Mergers and Product Quality: Evidence from the Airline Industry*

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Abstract

Retrospective studies of horizontal mergers have focused on their price effects, leaving the important question of how mergers affect product quality largely unanswered. This paper empirically investigates this issue for two recent airline mergers. Consistent with the theory that mergers facilitate coordination but diminish competitive pressure for quality improvement, we find that each merger is associated with a quality decrease (increase) in markets where the merging firms had (had no) pre-merger competition with each other, and the quality change can have a U-shaped relationship with pre-merger competition intensity. Consumer gains/losses associated with quality changes, which we monetize, are substantial.

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1 Introduction

A long-standing interest in economics and public policy discussions is the competitive effects of horizontal mergers. To evaluate these effects, one natural approach is to study actual mergers retrospectively. Such studies in the economics literature have focused on a merger's price effects, which are often used to infer relative changes in market power and cost efficiencies associated with the merger (See, for example, Whinston (2006) for a discussion of this literature).[1] However, price increases or decreases associated with a merger could be closely related to product quality changes. Given the importance of product quality to consumers, it is surprising that little attention has been directed to the quality effects of mergers.[2] In this paper, we aim to shed light on the relationship between mergers and product quality by empirically investigating two recent airline mergers — the Delta/Northwest (DL/NW) and the Continental/United (CO/UA) merger.

To guide the empirical analysis, we first present a theoretical model that captures what we term as the *coordination* and *incentive* effects of a merger on product quality. A horizontal merger allows two firms to share technology information and coordinate production, which can positively affect the quality of their products. On the other hand, the merger also reduces the competitive pressure on the merging firms. This tends to reduce their incentive to improve product quality, but the magnitude of this negative incentive effect may not monotonically increase with the pre-merger competition intensity, because the diminished profit under competition, especially when competition intensity goes beyond a certain point, can weaken the incentive for costly quality provision. Exploring these possibilities, the model generates two predictions. First, a merger will increase the product quality of the merging firms if they had little pre-merger competition with each other, but will likely reduce quality if they had substantial pre-merger competition with each other. Second, the quality change due to the merger may vary non-monotonically as the intensity of pre-merger competition increases, possibly exhibiting a U-shaped relationship.

The Delta/Northwest and the Continental/United mergers offer an interesting opportunity for us to study a merger's quality effect. In each case, the merging firms produce in multiple markets.

[1] Also see Kwoka (2015); Kwoka (2013); Kwoka and Gu (2013); Ashenfelter and Hosken (2008); Ashenfelter, Hosken, Vita and Weinberg (2011); and Weinberg (2008).

[2] Notable exceptions include several studies of hospital mergers (see Mutter, Romano and Wong, 2011; Ho and Hamilton, 2000; and Romano and Balan, 2011). These studies find mixed results on the effect of hospital mergers on various measures of clinical quality, but a disproportionate portion of the evidence suggests clinical quality declines with hospital mergers. Also see Kwoka and Pollitt (2010) for an analysis of measuring merger efficiencies in US electric power sector.

In some of the markets, the firms did not have pre-merger competition with each other, whereas in others they competed directly, with varying degrees of competition intensity.[3] Therefore, we can examine not only how the overall product quality is affected by a merger, but also how the quality effects differ across markets, in light of our theoretical predictions.

Our specific measure of air travel product quality is what we refer to as *Routing Quality.* (In Section 3, we discuss in detail why we choose this measure in view of alternative measures of quality.) Related to travel convenience of the air travel product itinerary, routing quality is measured by the percentage ratio of nonstop flight distance to the product's itinerary flight distance used to get passengers from the origin to destination. Since some products have itineraries that require intermediate airport stop(s) that are not on a straight path between the origin and destination, each of these products will have an itinerary flight distance that is longer than the nonstop flight distance. The presumption here is that passengers find a nonstop itinerary most convenient to get to their destination. Therefore, the closer is the product's itinerary flight distance to the nonstop flight distance, i.e. higher values of our routing quality measure, the more desirable is the travel itinerary to passengers.[4]

Our empirical analysis starts by estimating a discrete choice model of air travel demand. This serves two purposes. First, it verifies that passengers' choice behavior is consistent with the hypothesis that a higher routing quality measure is associated with a more passenger-desirable travel itinerary. Second, estimates of the pre-merger cross-price elasticities of demand between the two merging firms, in markets where they competed directly, serve as a useful indicator of the competition intensity. We then proceed to use a reduced-form regression equation of routing quality to evaluate effects that each of the two mergers have on product quality of the merged firms.

Consistent with theory, the regression estimates suggest that each merger is associated with an increase in routing quality, on average 0.45% and 5.28% for DL/NW and CO/UA respectively, in markets where the merging firms did not compete with each other prior to the merger; but with a decline in routing quality, on average 1.35% and 1.05% respectively for the two mergers, in markets where they did. Moreover, in the case of the CO/UA merger, the change in product quality appears to exhibit a U-shaped relationship with the two firms' pre-merger competition intensity.

