of products belonging to group g .

The demand for product j is given by:

$$d_j = POP \times s_j(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}; \phi^p, \phi^x, \delta), \quad (4)$$

where POP is population size in the origin city, which is our measure of market size. \mathbf{x} , \mathbf{p} , and $\boldsymbol{\xi}$ are vectors of observed non-price product characteristics, price, and the unobserved vector of product characteristics respectively. ϕ^p , ϕ^x , and δ are demand parameters to be estimated.

4.2 Variable Profit, Product Markups and Product Marginal Costs

Each airline i offers a set of B_i products for sale. Thus, airline i has the variable profit function:

$$VP_i = \sum_{j \in B_i} (p_j - c_j) q_j, \quad (5)$$

where p_j , c_j , and q_j are the respective price, marginal cost, and the quantity of product j sold by airline i . In equilibrium, the amount of product j an airline sells equals to the demand, that is, $q_j = d_j$, which implies:

$$q_j = POP \times s_j(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}; \phi^p, \phi^x, \delta). \quad (6)$$

We assume that airlines set prices according to a static Nash-Bertrand game. Therefore, the Nash-Bertrand equilibrium is characterized by the following system of J first-order equations:

$$\sum_{k \in B_i} (p_k - c_k) \frac{\partial s_k}{\partial p_j} + s_j = 0 \text{ for all } j = 1, \dots, J \quad (7)$$

Equation (7) can be rearranged to compute product markups:

$$p_j - c_j = markup_j(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}; \widehat{\Phi}^d) \quad (8)$$

where $\widehat{\Phi}^d = (\widehat{\phi}^p, \widehat{\phi}^x, \widehat{\delta})$ is the vector of demand parameter estimates; and $markup_j(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}; \widehat{\Phi}^d)$ is the product markup function which depends exclusively on demand-side variables and parameter estimates.

With computed product markups in hand, product marginal costs can be recovered by:

$$\hat{c}_{jmt} = p_{jmt} - markup_{jmt}(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}; \widehat{\Phi}^d) \quad (9)$$

In addition, an airlines' variable profit in a market can be computed by:

$$VP_{imt} = \sum_{j \in B_i} markup_{jmt}(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}; \widehat{\Phi}^d) * q_{jmt} \quad (10)$$

5. Dynamic Entry/Exit Game

In every period (quarter), each airline decides which market(s) to be active in to maximize its expected intertemporal profits. Let airlines be indexed by i , markets by m , and period by t . An airline's expected discounted stream of profit in market m is given by:

$$E_t\left(\sum_{r=0}^{\infty} \beta^r \Pi_{im,t+r}\right), \quad (11)$$

where $\Pi_{im,t+r}$ is the per-period profit of the airline in market m and $\beta \in (0,1)$ is the time discount factor. Each airline's per-period profit is specified as the difference between variable profit and the sum of fixed and one-time market entry costs:

$$\Pi_{imt} = R_{imt}^* - a_{imt}(FC_{imt} + \varepsilon_{imt} + (1 - s_{imt})EC_{imt}), \quad (12)$$

where $R_{imt}^* = s_{imt}VP_{imt}$ is the variable profit of airline i in market m during period t . The value VP_{imt} is computed from the static Nash-Bertrand game described previously. s_{imt} is a zero-one indicator variable that equals to 1 if airline i was active in market m in period $t - 1$. a_{imt} is also a zero-one indicator variable, but unlike s_{imt} , a_{imt} equals to 1 if airline i decides in period t to be active in $t + 1$. Therefore, by definition $s_{imt} = a_{im,t-1}$.

After deciding to be active in a market, we assume that it takes time (one period) for airline i to actually begin operating in market m - time-to-build assumption. This time-to-build assumption implies that if $a_{imt} = 1$ and $s_{imt} = 0$, then airline i pays fixed and entry costs in period t even though flight operations do not actually begin until $t + 1$. Note that in period t , a_{imt} is a decision variable, while s_{imt} is a state variable. So we use different letters (a_{imt} versus s_{imt}) to make the distinction between an airline's decision versus a state variable.

FC_{imt} and EC_{imt} are the deterministic portions of fixed and entry costs functions respectively and are common knowledge for all airlines. ε_{imt} however represents private information shocks to fixed and entry costs that we assume to be independent and identically distributed (i.i.d) over airlines, markets and time period based on a specific probability distribution function, which we assume is the type 1 extreme value distribution. We specify the deterministic portions of fixed and entry costs functions as follows:

$$\begin{aligned}
FC_{imt} = & \theta_0^{FC} + \theta_1^{FC} Pres_{imt} + \theta_2^{FC} Post_Merger_Period_t + \\
& \theta_3^{FC} A_Merging_Firm_{imt} + \\
& \theta_4^{FC} Post_Merger_Period_t \times A_Merging_Firm_{imt}, \tag{13}
\end{aligned}$$

$$\begin{aligned}
EC_{imt} = & \theta_0^{EC} + \theta_1^{EC} Pres_{imt} + \theta_2^{EC} Post_Merger_Period_t + \\
& \theta_3^{EC} A_Merging_Firm_{imt} + \\
& \theta_4^{EC} Post_Merger_Period_t \times A_Merging_Firm_{imt}. \tag{14}
\end{aligned}$$

$Pres_{imt}$ is a measure of an airline's presence at the endpoint airports of origin-destination market m , which we define as the mean number of destinations the airline serves from the market's endpoint airports using nonstop flights. $Post_Merger_Period_t$ is a zero-one time-period dummy variable that takes the value 1 only during the post-merger period for the relevant merger being studied. $A_Merging_Firm_{imt}$ is a zero-one airline dummy variable that takes the value 1 if the airline is one of the airlines that is a part of the relevant merger being studied. The structural parameters to be estimated are:

$$\{\theta_0^{FC}, \theta_1^{FC}, \theta_2^{FC}, \theta_3^{FC}, \theta_4^{FC}, \theta_0^{EC}, \theta_1^{EC}, \theta_2^{EC}, \theta_3^{EC}, \theta_4^{EC}\}'$$

θ_0^{FC} and θ_0^{EC} measure the mean fixed and entry costs across airlines, markets and time, respectively. θ_1^{FC} and θ_1^{EC} capture the effects of the size of airport presence on fixed and entry costs. θ_2^{FC} and θ_2^{EC} capture how fixed and entry costs change for all other airlines except the merging parties across the pre and post-merger periods. θ_3^{FC} and θ_3^{EC} measure any persistent systematic difference in mean fixed and entry costs of the merging airlines relative to other airlines. The coefficients of interest are θ_4^{FC} and θ_4^{EC} which identify changes in fixed and entry costs resulting from the relevant merger being studied, that is, these parameters capture the possible fixed and entry cost efficiency gains associated with a merger.

