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.

K*eywords:* Merger Cost Efficiencies; Airline Mergers; Dynamic Entry/Exit Model

JEL Classification codes: L40, L93

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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 [also see Weinberg (2008); Ashenfelter and Hosken (2008); Ashenfelter, Hosken and Weinberg (2009); Ashenfelter, Hosken, Vita and Weinberg (2011); Kwoka (2015); Kwoka (2013); Kwoka and Gu (2013); and Hunter, Leonard and Olley (2008)].[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)].[3]

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,

[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.

[3] See Kwoka and Pollitt (2010) for an analysis of measuring merger efficiencies in US electric power sector.

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 have individually entered without the merger [Benkard, Bodoh-Creed, and Lazarev (2010)].[4] 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 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.

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[4] 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.

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. Again applying the difference-in-differences methodology used for computing relative fare changes, the authors compute relative changes in industry concentration (relative changes in Herfindahl-Hirschman Index (HHI)). The authors infer that 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 Bertand-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. Weinberg and Hosken (2013) performed an analysis similar to Peters (2006), but Weinberg and Hosken performed their analysis on the motor oil and syrup industries rather than airlines, yet also find discrepancies between observed pre- post-merger price changes and price changes predicted by a supply-side model that assumes marginal cost is unaffected by the merger. However, Weinberg and Hosken argue that many of the discrepancies are unlikely to be solely driven by merger cost effects.

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 first estimate a discrete choice model of air travel demand. For the short-run supply aspect of the model, we assume that multiproduct airlines simultaneously set prices for their differentiated air travel products according to a Nash equilibrium price-setting game. The Nash price-setting game 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 market entry cost. In the dynamic entry/exit game, each airline chooses markets in which to be active 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 is not currently serving the market but plans to do so next period. The dynamic entry/exit game allows us to estimate fixed and entry costs by exploiting estimates of variable profits previously computed from the static Nash price-setting game along with 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 regressions in which a variable of product markups generated from the structural model is regressed on several determinants of markup. Results from product markup regressions reveal that only the DL/NW merger had a statistically significant increase on markup, but the economic magnitude of the increase is negligible and is only evident in markets where the merging firms' services overlapped prior to merging. As such, the evidence suggests that short-run market power effects of these mergers were negligible.

Results from our structural model are consistent with results from reduced-form price regressions we estimate. The reduced-form price regressions reveal evidence that each merger is associated with price decreases, which suggests the marginal cost efficiencies outweigh market power increases. However, the reduced-form price regressions are 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 parts of the model, respectively. Section 6 describes the estimation procedure of the static part of the model. A brief discussion of those estimation results follows in section 7. Section 8 describes the estimation method for the dynamic part of the 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. At the time, Delta and Northwest 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:[5]

"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 in excess of $1 billion a year will be achieved.[6] 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.

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[5] 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>

[6] 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>

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.[7] 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.

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.[8] 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. The data are quarterly and constitute a 10 percent sample of airline tickets from reporting carriers. Each observation is a flight itinerary that

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[7] 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

[8] 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>

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 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.[9] 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

[9] Population estimates of each year were used even though only year 2009 estimates are reported.

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 $\boldsymbol{S}_j$) are constructed by dividing quantity of product j purchased (subsequently denoted by q_j) by the market size (subsequently denoted by *POP*). As in Berry, Carnall and Spiller (2006) and Berry and Jia (2010), we use the geometric mean of a market's origin city population and destination city population as a measure of the market size.[10]

[10] Since we find that many products have extremely small product shares based on the definition of market size used, we scaled up all product shares in the data set by a common factor. The common factor used is the largest integer such that the outside good share ($\boldsymbol{S}_0 = 1 - \sum_{j=1}^{J} \boldsymbol{S}_j$) in each market remains positive. In our data set this common factor is 35. It turns out that estimation results are qualitatively similar with or without using this scaling factor.

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 travel 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. In essence, *Inconvenience* is a flying-distance-based measure of itinerary routing quality, where larger values taken by the *Inconvenience* variable implies that the itinerary has poorer routing quality [see Chen and Gayle (2015)]. Note that products within a given origin-destination market that have equivalent number of intermediate stops may have differing routing quality due to location differences of the intermediate stops across the products.

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.

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.

Table 1
Cities, Airports and Population

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			

Table 2
List of Airlines in Sample

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)

Table 3 **Descriptive Statistics** Time period span of data: 2005:Q1 to 2011:Q3				
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 ($\boldsymbol{S}_j$)	0.0090	0.0261	5.39e-5	0.9785
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.

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.[11] 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 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

[11] 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).

3.1 Preliminary Aggregated Analysis of Merger Price Effects

To help motivate the need for our subsequent structural model analysis, we start by examining how each merger affects price using simple descriptive summary data analysis. Figure 1 and Figure 2 show time series plots of mean prices across various markets for carriers. The figures plot mean prices across products offered by either Delta or Northwest separate from mean prices across products offered by other carriers. The mean prices across products offered by other carriers in various categories of markets considered are intended to serve as controls for comparing time path movements in the merging firms' prices. The figures show two separate control comparison price series: *(i)* prices for other carriers in the DL/NW markets being analyzed; and *(ii)* prices for other carriers in markets that neither DL nor NW offer service. The vertical line in each figure represents occurrence of the DL/NW merger event.

Figure 1 focuses on analyzing time path movements of DL/NW prices in markets where these merging firms' air travel services overlapped prior to their merger. The figure shows that prior to the DL/NW merger, DL/NW mean price across their overlap markets is consistently lower than the mean price of other carriers in the same markets, but higher than the mean prices of other carriers in markets that neither DL nor NW offer service. However, after an initial drop in mean price of all carriers immediately following occurrence of the DL/NW merger event, the mean price of the newly merged DL/NW carrier seems to increase at a faster rate compared to the mean prices of other carriers - eventually climbing to a higher level than the mean price of other carriers in the same markets, and widening the gap between its mean price and the mean price of other carriers in markets that DL/NW does not offer service. It is reasonable to infer that the merger is responsible for the apparent relatively faster growth of DL/NW prices during the post-merger period.

Figure 2 focuses on analyzing time path movements of DL/NW prices in markets where these merging firms' air travel services did not overlap prior to their merger, i.e., prior to merging either DL or NW, not both, provide air travel service in each of these markets. The figure shows that DL/NW mean price across their non-overlap markets is consistently higher than the mean price of other carriers in the same markets, as well as higher than the mean price of other carriers in markets that neither DL nor NW offer service. While all carriers experienced a drop in mean price immediately following the DL/NW merger, the fall in DL/NW mean price seems relatively more substantial, which initially narrows the gap between DL/NW mean price and the mean price of other carriers. However, the rise in mean prices during the post-merger period shows DL/NW mean price rising relatively faster than other carriers' mean prices. The relatively sharper movements in DL/NW mean price during the post-merger period may be attributed to the merger.

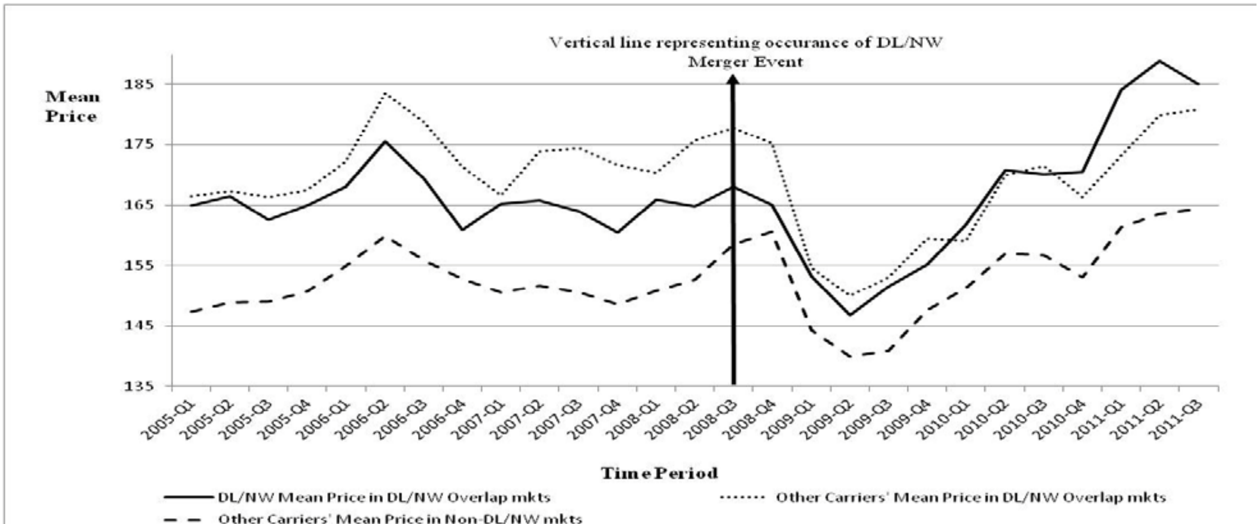

Figure 1: Time series plots of mean prices for carriers across various markets, where focus is on markets in which DL and NW services overlapped prior to their merger.

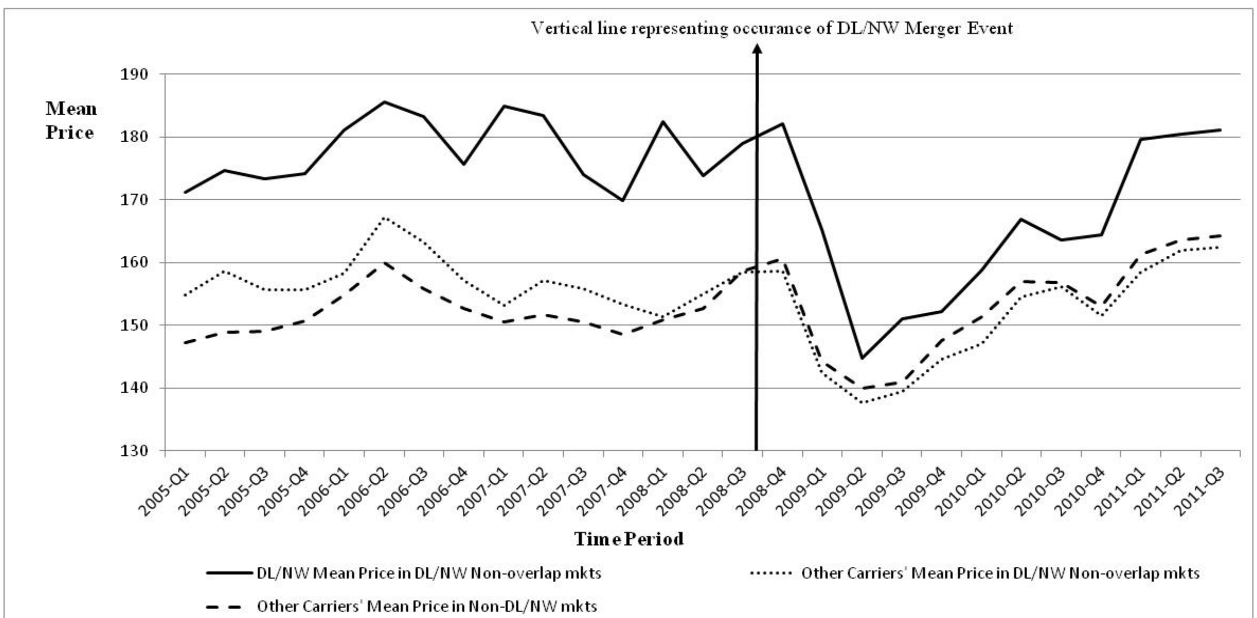

Figure 2: Time series plots of mean prices for carriers across various markets, where the focus is markets in which DL and NW services did not overlap prior to their merger.