[3] The intensity of competiton may differ across markets, possibly because product offerings by the two firms differed across markets, or consumers have different preference diversities across markets (as, for example, in Chen and Savage, 2011). Our empirical work will estimate the cross-price elasticities of demand between the two firms' products, which serve as a measure of product differentiation and competition intensity.

[4] See Chen and Gayle (2013) for an earlier version of the discussion in this paper.

Our structural demand estimates further allow us to monetize the consumer gains and losses associated with quality changes. Specifically, in markets where the merging firms had no pre-merger competition, due to their quality improvements, a typical consumer is estimated to experience an increase in utility equivalent to $1.00 and $11.77 for the DL/NW and CO/UA mergers, respectively. In contrast, in markets the merging firms competed prior to their merger, due to their quality declines, a typical consumer is estimated to experience a decrease in utility equivalent to $3.01 and $2.34 respectively for the DL/NW and CO/UA mergers. There are several markets in the sample in which the estimates suggest a typical consumer in these markets experienced a decline in utility greater than $21 due to routing quality declines associated with the merger. These consumer welfare effects are substantial, considering that many of the markets in our sample have populations greater than a million.

Since the deregulation of the US airline industry in 1978, there have been a number of mergers. Empirical studies of these mergers, similar to merger studies in other industries, have largely focused on price effects, and sometimes used these price effects to infer relative changes in market power and cost efficiencies associated with a merger (Werden, Joskow and Johnson, 1989; Borenstein, 1990; Kim and Singal, 1993; Peters, 2006; Luo, 2014). In case of the recent DL/NW and UA/CO mergers, Gayle and Le (2016) estimate marginal, recurrent fixed and sunk entry cost effects associated with these mergers. We are only aware of two concurrent studies in the airline industry that examine the effect of mergers on product quality, Prince and Simon (2017) and Rupp and Tan (2017). Prince and Simon (2017) find that airline mergers have minimal negative impacts on quality, and likely result in long-run improvements. Rupp and Tan (2017) examine how merger-induced de-hubbing impacts product quality. De-hubbing is the phrase used when airlines choose to stop using a particular airport as a hub in their route network structure. Rupp and Tan (2017) find that product quality improvements are associated with merger-induced de-hubbing events, but such quality improvements are not evident when de-hubbing is unrelated to a merger. Unlike our study, neither of these studies consider the possibility that a merger's impact on product quality depends on intensity of pre-merger competition between the carriers that merge.

Several studies of the airline industry examine the relationship between service quality and market structure/competition. For example, Mazzeo (2003) and Rupp, Owens and Plumly (2006) all find evidence that airlines provide worse on-time performance on less competitive routes. Our paper contributes to this literature, as well as to understanding more generally how mergers affect product quality.[5]

In the rest of the paper, we provide the theoretical motivation in section 2, describe the mergers and the data in section 3, and present the empirical model in section 4. Section 5 contains the empirical results, and section 6 concludes.

2 Theoretical Motivation

A merger by two firms allows them to share technology and coordinate production activities, which can positively affect the quality of their products. We call this the *coordination* effect of a merger. For example, an airline merger may allow the two airlines to coordinate their flight schedules to better serve consumer needs. On the other hand, a merger reduces the competitive pressure on quality improvement, which can negatively affect the quality of their products. In the context of an airline merger, this could be reduced product offerings that lessen travel convenience.[6] We call this the *incentive* effect of a merger. Our basic theoretical premise is that whether a merger will raise or lower product quality depends on the interaction of these two potential effects. When pre-merger competition between the two firms is weak, the coordination effect is likely to dominate. Otherwise, the merger is more likely to reduce product quality.

To fix ideas, consider the following simple model. Suppose that the two firms and their respective products are denoted as A and B. Their demand functions are, respectively:

$$\begin{aligned} q_A &= v_A - p_A + \beta\left(p_B - v_B\right), \\ q_B &= v_B - p_B + \beta\left(p_A - v_A\right), \end{aligned}$$

for $\beta \in [0,1)$, where β is a measure of product differentiation, and v_i represents the quality of product i for $i = A, B$. When $\beta = 0$, there is no competition between the two products, whereas a higher β indicates that the two products are closer substitutes, or the two firms have more intense pre-merger competition. Notice that for $\beta > 0$, the demand for product i is higher if the quality-adjusted price for the competing product, $p_j - v_j$, is higher.

[5] Draganska, Mazzeo and Seim (2009) and Fan (2013) constitute important methodological contributions in using econometric models to predict how mergers may influence non-price product characteristic choices. Draganska, Mazzeo and Seim (2009) applied their merger simulation analysis to the ice-cream industry, whereas Fan (2013) applied her merger simulation analysis to the newspaper industry. However, neither study is a retrospective analysis of how non-price product characteristics actually change subsequent to a merger, which is the focus of our study.