5.1 Reducing the Dimensionality of the State Space

Recall that the variable profit function is defined as:

$$R_{imt}^* = \alpha_{im,t-1} VP_{imt}, \quad (15)$$

where

$$VP_{imt}(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}; \widehat{\Phi}^d) = \sum_{j \in B_i} \{ markup_{jmt}(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}; \widehat{\Phi}^d) * s_j(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi}; \widehat{\Phi}^d) * POP_{mt} \}. \quad (16)$$

Note that variable profits are functions of state variables $(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi})$. Aguirregabiria and Ho (2012) suggest that these state variables can be aggregated into a single state variable, R_{imt}^* rather than treating $(\mathbf{x}, \mathbf{p}, \boldsymbol{\xi})$ as separate state variables. In other words, we can treat $R_{imt}^*(\cdot)$ as a firm-specific state variable rather than treating \mathbf{x} , \mathbf{p} , and $\boldsymbol{\xi}$ as separate state variables, which serves to significantly reduce the dimensionality of the state space. The vector of payoff-relevant state variables is the following:

$$y_{imt} = \{s_{imt}, R_{imt}^*, Pres_{imt}, Post_Merger_Period_t\} \quad (17)$$

Each airline has the same vector of state variables which it takes into account when making decisions. Decision-making of each airline also depends on the strategies and actions of other airlines via R_{imt}^* . Recall that R_{imt}^* depends on competition from other incumbents currently in the market, which implies that this state variable depends on the previous period's entry/exit decisions of other airlines. Thus, our dynamic entry-exit model does implicitly take into account this strategic interaction among competitors.

5.2 Markov Perfect Equilibrium (MPE)

For notational convenience, we drop the market subscript. Let $\sigma \equiv \{\sigma_i(y_{it}, \varepsilon_{it})\}$ be the vector of strategies for each airline where $y_{it} = \{s_{it}, R_{it}^*, Pres_{it}, Post_Merger_Period_t\}$ is a vector of common knowledge state variables and ε_{it} is assumed to be i.i.d. In a Markov Perfect

Equilibrium each airline behaves according to its best response strategy, which maximizes its own value function given the state and strategies of other airlines.

Let $V_i^\sigma(y_t, \varepsilon_{it})$ be the value function for airline i . This value function is the unique solution to the following Bellman equation:

$$V_i^\sigma(y_t, \varepsilon_{it}) = \underset{a_{it} \in \{0,1\}}{\text{Max}} \left\{ \begin{array}{l} \Pi_{it}^\sigma(a_{it}, y_t) - \varepsilon_{it} * a_{it} \\ + \beta \int V_i^\sigma(y_{t+1}, \varepsilon_{i,t+1}) dG_i(\varepsilon_{i,t+1}) F_i^\sigma(y_{t+1} | y_t, a_{it}) \end{array} \right\} \quad (18)$$

$\Pi_{it}^\sigma(a_{it}, y_t)$ is the expected per-period profit function and $F_i^\sigma(y_{t+1} | y_t, a_{it})$ is the expected transition of state variables. We describe how state variables transition in the appendix. The profile of strategies in σ is a MPE if, for every airline i and every state (y_t, ε_{it}) , we have:

$$\sigma_i(y_t, \varepsilon_{it}) = \underset{a_{it} \in \{0,1\}}{\text{argmax}} \left\{ \begin{array}{l} \Pi_{it}^\sigma(a_{it}, y_t) - \varepsilon_{it} * a_{it} \\ + \beta \int V_i^\sigma(y_{t+1}, \varepsilon_{i,t+1}) dG_i(\varepsilon_{i,t+1}) F_i^\sigma(y_{t+1} | y_t, a_{it}) \end{array} \right\} \quad (19)$$

Recall that the per-period profit function is given as:

$$\Pi_{imt}(a_{it}, y_t) = R_{imt}^* - a_{imt}(FC_{imt} + (1 - s_{imt})EC_{imt}),$$

which implies that,

$$\Pi_{imt}(0, y_t) = R_{imt}^* \quad (20)$$

$$\Pi_{imt}(1, y_t) = R_{imt}^* - FC_{imt} - (1 - s_{imt})EC_{imt}. \quad (21)$$

Let

$$z_{imt}(0, y_t) = \{R_{imt}^*, 0, 0, 0, 0, 0, 0, 0, 0, 0\}, \quad (22)$$

$$\begin{aligned}
z_{imt}(1, y_t) = & \\
& \{R_{imt}^*, -1, -Pres_{imt}, -Post_Merger_Period_t, -A_Merging_Firm_{imt}, \\
& -Post_Merger_Period_t \times A_Merging_Firm_{imt}, -(1 - s_{imt}), -(1 - s_{imt})Pres_{imt}, \\
& -(1 - s_{imt})Post_Merger_Period_t, -(1 - s_{imt})A_Merging_Firm_{imt}, -(1 - \\
& s_{imt})Post_Merger_Period_t \times A_Merging_Firm_{imt}\}, \tag{23}
\end{aligned}$$

and

$$\theta = \{1, \theta_0^{FC}, \theta_1^{FC}, \theta_2^{FC}, \theta_3^{FC}, \theta_4^{FC}, \theta_0^{EC}, \theta_1^{EC}, \theta_2^{EC}, \theta_3^{EC}, \theta_4^{EC}\}'. \tag{24}$$

Therefore, we can rewrite the per-period profit function as:

$$\Pi_{imt}(0, y_t) = z_{imt}(0, y_t) \times \theta, \tag{25}$$

$$\Pi_{imt}(1, y_t) = z_{imt}(1, y_t) \times \theta. \tag{26}$$

An MPE can also be represented as a vector of conditional choice probabilities (CCPs) that solves the fixed point problem $\mathbf{P} = \Psi(\theta, \mathbf{P})$, where $\mathbf{P} = \{P_i(\mathbf{y}): \text{for every firm and state } (i, \mathbf{y})\}$. $\mathbf{P} = \Psi(\theta, \mathbf{P})$ is a vector of best response probability mapping:

$$\left\{ \Psi \left(\tilde{Z}_i^{\mathbf{P}}(\mathbf{y}) \frac{\theta}{\sigma_\varepsilon} + \tilde{e}_i^{\mathbf{P}}(\mathbf{y}) \right) : \text{for every firm and state } (i, \mathbf{y}) \right\} \tag{27}$$

where $\Psi(\cdot)$ is the CDF of the type 1 extreme value distribution, and

$$\tilde{Z}_i^{\mathbf{P}}(\mathbf{y}) = Z_i(1, y_t) - Z_i(0, y_t) + \beta[\mathbf{F}_{iy}^{\mathbf{P}}(1) - \mathbf{F}_{iy}^{\mathbf{P}}(0)] \times \mathbf{W}_{z,i}^{\mathbf{P}}, \tag{28}$$

$$\tilde{e}_i^{\mathbf{P}}(\mathbf{y}) = \beta[\mathbf{F}_{iy}^{\mathbf{P}}(1) - \mathbf{F}_{iy}^{\mathbf{P}}(0)] \times \mathbf{W}_{e,i}^{\mathbf{P}}, \tag{29}$$