We now use simple regression analysis to better evaluate the statistical significance of the merger impact on the time series patterns in prices observed in Figure 1 and Figure 2 respectively. Regression results are reported in Table 5. The dependent variable in each regression is mean price, which are the data observed in Figure 1 and Figure 2. DN_t is a zero-one airline dummy variable that equals 1 for mean price of Delta and Northwest at time period *t*. T_t^{dn} is a zero-one time period dummy variables that takes the value 1 only in the post-merger period for the DL/NW merger. The coefficient on the interaction variable, $T_t^{dn} \times DN_t$ measures how DL/NW mean price change relative to the mean price of non-merging airlines over the respective pre and post-merger periods, while the coefficient on T_t^{dn} measures how non-merging airlines' mean price change over the respective pre-post merger periods. *Trend* is a time trend variable used to control for time trends in the mean price series that are not associated with the merger event. Since mean prices seem to be lower for all carriers in the second quarter of 2009, as revealed in Figure 1 and Figure 2, we control for this drop in mean price using a zero-one time period dummy variable, $D_{2009-Q2}$, that equals 1 for the second quarter of 2009.

The first two columns in Table 5 focus on evaluating merger price effects in markets where DL and NW services overlapped prior to their merger. The regression in column 1 uses prices of other carriers in DL/NW overlapping markets as control comparison prices, while the regression in column 2 uses prices of other carriers in markets that neither DL nor NW offer service as control comparisons. The negative coefficient estimate on dummy variable DN_t in column 1 suggests that across the entire sample period, on average, DL/NW mean price across markets in which their services overlapped prior to merging is lower than the mean price of other carriers in these markets. Even with the significant negative drop in mean prices during the second quarter of 2009, as captured by the negative coefficient estimate on dummy variable $D_{2009-Q2}$, the positive coefficient estimate on the *Trend* variable suggests that across the entire sample period, on average, mean prices in the relevant markets have an upward trend. In the case where prices of other carriers in DL/NW overlapping markets are the control comparisons (column 1), the positive coefficient estimate on $T_t^{dn} \times DN_t$ and negative, but larger in absolute terms, coefficient estimate on T_t^{dn} suggest that, on average, mean price across all carriers in these markets declined in the post-merger period relative to the pre-merger period, but the mean price of DL/NW products experienced a relatively smaller decline. The relatively smaller decline in mean price of DL/NW products may be attributed to the impact of the merger. However, when prices of other carriers in markets that neither DL nor NW offer service are used as control comparisons (column 2), the coefficient estimates suggest that: *(i)* across the entire sample period, on average, DL/NW mean price is higher than these alternate control comparison mean prices; and *(ii)* mean price across all carriers declined in the post-merger period relative to the pre-merger period, and there is no statistically significant difference in DL/NW post-merger mean price decline compared to the post-merger mean price decline in prices of other carriers in markets that neither DL nor NW offer service.

Table 5
Estimation Results for Mean Price Time-series Regressions Focused on Evaluating the DL/NW Merger
54 observations: 2005-Q1 to 2011-Q3

	Dependent Variable: Mean Price Per Time Period for Carriers Across Various Markets			
	Markets in which DL and NW services overlapped prior to merger		Markets in which either DL or NW serve prior to merger	
	Control Group 1[a]	Control Group 2[b]	Control Group 1	Control Group 2
	Column 1	**Column 2**	**Column 3**	**Column 4**
Variable	Coefficient Estimate (Robust Standard Error)	Coefficient Estimate (Robust Standard Error)	Coefficient Estimate (Robust Standard Error)	Coefficient Estimate (Robust Standard Error)
DN_t	**-6.48***** (2.01)	**13.62***** (1.78)	**20.76***** (1.89)	**25.60***** (1.76)
T_t^{dn}	**-16.96***** (4.79)	**-7.69*** (4.34)	**-9.76**** (4.53)	**-4.93** (4.41)
$T_t^{dn} \times DN_t$	**7.28*** (4.22)	**-0.12** (3.98)	**-6.14** (4.16)	**-13.14***** (4.03)
Trend	**0.90***** (0.25)	**0.76***** (0.23)	**0.40** (0.25)	**0.56**** (0.24)
$D_{2009-Q2}$	**-16.33***** (2.72)	**-15.47***** (3.26)	**-17.42***** (3.73)	**-16.78***** (3.75)
Constant	**165.08***** (2.43)	**146.14***** (2.12)	**153.81***** (2.30)	**147.71***** (2.14)
R-Squared	0.41	0.61	0.72	0.76

Notes: [a] Control Group 1 comprises mean prices of other carriers within relevant markets served by the firms that merge. [b] Control Group 2 comprises mean prices of other carriers within markets not served by the firms that merge. *** indicates statistical significance at the 1% level, ** indicates statistical significance at the 5% level, while * indicates statistical significance at the 10% level.

Column 3 and column 4 in Table 5 focus on evaluating merger price effects in markets where DL and NW services do not overlap prior to their merger. The regression in column 3 uses prices of other carriers in DL/NW non-overlap markets as control comparison prices, while the regression in column 4 uses prices of other carriers in markets that neither DL nor NW offer service as control comparisons. The positive coefficient estimates on dummy variable DN_t in columns 3 and 4 suggest that across the entire sample period, on average, DL/NW mean price across markets in which their services do not overlap prior to merging is higher than the mean price of other carriers in these markets, as well as higher than the mean price of carriers in markets that neither DL nor NW offer service. After controlling for the significant negative drop in mean prices during the second quarter of 2009, as captured by the negative coefficient estimate on dummy variable $D_{2009-Q2}$, there seems not to be a statistically significant trend in mean price across DL/NW non-overlap markets as suggested by the statistically insignificant coefficient estimate on the *Trend* variable in column 3. The positive and statistically significant coefficient estimate on the *Trend* variable in column 4 is therefore likely driven by prices of other carriers in markets that neither DL nor NW offer service. In the case where prices of other carriers in DL/NW non-overlap markets are the control comparisons (column 3), the negative and statistically significant coefficient estimate on T_t^{dn}, and statistically insignificant coefficient estimate on $T_t^{dn} \times DN_t$ suggest that, on average, mean price across all carriers in these markets declined in the post-merger period relative to the pre-merger period, and there is no relative difference in the decline of DL/NW mean price. However, when prices of other carriers in markets that neither DL nor NW offer service are used as control comparisons (column 4), the coefficient estimates on T_t^{dn} and $T_t^{dn} \times DN_t$ suggest that there is no statistically significant change in mean price of the control comparisons, but DL/NW mean price across their non-overlap markets experienced a statistically significant decline in the post-merger period relative to the pre-merger period. We may attribute this relative decline in DL/NW mean price across their non-overlap markets to the impact of the merger.

In summary, the simple aggregated descriptive analysis of price effects of the DL/NW merger suggests that, by using prices of other carriers as the control comparison, the merger is associated with either a relatively smaller decline or no impact on DL/NW prices in markets where their services overlap prior to merging, but a relatively larger decline or no price impact in their non-overlap markets. The evidence of price declines suggests that the merger is likely associated with cost efficiency gains, but it is difficult to quantify the magnitude of cost efficiencies without controlling for potential market power effects embodied in the price effects.

Price effects are the net results of the counteracting impacts of market power increases and cost efficiency gains.

Analogous to Figure 1 and Figure 2, Figure 3 and Figure 4 show time series plots of mean prices across products offered by either Continental or United - the carriers that merge - separate from mean price across products offered by other carriers. Figure 3 and Figure 4 show two separate control comparison prices series: *(i)* prices for other carriers in the CO/UA markets being analyzed; and *(ii)* prices for other carriers in markets that neither CO nor UA offer service. The vertical line in Figure 3 and Figure 4 represents occurrence of the CO/UA merger event.

Figure 3 focuses on analyzing time path movements of CO/UA prices in markets where these merging carriers' air travel services overlapped prior to their merger. The figure shows that CO/UA mean price across their overlap markets is consistently higher than the mean price of other carriers in the same markets, as well as higher than the mean price of other carriers in markets that neither CO nor UA offer service. The most substantial drop in mean prices occurred in the second quarter of 2009, but these price series show a relatively uniform upward trend across all carriers subsequent to the second quarter of 2009. The uniformity in movements of the mean price series subsequent to the second quarter of 2009 suggests that occurrence of the CO/UA merger event in the third quarter of 2010 had minimal price impact.

Figure 4 focuses on analyzing time path movements of CO/UA prices in markets where these merging firms' air travel services did not overlap prior to their merger, i.e., prior to merging either CO or UA, not both, provide air travel service in each of these markets. The figure shows that the mean prices for all groups of carriers had a downward trend from the beginning of the sample period to the second quarter of 2009, but during this period the mean price of CO/UA seems to have a faster rate of decline relative to other carriers. Subsequent to the second quarter of 2009 we can observe an upward trend in the mean price series of all carriers, with little distinction in the relative growth rate across these price series before versus after occurrence of the CO/UA merger event. As such, the time path movements of the mean price series in Figure 4 do not suggest a discernible price impact of the CO/UA merger event.

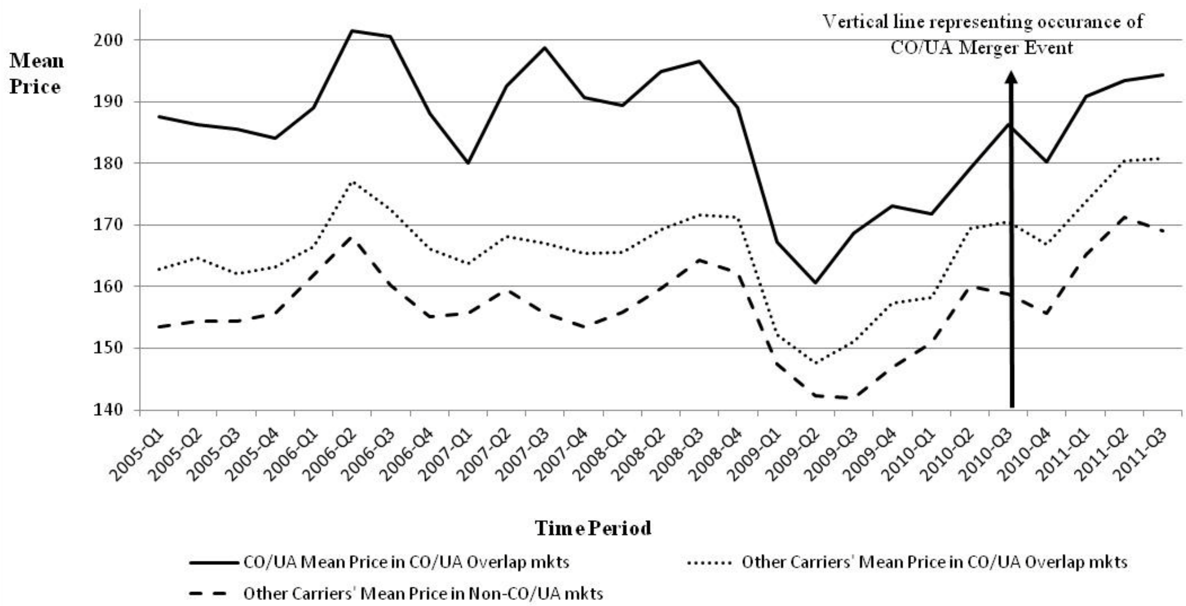

Figure 3: Time series plots of mean prices for carriers across various markets, where the focus is markets in which CO and UA services overlapped prior to their merger.