[6] For example, competing airlines in a market may each provide nonstop and intermediate stop(s) products prior to merging, but find it profitable to eliminate the more travel-convenient nonstop product post-merger.

Suppose that firm i can choose v_i at cost $\frac{1}{3}v_i^3$, and it chooses v_i and p_i at the same time.[7] Under competition, the two firms make their quality and price choices simultaneously. After merger, the merged firm M can choose v_i with cost $\alpha\frac{1}{3}v_i^3$, where $\alpha \in (1/2, 1]$ reflects the idea that M is able to coordinate its production to possibly have a lower cost for quality. Hence, a lower α indicates a stronger coordination effect. Other costs of production are normalized to zero.

Under competition, the firms' profit functions are:

$$\begin{aligned}\pi_A &= p_A\left[v_A - p_A - \beta\left(v_B - p_B\right)\right] - \frac{1}{3}v_A^3,\\ \pi_B &= p_B\left[v_B - p_B - \beta\left(v_A - p_A\right)\right] - \frac{1}{3}v_B^3.\end{aligned}$$

At a Nash equilibrium, firm $i's$ strategy (p_i, v_i), $i = A, B$, satisfies $\partial\pi_i/p_i = 0$ and $\partial\pi_i/v_i = 0$. The unique symmetric equilibrium, which solves these first-order conditions, give

$$p^d = \frac{(1-\beta)^2}{(2-\beta)^2}; \qquad v^d = \frac{1-\beta}{2-\beta}, \tag{1}$$

and this is also the unique Nash equilibrium when $\beta \leq 0.56$. We shall focus on the symmetric equilibrium for the rest of our analysis.

After the merger, M chooses p_A, p_B, v_A, v_B to maximize its joint profit from both products:

$$\pi_M = p_A\left[v_A - p_A - \beta\left(v_B - p_B\right)\right] + p_B\left[v_B - p_B - \beta\left(v_A - p_A\right)\right] - \frac{\alpha}{3}\left(v_A^3 + v_B^3\right).$$

From the first-order conditions, $\partial\pi_M/p_i = 0$ and $\partial\pi_M/v_i = 0$, $i = A, B$, the merged firm's optimal choices of price and quality are obtained as

$$p^M = \frac{1-\beta}{4\alpha}, \qquad v^M = \frac{1-\beta}{2\alpha}. \tag{2}$$

Notice that the change in product quality due to the merger is

$$v^M - v^d = \left(\frac{1}{2\alpha} - \frac{1}{2-\beta}\right)(1-\beta). \tag{3}$$

It follows that $v^M - v^d < (>)\ 0$ if $2(1-\alpha) < (>)\ \beta$. That is, a merger reduces product quality in markets where the coordination benefit is weak relative to the pre-merger competition incentive (i.e., $2(1-\alpha) < \beta$), but increases product quality in markets where the coordination effect dominates the competition effect (i.e., $2(1-\alpha) > \beta$). We summarize this discussion in the following:

[7] It is possible to extend this analysis to allow q_i to be more general functions of v_i, v_j, p_i, and p_j, as well as to allow more general cost functions of providing v_i. With our more restrictive functional-form assumptions, we aim to obtain closed-form solutions and to illustrate the economic forces in a most transparent way.

Proposition 1. For given $\alpha \in (1/2, 1]$, a merger increases product quality when the pre-merger competition intensity is low (i.e., $\beta < 2(1-\alpha)$), but decreases quality when the pre-merger competition intensity is high (i.e., $\beta > 2(1-\alpha)$). Furthermore, the quality change from the merger, $v^M - v^d$, is a U-shaped function of β, first decreasing and then increasing, reaching its minimum at $\hat{\beta} = 2 - \sqrt{2\alpha}$.

Figure 1 provides a visual representation of the relationship between β and the change in product quality due to the merger, $v^M - v^d$, for given α. Recall that $\alpha \in (0.5, 1]$ and $\beta \in [0, 1)$. As β increases, the curve is initially positive and falling, and it then becomes negative, reaching its minimum at $\hat{\beta} = 2 - \sqrt{2\alpha}$, before rising again. That is, the change in product quality due to the merger varies non-monotonically in β, the measure of competition intensity between the firms before merger. This suggests that the incentive to raise product quality under duopoly is often the highest at some intermediate strength of competition.[8] Intuitively, while competitive pressure motivates firms to improve product quality, the diminished profit under competition, especially when competition strength goes beyond certain point, can weaken the incentive for costly quality provision. Therefore, the change in product quality due to a merger may be a U-shaped function of the competitiveness between the two firms prior to the merger.