where

$$\mathbf{W}_{z,i}^P = (\mathbf{I} - \beta * \overline{\mathbf{F}}_{ly}^P)^{-1} \times [\mathbf{P}_i(\mathbf{y}) * \mathbf{Z}_i(1, \mathbf{y}) + (1 - \mathbf{P}_i(\mathbf{y})) * \mathbf{Z}_i(0, \mathbf{y})], \quad (30)$$

$$\mathbf{W}_{e,i}^P = (\mathbf{I} - \beta * \overline{\mathbf{F}}_{ly}^P)^{-1} \times [\mathbf{P}_i(\mathbf{y}) * \mathbf{e}_i^P], \quad (31)$$

and

$$\overline{\mathbf{F}}_{ly}^P = [(\mathbf{P}_i(\mathbf{y}) \times \mathbf{1}'_M) * \mathbf{F}_{ly}^P(1) + ((1 - \mathbf{P}_i(\mathbf{y})) \times \mathbf{1}'_M) * \mathbf{F}_{ly}^P(0)]. \quad (32)$$

$\mathbf{W}_{z,i}^P$ and $\mathbf{W}_{e,i}^P$ are vectors of valuations that depend on CCPs and transition probabilities, but not on the dynamic parameters being estimated. Since ε_{it} is assumed to be distributed extreme value type 1, $\mathbf{e}_i^P(\mathbf{P}_i(\mathbf{y})) = \gamma - \ln(\mathbf{P}_i(\mathbf{y}))$, where $\gamma = 0.577215665$ is Euler's constant.

6. Demand and Marginal Cost Estimation

Our strategy for estimating the demand parameters (ϕ^p, ϕ^x, δ) is such that the observed market shares, \mathbf{S}_{jmt} , are equal to the market shares predicted by the model s_{jmt} . As shown in Berry (1994), in the case of the nested logit model, such an estimation strategy implies the following linear equation to be estimated:

$$\ln(\mathbf{S}_{jmt}) - \ln(\mathbf{S}_{0mt}) = x_{jmt}\phi^x + \phi^p p_{jmt} + \delta \ln(\mathbf{S}_{jmt/g}) + \eta_j + v_t + origin_m + dest_m + \xi_{jmt}, \quad (33)$$

where \mathbf{S}_{0mt} is the observed share of the outside good and $\mathbf{S}_{jmt/g}$ is the observed within group share of product j . Equation (33) can be estimated by Two Stage Least Squares (2SLS) given that the equation is linear, and p_{jmt} and $\ln(\mathbf{S}_{jmt/g})$ are endogenous.

We use the following linear specification for the marginal cost function:

$$\hat{c}_{jmt} = \tau_0 + \tau_1 W_{jmt} + \tau_2 T_t^{dn} + \tau_3 T_t^{dn} \times DN_{jmt} + \tau_4 T_t^{cu} + \tau_5 T_t^{cu} \times CU_{jmt} + \psi_j + \lambda_t + origin_m + dest_m + \varepsilon_{jmt}^{mc}, \quad (34)$$

where \hat{c}_{jmt} represents product-level marginal cost estimates that were recovered using equation (9). W_{jmt} is a vector of observed marginal cost-shifting variables and τ_1 is the associated vector of parameters to be estimated. Recall that T_t^{dn} is a zero-one time-period dummy variable that equals 1 during time periods after the DL/NW merger. DN_{jmt} is a zero-one airline-product dummy variable that equals 1 for all products that are associated with either Delta or Northwest. τ_2 is a parameter that measures, on average, how marginal cost changes over the pre-post DL/NW merger periods for products that are not associated with Delta or Northwest. However, τ_3 is a parameter that measures, on average, how marginal cost changes over the pre-post DL/NW merger periods for Delta and Northwest products. Therefore, τ_3 measures the possible marginal cost efficiencies associated with the DL/NW merger.

T_t^{cu} is a zero-one time-period dummy variable that equals 1 during time periods after the UA/CO merger. CU_{jmt} is a zero-one airline-product dummy variable that equals 1 for all products associated with either United or Continental. τ_4 is a parameter that measures, on average, how marginal cost changes over the pre-post UA/CO merger periods for products that are not associated with United or Continental. However, τ_5 is a parameter that measures, on average, how marginal cost changes over the pre-post UA/CO merger periods for United and Continental products. Therefore, τ_5 measures the possible marginal cost efficiencies associated with the UA/CO merger.

ψ_j is an airline-specific component of marginal cost captured by airline dummy variables. λ_t captures time-varying effects on marginal cost that are unobserved by us the researchers. These unobserved time-varying effects are measured using quarter and year dummy variables. $origin_m$ and $dest_m$ are sets of origin and destination city dummy variables respectively. Finally, ε_{jmt}^{mc} is an unobserved random component of marginal cost. Equation (34) is estimated via ordinary least squares (OLS).

6.1 Instruments

It is likely that in the demand equation, equation (33), the product price (p_{jmt}) and the within group share ($\mathbf{S}_{jmt/g}$) are correlated with unobserved product characteristics, ξ_{jmt} . For example, an airline may have a very effective advertising campaign to promote its brand. Even though this activity is unobservable to the researcher, it is observable to the consumers and to the airline and therefore may affect how that airline sets prices for its products. To estimate equation (33) consistently, we need a set of variables (instruments) that are uncorrelated with the demand residual but correlated with price and within group share. The instruments that we use are: (1) number of competitor products in the market; (2) number of competing products offered by other airlines with an equivalent number of intermediate stops; (3) itinerary distance; (4) the squared deviation of a product's itinerary distance from the average itinerary distance of competing products offered by other airlines; (5) number of other products offered by an airline in a market; and (6) mean number of intermediate stops across products offered by an airline in a market.

As discussed in Gayle (2007 and 2012), instruments (1)-(5) are motivated by supply theory, which predicts that a product's price and within group product share are affected by changes in its marginal cost and markup. The number and the closeness of competing products in the market influence the size of a product's markup, while a product's itinerary distance is likely to be correlated with its marginal cost. For example, increases in instruments (1) and (2) will likely put downward pressure on price because of the increase in choices offered by competitors. The intuition for instrument (6) is that a passenger may prefer a set of products offered by a particular airline over other airlines.