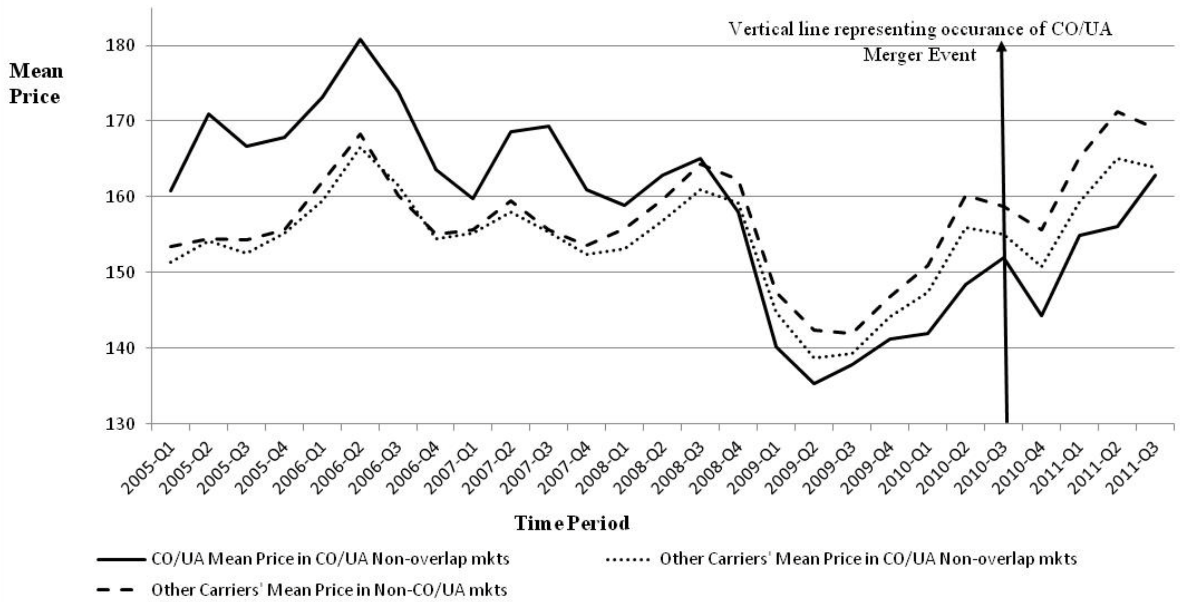

Figure 4: Time series plots of mean prices for carriers across various markets, where focus is on markets in which CO and UA services did not overlap prior to their merger.

We now use simple regression analysis to better evaluate the statistical significance of the merger impact on the time series patterns in prices observed in Figure 3 and Figure 4 respectively. Regression results are reported in Table 6. The dependent variable in each regression is mean price, which are the data observed in Figure 3 and Figure 4. Since the objective of this analysis is to identify potential price effects of the CO/UA merger, the data in Figure 3 and Figure 4 suggest that a more accurate evaluation of potential price effects should focus on data subsequent to the second quarter of 2009, which is the sample period used for estimating the regressions in Table 6.

CU_t is a zero-one airline dummy variable that equals 1 for mean price of Continental and United at time period *t*. T_t^{cu} is a zero-one time period dummy variables that takes the value 1 only in the post-merger period for the CO/UA merger. The first two columns in Table 6 focus on evaluating merger price effects in markets where CO and UA services overlapped prior to their merger. The regression in column 1 uses prices of other carriers in CO/UA overlapping markets as control comparison prices, while the regression in column 2 uses prices of other carriers in markets that neither CO nor UA offer service as control comparisons.

The positive coefficient estimate on dummy variable CU_t in column 1 suggests that across the sample period used for the regression, on average, CO/UA mean price across markets in which their services overlapped prior to merging is higher than the mean price of other carriers in these markets. The same result holds true in column 2 when the control comparison is the mean price series of other carriers in markets that neither CO nor UA offer service. The positive coefficient estimates on the *Trend* variable in both columns 1 and 2 control for the strong upward trend in mean prices over the relevant sample period. Across columns 1 and 2, the negative and statistically significant coefficient estimate on T_t^{cu}, and statistically insignificant coefficient estimate on $T_t^{cu} \times CU_t$ suggest that, on average, mean price across all carriers in these markets declined in the post-merger period relative to the pre-merger period, and there is no relative difference in the decline of CO/UA mean price. These coefficient estimates suggest little or no merger price effects associated with the CO/UA merger in market that their services overlapped prior to merging.

Table 6
Estimation Results for Mean Price Time-series Regressions Focused on Evaluating the CO/UA Merger
18 observations: 2009-Q3 to 2011-Q3

	Dependent Variable: Mean Price Per Time Period for Carriers Across Various Markets			
	Markets in which CO and UA services overlapped prior to merger		Markets in which either CO or UA serve prior to merger	
	Control Group 1[a]	Control Group 2[b]	Control Group 1	Control Group 2
	Column 1	**Column 2**	**Column 3**	**Column 4**
Variable	Coefficient Estimate (Robust Standard Error)	Coefficient Estimate (Robust Standard Error)	Coefficient Estimate (Robust Standard Error)	Coefficient Estimate (Robust Standard Error)
CU_t	**14.53***** (1.67)	**24.12***** (1.61)	**-4.10***** (1.25)	**-7.47***** (1.41)
T_t^{cu}	**-6.75***** (2.41)	**-6.54**** (3.13)	**-8.10***** (2.80)	**-6.58**** (3.17)
$T_t^{cu} \times CU_t$	**-0.30** (2.48)	**0.30** (2.83)	**-1.10** (2.38)	**-3.26** (2.65)
Trend	**4.64***** (0.38)	**4.46***** (0.46)	**4.33***** (0.43)	**4.47***** (0.47)
Constant	**63.86***** (7.70)	**58.05***** (9.24)	**57.49***** (8.67)	**57.87***** (9.55)
R-Squared	0.96	0.97	0.94	0.94

Notes: [a] Control Group 1 comprises mean prices of other carriers within relevant markets served by the firms that merge. [b] Control Group 2 comprises mean prices of other carriers within markets not served by the firms that merge. *** indicates statistical significance at the 1% level, ** indicates statistical significance at the 5% level, while * indicates statistical significance at the 10% level.

Column 3 and column 4 in Table 6 focus on evaluating merger price effects in markets where CO and UA services do not overlap prior to their merger. The regression in column 3 uses prices of other carriers in CO/UA non-overlap markets as control comparison prices, while the regression in column 4 uses prices of other carriers in markets that neither CO nor UA offer service as control comparisons. The negative coefficient estimate on dummy variable CU_t in column 3 suggests that across the sample period used for the regression, on average, CO/UA mean price across markets in which their services do not overlap prior to merging is lower than the mean price of other carriers in these markets. The same result holds true in column 4 when the control comparison is the mean price series of other carriers in markets that neither CO nor UA offer service. The positive coefficient estimates on the *Trend* variable in both columns 3 and 4 control for the strong upward trend in mean prices over the relevant sample period. Across columns 3 and 4, the negative and statistically significant coefficient estimate on T_t^{cu}, and statistically insignificant coefficient estimate on $T_t^{cu} \times CU_t$ suggest that, on average, mean price across all carriers in these markets declined in the post-merger period relative to the pre-merger period, and there is no relative difference in the decline of CO/UA mean price. Similar to our merger price effects findings in markets where CO and UA services overlapped prior to merging, the results in columns 3 and 4 suggest little or no merger price effects associated with the CO/UA merger in market that their services did not overlap prior to merging.

In summary, the simple aggregated descriptive analysis of price effects of the CO/UA merger suggests that, by using prices of other carriers as control comparisons, the merger is not associated with an impact on the merging firms' prices. However, since price effects are often net results of the counteracting impacts of market power increases and cost efficiency gains, findings of no merger price effects does not necessarily imply the merger is not associated with cost efficiency gains. Findings of no merger price effects could simply be the result of market power increases being offset by cost efficiency gains, hence the need for a structural model to disentangle and separately identify market power changes and cost effects associated with a merger.

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.

Potential passenger c solves the following utility maximization problem:

$$\underset{j\epsilon\{0,1,\ldots J_{mt}\}}{Max}\left\{U_{cjmt} = x_{jmt}\phi_c^x + \phi_c^p p_{jmt} + \xi_{jmt} + \varepsilon_{cjmt}^d\right\}, \tag{1}$$

where U_{cjmt} is passenger c's indirect utility from choosing product j; x_{jmt} is a vector of observed non-price characteristics of product j;[12] ϕ_c^x is a vector of consumer-specific marginal

[12] Non-price product characteristic variables in x_{jmt} include: (1) Origin Presence; (2) Interstop; (3) Inconvenience; (4) Quarter fixed effects; (5) Year fixed effects; (6) Carrier fixed effects; (7) Market Origin fixed effects; and (8) Market Destination fixed effects.

utilities (assumed to vary randomly across consumers) associated with non-price characteristics in x_{jmt}; p_{jmt} is the price the consumer must pay to obtain product j; ϕ_c^p is the consumer-specific marginal utility of price, which is assumed to vary randomly across consumers; ξ_{jmt} captures product characteristics that are observed by consumers and airlines, but not observed by us the researchers; and ε_{cjmt}^d is a mean-zero independently and identically distributed (across products, consumers, markets and time) random component of utility.

The random coefficients vary across consumers based on the following specification:

$$\begin{pmatrix} \phi_c^p \\ \phi_c^x \end{pmatrix} = \begin{pmatrix} \phi^p \\ \phi^x \end{pmatrix} + \begin{pmatrix} \phi_p^v & 0 & 0 & 0 & 0 \\ 0 & \phi_1^v & 0 & 0 & 0 \\ 0 & 0 & . & 0 & 0 \\ 0 & 0 & 0 & . & 0 \\ 0 & 0 & 0 & 0 & \phi_L^v \end{pmatrix} \times \begin{pmatrix} v_{cp} \\ v_{c1} \\ \cdot \\ \cdot \\ v_{cL} \end{pmatrix} \tag{2}$$

where ϕ^p is the mean (across consumers) marginal utility of price; ϕ^x is a vector of mean marginal utilities for respective non-price product characteristics; $\phi^v = \left(\phi_p^v, \phi_1^v, \dots, \phi_L^v\right)$ is a set of parameters that measure variation across consumers in random taste shocks for respective product characteristics; and $v_c = \left(v_{cp}, v_{c1}, \dots, v_{cL}\right)$ is a set of consumer c's random taste shocks for respective product characteristics. We assume that v_c follows a standard normal probability distribution across consumers. For notational convenience, we drop the market and time subscripts in some subsequent variables and equations.

Following much of the literature on discrete choice demand model [see Nevo (2000a)], we assume that ε_{cj}^d in equation (1) is governed by an independent and identically distributed extreme value probability density. As such, the probability that product j is chosen, or equivalently the predicted market share of product j is:

$$s_j\left(x_j, p_{j,}\xi_j; \phi^x, \phi^p, \phi^v\right) = \int \frac{\exp\left(\delta_j + \mu_{cj}\right)}{1 + \sum_k^J \exp(\delta_k + \mu_{ck})} dG(v) \tag{3}$$

where $\delta_j = x_j\phi^x + \phi^p p_j + \xi_j$ is the mean utility obtained across consumers who choose product j; $\mu_{cj} = \phi_p^v p_j v_{cp} + \sum_{l=1}^L \phi_l^v x_{jl} v_{cl}$ is a consumer-specific deviation from the mean utility level; and $G(\cdot)$ is the standard normal distribution function for the taste shocks. Since there is no closed-form solution for the integral in equation (3), this integral is approximated numerically using random draws from $G(v)$.[13]

The quantity demand for product j is specified to equal to the total number of potential consumers in the market, POP, multiplied by the probability that product j is chosen:

$$d_j = POP \times s_j(p, x, \xi; \Phi^{\mathrm{d}}), \tag{4}$$

where POP is measured by the geometric mean between the origin city population and destination city population, which is our measure of market size; and $\Phi^{\mathrm{d}} = (\phi^p, \phi^x, \phi^v)$ is the vector of 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:

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

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 quantity of product j an airline sells equals to the quantity demanded, that is, $q_j = d_j = POP \times s_j(p, x, \xi; \Phi^{\mathrm{d}})$.