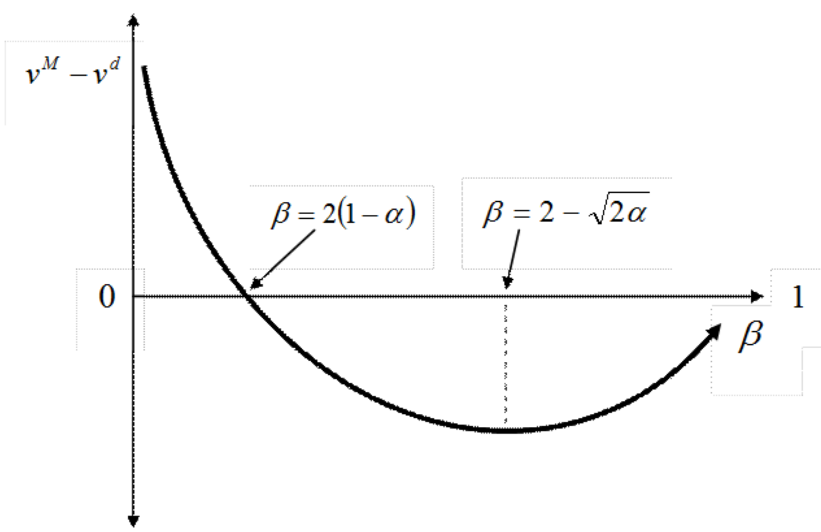

Figure 1: Relationship between β and $v^M - v^d$

[8] This has an interesting connection to the literature on the relationship between competition and innovation, where it has been found that the innovation incentive generally varies non-monotonically in competition intensity, with the highest incentive occurring at some intermediate level (Aghion, et al., 2005).

An alternate interpretation of Proposition 1 is that product quality can be higher under either a multiproduct monopoly or duopoly competition, depending on the relative sizes of the coordination and incentive effects. This is related to Chen and Schwartz (2013), who find that product innovation incentives can be higher under either monopoly or (duopoly) competition, depending on the balance of what they term as the price coordination and the profit diversion effects. Their result is obtained in a spatial framework with fixed total industry output.[9] While our model here is illustrative, it adds to the literature by suggesting that a comparison of innovation incentives similar to that in Chen and Schwartz (2013) can be made also when total output is not fixed.[10]

To provide a clear illustration of the potential quality effects of a merger, our model has made strong assumptions on the functional forms and abstracted from considerations of other possible competitors in the market (which we will control for in our empirical analysis). Despite these restrictions, we believe that the economic forces illustrated here are general, and the trade-offs between the coordination and incentive effects, as well as their implications, will be valid in more general settings. This theoretical model thus serves the purpose of motivating our empirical analysis. Its first implication, that a merger increases product quality in markets where the two firms have little pre-merger competition but may reduce quality when pre-merger competition is significant, does not depend on the specifics of the model. Its second implication, that there is a U-shaped relationship between pre-merger competition intensity and the quality change from the merger, is more likely to hinge on the specific functional forms we have assumed. In light of these theoretical insights, we next turn to empirical analysis.

3 The Mergers and the Data

This section describes the mergers, our quality measure, and the data.

3.1 The Mergers

Delta Airlines (DL) and Northwest Airlines (NW) announced their plan to merge on April 14, 2008. At the time of the merger, Delta and Northwest were the third and fifth largest airlines in

[9] In his seminal contribution, Arrow (1962) shows that a monopolist has lower incentive than competing firms for *process innovation*, because the cost reduction from the innovation applies to a smaller output under monopoly. Chen and Schwartz (2013) shows, howerver, that *product innovation* incentive could be higher under monopoly than under competition due to a different tradoff.

[10] The effect of competition on innovation has also been examined in models of continual innovation, where intensified competition motivates a firm to innovate more in order to escape competition, but may also decrease innovation incentive—through the Schumpeterian effect—by reducing the profit gain from innovation (e.g., Aghion et al, 2005).

the United States, with Delta having its primary hub in Atlanta, Georgia and Northwest having its primary hub in Minneapolis, Minnesota. On October 29, 2008, the U.S. Department of Justice (DoJ) approved the merger after being convinced that it should have minimal anti-competitive effects.[11]

The executives of the two airlines asserted that the merger will benefit customers, employees, shareholders, and the communities they serve.[12] Moreover, they argued that the merger will help create a more resilient airline for long-term success and financial stability. In terms of possible efficiency gains from the merger, they anticipated that cost synergies will be achieved by 2012. Benefits are 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.

United Airlines (UA) and Continental Airlines (CO) announced their plan to merge on May 3, 2010. 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. It is believed that UA and CO are compatible partners in many ways.[13] For example, both have similar fleets and operated in different geographic markets that complement each other. Flying mainly Boeing aircrafts is likely to help with reducing costs associated with multiple orders. Operating in distinct geographical markets is likely to enable 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.

While cost efficiency gains are anticipated from both mergers, it is more difficult to predict whether the quality of products offered by the newly merged firms will be higher or lower.