7. Estimation Results for Demand, Markup and Marginal Cost

7.1 Demand Results

Table 6 presents OLS and 2SLS estimates of the nested logit demand model. Recall that p_{jmt} and $\ln(\mathbf{S}_{jmt/g})$ are likely to be endogenous, which is not taken in account by OLS estimates. Notice that the coefficient estimate on price in the OLS regression has the incorrect sign. Although the OLS and 2SLS coefficient estimates on $\ln(\mathbf{S}_{jmt/g})$ lie between zero and one as required by utility maximization theory, they are very different in size. We perform Hausman tests, reported in the last row of Table 6, to assess the endogeneity of these variables. The results

of these endogeneity tests show that we can reject the hypothesis that p_j and $\ln(\mathbf{S}_{j/g})$ are exogenous. Therefore, instruments are needed. As a check on how well the instruments can explain variations in the endogenous variables, we regress each endogenous variable against the instruments using OLS. R^2 measures for the regressions of price against instruments and within group product share against instruments are 0.186 and 0.486 respectively, which suggest that the instruments can explain variations in the endogenous variables.

Based on the clear need to instrument for price and within group product shares, we now turn to the 2SLS estimation results for discussion. The coefficient on price now has the correct sign (negative) and its magnitude has increased. The magnitude of the coefficient on the within group product share becomes smaller and approaches zero rather than one. This suggests that although consumers do exhibit some loyalty to respective airlines, their loyalty is not as strong. Nonetheless, both coefficients are statistically significant at conventional levels.

Consistent with what we expect, the coefficient on the *Interstop* variable is negative, which indicates that consumer's utility decreases as the number of intermediate stop(s) increases. The *Inconvenience* variable is the ratio of itinerary distance to nonstop distance between the origin and destination city. The intuition is that two itineraries can have the same number of intermediate stop(s), but depending on differences across the two itineraries in where the intermediate stop(s) is(are) relative to the origin and destination cities, the two itineraries may yield different levels of travel convenience for the passenger (Gayle 2007). Therefore, this variable captures aspects of the itinerary inconvenience that the variable *Interstop* does not. As expected, the coefficient associated with the *Inconvenience* variable is negative and statistically significant, suggesting that, among itineraries with equivalent number of intermediate stop(s), passengers prefer itineraries with intermediate stop(s) that best minimize travel distances.

The positive coefficient on the *Origin presence* variable suggests that all else equal, passengers' utilities are higher when an airline offers nonstop service to more cities from the passengers' local airport. In other words, consumers are more likely to choose air travel products offered by the airline that serves the larger number of destinations via nonstop flight from the consumer's origin city's airport. This result can be interpreted as capturing a "hub-size" effect on air travel demand. Positive marginal utility associated with "hub-size" may indicate that consumers are possibly reaping the benefits from these airlines in the form of better

services such as convenient departure times, gate locations or benefits from participating in frequent flyer programs.

The coefficients on the dummy variables for different seasons suggest that air travel demand display seasonal variations. Specifically, air travel demand seems to be highest in Spring and Summer, which accords with our expectation.

Our demand model yields a mean own-price elasticity estimate of -1.48. Oum, Gillen and Noble (1986), and Brander and Zhang (1990) argue that a reasonable range for own price elasticity in the airline industry is from -1.2 to -2.0. Berry and Jia (2010) find own-price elasticity estimates ranging from -1.89 to -2.10 in their 2006 sample, while Peters (2006) study of the airline industry produces own-price elasticity estimates ranging from -3.2 to -3.6. Although our elasticity estimate is on the lower range, we believe that it is reasonable and accord with evidence in the existing literature.

Table 6				
Demand Estimation Results				
647,167 observations: 2005-Q1 to 2011-Q3				
	OLS		2SLS	
Variable	Estimates	Std. Error	Estimates	Std. Error
Price	0.0004***	(0.00003)	-0.0083***	(0.0001)
$\ln(S_{j/g})$	0.5044***	(0.0011)	0.1435***	(0.0023)
Interstop	-0.9315***	(0.0033)	-1.2046***	(0.0042)
Inconvenience	-1.0331***	(0.0062)	-1.1510***	(0.0071)
Origin presence	0.0147***	(0.0001)	0.0115***	(0.0001)
Spring	0.1202***	(0.0034)	0.1340***	(0.0038)
Summer	0.1111***	(0.0034)	0.1294***	(0.0039)
Fall	0.0903***	(0.0035)	0.0905***	(0.0041)
Constant	-8.2387***	(0.0279)	-6.6218***	(0.0338)
Operating carrier effects	YES		YES	
Origin airport effects	YES		YES	
Destination airport effects	YES		YES	
Year effects	YES		YES	
R^2	0.6404		0.5289	
Wu-Hausman:	24821.6***	F(2; 647,002)	Prob_Value = 0.0000	
Durbin-Wu-Hausman:	46117.3***	$\chi^2(2)$	Prob_Value = 0.0000	

*** Statistical significance at the 1% level.

7.2 Computed Variable Profits and Recovered Marginal Costs

Table 7 shows that the overall mean price and product markup are \$165.90 and \$121.03, respectively. The Lerner Index is the ratio of product markup to price. Overall, airlines are able to raise their price above marginal costs by a mean 79.22%. Mean product-level marginal cost is \$44.87. The mean number of miles flown on an itinerary in the sample is 1,544.25 miles (see summary statistics for “Market miles flown” variable in Table 3). Therefore, our model predicts a marginal cost per mile of 2.9 cents. Table 7 also reveals variations across airlines in the measured statistics. For example, Southwest Airlines and airlines in the “Other carriers” category have the lowest mean price and marginal cost. However, United Airlines and Continental Airlines have the highest mean price and marginal cost.

Table 8 shows the mean and median quarterly market-level variable profits by airline measured in constant year 1999 dollars.⁹ They are computed using equations (8) and (10) along with the demand estimates. It is useful at this point to put in context the magnitudes of quarterly market-level variable profit estimates reported in Table 8. Recall that the original data base, before any cleaning, is only a 10% sample of air travel tickets sold. This implies that the magnitudes of variable profit estimates are at most roughly 10% of actual variable profits.

Table 8 shows that variable profits vary across airlines even though product markups in Table 7 are about the same (\$121.03) for all airlines. Recall that market-level variable profit for an airline are computed by aggregating product-level variable profits, and product-level variable profits are computed by multiplying product markups by the corresponding number of passengers that purchase these products. Therefore, the primary source of the variation in variable profit seems to come from differences in the number of passengers that bought products by airline, as shown in Table 7. In other words, airlines may have similar markups but the number of passengers that purchase their products differs leading to variation in variable profits. Delta and Northwest have a lower mean number of passengers per product compare to United and Continental. Therefore the mean and median market-level variable profits for Delta and Northwest are also lower compare to United and Continental.

⁹ While the demand model is estimated using all years in the data set (2005Q1-2011Q3), due to significant computational burden, we find that the dynamic entry/exit model can only feasibly be estimated using, at most, four quarters of the data. Even with just four quarters of data, the computer code for the dynamic entry/exit model took more than two weeks of continuous running before convergence is achieved. However, the variable profit data in Table 7 use the entire dataset.