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

$$\sum_{k \epsilon B_i} (p_k - c_k) \frac{\partial s_k}{\partial p_j} + s_j = 0 \text{ for all } j = 1, \dots, J \tag{6}$$

Using matrix notation, the system of first-order conditions in equation (6) is represented by:

$$s + (\Omega .* \Delta) \times (p - mc) = 0, \tag{7}$$

where s, p, and mc are $J\times 1$ vectors of predicted product shares, product prices, and marginal costs respectively, Ω is $J\times J$ matrix of appropriately positioned zeros and ones that describes airlines' ownership structure of the J products, $.*$ is the operator for element-by-element matrix

[13] We use 200 random draws from $G(\cdot)$ for the numerical approximation of $s_j(\cdot)$.

multiplication, and Δ is a $J \times J$ matrix of first-order derivatives of product market shares with respect to prices, where element $\Delta_{jk} = \frac{\partial s_k}{\partial p_j}$.

The structure of matrix Ω effectively determines groups of products in a market that are jointly priced. Therefore, the structure of Ω is different in pre-merger periods compared to post-merger periods. In pre-merger periods Ω reflects the fact that separately owned airlines non-cooperatively price their products, however in post-merger periods we appropriately update the structure of Ω to reflect the fact that products offered by the airlines that merged are jointly priced.[14]

Re-arranging equation (7), we can obtain a vector of product markups:

$$\boldsymbol{Mkup}\left(\mathbf{x}, \boldsymbol{\xi}; \widehat{\Phi^{\mathrm{d}}}\right) = p - mc = -(\Omega.* \Delta)^{-1} \times s. \tag{8}$$

where $\widehat{\Phi^{\mathrm{d}}} = (\widehat{\phi^p}, \widehat{\phi^x}, \widehat{\phi^v})$ is the vector of demand parameter estimates. Let $markup_j(\mathbf{x}, \boldsymbol{\xi}; \widehat{\Phi^d})$ be an element in $\boldsymbol{Mkup}\left(\mathbf{x}, \boldsymbol{\xi}; \widehat{\Phi^{\mathrm{d}}}\right)$. Note that $markup_j(\mathbf{x}, \boldsymbol{\xi}; \widehat{\Phi^d})$ is a 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:

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

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

$$VP_{imt} = \sum_{j \epsilon B_{imt}} markup_{jmt}\left(\mathbf{x}, \boldsymbol{\xi}; \widehat{\Phi^d}\right) * q_{jmt} \tag{10}$$

5. Dynamic Entry/Exit Game

In every period (quarter), each airline decides on market(s) in which to be active in order 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:

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

[14] See Nevo (2000b) for details on how matrix Ω differs pre-merger versus post-merger.

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:

$$\Pi_{imt} = R^*_{imt} - a_{imt}\{FC_{imt} + \epsilon^{FC}_{imt} + (1 - s_{imt})[EC_{imt} + \epsilon^{EC}_{imt}]\}, \tag{12}$$

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 Nash price-setting game described previously. s_{imt} is a zero-one indicator variable that equals to 1 if airline i had decided in period $t-1$ to be active in market m during period t. 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^{FC}_{imt} and ϵ^{EC}_{imt} represent private information shocks to fixed and entry costs respectively. The composite shock $\varepsilon_{imt} = \epsilon^{FC}_{imt} + (1 - s_{imt})\epsilon^{EC}_{imt}$ is assumed 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 cost functions as follows:

$$\begin{aligned} FC_{imt} \; = \; & \theta^{FC}_0 + \theta^{FC}_1 Pres_{imt} + \theta^{FC}_2 Post\_Merger\_Period_t + \\ & \theta^{FC}_3 A\_Merging\_Firm_{imt} + \\ & \theta^{FC}_4 Post\_Merger\_Period_t \times A\_Merging\_Firm_{imt}, \end{aligned} \tag{13}$$

$$\begin{aligned} EC_{imt} \; = \; & \theta^{EC}_0 + \theta^{EC}_1 Pres_{imt} + \theta^{EC}_2 Post\_Merger\_Period_t + \\ & \theta^{EC}_3 A\_Merging\_Firm_{imt} + \\ & \theta^{EC}_4 Post\_Merger\_Period_t \times A\_Merging\_Firm_{imt}. \end{aligned} \tag{14}$$

$Pres_{imt}$ 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:

$$R_{imt}^{*} = a_{im,t-1} VP_{imt}, \tag{15}$$

where

$$VP_{imt}\left(\mathbf{x}, \boldsymbol{\xi}; \widehat{\Phi^d}\right) = \sum_{j \in B_{imt}} \left\{markup_{jmt}(\mathbf{x}, \boldsymbol{\xi}; \widehat{\Phi^d}) * q_{jmt}\right\}. \tag{16}$$

Note that variable profits are functions of state variables $(\mathbf{x}, \boldsymbol{\xi})$. Aguirregabiria and Ho (2012) suggest that these state variables can be aggregated into a single state variable, R_{imt}^{*} rather than treating $(\mathbf{x}, \boldsymbol{\xi})$ as separate state variables. In other words, we can treat $R_{imt}^{*}(\cdot)$ as a firm-specific state variable rather than treating $\mathbf{x}$ 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:

$$y_{imt} = \{s_{imt}, R^*_{imt}, Pres_{imt}, Post\_Merger\_Period_t\} \tag{17}$$

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:

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

$\Pi_{it}^\sigma(a_{it}, y_t)$ 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 Appendix A. The profile of strategies in σ is a MPE if, for every airline *i* and every state (y_t, ε_{it}), we have:

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

In Appendix B we illustrate that the 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 $\mathbf{P} = \{P_i(\mathbf{y})\text{: for every firm and state } (i, \boldsymbol{y})\}$. $\mathbf{P} = \Psi(\theta, \mathbf{P})$ is a vector of best response probability mapping, where $\Psi(\cdot)$ is the *CDF* of the type 1 extreme value distribution.

6. Demand and Marginal Cost Estimation

The demand model is estimated using Generalized Methods of Moments (GMM). Following Berry (1994), Berry, Levinsohn, and Pakes (1995), and Nevo (2000a), we can

solve for ξ_j as a function of demand parameters and the data, where $\xi_j = \delta_j - x_j\phi^x - \phi^p p_j$. ξ_j is the error term used to formulate the GMM optimization problem:

$$\min_{\phi^x,\phi^p,\phi^v} \xi' Z^d W Z^{d\prime} \xi \tag{20}$$

where Z^d is the matrix of instruments that are assumed orthogonal to the error vector ξ, while W is the standard weighting matrix, $W = \left[\frac{1}{n} Z^{d\prime} \xi \xi' Z^d\right]^{-1}$. Since parameters ϕ^p and ϕ^x enter the error term linearly, we can restructure the GMM optimization problem in (20) such that the search to minimize the objective function, $\xi' Z^d W Z^{d\prime} \xi$, is done exclusively over parameter vector ϕ^v, i.e., the GMM optimization problem reduces to $\min_{\phi^v} \xi' Z^d W Z^{d\prime} \xi$. Once the optimization over ϕ^v is complete, we can recover estimates of ϕ^p and ϕ^x.[15]

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

$$\hat{c}_{jmt} = \tau_0 + \tau_1 W_{jmt} + \tau_2 T_t^{Post-merger} + \tau_3 T_t^{Post-merger} \times Merging\_Firms_{jmt} + \psi_j + \lambda_t + origin_m + dest_m + \varepsilon_{jmt}^{mc}, \tag{21}$$

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. $T_t^{Post-merger}$ is a zero-one time-period dummy variable that equals 1 during time periods subsequent to occurrence of the relevant merger event being analyzed. $Merging\_Firms_{jmt}$ is a zero-one airline-product dummy variable that equals 1 for all products that are associated with the merging firms. τ_2 is a parameter that measures, on average, how marginal cost changes over the pre-post merger periods for products that are not associated with the merging firms. However, τ_3 is a parameter that measures, on average, how marginal cost changes over the pre-post merger periods for the merging firms' products relative to

[15] For details of this estimation algorithm of a random coefficients logit model, see Nevo (2000a).

products not associated with the merging firms. Therefore, τ_3 measures the possible marginal cost efficiencies associated with the relevant merger being analyzed.

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. To properly identify the merger effects, it is important to control for these unobserved time-varying effects, which we control for using quarter and year dummy variables. $origin_m$ and $dest_m$ are sets of origin and destination city dummy variables respectively, which control for market endpoint characteristics that are unobserved by us the researchers. Finally, ε_{jmt}^{mc} is an unobserved random component of marginal cost. Equation (21) is estimated via ordinary least squares (OLS).

6.1 Instruments

In the demand model it is likely that product price (p_{jmt}) is correlated with product characteristics unobserved by us the researchers, 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 partly control for product characteristics unobserved by us the researchers, we include in the demand model carrier fixed effects, quarter fixed effects, year fixed effects, market origin fixed effects, and market destination fixed effects. These fixed effects do help alleviate the endogeneity problem since endogeneity can only be driven by residual shocks to demand that vary beyond the fixed effects included in the model.

To estimate the demand parameters consistently, we need a set of variables (instruments) that are uncorrelated with the residual shocks to demand but correlated with price. The instruments that we use are: (1) itinerary distance; (2) interaction of jet fuel price with itinerary distance; (3) interaction of jet fuel price with operating carrier dummies; (4) the squared deviation of a product's itinerary distance from the average itinerary distance of competing products offered by other airlines; and (5) the number of other products in the market with an equivalent number of intermediate stops, where these other competing products are not offered by the airline that offers the product for which the instrument variable value is computed.

The instruments for price are guided by the fact that price is composed of a markup and marginal cost component. As discussed in Gayle (2007 and 2013), instruments (1)-(3) are motivated by the fact that a product's price is influenced by the marginal cost of providing the product. The intuition for instrument (1) is that flying distance covered by an air travel product is likely to be correlated with the marginal cost of providing the product. The intuition for instruments (2) and (3) is that airlines' marginal costs are likely to change differently when there are shocks to jet fuel price.[16] This differential effect across airlines is due to the fact that airlines differ in the intensity with which they use jet fuel because: (i) they differ in their mix of aircrafts; and (ii) they differ in their route network structures, and therefore itinerary flight distances may differ across airlines.[17] The rationale for instruments (4) and (5) is that they are measures of the degree of competition that a product faces, which affects the size of a product's markup.

The arguments made in the previous paragraph provide reasons to believe that our instruments are likely correlated with price. However, it is also important that the instruments are unlikely to be correlated with the shocks to demand captured by ξ_{jmt}. For the latter property of our instruments we rely on the fact that the menu of products offered by airlines in a market is predetermined at the time of shocks to demand. Furthermore, unlike price, the menu of products offered and their associated non-price characteristics are not routinely and easily changed during a short period of time, which mitigates the influence of demand shocks on the menu of products offered and their non-price characteristics. For example, a product's itinerary flying distance is predetermined during the short-run period of price-setting by airlines and product choice by passengers, which makes this a valid non-price product characteristics to use for constructing instruments. Last, fuel price shocks are unlikely to be correlated with ξ_{jmt}.

7. Estimation Results for Demand, Markup and Marginal Cost

7.1 Demand Results

We first estimate a standard logit specification of the demand model, which is more restrictive than the random coefficients logit demand model outlined previously in the sense that the standard logit model does not allow marginal utilities for product characteristics to vary across consumers. Table 7 reports both Ordinary Least Square (OLS) and Two-stage Least Squares (2SLS) estimates of the standard logit model. First, focusing on coefficient estimates for

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[16] Jet fuel price data are drawn from the U.S. Energy Information Administration.