3.2 Measuring Product Quality

A challenge that empirical work faces in studying the relationship between merger and product quality is to find reasonable measure(s) of product quality. The literature on the airline industry correctly views timeliness of service as an important dimension of air travel service quality.[14] Var-

[11] Department of Justice (2008), "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>

[12] Seeking Alpha (2008), "Delta Air Lines, Northwest Airlines Merger Call Transcript." 16 April 2008. <http://seekingalpha.com/article/72537-delta-air-lines-northwest-airlines-merger-call-transcript>

[13] 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>

[14] Another important quality measure that has been considered in the literature is airline safety (e.g., Rose, 1990).

ious papers have analyzed different aspects of timeliness. The three main quality dimensions of service timeliness analyzed in the literature are: (i) "On-time performance," measured by carrier delay time when servicing a given set of itineraries; (ii) "Schedule delay", which is a gap between a passenger's preferred departure time and actual departure time; and (iii) travel time required to complete a given itinerary in getting the passenger from the origin to destination. Studies in the literature typically measure (i) directly from available data on flight delay,[15] but quality dimensions (ii) and (iii) are typically measured indirectly using data that are posited to be correlated with these quality dimensions.[16]

Indirect measures of quality dimension (iii) used in the literature, which is the focus of our paper, are typically itinerary flight distance-based. For example, Dunn (2008) uses the flight distance required for a product with intermediate stop relative to the nonstop flight distance between the origin and destination. A nonstop flight between the origin and destination will have the shortest itinerary flight distance. Since some products require intermediate airport stop(s) that are not on a straight path between the origin and destination, each of these products will have an itinerary flight distance that is longer than the nonstop flight distance. The rationale is that "directness" of the travel itinerary is correlated with required travel time, and the itinerary flight distance relative to nonstop flight distance is a measure of "directness". The greater the itinerary flight distance of an intermediate stop product relative to the nonstop flight distance, the lower the quality of this intermediate stop product. Other studies that have used this distance-based measure of air travel itinerary quality, which is referred to as itinerary convenience/inconvenience in some studies, include: Reiss and Spiller (1989); Borenstein (1989); Ito and Lee (2007); Fare, Grosskopf and Sickles (2007); and Gayle (2007 and 2013).

Our specific measure of air travel product quality, which we refer to as *Routing Quality*, is the percentage ratio of nonstop flight distance to the product's itinerary flight distance used to get passengers from the origin to destination. Therefore, the *Routing Quality* variable has only strictly positive values, where the maximum value is 100 in the case that the product itinerary consists of a nonstop flight. As suggested above, the presumption is that passengers find a nonstop itinerary

[15] Studies that analyze these direct measures of "On-time performance" include: Gayle and Yimga (forthcoming); Prince and Simon (2017); Fare, Grosskopf and Sickles (2007); Mazzeo (2003); Mayer and Sinai (2003); Rupp, Owens and Plumly (2006); Rupp and Sayanak (2008); Rupp and Tan (2017); among others.

[16] An indirect measure of quality dimension (ii) used in the literature is flight frequency [see Brueckner (2004); Brueckner and Girvin (2008); Brueckner and Pai (2009); Brueckner and Luo (2014); Fare, Grosskopf and Sickles (2007); Girvin (2010)].

most convenient to get to their destination, so higher values of *Routing Quality* are associated with a more passenger-desirable travel itinerary. While this seems reasonable, the structural demand model that we subsequently describe will provide empirical validation to this presumption.

Optimal integration of the merging airlines' route networks may involve elimination of some products, and creation of others. Depending on what types of products are eliminated versus what types are kept or created, the merging airlines' average routing quality in a market may either increase or decrease. As pointed out in Rupp and Tan (2017), mergers often induce the merged airline to cease using an airport as a hub in its route network system, a phenomenon known as de-hubbing. Merger-induced de-hubbing may also result in a change in the routing quality of products offered by the merged airline. Rupp and Tan (2017) document that both the Delta/Northwest and United/Continental mergers are associated with de-hubbing decisions. Figures 2 and 3 give examples of how routing quality may change due to an airline merger.

First, consider Figure 2 which illustrates possible product offerings in origin-destination market B to C. Prior to merger there are two airlines, A1 and A2, but these airlines do not compete in market B to C since A1 is the only airline that transports passengers from city B to city C via its most travel-convenient intermediate-stop hub city H1. A2 only transports passengers from its hub city H2 to city C. In the absence of a merger, if A1 wants to improve its routing quality in market B-C, it has to undertake a costly investment of adding its own nonstop flight from B to C. It is possible that the effective cost to A1 of adding and operating such a nonstop flight is prohibitive. However, since A2 already offers service from H2 to C, by merging with A2, the merged firm only needs to undertake the investment of adding a flight from B to H2 in order to offer an intermediate-stop product of better routing quality compared to the pre-merger intermediate-stop product. To service the B-C market, it is possibly more cost-efficient for an airline to leverage an already existing network through hub city H2 by simply adding a flight from B to H2, compared to operating a new direct flight from B to C. In fact, as Rupp and Tan (2017) argue, the merged airline may even find it optimal to abandon hub H1 given the existence of its hub at H2, a merger-induced de-hubbing decision. This example directly relates to the positive *coordination effect* of a merger on product quality discussed earlier.