Table 7
Summary Statistics on Price,
Computed Product Markups, Lerner Indices,
Recovered Marginal Cost, and Number of Passengers per Product
by Airline
(Statistics in dollars (\$) are measured in year 1999 dollars)

Airlines	Price (\$)	Product Markup (\$)	Product Markup as a percent of price (Lerner Index) (%)	Recovered Marginal Cost (\$)	Number of Passengers per Product	Number of observations used (No. of products)
	Mean (Std. error)	Mean (Std. error)	Mean (Std. error)	Mean (Std. error)	Mean (Std. error)	
Delta Air Lines Inc.	169.91*** (0.1777)	121.03*** (0.00070)	78.02*** (0.0763)	48.89*** (0.1776)	167.29*** (1.7189)	94,761
Northwest Airlines Inc.	158.98*** (0.2655)	121.01*** (0.00074)	83.77*** (0.1330)	37.97*** (0.2654)	156.92*** (2.4441)	38,029
United Air Lines Inc.	183.94*** (0.2339)	121.04*** (0.00071)	72.51*** (0.0869)	62.90*** (0.2337)	206.98*** (2.2451)	69,386
Continental Air Lines Inc.	179.70*** (0.3077)	121.00*** (0.00087)	73.22*** (0.1168)	58.70*** (0.3075)	254.12*** (3.7659)	32,940
American Airlines Inc.	176.71*** (0.1822)	121.05*** (0.00079)	73.80*** (0.0674)	55.66*** (0.1821)	256.86*** (2.2735)	86,918
US Airways Inc.	174.06*** (0.1873)	121.02*** (0.00052)	74.98*** (0.0809)	53.04*** (0.1873)	175.33*** (1.7322)	69,514
Southwest Airlines Co.	156.07*** (0.0942)	121.07*** (0.00065)	81.91*** (0.0561)	35.00*** (0.0944)	237.00*** (1.9894)	137,946
Other carriers	149.10*** (0.1284)	121.00*** (0.00041)	87.72*** (0.0712)	28.11*** (0.1284)	226.38*** (1.5134)	117,673
Overall	165.90*** (0.0630)	121.03*** (0.00025)	79.22*** (0.0286)	44.87*** (0.0630)	213.85*** (0.7509)	647,167

*** Statistical significance at the 1% level.

Airlines	Quarterly Market-level Variable Profit		Number of observations used (No. of market-time period combinations)
	Mean (Std. error) (\$)	Median (\$)	
Delta Air Lines Inc.	92,284.75*** (1,074.60)	40,193.09	18,977
Northwest Airlines Inc.	92,169.51*** (1,596.40)	38,218.43	6,965
United Air Lines Inc.	108,327.50*** (1,261.46)	44,844.94	14,879
Continental Air Lines Inc.	116,246.50*** (1,760.54)	47,174.96	7,909
American Airlines Inc.	99,024.01*** (988.50)	40,661.21	25,647
US Airways Inc.	84,229.79*** (820.93)	39,317.42	16,018
Southwest Airlines Co.	126,588.4*** (1,072.71)	61,088.52	30,515
Other carriers	64,983.27*** (503.76)	39,828.15	20,529
Overall	99,054.69*** (395.86)	43,813.20	141,439

*** Statistical significance at the 1% level.

7.3 Product markup function estimation results

Table 9 shows estimation results for a regression in which a variable of product markups generated from the structural model is regressed on several determinants of markup, including the relevant dummy variables needed to investigate how product markup change with implementation of each respective merger. The variables of interest are $T_t^{dn} \times DN_{jmt}$ and $T_t^{cu} \times CU_{jmt}$. Their coefficients indicate whether product markups are any different over the relevant pre-post merger periods for each merger.

As expected, the positive coefficient estimate on the $T_t^{dn} \times DN_{jmt}$ variable suggests that the DL/NW merger is associated with higher markup for the products offered by the newly merged DL/NW airline. However, the economic magnitude of the coefficient is small. Markup

for products offered by DL/NW only increases by an average 0.02 cents following the merger, which corresponds to a 0.017% increase over these airlines' pre-merger mean markup. Similarly the coefficient estimate on $T_t^{cu} \times CU_{jmt}$ is positive and also small in magnitude, suggesting a markup increase of only 0.003 cents for UA/CO products.

Other control variables in the markup regression include: (i) size of an airline's presence at the origin airport, measured by the *Origin presence* variable; and (ii) the number of intermediate stops required by a flight itinerary, measured by the *Interstop* variable. As expected, *Origin presence* has a positive effect on product markup, which is consistent with the argument in the literature that airlines are able to charge a premium at their hub airport [Berry (1990); Berry, Carnall and Spiller (2006); Borenstein (1989)]. An increase in the number of intermediate stops in a product reduces markup. This result is also expected because passengers usually prefer nonstop flights to their destinations, as confirmed by our demand equation estimation results.

In summary, both mergers increase markup but the economic magnitude is negligible. Since product markup measures market power, these results suggest that the mergers, on average, did not reduce the level of competition in the industry.

Table 9 Estimation Results for Product Markup Regressed on Several of its Determinants 647,167 observations: 2005-Q1 to 2011-Q3		
Variable	Coefficient Estimate	Robust Standard Errors
T_t^{dn}	-0.0069***	0.0014
$T_t^{dn} \times DN_{jmt}$	0.0195***	0.0013
T_t^{cu}	0.0063***	0.0013
$T_t^{cu} \times CU_{jmt}$	0.0030*	0.0016
Origin presence	0.0023***	0.00002
Interstop	-0.0379***	0.00077
Constant	120.90 ***	0.0024
Operating carrier effects	YES	
Origin city effects	YES	
Destination city effects	YES	
Quarter and Year effects	YES	

* Statistically significant at the 10% level.

*** Statistically significant at the 1% level.

Model estimated using ordinary least squares.

7.4 Marginal cost function estimation results

Table 10 presents OLS estimates of the marginal cost equation. The coefficient on *Itinerary distance flown* (from origin to destination) has the expected positive sign and is statistically significant. All else equal, marginal cost increases by \$3.57 with each 100 miles increment in distance flown.

The sign pattern of the coefficients on the airport presence variables suggest that marginal cost initially increases in airport presence, then eventually declines with further increases in airport presence. The coefficients on the airport presence variables can be interpreted as capturing the effect of “hub-size” on marginal cost. In other words, coefficients on the “hub-size” variables indicate that airlines will not be able to achieve marginal cost efficiencies until they reach a certain scale of operation. Therefore, we believe these variables indirectly capture economies of traffic densities that airlines can enjoy by channeling a relatively large volume of passengers through these endpoint airports.

Relative to the DL/NW pre-merger time period, there is no evidence that marginal costs for non-DL/NW products change in the post-merger period. However, the DL/NW merger is associated with a decline of \$7.23 in the marginal cost of DL/NW products. These inferences are drawn from the coefficients on T_t^{dn} and $T_t^{dn} \times DN_{jmt}$ respectively. Therefore, the results suggest that there are marginal cost efficiencies associated with the DL/NW merger.