[17] See Villas-Boas (2007) for similarly motivated types of instruments.

the variable, *Price* (p_j), we find that even though the sign of the OLS and 2SLS coefficient estimates on *Price* is consistent with intuition, there is a large difference in the size of the two coefficient estimates. This preliminary evidence suggests that the OLS coefficient estimate for *Price* is biased and inconsistent and thus instruments are needed for this potentially endogenous variable.

Table 7
Demand Estimation Results
647,167 observations: 2005-Q1 to 2011-Q3

	Standard Logit Model				Random Coefficients Logit Model	
	OLS		2SLS		GMM	
Mean marginal utility parameter estimates (ϕ^p and ϕ^x)	Parameter Estimates	Robust Std. Error	Parameter Estimates	Robust Std. Error	Parameter Estimates	Robust Std. Error
Price (in thousand $)	-1.273***	0.0334	-11.141***	0.1022	-20.139***	0.8501
Interstop	-1.465***	0.0049	-1.342***	0.0054	-1.375***	0.0298
Inconvenience	-1.203***	0.0059	-1.160***	0.0072	-0.900***	0.0161
Origin presence	0.598***	0.0079	1.014***	0.0096	1.452***	0.0230
Spring	0.123***	0.0039	0.161***	0.0042	0.368***	0.0093
Summer	0.111***	0.0039	0.151***	0.0042	0.322***	0.0083
Fall	0.083***	0.0041	0.102***	0.0044	0.233***	0.0082
Constant	-3.797***	0.0305	-2.546***	0.0365	-4.855***	0.1098
Carrier fixed effects	YES		YES		YES	
Market Origin fixed effects	YES		YES		YES	
Market Destination fixed effects	YES		YES		YES	
Year fixed effects	YES		YES		YES	
Taste variation parameter estimates (ϕ^v)						
Constant	-	-	-	-	2.992***	0.0616
Price (in thousand $)	-	-	-	-	0.324	10.498
Interstop	-	-	-	-	0.234*	0.1321
R^2	0.4365		-			
Value of GMM objective function	-		-		10016.15	
Tests of endogeniety Ho: Price variable is exogenous	Durbin-Wu-Hausman test: $\chi^2(1)$ = 13190.5*** Prob_Value = 0.0000 Robust regression *F*-test: F(1; 647,004) = 13935.9*** Prob_value = 0.0000					

*** indicates statistical significance at the 1% level, while * indicates statistical significance at the 10% level. For the Standard Logit Model, the well-known linear equation used for estimating the parameters is: $ln(S_j) - ln(S_0) = x_j\phi^x + \phi^p p_j + \xi_j$, where $S_j = {}^{q_j}/_{POP}$ is the observed share of product j, $S_0 = 1 - \sum_{j=1}^{J} S_j$ is the observed share of the outside good, and ξ_j is the error term of the equation.

To formally confirm that *Price* is endogenous, we perform a Hausman exogeneity test. The result of the Hausman test shown in Table 8 easily rejects the exogeneity of *Price* at conventional levels of statistical significance. To evaluate whether the instruments have statistically significant explanatory power of variations in *Price*, we estimate a first-stage reduced-form regression in which *Price* is the dependent variable. R-squared is 0.35 in the reduced-form *Price* regression. An *F*-test of the joint statistical significance of instruments in the reduced-form *Price* regression yield an *F*-statistic value of *F*(35, 646971) = 3418.59. The *p*-value for the *F*-statistic is 0.000, suggesting that the instruments do have statistically significant explanatory power of variations in *Price*.

The following discussion of demand regression results in Table 7 focuses on the less restrictive random coefficients logit model. The upper panel of the table reports the mean marginal (dis)utilities for each product characteristic (ϕ^p and ϕ^x), while the lower panel of the table reports the parameter estimates that measure taste variation across consumers for respective product characteristics (ϕ^v) .

The coefficient estimate on *Price* has the expected negative sign, suggesting that higher air fares are associated with lower levels of passenger utility, ceteris paribus. In other words, all else equal, passengers prefer cheaper air travel products.

Consistent with what we expect, the coefficient estimate on the *Interstop* variable is negative, which indicates that consumer utility decreases as the number of intermediate stop(s) increases. The *Inconvenience* variable measures each product's itinerary flying distance divided by nonstop flying distance between the origin and destination city. The intuition is that two distinct itineraries in an origin-destination market can have the same number of intermediate stop(s), but depending on the location(s) of the intermediate stop(s), the two itineraries may be associated with very different flying distances and therefore yield different levels of travel convenience for the passenger (Gayle 2007). Therefore, this variable captures aspects of the itinerary travel-inconvenience that the variable *Interstop* does not. As expected, the coefficient estimate associated with the *Inconvenience* variable is negative, 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 estimate 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 a 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 an airline's "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 coefficient estimates 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.

The taste variation parameters that are statistically significant at conventional levels of statistical significance suggest that, overall, passengers have heterogeneous taste for air travel, and in particular they have heterogeneous taste for the travel convenience of the air travel itinerary as measured by the number of intermediate stops required. Such evidence favor using the random coefficients logit model over the standard logit model to capture air travel demand.

Our demand model yields a mean own-price elasticity estimate of -3.18. 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. Therefore, our elasticity estimate seems reasonable and accord with evidence in the existing literature.

7.2 Computed Variable Profits and Recovered Marginal Costs

All monetary variables in this study are measured in constant year 1999 dollars. The overall mean price and product markup are \$165.90 and \$56.88, respectively. We find that airlines are able to raise their price above marginal cost by a mean 37.19%. Mean product-level marginal cost is \$109.01. 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 7 cents, which is consistent with the marginal cost estimate in Berry and Jia (2010) of 6 cents per mile.

Quarterly market-level variable profits by airline are computed using equation (10) along with the demand parameter estimates. It is useful at this point to put in context the magnitudes of quarterly market-level variable profit estimates. Recall that the original database, 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. Mean quarterly market-level variable profit for an airline in the sample is $27,230.32.

7.3 Product markup function estimation results

Table 8 shows estimation results for regressions 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 key right-hand-side variables in the regressions are: DN_{jmt}, T_t^{dn}, $T_t^{dn} \times DN_{jmt}$, CU_{jmt}, T_t^{cu} and $T_t^{cu} \times CU_{jmt}$. T_t^{dn} and T_t^{cu} are zero-one merger time period dummy variables previously defined. 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 product markups change relative to product markups of non-merging airlines over the respective pre and post-merger periods, while the coefficients on T_t^{dn} and T_t^{cu} measure how non-merging airlines' product markups change over the respective pre-post merger periods. The other right-hand-side variables are controls for various product, airline, market and time period characteristics, where some characteristics controlled for are observed in the data, while characteristics unobserved by the researchers are controlled for using various fixed effects dummy variables.

Regressions in columns 1 and 2 focus on the DL/NW merger, while columns 3 and 4 focus on the CO/UA merger, where each column of regression estimates are obtained using a different subsample of the data most relevant for identifying markup effects of interest. The regression estimates in column 1 are based on the subsample of markets in which Delta and Northwest air travel services overlapped prior to their merger, while regression estimates in column 2 are based on the subsample of markets in which either Delta or Northwest, but not both, provides air travel service prior to their merger. Analogously, the regression estimates in column

3 are based on the subsample of markets in which Continental and United air travel services overlapped prior to their merger, while regression estimates in column 4 are based on the subsample of markets in which either Continental or United, but not both, provides air travel service prior to their merger.

Table 8
Estimation Results for Product Markup Regressed on Several of its Determinants

	Dependent Variable: Product Markups			
	Subsample of Markets Relevant to Evaluate the DL/NW Merger		Subsample of Markets Relevant to Evaluate the CO/UA Merger	
	Markets in which DL and NW services overlapped prior to merger	Markets in which either DL or NW serve prior to merger	Markets in which CO and UA services overlapped prior to merger	Markets in which either CO or UA serve prior to merger
	Column 1	**Column 2**	**Column 3**	**Column 4**
Variable	Coefficient Estimate (Robust Standard Error)	Coefficient Estimate (Robust Standard Error)	Coefficient Estimate (Robust Standard Error)	Coefficient Estimate (Robust Standard Error)
DN_{jmt}	**3.999***** (0.12)	**4.80***** (0.28)	-	-
T_t^{dn}	**-0.36***** (0.07)	**0.17** (0.18)	-	-
$T_t^{dn} \times DN_{jmt}$	**0.97***** (0.05)	**-0.65***** (0.17)	-	-
CU_{jmt}	-	-	**4.68***** (0.32)	**2.55***** (0.36)
T_t^{cu}	-	-	**0.31***** (0.10)	**0.13** (0.24)
$T_t^{cu} \times CU_{jmt}$	-	-	**-0.66***** (0.10)	**-1.43***** (0.21)
Origin presence	**0.17***** (0.0006)	**0.13***** (0.002)	**0.17***** (0.001)	**0.13***** (0.002)
Interstop	**-0.97***** (0.04)	**-4.21***** (0.12)	**-0.43***** (0.06)	**-3.40***** (0.15)
Inconvenience	**-1.93***** (0.06)	**-0.23** (0.18)	**-1.15***** (0.11)	**-0.95***** (0.19)
Constant	**48.09***** (0.17)	**58.63***** (0.46)	**49.18***** (0.41)	**54.43***** (0.57)
Carrier fixed effects	YES			
Market origin fixed effects	YES			
Market destination fixed effects	YES			
Quarter and Year fixed effects	YES			
R-Squared	0.32	0.33	0.33	0.39
Number of observations	501082	116427	158385	52550
Sample Period	2005-Q1 to 2011-Q3		2009-Q3 to 2011-Q3	

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

The coefficient estimate on T_t^{dn} in column 1 is negative and statistically significant at conventional levels of statistical significance, suggesting that in DL/NW overlap markets non-merging airlines' markup, on average, declined (approximately \$0.36 corresponding to only $0.64\% = \frac{0.36}{56.21} \times 100$) over the pre-post DL/NW merger periods. The fact that the coefficient estimate on $T_t^{dn} \times DN_{jmt}$ is positive, statistically significant, and larger in absolute terms than the coefficient estimate on T_t^{dn}, indicate that markup on products offered by Delta and Northwest in these markets increase (approximately \$0.61 = \$0.97 - \$0.36), on average, over the pre-post DL/NW merger periods, which corresponds to approximately 1% ($= \frac{0.61}{55.13} \times 100$) increase relative to pre-merger mean markup on their products. This evidence suggests that the DL/NW merger marginally increases the merging firms' market power in markets where their air travel services overlapped prior to the merger.

The coefficient estimate on T_t^{dn} in column 2 is not statistically significant at conventional levels of statistical significance, suggesting that in DL/NW non-overlap markets non-merging airlines' markup, on average, did not change over the pre-post DL/NW merger periods. However, the coefficient estimate on $T_t^{dn} \times DN_{jmt}$ is negative and statistically significant at conventional levels of statistical significance, suggesting that markup on products offered by Delta and Northwest in their non-overlap markets, on average, declined (approximately \$0.65) over the pre-post DL/NW merger periods, which corresponds to approximately 1% ($= \frac{0.65}{57.26} \times 100$) decline relative to pre-merger mean markup on their products in these markets. A possible reason why the merger may cause the merging firms to reduce markup on their products is that the merger may be associated with fixed and/or entry cost savings, which implies that these types of costs can be paid for with lower levels of variable profits.