A merger may still result in improved routing quality of the merged airline's products even absent the merged airline's optimal reconfiguration of its route network described above. In particular, since a merged airline often keeps most of the hubs of the pre-merger partners, the result is usually a better geographic spacing of hubs, which in turn makes the most-direct connecting route shorter than before. So better product quality can just be the result a denser pattern of hubs, with no subtle strategic effects, although strategic effects may also be at work.

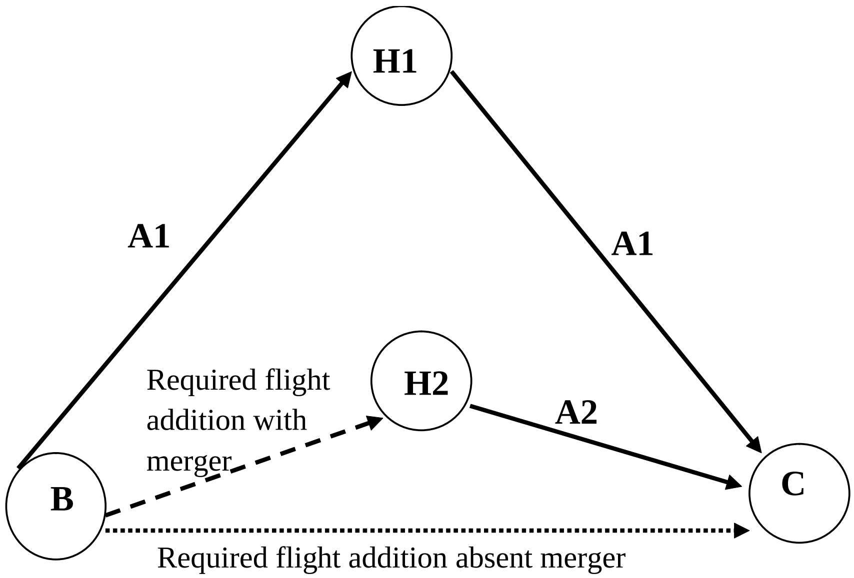

Figure 2: Options for Improvement in *Routing Quality* in origin-destination market B to C.

Second, consider Figure 3 which illustrates possible product offerings in origin-destination market D to E. Prior to merger, airline A1 is a multi-product firm in market D-E, offering a nonstop product from city D to city E, as well as a differentiated substitute intermediate-stop product via its hub city H1. Furthermore, prior to merger, airline A2 directly competes with A1 in market D-E by offering its own nonstop product between the two cities. A merger between A1 and A2 may incentivize the merged firm to eliminate the intensely competing, but travel-convenient, nonstop products. In this case the merger would reduce routing quality of the merged firm in origin-destination market D-E, an outcome we would attribute to the negative *incentive effect* discussed earlier.

A reason it may be optimal to eliminate the nonstop products post-merger in Figure 3 is owing to a combination of two reinforcing economic forces: (1) the intermediate-stop product may offer the newly merged airline better opportunities to exploit economies of passenger-traffic densities - i.e. achieve lower transport cost per passenger when transporting a higher volume of passengers - since the airline can better fill a single plane with passengers that have either city H1 or city E as their final destination; and (2) the competitive pressure from airline A2 that incentivized airline A1 to offer the potentially more transport-costly nonstop product in the pre-merger period is now absent in the post-merger period due to the merger. So the merger reduces the competitive intensity, which may consequently expand opportunities for the merged firm to better exploit economies of passenger-traffic densities.

A reasonable question to raise at this point is: In the post-merger period why not choose to eliminate the intermediate-stop product instead and use the non-stop product to exploit economies of passenger-traffic density?[17] The reason is that, holding all other factors constant, the intermediate-stop product is likely better for exploiting economies of passenger-traffic density compared to the nonstop product because the intermediate-stop product has an extra city on the itinerary that itself is a destination of interest for a set of passengers that the airline can use for increasing the volume of passengers it transports on a segment of the intermediate-stop itinerary. So the lower routing quality product may offer better opportunities for the airline to exploit economies of passenger-traffic density, but from a consumer perspective these products are less convenient for travel.[18]