There is strong evidence that the UA/CO merger lowers marginal cost even more than the DL/NW merger. Marginal cost of non-UA/CO products seem to be higher comparing UA/CO pre-merger and post-merger time periods. However, the marginal cost of United/Continental products seems to decline substantially (approximately \$13.37=\$1.30-14.67) when comparing the pre-merger and post-merger periods.

In summary, there are marginal cost efficiencies associated with both mergers, but the magnitude of the marginal cost decrease associated with the UA/CO merger is greater than that associated with the DL/NW merger. These marginal cost efficiency gains closely reflect the reduced-form price effects of the mergers reported in Table 5.

Table 10		
Marginal Cost Estimation Results		
647,167 observations: 2005-Q1 to 2011-Q3		
Variable	Estimate	(S.E.)
Itinerary distance flown (miles)	0.03576***	0.00011
Origin presence	0.49842***	0.00856
(Origin presence) ²	-0.00028***	0.000075
Dest. presence	0.53176***	0.00867
(Dest. presence) ²	-0.00047***	0.000078
T_t^{dn}	-0.2103	0.3340
$T_t^{dn} \times DN_{jmt}$	-7.2332***	0.3131
T_t^{cu}	1.2942***	0.2975
$T_t^{cu} \times CU_{jmt}$	-14.6667***	0.5414
Constant	-7.7405***	1.2018
Operating carrier effects		YES
Origin city effects		YES
Destination city effects		YES
Quarter and Year effects		YES

*** Statistically significant at the 1% level.

8. Estimation of Dynamic Model

Consider the following pseudo log likelihood function:

$$Q(\theta, \mathbf{P}) = \sum_{m=1}^M \sum_{i=1}^N \sum_{t=1}^T \left\{ \begin{array}{l} a_{imt} \ln \Psi(\tilde{Z}_{imt}^{\mathbf{P}} \boldsymbol{\theta} + \tilde{e}_{imt}^{\mathbf{P}}) \\ + (1 - a_{imt}) \ln \Psi(-\tilde{Z}_{imt}^{\mathbf{P}} \boldsymbol{\theta} - \tilde{e}_{imt}^{\mathbf{P}}) \end{array} \right\}, \quad (35)$$

where $Q(\theta, \mathbf{P})$ is called the “pseudo” log likelihood function because players’ conditional choice probabilities (CCPs) in \mathbf{P} are arbitrary and do not represent the equilibrium probabilities associated with θ implied by the model. We begin by implementing a two-step pseudo maximum likelihood estimator (PML). The first step involves estimating the relevant state transition equations and obtaining nonparametric estimates of the choice probabilities, $\hat{\mathbf{P}}_0$. Estimating the state transition equations allow us to construct the state transition matrices, $\mathbf{F}_{iy}^{\mathbf{P}}(1)$ and $\mathbf{F}_{iy}^{\mathbf{P}}(0)$. Nonparametric estimates of choice probabilities allow us to construct consistent

estimates of $\tilde{z}_{imt}^{\hat{\mathbf{P}}_0}$ and $\tilde{e}_{imt}^{\hat{\mathbf{P}}_0}$. With $\mathbf{F}_{iy}^{\mathbf{P}}(1)$, $\mathbf{F}_{iy}^{\mathbf{P}}(0)$, $\tilde{z}_{imt}^{\hat{\mathbf{P}}_0}$ and $\tilde{e}_{imt}^{\hat{\mathbf{P}}_0}$ in hand, we can construct the pseudo log likelihood function, $Q(\theta, \hat{\mathbf{P}}_0)$.

In the second step, we estimate the vector of parameters by solving the following problem:

$$\hat{\theta}_{PML} = \arg \max_{\theta} Q(\theta, \hat{\mathbf{P}}_0), \quad (36)$$

where $\hat{\theta}_{PML}$ is the two-step pseudo maximum likelihood estimator (PML). The computation in the second step is simple as it only involves estimation of a standard discrete choice model. The main advantage of the two-step estimator is its computational simplicity because it does not require solving for an equilibrium in the dynamic game, which greatly reduces the computational burden. However, as discussed in Aguirregabiria and Mira (2007), the two-step PML estimator may be subjected to large finite sample bias. One reason for the bias is that the nonparametric probabilities, $\hat{\mathbf{P}}_0$, enter nonlinearly in the sample objective function that define the estimator, and the expected value of a nonlinear function of $\hat{\mathbf{P}}_0$ is not equal to that function evaluated at the expected value of $\hat{\mathbf{P}}_0$. Second, the nonparametric probability estimates themselves can have large finite sample bias, which in turn causes bias in the PML estimator. These potential problems with the PML estimator lead us to implement the Nested Pseudo Likelihood (NPL) estimator proposed by Aguirregabiria and Mira (2002, 2007).

Aguirregabiria and Mira (2002, 2007) consider a recursive K-step extension of the two-step PML estimator, which they refer to as the NPL estimator. Since we have the two-step estimator $\hat{\theta}_{PML}$ and the initial nonparametric estimates of CCPs, $\hat{\mathbf{P}}_0$, we can construct new CCP estimates, $\hat{\mathbf{P}}_1$, using the best response CCPs equation:

$$\hat{\mathbf{P}}_1 = \Psi(\hat{\mathbf{P}}_0, \hat{\theta}_{PML}). \quad (37)$$

We then solve the pseudo log likelihood function again using $\hat{\mathbf{P}}_1$ instead of $\hat{\mathbf{P}}_0$ to obtain new estimates for θ , that is, we solve: $\hat{\theta}_2 = \arg \max_{\theta} Q(\theta, \hat{\mathbf{P}}_1)$. We again construct new CCP estimates, $\hat{\mathbf{P}}_2$, using: $\hat{\mathbf{P}}_2 = \Psi(\hat{\mathbf{P}}_1, \hat{\theta}_2)$. This process is repeated K times:

$$\hat{\theta}_K = \arg \max_{\theta} Q(\theta, \hat{\mathbf{P}}_{K-1}) \quad (38)$$

and

$$\hat{\mathbf{P}}_K = \Psi(\hat{\mathbf{P}}_{K-1}, \hat{\theta}_K), \quad (39)$$

where on the K^{th} iteration the choice probability vector $\hat{\mathbf{P}}_K$ is sufficiently close to $\hat{\mathbf{P}}_{K-1}$ based on a tolerance level that we chose. The result is an NPL fixed point, which can be define as a pair (θ, \mathbf{P}) where θ maximizes the pseudo likelihood function, and \mathbf{P} is an equilibrium probability vector associated with θ . Aguirregabiria and Mira (2002, 2007) argue that the NPL algorithm significantly reduces the bias of the two-step PML estimator.