We now focus on the merger markup effects of the CO/UA merger. Given that a more accurate evaluation of potential price effects of the CO/UA merger required us to focus on data subsequent to the second quarter of 2009, we also focus on these periods for evaluation of markup and marginal cost effects of the merger. As such, this is the data sample period used for estimating the regressions in columns 3 and 4. The coefficient estimate on T_t^{cu} in column 3 is positive and statistically significant at conventional levels of statistical significance, suggesting that in CO/UA overlap markets non-merging airlines' markup marginally increase (approximately \$0.31 corresponding to $0.55\% = \frac{0.31}{56.38} \times 100$), on average, over the pre-post CO/UA merger periods. The fact that the coefficient estimate on $T_t^{cu} \times CU_{jmt}$ is negative, statistically significant, and larger in absolute terms than the coefficient estimate on T_t^{cu}, indicate that markup on products offered by Continental and United in these markets declined (approximately \$0.35 = \$0.66 - \$0.31), on average, over the pre-post CO/UA merger periods, which corresponds to approximately 0.6% ($= \frac{0.35}{54.59} \times 100$) decline relative to pre-merger mean markup on their products. While it is more natural to expect the merging firms to increase markup on their products in market where their services overlap prior to the merger, a possible reason why the merger may instead cause the merging firms to reduce markup is that the merger may be associated with fixed and/or entry cost savings, which implies that these types of costs can be paid for with lower levels of variable profits.

The coefficient estimate on T_t^{cu} in column 4 is not statistically significant at conventional levels of statistical significance, suggesting that in CO/UA non-overlap markets non-merging airlines' markup, on average, did not change over the pre-post CO/UA merger periods. However, the coefficient estimate on $T_t^{cu} \times CU_{jmt}$ is negative and statistically significant at conventional levels of statistical significance, suggesting that markup on products offered by Continental and United in their non-overlap markets, on average, declined (approximately \$1.42) over the pre-post CO/UA merger periods, which corresponds to approximately 3% ($= \frac{1.42}{53.38} \times 100$) decline relative to pre-merger mean markup on their products in these markets.

Other control variables in the markup regressions include: *(i)* size of an airline's presence at the origin airport, measured by the *Origin presence* variable; *(ii)* the number of intermediate stops required by a flight itinerary, measured by the *Interstop* variable; and *(iii)* another variable that captures the relative travel convenience to the consumer of a product's flight itinerary, captured by a flying-distance-based variable, *Inconvenience*. As expected, *Origin presence* consistently 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)]. Products have lower markup the larger the required number of intermediate stops, or the poorer their routing quality. These result are also expected because passengers usually prefer products with convenient routing, as confirmed by our demand equation estimation results.

In summary, the evidence suggests that only the DL/NW merger had a statistically significant increase on the merging firms' markup, but the economic magnitude of the increase is negligible and is only evident in markets where the merging firms' services overlapped prior to merging. Markup on DL/NW products actually declined in markets where their services did not overlap prior to merging. The CO/UA merger is associated with lower markup on their products, even in markets where their services overlapped prior to merging. Since product markup is often used as a measure of market power, these results suggest that the mergers, on average, did not reduce the level of short-run competition in the industry.

7.4 Marginal cost function estimation results

Table 9 reports estimation results for marginal cost equation regressions. We begin discussion of the results reported in column 1 that focus on merger marginal cost effects in markets which Delta and Northwest air travel services overlapped prior to their merger. The coefficient estimate on T_t^{dn} in column 1 is negative and statistically significant at conventional levels of statistical significance, suggesting that in DL/NW overlap markets non-merging airlines' marginal cost, on average, declined (approximately \$0.77 corresponding to only $0.66\% = \frac{0.77}{116.15} \times 100$) over the pre-post DL/NW merger periods. The negative and statistically significant coefficient estimate on $T_t^{dn} \times DN_{jmt}$ indicates that marginal costs of Delta and Northwest's products in these markets, on average, have an even larger decline (approximately \$4.01 = \$3.24 + \$0.77) over the pre-post DL/NW merger periods, which corresponds to 3.6% $(= \frac{4.01}{110.62} \times 100)$ decline relative to pre-merger mean marginal cost of their products.

The coefficient estimate on T_t^{dn} in column 2 is positive and statistically significant at conventional levels of statistical significance, suggesting that in DL/NW non-overlap markets non-merging airlines' marginal cost, on average, increased (approximately \$4.00 corresponding to $4\% = \frac{4.00}{102.55} \times 100$) over the pre-post DL/NW merger periods. However, the coefficient estimate on $T_t^{dn} \times DN_{jmt}$ is negative and slightly larger in absolute terms than the coefficient estimate on T_t^{dn}, suggesting that marginal costs of products offered by Delta and Northwest in their non-overlap markets, on average, declined (approximately \$0.08 = \$4.08 - \$4.00) over the pre-post DL/NW merger periods, which corresponds to 0.07% $(= \frac{0.08}{120.19} \times 100)$ decline relative to pre-merger mean marginal cost of their products in these markets. So even though DL/NW products only experienced a minor marginal cost decline in their non-overlap markets, this decline is in contrast to the 4% increase in marginal cost of products offered by the other carriers in these markets.

We now focus on the marginal cost effects of the CO/UA merger. As previously discussed, more accurate evaluation of price, markup and marginal cost effects associated with the CO/UA merger require us to focus on data subsequent to the second quarter of 2009, which is the data sample period used for estimating regressions in columns 3 and 4. The coefficient estimate on T_t^{cu} in column 3 is negative and statistically significant at conventional levels of statistical significance, suggesting that in CO/UA overlap markets non-merging airlines' marginal cost, on average, declined (approximately \$9.35 corresponding to $9\% = \frac{9.35}{105.12} \times 100$) over the pre-post CO/UA merger periods. The negative and statistically significant coefficient estimate on $T_t^{cu} \times CU_{jmt}$ indicates that marginal costs of products offered by Continental and United in these markets, on average, have an even larger decline (approximately \$22.38 = \$10.67 + \$9.35) over the pre-post CO/UA merger periods, which corresponds to 16.5% $(= \frac{20.02}{121.25} \times 100)$ decline relative to pre-merger mean marginal cost of their products.

The coefficient estimate on T_t^{cu} in column 4 is negative and statistically significant at conventional levels of statistical significance, suggesting that in CO/UA non-overlap markets non-merging airlines' marginal cost, on average, decreased (approximately \$9.10 corresponding to $10.2\% = \frac{9.10}{89.25} \times 100$) over the pre-post CO/UA merger periods. The coefficient estimate on $T_t^{cu} \times CU_{jmt}$ is negative and statistically significant at conventional levels of statistical significance, suggesting that marginal costs of products offered by Continental and United in their non-overlap markets, on average, have an even larger decline (approximately \$13.60 = \$9.10 + \$4.50) over the pre-post CO/UA merger periods, which corresponds to approximately 15% $(= \frac{13.60}{90.84} \times 100)$ decline relative to pre-merger mean marginal cost of their products in these markets.

Table 9
Estimation Results for Marginal Cost Function

	Dependent Variable: Product Marginal Costs			
	Subsample of Markets Relevant to Evaluate the DL/NW Merger		Subsample of Markets Relevant to Evaluate the CO/UA Merger	
	Markets in which DL and NW services overlapped prior to merger	Markets in which either DL or NW serve prior to merger	Markets in which CO and UA services overlapped prior to merger	Markets in which either CO or UA serve prior to merger
	Column 1	**Column 2**	**Column 3**	**Column 4**
Variable	Coefficient Estimate (Robust Standard Error)	Coefficient Estimate (Robust Standard Error)	Coefficient Estimate (Robust Standard Error)	Coefficient Estimate (Robust Standard Error)
DN_{jmt}	**-37.05***** (1.26)	**-21.37***** (2.05)	-	-
T_t^{dn}	**-0.76**** (0.38)	**4.01***** (0.70)	-	-
$T_t^{dn} \times DN_{jmt}$	**-3.24***** (0.30)	**-4.08***** (0.89)	-	-
CU_{jmt}	-	-	**-24.48***** (2.31)	**-17.93***** (2.37)
T_t^{cu}	-	-	**-9.35***** (0.51)	**-9.10***** (0.81)
$T_t^{cu} \times CU_{jmt}$	-	-	**-10.67***** (0.68)	**-4.49***** (1.25)
Origin presence	**0.31***** (0.01)	**0.34***** (0.02)	**0.33***** (0.02)	**0.27***** (0.03)
$(\text{Origin presence})^2$	**-0.00005** (0.00008)	**-0.0008***** (0.0002)	**-0.00004** (0.0002)	**-0.0007***** (0.0002)
Dest. presence	**0.34***** (0.01)	**0.41***** (0.02)	**0.38***** (0.02)	**0.29***** (0.03)
$(\text{Dest. presence})^2$	**-0.0002*** (0.00009)	**-0.001***** (0.0002)	**-0.0004**** (0.0002)	**-0.0006***** (0.0002)
Nonstop Distance	**0.04***** (0.0002)	**0.04***** (0.0004)	**0.04***** (0.0004)	**0.05***** (0.0005)
Interstop	**-2.75***** (0.19)	**8.59***** (0.36)	**-1.84***** (0.34)	**4.08***** (0.48)
Inconvenience	**36.15***** (0.49)	**23.25***** (0.86)	**44.94***** (0.94)	**29.57***** (0.93)
Constant	**37.00***** (1.57)	**23.30***** (2.43)	**33.54***** (2.88)	**4.80*** (2.86)
Carrier fixed effects	YES			
Market origin fixed effects	YES			
Market destination fixed effects	YES			
Quarter and Year fixed effects	YES			
R-Squared	0.34	0.40	0.35	0.46
Number of observations	501082	116427	158385	52550
Sample Period	2005-Q1 to 2011-Q3		2009-Q3 to 2011-Q3	

Notes: *** indicates statistical significance at the 1% level, ** indicates statistical significance at the 5% level, while * indicates statistical significance at the 10% level.

Before summarizing the key findings on the impact of the mergers on marginal cost, we now briefly discuss the coefficient estimates associated with the other control variables in the marginal cost regressions. It is reassuring that the coefficient estimates associated with other control variables in the marginal cost regressions do have the expected signs. For example, the coefficient estimate on the *Nonstop Distance* variable is positive, suggesting that distance between the origin and destination positively affect marginal cost, likely driven by the link between fuel usage and flying distance. Depending on the net impact of various cost factors, product marginal cost can either be positively or negatively correlated with number of intermediate stops. For example, a cost factor that likely causes marginal cost to be inversely related to number of intermediate stops is that airlines often channel passengers from different origins, who have common destinations, through common intermediate stop hub airport(s). This practice allows airlines to better fill individual flights, which can result in the airline incurring a lower cost per passenger to transport passengers, i.e., an airline can exploit economies of passenger-traffic density by using intermediate stop(s). On the other hand, due to inefficiency of fuel use associated with more required take-offs and landing during a given trip, the marginal cost of transporting a passenger could be positively related to number of intermediate stops. As such, the coefficient estimate on the *Interstop* variable in a marginal cost regression can either be negative or positive.

The coefficient estimate on the *Inconvenience* variable is consistently positive as expected, suggesting a positive relationship between the *Inconvenience* variable and marginal cost. Recall that the *Inconvenience* variable is calculated by dividing the itinerary distance flown from the origin to destination by the nonstop flight distance between the origin and destination. As such, conditional on number of intermediate stops, the greater the itinerary distance flown from the origin to destination (higher *Inconvenience* measure), the greater the required fuel for the trip, and therefore the greater the marginal cost the airline faces to provide the product.

The sign pattern of the coefficient estimates on the size of an airline's airport presence variables suggests that the size of an airline's airport presence has a positive marginal impact on the airline's marginal cost at relatively low levels of its airport presence, but eventually has a negative marginal impact on the airline's marginal cost at relatively high levels of its airport presence. These coefficient estimates can be interpreted as capturing the effect of an airline's "hub-size" on its marginal cost. In other words, the sign pattern of these coefficient estimates suggests that airlines will not be able to achieve marginal cost efficiencies until they reach a certain scale of operation. Therefore, we believe the size of an airline's airport presence variables indirectly capture economies of passenger-traffic densities that airlines can enjoy by channeling a relatively large volume of passengers through these endpoint airports.