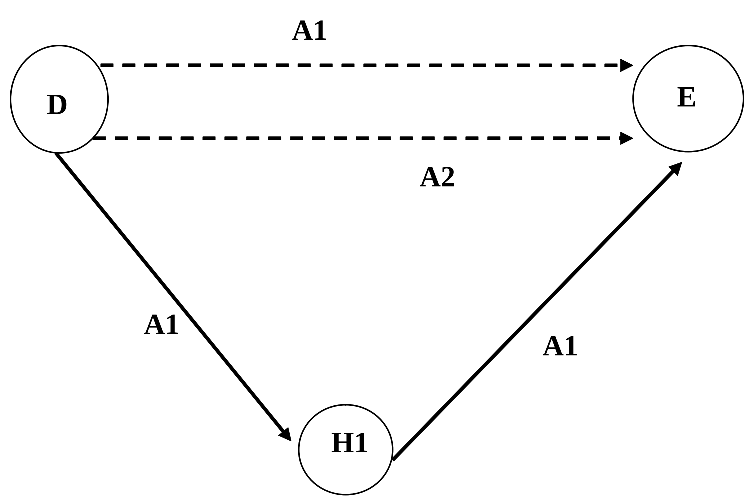

Figure 3: Potential Post-merger Decline in *Routing Quality* in origin-destination market D to E.

Even though airline on-time performance measures such as minutes delay have been used to measure product quality [Prince and Simon (2017); and Rupp and Tan (2017)], we believe that

[17] We thank an anonymous referee for raising this question.

[18] Absent economies of passenger-traffic densities considerations, in situations depicted in Figure 3 it is conceivable that the merged airline may choose to eliminate the lower routing quality product.

routing quality is one of the better measurable quality dimensions of air travel service that is more directly related to optimal choices of an airline. The task of our empirical analysis, then, is to understand how optimal integration of the merging airlines' networks influences their routing quality in a market.

3.3 Data

Data are drawn from the Origin and Destination Survey (DB1BMarket) published by the Bureau of Transportation Statistics. The data are quarterly and constitute a 10 percent random sample of airline tickets from reporting carriers. An observation is a flight itinerary that provides information on: (i) the identity of airline(s) associated with the itinerary; (ii) airfare; (iii) number of passengers that purchase the specific itinerary; (iv) market miles flown in getting the passenger from the origin to destination; and (v) the identity of origin, destination and intermediate stop(s) airports. Unfortunately, the DB1B data do not contain passenger-specific information, or information on ticket restrictions such as advance-purchase and length-of-stay requirements; such information would facilitate estimation of a richer demand model than the one we use based on available data.

The time span of the data we use is the first quarter of 2005 to the third quarter of 2013. This time span covers pre and post-merger periods for each merger. A market is defined as directional origin-destination-time period combination. Directional means that Dallas to Atlanta is a different market from Atlanta to Dallas. 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). Airports that serve a common metropolitan area are grouped to constitute a single endpoint for a defined market.[19] Therefore, our defined markets better correspond to "city" pairs rather than airport pairs, where the term "city" is loosely used in the sense that it corresponds to a metropolitan area at the endpoint of some markets in our sample. In Table 1, we report a list of the cities, corresponding airport groupings and population estimate in 2009. Potential market size is measured by the size of population in the origin city.

[19] As discussed in Brueckner, Lee and Singer (2014), there exists formal scientific methods to group airports across metropolitan areas, however we simply followed the airport grouping used in Aguirregabiria and Ho (2012).

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	Pittsburgh, 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			

A product is defined as an itinerary-operating carrier combination during a particular time period. An example is a direct flight from Dallas to Atlanta operated by American Airlines. We focus on products that use a single operating carrier for all segments of the trip itinerary. Table 2 reports the names and associated code of the carriers in our sample. We recode feeder/regional airlines to their matching major airlines. For example, American Eagle (MQ) operates on a regional airline level, and feeds passengers to American Airlines (AA). Therefore, American Eagle is recoded to take the code of the major airline to which it feeds passengers for the itinerary under consideration. The footnotes of Table 2 provide other regional carriers that were recoded to match their major carriers.

Table 2
List of Airlines in the 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)

An observation in the raw data is an itinerary showing airline(s), origin, destination and intermediate stop(s) airports associated with the itinerary, as well as the number of passengers that purchase this itinerary at a given price. Therefore, a given itinerary is listed multiple times in the raw data if different passengers paid different prices for the same itinerary. We focus on round-trip itineraries across all fare classes.[20] Our price and quantity variables are constructed by averaging the airfare and aggregating number of passengers, respectively, based on our product definition, and then collapse the data by product. Therefore, in the collapsed data that we use for analyses a product appears only once during a given time period. In order to avoid products that are not part of the regular offerings by an airline, we drop products that are purchased by less than 9 consumers during a quarter.

Observed product shares (denoted as upper case S_j) are constructed by dividing quantity of product j purchased (denoted as q_j) by origin city population (denoted as POP), i.e., $S_j = \frac{q_j}{POP}$. In addition to *Routing Quality*, we create two other non-price product characteristic variables: (i) *Origin Presence,* which is computed by aggregating the number of destinations that an airline connects with the origin city of the market 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. (ii) *Nonstop*, which is a zero-one dummy variable that equals to one only if the product uses a nonstop flight to get passengers from the origin to destination.