8.1 Fixed and Entry Cost Estimation Results

Tables 11 and 12 present our recurrent fixed and sunk market entry cost estimation results for the two mergers. We begin by discussing recurrent fixed cost results for both mergers and then turn to discussing sunk market entry cost results. First, the parameters that measure mean fixed cost as well as coefficients on the size of an airline's airport presence—measured by the mean number of destinations that an airline connects from the market's endpoint airports using non-stop flight—are unreasonably small and not precisely estimated. We expected these coefficients to be positive, reflecting that mean fixed cost is positive and increasing in the size of an airline's operations at the market endpoint airports. The reason for this expected result is that, the larger the size of an airline's operations at an airport, the more gates and ground crew the airline will need for operations, which imply higher fixed expenses.

Table 11 Recurrent Fixed and Sunk Market Entry Cost Functions Parameter Estimates for the Sample used to Evaluate the United/Continental Merger Pre-merger period - 2009:Q1-Q2 Post-merger period - 2011:Q1-Q2			
	Theta (in \$10,000)	Standard Error	T-stat
Fixed Cost Function:			
Mean Fixed Cost	7.34e-12	0.006909	1.06e-9
$Presence_{imt}$	5.21e-13	0.000171	3.04e-09
CU_{imt}	-0.647919***	0.058127	-11.1465
T_t^{cu}	2.17e-11	0.011876	1.83e-09
$T_t^{cu} \times CU_{imt}$	-1.846194***	0.165353	-11.1652
Entry Cost Function:			
Mean Entry Cost	3.112897***	0.036938	84.2732
$Presence_{imt}$	-0.011294***	0.000424	-26.6634
CU_{imt}	0.999406***	0.073622	13.5749
T_t^{cu}	-0.276177***	0.053162	-5.1950
$T_t^{cu} \times CU_{imt}$	3.056917***	0.209776	14.5723

*** indicates statistical significance at the 1% level.

Table 12 Recurrent Fixed and Sunk Market Entry Cost Functions Parameter Estimates for the Sample used to Evaluate the Delta/Northwest Merger Pre-merger period - 2007:Q1-Q2 Post-merger period - 2011:Q1-Q2			
	Theta (in \$10,000)	Standard Error	T-stat
Fixed Cost Function:			
Mean Fixed Cost	8.53e-05	0.031992	0.0027
$Presence_{imt}$	-5.87e-07	0.000279	-0.0021
DN_{imt}	-0.547928***	0.054562	-10.0423
T_t^{dn}	-6.76e-07	0.032995	-2.05e-05
$T_t^{dn} \times DN_{imt}$	-2.757493***	0.205332	-13.4294
Entry Cost Function:			
Mean Entry Cost	3.099294***	0.044011	70.4211
$Presence_{imt}$	-0.011923***	0.000415	-28.7284
DN_{imt}	0.580087***	0.068123	8.5153
T_t^{dn}	0.214136***	0.054840	3.9405
$T_t^{dn} \times DN_{imt}$	2.734495***	0.223871	12.2146

*** indicates statistical significance at the 1% level.

The fixed cost function coefficient estimates on dummy variable CU_{imt} in Table 11 and dummy variable DN_{imt} in Table 12 are both negative and statistically significant at conventional levels of statistical significance. The negative coefficient on CU_{imt} suggests that over the pre- and post-merger sample periods used for evaluating the UA/CO merger, United and Continental Airlines have lower mean fixed cost relative to the mean fixed cost across other airlines. The coefficient estimate suggests that, for a typical origin-destination market during the relevant sample period, the mean quarterly fixed cost of Continental and United Airlines is approximately \$6,479.19 lower than the mean quarterly fixed cost across other airlines. Similarly, the negative coefficient on DN_{imt} suggests that over the pre- and post-merger sample periods used for evaluating the DL/NW merger, Delta and Northwest Airlines have lower mean quarterly fixed cost relative to the mean quarterly fixed cost across other airlines. The coefficient estimate suggests that, for a typical origin-destination market during the relevant sample period, the mean quarterly fixed cost of Delta and Northwest Airlines is approximately \$5,479.28 lower than the mean quarterly fixed cost across other airlines.

The fixed cost function coefficient on variable T_t^{cu} in Table 10 and variable T_t^{dn} in Table 12 measure the extent to which non-merging airlines' fixed cost change between the respective pre- and post-merger periods under consideration. The coefficients on T_t^{cu} and T_t^{dn} are not statistically different from zero in both cases, suggesting that non-merging airlines' fixed cost did not change between the respective pre- and post-merger periods under consideration.

The fixed cost function coefficients on the interaction variables $T_t^{cu} \times CU_{imt}$ and $T_t^{dn} \times DN_{imt}$ in Tables 11 and 12 respectively, measure if the merging airlines cost change is different relative to other airlines between the respective pre- and post-merger periods. Therefore, these coefficients capture possible merger efficiencies with respect to fixed costs. The coefficients on both interaction terms are negative and statistically significant, suggesting that both airline mergers have fixed cost savings associated with it. The coefficient estimates suggest that the UA/CO and DL/NW mergers reduce these airlines quarterly fixed cost by an average \$18,461.94 and \$27,574.93 respectively in the typical origin-destination market served by these carriers. Therefore, the fixed cost efficiency gains from the DL/NW merger are greater in magnitude compare to the UA/CO merger.

We now turn to discussing the results on market entry costs. All the variables that enter the entry cost function are the same as the variables in the fixed cost function. The coefficient

estimates in the entry cost functions in Tables 11 and 12 are all statistically significant at the one percent level. The one-time mean cost to enter a market is approximately \$31,000 on average across all airlines in both samples. Based on the static model estimates previously discussed, the median quarterly variable profit an airline earns in an origin-destination market is approximately \$43,800. Therefore, our models suggest that mean entry cost takes up more than half (70.78%) the size of median variable profit.

The entry cost function coefficient on the size of market endpoint airport presence across Tables 11 and 12 are both negative as expected. In other words, greater endpoint airport presence seems to lower the airlines' entry cost to begin actually serving the market. This result is consistent with much of the airline literature that discusses the determinants of market entry [for example see Berry (1992) and Goolsbee and Syverson (2008)].

The entry cost coefficient estimates on dummy variable CU_{imt} in Table 11 and dummy variable DN_{imt} in Table 12 are both positive. The positive coefficient on CU_{imt} suggests that over the pre- and post-merger sample periods used for evaluating the UA/CO merger, United and Continental Airlines have higher mean entry cost relative to the mean entry cost across other airlines. The coefficient estimate suggests that, for a typical origin-destination market during the relevant sample period, the mean entry cost of Continental and United Airlines is approximately \$9,994.06 higher than the mean entry cost across other airlines. Similarly, the positive coefficient on DN_{imt} suggests that over the pre- and post-merger sample periods used for evaluating the DL/NW merger, Delta and Northwest Airlines have higher mean entry cost relative to the mean entry cost across other airlines. The coefficient estimate suggests that, for a typical origin-destination market during the relevant sample period, the mean entry cost of Delta and Northwest Airlines is approximately \$5,800.87 higher than the mean entry cost across other airlines.