Brueckner and Spiller (1994) find robust direct evidence of economies of passenger-traffic densities. They use a structural econometric model to show that marginal cost per passenger on a route falls as airlines channel large volumes of passengers on segments of the route.

In summary, there are marginal cost efficiencies associated with both mergers, but the magnitudes of the marginal cost decreases associated with the UA/CO merger are greater than those associated with the DL/NW merger. The DL/NW merger is associated with approximately 4% decline in marginal cost of the merging firms' products across markets in which their services overlap prior to merging, but only a 0.07% decline across markets in which their services did not overlap prior to merging. However, it should be noted that even though DL/NW products only experienced a minor marginal cost decline in their non-overlap markets, this decline is in contrast to the 4% increase in marginal cost of products offered by the other carriers in these markets. In case of the CO/UA merger, we find that the merger is associated with approximately 16% decline in marginal cost of the merging firms' products across markets in which their services overlap prior to merging, and a 15% decline across markets in which their services did not overlap prior to merging.

7.5 Results from Reduced-form Price Regression

Since standard oligopoly theory predicts that equilibrium price is equal to marginal cost plus markup, this implies that changes in markup and marginal cost should be reflected in price. An advantage of directly using a reduced-form price regression is that it does not embed the strong assumptions required for a structural model. Of course, the strong assumptions of the structural model buy us the advantage of being able to separately analyze markup and marginal cost. So both approaches, reduced-form versus structural, have advantages and disadvantages. Analogous to identifying markup and marginal cost effects associated with the mergers, identification of merger price effects within the reduced-form price regressions employed 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 [see Weinberg (2008) and Ashenfelter and Hosken (2008)].

Table 10 shows estimation results from the reduced-form price equations, where the dependent variable in each regression is the price of a product. We begin discussion of the results reported in column 1 that focus on merger price effects in markets which Delta and Northwest air travel services overlapped prior to their merger. The coefficient estimate on T_t^{dn} in column 1 is negative and statistically significant at conventional levels of statistical significance, suggesting that in DL/NW overlap markets non-merging airlines' price, on average, declined (approximately \$1.35 corresponding to only $0.8\% = \frac{1.35}{172.35} \times 100$) over the pre-post DL/NW merger periods. 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 in these markets, on average, have an even larger decline (approximately \$4.70 = \$1.35 + \$3.35) over the pre-post DL/NW merger periods, which corresponds to approximately 3% ($= \frac{4.70}{165.75} \times 100$) decline relative to pre-merger mean price level of their products.

The coefficient estimate on T_t^{dn} in column 2 is positive and statistically significant at conventional levels of statistical significance, suggesting that in DL/NW non-overlap markets non-merging airlines' price, on average, increased (approximately \$3.98 corresponding to $2.5\% = \frac{3.98}{160.83} \times 100$) over the pre-post DL/NW merger periods. However, the coefficient estimate on $T_t^{dn} \times DN_{jmt}$ is negative and larger in absolute terms than the coefficient estimate on T_t^{dn}, suggesting that the prices of products offered by Delta and Northwest in their non-overlap markets, on average, declined (approximately \$0.51 = \$4.49 - \$3.98) over the pre-post DL/NW merger periods, which corresponds to approximately 0.3% ($= \frac{0.51}{177.45} \times 100$) decline relative to pre-merger mean price level of their products in these markets. So even though DL/NW products only experienced a minor decline in their non-overlap markets, this decline is in contrast to the 2.5% increase in price of products offered by the other carriers in these markets.

Table 10 Estimation Results for Reduced-form Price Equations				
	Dependent Variable: Product Prices			
	Subsample of Markets Relevant to Evaluate the DL/NW Merger		Subsample of Markets Relevant to Evaluate the CO/UA Merger	
	Markets in which DL and NW services overlapped prior to merger	Markets in which either DL or NW serve prior to merger	Markets in which CO and UA services overlapped prior to merger	Markets in which either CO or UA serve prior to merger
	Column 1	**Column 2**	**Column 3**	**Column 4**
Variable	Coefficient Estimate (Robust Standard Error)	Coefficient Estimate (Robust Standard Error)	Coefficient Estimate (Robust Standard Error)	Coefficient Estimate (Robust Standard Error)
DN_{jmt}	**-35.07***** (1.25)	**-17.96***** (2.05)	-	-
T_t^{dn}	**-1.36***** (0.38)	**3.98***** (0.67)	-	-
$T_t^{dn} \times DN_{jmt}$	**-3.35***** (0.30)	**-4.49***** (0.86)	-	-
CU_{jmt}	-	-	**-21.02***** (2.35)	**-14.82***** (2.38)
T_t^{cu}	-	-	**-9.14***** (0.51)	**-9.12***** (0.78)
$T_t^{cu} \times CU_{jmt}$	-	-	**-13.25***** (0.69)	**-7.11***** (1.26)
Origin presence	**0.45***** (0.01)	**0.49***** (0.02)	**0.46***** (0.018)	**0.44***** (0.03)
(Origin presence)^2	**0.0002***** (0.00008)	**-0.0008***** (0.0002)	**0.0003**** (0.0002)	**-0.0009***** (0.0002)
Dest. Presence	**0.48***** (0.01)	**0.57***** (0.02)	**0.52***** (0.02)	**0.47***** (0.027)
(Dest. presence)^2	**0.00007** (0.00009)	**-0.001***** (0.0002)	**-0.0001** (0.0002)	**-0.0009***** (0.0002)
Nonstop Distance	**0.04***** (0.0002)	**0.04***** (0.0003)	**0.04***** (0.0004)	**0.04***** (0.0005)
Interstop	**-2.69***** (0.19)	**7.19***** (0.35)	**-1.40***** (0.34)	**3.11***** (0.47)
Inconvenience	**34.36***** (0.49)	**21.73***** (0.87)	**43.37***** (0.94)	**27.38***** (0.93)
Constant	**86.75***** (1.56)	**83.25***** (2.43)	**84.29***** (2.91)	**57.49***** (2.85)
Carrier fixed effects	YES			
Market origin fixed effects	YES			
Market destination fixed effects	YES			
Quarter and Year fixed effects	YES			
R-Squared	0.36	0.39	0.37	0.45
Number of observations	501082	116427	158385	52550
Sample Period	2005-Q1 to 2011-Q3		2009-Q3 to 2011-Q3	

Notes: *** indicates statistical significance at the 1% level, while ** indicates statistical significance at the 5% level.

We now focus on the merger price effects of the CO/UA merger. As previously discussed, more accurate evaluation of price, markup and marginal cost effects associated with the CO/UA merger require us to focus on data subsequent to the second quarter of 2009, which is the sample period used for estimating the regressions in columns 3 and 4. The coefficient estimate on T_t^{cu} in column 3 is negative and statistically significant at conventional levels of statistical significance, suggesting that in CO/UA overlap markets non-merging airlines' price, on average, declined (approximately \$9.14 corresponding to $5.66\% = \frac{9.14}{161.49} \times 100$) over the pre-post CO/UA merger periods. The negative and statistically significant coefficient estimate on $T_t^{cu} \times CU_{jmt}$ indicates that the prices of products offered by Continental and United in these markets, on average, have an even larger decline (approximately \$22.38 = \$13.24 + \$9.14) over the pre-post CO/UA merger periods, which corresponds to approximately 13% $(= \frac{22.38}{175.84} \times 100)$ decline relative to pre-merger mean price level of their products.

The coefficient estimate on T_t^{cu} in column 4 is negative and statistically significant at conventional levels of statistical significance, suggesting that in CO/UA non-overlap markets non-merging airlines' price, on average, decreased (approximately \$9.12 corresponding to $6.12\% = \frac{9.12}{147.98} \times 100$) over the pre-post CO/UA merger periods. The coefficient estimate on $T_t^{cu} \times CU_{jmt}$ is negative and statistically significant at conventional levels of statistical significance, suggesting that the prices of products offered by Continental and United in their non-overlap markets, on average, have an even larger decline (approximately \$16.23 = \$9.12 + \$7.11) over the pre-post CO/UA merger periods, which corresponds to approximately 11.3% $(= \frac{16.23}{144.23} \times 100)$ decline relative to pre-merger mean price level of their products in these markets.

In summary, evidence from the reduced-form price regressions suggests that both mergers are associated with lowering the merging firms' prices. Recall that results from our structural model analysis suggest that marginal cost decreases associated with the mergers are more widespread across markets and relatively more substantial than markup increases. Therefore, the merger price effects findings from reduced-form price regressions are consistent with markup and marginal cost merger effects findings from our structural model. Last, the evidence suggest that the UA/CO merger is associated with a larger decline in prices, both in terms of dollars and percentage, compared to the DL/NW merger, a finding also consistent with merger markup and marginal cost results from our structural model analysis.

Coefficient estimates associated with other control variables in the reduced-form price regressions do have the expected signs. For example, the coefficient estimate on the *Nonstop Distance* variable is positive, suggesting that distance between the origin and destination positively affect price, likely driven by the link between fuel usage and marginal cost. Depending on the net impact of demand and marginal cost factors, product price can either be positively or negatively correlated with number of intermediate stops. For example, a demand factor that likely causes price to be inversely related to number of intermediate stops is that, for travel convenience, consumers prefer products with fewer intermediate stops. On the other hand, due to inefficiency of fuel use associated with more required take-offs and landing during a given trip, the marginal cost of transporting a passenger could be positively related to number of intermediate stops. As such, the coefficient estimate on the *Interstop* variable in the reduced-form price regressions can either be negative or positive. Likewise, the sign of the coefficient estimate on the *Inconvenience* variable in the price regressions depends on the net impact of demand and marginal cost factors. From a consumer demand standpoint, product price should be lower for products that have poorer routing quality, i.e. products with higher *Inconvenience* measure. From a marginal cost standpoint, products that use longer than necessary routing to transport passengers (products with higher *Inconvenience* measure) should be associated with higher marginal cost due to greater fuel requirements, which in turn puts upward pressure on price, an argument supported by results from our marginal cost regression discussed above.

The size of an airlines' presence at the endpoint airports of a market may either positively or negatively affect price depending on the net impact of demand and marginal cost factors. From a demand perspective consumers prefer to choose the airline that serves a larger number of destinations via nonstop flight from the consumer's origin city's airport, which implies a positive correlation between price and *Origin presence*. On the other hand, due to marginal cost effects related to economies of passenger-traffic density, the size of an airline's presence at market endpoint airports could negatively affect price. Economies of passenger-traffic density implies that an airline can achieve lower marginal cost of transporting a passenger by channeling large number of passengers though their major hub airports. Therefore, the larger the size of an airline presence at market endpoint airports, as captured by variables *Origin presence* and *Dest.*

Presence, the greater is the opportunity for the airline to exploit economies of passenger-traffic density.

8. Estimation of Dynamic Model

Consider the following pseudo log likelihood function:

$$Q(\theta, \mathbf{P}) \;=\; \sum_{m=1}^{M}\sum_{i=1}^{N}\sum_{t=1}^{T}\left\{\begin{array}{c} a_{imt}\ln\Psi\left(\tilde{Z}_{imt}^{\mathbf{P}}\boldsymbol{\theta}+\tilde{e}_{imt}^{\mathbf{P}}\right) \\ +\,(1-a_{imt})\ln\Psi\left(-\tilde{Z}_{imt}^{\mathbf{P}}\boldsymbol{\theta}-\tilde{e}_{imt}^{\mathbf{P}}\right) \end{array}\right\}, \tag{21}$$

where $Q(\theta, \mathbf{P})$ is called the "pseudo" log likelihood function because players' conditional choice probabilities (CCPs) in **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, $\widehat{\mathbf{P}}_0$. Estimating the state transition equations allow us to construct the state transition matrices, $\mathbf{F}_{iy}^{\mathbf{P}}(1)$ and $\mathbf{F}_{iy}^{\mathbf{P}}(0)$.[18] Nonparametric estimates of choice probabilities allow us to construct consistent estimates of $\tilde{Z}_{imt}^{\widehat{\mathbf{P}}_0}$ and $\tilde{e}_{imt}^{\widehat{\mathbf{P}}_0}$. $\tilde{Z}_{imt}^{\widehat{\mathbf{P}}_0}$ and $\tilde{e}_{imt}^{\widehat{\mathbf{P}}_0}$ are components of expected profit, which we define in Appendix B. With $\mathbf{F}_{iy}^{\mathbf{P}}(1)$, $\mathbf{F}_{iy}^{\mathbf{P}}(0)$, $\tilde{Z}_{imt}^{\widehat{\mathbf{P}}_0}$ and $\tilde{e}_{imt}^{\widehat{\mathbf{P}}_0}$ in hand, we can construct the pseudo log likelihood function, $Q\left(\theta, \widehat{\mathbf{P}}_0\right)$.

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

$$\hat{\theta}_{PML} = \arg\max_{\theta}\; Q\left(\theta, \widehat{\mathbf{P}}_0\right), \tag{22}$$

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

[18] To facilitate construction of the transition matrices, continuous state variables are discretized. The two continuous state variables are, variable profit (R_{imt}^{*}), and size of an airline's presence at endpoint airports of a market ($Pres_{imt}$). R_{imt}^{*} is discretized using intervals based on the 20th, 40th , 60th and 80th percentiles of the continuous variable, while $Pres_{imt}$ is discretized based on the 25th, 50th and 75th percentiles of the continuous variable.

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 finite sample bias. To deal with such potential bias, we follow Aguirregabiria and Mira (2007) and implement a recursive K-step extension of the two-step PML estimator, which they refer to as the Nested Pseudo Likelihood (NPL) estimator.[19] In Appendix C we provide more discussion on implementing the NPL 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 respectively. We begin by discussing recurrent fixed cost results for each merger, and then turn to discussing sunk market entry cost results for each merger. 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.

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 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

[19] 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.

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 \$5,476 lower than the mean quarterly fixed cost across other airlines.

The fixed 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' 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 \$18,462 and \$27,597 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 conventional levels of statistical significance. 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 mean quarterly variable profit an airline earns in an origin-destination market is approximately \$27,230. Therefore, our models suggest that the size of the mean entry cost is greater than one-period mean variable profit, which implies that airlines are forward-looking when making market entry decisions since it requires more than one period of profits to recoup sunk market entry cost.

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	7.71e-12	0.0076	1.01e-9
$Presence_{imt}$	5.48e-13	9.48e-5	5.78e-09
CU_{imt}	-0.6479***	0.0599	-10.82
T_t^{cu}	2.29e-11	0.0094	2.43e-09
$T_t^{cu} \times CU_{imt}$	-1.8462***	0.1662	-11.11
Entry Cost Function:			
Mean Entry Cost	3.1129***	0.0357	87.12
$Presence_{imt}$	-0.0113***	0.0004	-29.14
CU_{imt}	0.9994***	0.0740	13.51
T_t^{cu}	-0.2762***	0.0466	-5.93
$T_t^{cu} \times CU_{imt}$	3.0569***	0.2101	14.55

*** 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	8.72e-05	0.0316	0.0027
$Presence_{imt}$	-6.01e-07	0.0003	-0.0022
DN_{imt}	-0.5476***	0.0545	-10.04
T_t^{dn}	-6.82e-07	0.0314	-2.17e-05
$T_t^{dn} \times DN_{imt}$	-2.7597***	0.2054	-13.43
Entry Cost Function:			
Mean Entry Cost	3.0897***	0.0436	70.81
$Presence_{imt}$	-0.0120***	0.0004	-28.90
DN_{imt}	0.5841***	0.0681	8.57
T_t^{dn}	0.2231**	0.0548	4.07
$T_t^{dn} \times DN_{imt}$	2.7345***	0.2247	12.17

*** indicates statistical significance at the 1% level.
** indicates statistical significance at the 5% level.

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, an airline's 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 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 \$5,841 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 \$2,231 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 above the increase in entry cost experienced by non-merging airlines. The UA/CO merger is associated with an increase in UA and CO market entry costs, approximately $27,807 (= 30,569 – 2,762), which is in contrast to the $2,762 decline in entry cost of non-merging airlines across the pre-post UA/CO merger periods.

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 merger. 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 regressions in which a variable of product markups generated from the structural model is regressed on several determinants of markup. Results from these product markup regressions reveal that only the DL/NW merger had a statistically significant increase on markup, but the economic magnitude of the increase is negligible and is only evident in markets where the merging firms' services overlapped prior to merging. As such, the evidence suggests that short-run market power effects of these mergers were negligible.

Results from our structural model are consistent with results from reduced-form price regressions we estimate. The reduced-form price regressions reveal evidence that each merger is associated with price decreases, which suggests that marginal cost efficiencies outweigh market power increases. However, the reduced-form price regressions are 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 A: Transition Rules for State Variables

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:

$$Pr\ (Post\_Merger\_Period_{t+1} = 1 | y_t) = \Phi(\alpha_0^T + \alpha_1^T s_{it} + \alpha_2^T R_{it}^* + \alpha_3^T Pres_{it}). \tag{A4}$$

Appendix B: Representation of Markov Perfect Equilibrium (MPE) using Conditional Choice Probabilities (CCPs)

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,

$$\Pi_{imt}(0, y_t) = R^*_{imt}, \tag{B1}$$

$$\Pi_{imt}(1, y_t) = R^*_{imt} - FC_{imt} - (1 - s_{imt})EC_{imt}. \tag{B2}$$

Let

$$z_{imt}(0, y_t) = \{R^*_{imt}, 0,0,0,0,0,0,0,0,0,0\}, \tag{B3}$$

$$\begin{aligned} z_{imt}(1, y_t) \;=\; &\{R^*_{imt},\ -1,\ -Pres_{imt},\ -Post\_Merger\_Period_t, -A\_Merging\_Firm_{imt}, \\ &-Post\_Merger\_Period_t \times A\_Merging\_Firm_{imt},\ -(1 - s_{imt}),\ -(1 - s_{imt})Pres_{imt}, \\ &-(1 - s_{imt})Post\_Merger\_Period_t,\ -(1 - s_{imt})A\_Merging\_Firm_{imt},\ -(1 - \\ &s_{imt})Post\_Merger\_Period_t \times A\_Merging\_Firm_{imt}\}, \end{aligned} \tag{B4}$$

and

$$\theta = \{1, \theta_0^{FC}, \theta_1^{FC}, \theta_2^{FC}, \theta_3^{FC}, \theta_4^{FC}, \theta_0^{EC}, \theta_1^{EC}, \theta_2^{EC}, \theta_3^{EC}, \theta_4^{EC}\}'. \tag{B5}$$

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

$$\Pi_{imt}(0, y_t) = z_{imt}(0, y_t) \times \theta, \tag{B6}$$

$$\Pi_{imt}(1, y_t) = z_{imt}(1, y_t) \times \theta. \tag{B7}$$

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 $\mathbf{P} = \{P_i(\mathbf{y})\text{: for every firm and state } (i, \boldsymbol{y})\}$. $\mathbf{P} = \Psi(\theta, \mathbf{P})$ is a vector of best response probability mapping:

$$\left\{\Psi\left(\tilde{Z}_i^{\mathbf{P}}(\boldsymbol{y})\frac{\theta}{\sigma_\varepsilon} + \tilde{e}_i^{\mathbf{P}}(\mathbf{y})\right)\text{: for every firm and state } (i, \mathbf{y})\right\} \tag{B8}$$

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

$$\tilde{Z}_i^{\mathbf{P}}(\mathbf{y}) = Z_i(1, y_t) - Z_i(0, y_t) + \beta[\mathbf{F}_{iy}^{\mathbf{P}}(1) - \mathbf{F}_{iy}^{\mathbf{P}}(0)] \times \mathbf{W}_{z,i}^{\mathbf{P}}, \tag{B9}$$

$$\tilde{e}_i^{\mathbf{P}}(\mathbf{y}) = \beta[\mathbf{F}_{iy}^{\mathbf{P}}(1) - \mathbf{F}_{iy}^{\mathbf{P}}(0)] \times \mathbf{W}_{e,i}^{\mathbf{P}}, \tag{B10}$$

where

$$\mathbf{W}_{z,i}^{\mathbf{P}} = (\mathbf{I} - \beta * \overline{\mathbf{F}_{iy}^{\mathbf{P}}})^{-1} \times [\mathbf{P}_i(\boldsymbol{y}) * \boldsymbol{Z}_i(1, y) + (1 - \mathbf{P}_i(\mathbf{y})) * \boldsymbol{Z}_i(0, y)], \tag{B11}$$

$$\mathbf{W}_{e,i}^{\mathbf{P}} = (\mathbf{I} - \beta * \overline{\mathbf{F}_{iy}^{\mathbf{P}}})^{-1} \times [\mathbf{P}_i(\mathbf{y}) * \mathbf{e}_i^{\mathbf{P}}], \tag{B12}$$

and

$$\overline{\mathbf{F}_{iy}^{\mathbf{P}}} = [(\mathbf{P}_i(\mathbf{y}) \times \mathbf{1}'_M) * \mathbf{F}_{iy}^{\mathbf{P}}(1) + \left(\left(1 - \mathbf{P}_i(\mathbf{y})\right) \times \mathbf{1}'_M\right) * \mathbf{F}_{iy}^{\mathbf{P}}(0)]. \tag{B13}$$

$\mathbf{W}_{z,i}^{\mathbf{P}}$ and $\mathbf{W}_{e,i}^{\mathbf{P}}$ 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, $\mathbf{e}_i^{\mathbf{P}}(\mathbf{P}_i(\boldsymbol{y})) = \gamma - \ln(\mathbf{P}_i(\mathbf{y}))$, , where $\gamma = 0.577215665$ is Euler's constant.

Appendix C: Implementing the Nested Pseudo Likelihood (NPL) Estimator

As discussed in Aguirregabiria and Mira (2007), the two-step PML estimator may be subjected to finite sample bias. One reason for the bias is that the nonparametric probabilities, $\widehat{\mathbf{P}}_0$, enter nonlinearly in the sample objective function that define the estimator, and the expected value of a nonlinear function of $\widehat{\mathbf{P}}_0$ is not equal to that function evaluated at the expected value of $\widehat{\mathbf{P}}_0$. Second, the nonparametric probability estimates themselves can have 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, $\widehat{\mathbf{P}}_0$, we can construct new CCP estimates, $\widehat{\mathbf{P}}_1$, using the best response CCPs equation:

$$\widehat{\mathbf{P}}_1 = \Psi\big(\widehat{\mathbf{P}}_0, \hat{\theta}_{PML}\big). \tag{C1}$$

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

$$\hat{\theta}_K = \arg\max_{\theta} \; Q\big(\theta, \widehat{\mathbf{P}}_{K-1}\big) \tag{C2}$$

and

$$\widehat{\mathbf{P}}_K = \Psi\big(\widehat{\mathbf{P}}_{K-1}, \hat{\theta}_K\big), \tag{C3}$$

where on the K^{th} iteration the choice probability vector $\widehat{\mathbf{P}}_K$ is sufficiently close to $\widehat{\mathbf{P}}_{K-1}$ based on a tolerance level that we chose. The result is an NPL fixed point, which can be define as a pair $(\theta, \mathbf{P})$ 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.

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