The entry cost function coefficient on variable T_t^{cu} in Table 11 and variable T_t^{dn} in Table 12 measure the extent to which non-merging airlines' market entry cost change between the respective pre- and post-merger periods under consideration. The negative coefficient on T_t^{cu} suggests that non-merging airlines' market entry cost fell between the pre- and post-merger sample periods used to evaluate the UA/CO merger. On the contrary, the positive coefficient on T_t^{dn} suggests that non-merging airlines' market entry cost increase between the pre- and post-merger sample periods used to evaluate the DL/NW merger. All else equal, non-merging

airlines' market entry costs increase about \$2,141 after DL and NW merged, however non-merging airlines' market entry cost fall about \$2,762 after UA and CO merged.

Although we have found evidence of fixed cost savings, we are also interested in knowing whether those mergers lower the merging firms' market entry costs. Interestingly, the entry cost function coefficients on the interaction variables $T_t^{cu} \times CU_{imt}$ and $T_t^{dn} \times DN_{imt}$ in Tables 11 and 12 respectively, suggest that the merging airlines' market entry costs rise as a result of the mergers. The DL/NW merger increases DL and NW market entry costs by approximately \$27,345, while the UA/CO merger is associated with a larger increase in UA and CO market entry costs, approximately \$30,569.

In summary, we find evidence that fixed cost efficiency gains are associated with both mergers. The DL/NW merger experiences a greater magnitude of reduction in fixed costs compare to the merger between United and Continental. Market entry costs for the merging airlines however increased as a result of the mergers. The UA/CO merger is associated with a larger increase in the merging airlines' market entry cost as compared to the increase in the merging airlines' entry cost associated with the DW/NW merger. In the case of non-merging airlines, we find that their fixed costs are unchanged throughout the entire evaluation periods for both mergers. However, non-merging airlines' market entry cost increase after the DL/NW merger, but decrease after the UA/CO merger.

9. Discussion

Since merging airlines are likely to be more efficient with the use of their aircraft fleets, and handling of their airport operations, it is not surprising to find evidence of fixed costs savings, as we do, associated with the mergers. However, we thought that the merging airlines' market entry cost would also decline, rather than increase as the estimates suggest. So the increase in the market entry cost of the merging airlines' is a bit surprising. One possible explanation for this may be related to the fixed cost efficiency gains that we found. The argument is as follows. With lower recurrent fixed cost, the merged airlines can now profitably operate in markets that are more costly to enter compared to the type of markets that they typically enter prior to the merger. In other words, without the merger-specific fixed-cost efficiencies, entry into these markets may not have been possible otherwise. In this case, the merging firms' new market entry choice behavior in the post-merger period reveals the higher

entry cost markets that the merged firm is now entering. This argument is consistent with data in Table 4, which indicate that in the post-merger period, UA/CO has entered into 65 new markets—markets where neither operated before merging. Likewise, the table shows that DL/NW has entered into as many as 123 new markets—markets where neither operated before they merged. Perhaps these markets are the high cost-to-enter markets where if it were not for the merger, they would not have entered.

An interesting result that merits further discussion is that non-merging airlines' market entry cost increases following the DL/NW merger, but declines following the UA/CO. In other words, rivals to the newly merged DL/NW airlines find it more difficult in the post-merger period to enter markets and possibly compete with the newly merged airline. On the other hand, rivals to the newly merged UA/CO airline find it easier in the post-merger period to enter markets and possibly compete with the newly merged airline. An implication of this result is that initial increases in market concentration due to the DL/NW merger might persist longer compared to initial increases in market concentration due to the UA/CO merger.

10. Concluding Remarks

Researchers have long been interested in measuring possible cost efficiency gains associated with mergers. We are unaware of papers in the literature that explicitly separate merger cost effects into these three main categories of cost: (1) marginal cost; (2) recurrent fixed cost; and (3) sunk entry cost. Therefore, the main objective and contribution of our paper is to empirically estimate marginal, recurrent fixed and sunk entry cost effects associated with two recent airline mergers – Delta/Northwest and United/Continental mergers – using a methodology that does not require the researcher to have cost data.

Our empirical results reveal that for the merging airlines: (1) Marginal cost efficiency gains are associated with both DL/NW and UA/CO mergers; (2) Fixed cost efficiency gains are associated with both DL/NW and UA/CO mergers; (3) Both mergers however are associated with increased market entry costs; and (4) The magnitudes of these effects differ across the two mergers. The magnitude of marginal cost savings associated with the DL/NW merger is smaller than that of the UA/CO merger. In contrast, the magnitude of fixed cost savings associated with the DL/NW merger is greater than that of the UA/CO merger. The magnitude of the increase in market entry costs associated with the UA/CO merger is greater than that of the DL/NW merger.

In the case of non-merging airlines, we find that their fixed costs are unchanged throughout the entire evaluation periods for both mergers. However, non-merging airlines' market entry costs increase after the DL/NW merger, but decrease after the UA/CO merger. An implication of this last result is that initial increases in market concentration due to the DL/NW merger might persist longer compared to initial increases in market concentration due to the UA/CO merger.

We also estimate a regression in which a variable of product markups generated from the structural model is regressed on several determinants of markup. Results from this product markup regression reveal that both mergers led to only small increases in markups, suggesting that market power effects of these mergers were negligible.

Results from our structural model are consistent with results from a reduced-form price regression we estimate. The reduced-form price regression reveals evidence that each merger is associated with price decreases, which suggests that marginal cost efficiencies outweigh market power increases. However, the reduced-form price regression is not able to separately measure the magnitudes of marginal cost efficiencies and markup increases associated with the mergers, hence the need for our structural model analysis.

Appendix

The vector of state variables: $y_t = \{s_{it}, R_{it}^*, Pres_{it}, Post_Merger_Period_t\}$. The following are the state transition equations:

$$s_{i,t+1} = a_{it}, \tag{A1}$$

$$R_{i,t+1}^* = a_{it}(\alpha_0^R + \alpha_1^R R_{it}^* + \xi_{it}^R), \tag{A2}$$

$$Pres_{i,t+1} = \alpha_0^{Pres} + \alpha_1^{Pres} Pres_{it} + \xi_{it}^{Pres}. \tag{A3}$$

Variable profit and airline presence follow an exogenous Markov process with probability distribution $F_{\xi_{it}^R}$ and $F_{\xi_{it}^{Pres}}$, respectively, that we assume to be normally distributed.

We assume that the probability that next period ($t+1$) is a post-merger period for the relevant merger being studied is exogenously determined by information firms have about the

current state. Furthermore, we assume that the parametric probability distribution governing this process is normal, which implies the following probit model:

$$Pr(\text{Post_Merger_Period}_{t+1} = 1|y_t) = \Phi(\alpha_0^T + \alpha_1^T s_{it} + \alpha_2^T R_{it}^* + \alpha_3^T \text{Pres}_{it}). \quad (\text{A4})$$

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