There are two variables we use to measure level of competition faced by a given product in a market, possibly from competitors other than a merging airline: (i) *N_ comp_ nonstop,* which is the number of nonstop products offered by an airline's competitors in the market; and (ii) *N_ comp_ connect*, which is the number of products that require intermediate stop(s) offered by an airline's competitors in the market.

Summary statistics of variables used in estimation are reported in Table 3.

[20] In the discrete choice demand model we estimate an implicit constraint is that choice effects are the same across fare classes.

Table 3
Descriptive Statistics
Time period span of data: 2005:Q1 to 2013:Q3

Variable	Mean	Std. Dev.	Min	Max
Price[a]	168.45	50.2468	38.51	1522.46
Quantity	213.1456	601.8889	9	11643
Observed Product Shares (??)	0.0003	0.00095	1.01E-06	0.0458
Origin presence	30.2667	26.205	0	177
Destination presence	30.1597	26.003	0	176
Nonstop (dummy variable)	0.238	0.426	0	1
Itinerary distance flown (miles)[b]	1533.106	720.817	36	4099
Nonstop flight distance (miles)	1371.844	668.652	36	2724
Routing Quality (measured in %)	89.96	12.70	32.33	100
N_comp_nonstop	2.33	2.49	0	23
N_comp_connect	8.62	7.87	0	71
Number of Products	804,242			
Number of markets[c]	97,593			

[a] Inflation-adjusted.
[b] In DB1B database this variable is reported as "Market miles flown".
[c] A market is defined as an origin-destination-time period combination.

4 The Empirical Model

In the spirit of Peters (2006), Gayle and Le (2016), and among others, we first specify a discrete choice model of air travel demand. This demand model is used to empirically validate that consumers' choice behavior is consistent with our presumption that higher values of *Routing Quality* is associated with a more passenger-desirable travel itinerary. It also provides estimates of the pre-merger cross-price elasticities of demand between the two merging firms in markets where they competed directly. These cross-price elasticities serve as a useful indicator of their pre-merger competition intensity. A reduced-form regression model of routing quality is subsequently specified to identify the merger's quality effects.

4.1 Air Travel Demand

Air travel demand is based on a nested logit model. Potential passenger i in market m during time period t faces a choice between $J_{mt}+1$ alternatives. There are $J_{mt}+1$ alternatives because we allow passengers the option not to choose one of the J_{mt} differentiated air travel products. Products in a market are thus assumed to be organized into $G+1$ exhaustive mutually exclusive groups/nests,

$g = 0, 1, ..., G$, in which the outside good, $j = 0$, is the only member of group 0.

A passenger solves the following optimization problem:

$$\underset{j \in \{0,...,J_{mt}\}}{Max} \left\{ U_{ijmt} = \delta_{jmt} + \sigma \zeta_{imtg} + (1 - \sigma) \varepsilon_{ijmt} \right\}, \tag{4}$$

where U_{ijmt} is the level of utility passenger i will obtain if product j is chosen, while δ_{jmt} is the mean level of utility across passengers that consume product j. δ_{jmt} is a function of the characteristics of product j, as we will describe shortly. ζ_{imtg} is a random component of utility that is common to all products in group g, whereas the random term ε_{ijmt} is specific to product j and is assumed to have an extreme value distribution.

The parameter σ, lying between 0 and 1, measures the correlation of the consumers' utility across products belonging to the same group. Since products are grouped by airlines, σ measures the correlation of the consumers' utility across products offered by a given airline. As σ increases, the correlation of preferences among products offered by the same airline within a market increases; hence, the closer σ is to 1, the more airline-loyal consumers are.

The mean utility function is specified as:

$$\begin{aligned} \delta_{jmt} &= \beta_0 + \beta_1 Price_{jmt} + \beta_2 Origin\ Presence_{jmt} + \beta_3 Nonstop_{jmt} \\ &\quad + \beta_4 Routing\ Quality_{jmt} + \lambda_a + \eta_t + origin_m + dest_m + \xi_{jmt}, \end{aligned} \tag{5}$$

where β_1, β_2, β_3, and β_4 are consumer taste parameters (marginal utilities) associated with the measured product characteristics, λ_a are airline fixed effects captured by airline dummy variables, η_t are time period fixed effects captured by quarter and year dummy variables, $origin_m$ and $dest_m$ are respectively market origin and destination fixed effects, and ξ_{jmt} captures unobserved (by the researchers but observed by passengers) product characteristics. The expected signs of the marginal utility parameters are: $\beta_1 < 0$; $\beta_2 > 0$; $\beta_3 > 0$; and $\beta_4 > 0$. A positive and statistically significant estimate of β_4 would empirically validate that consumers' choice behavior is consistent with that higher values of our *Routing Quality* measure are associated with a more desirable travel itinerary.

It is well-known in empirical industrial organization that the model above results in the following linear equation to be estimated:

$$\begin{aligned} \ln(S_{jmt}) - \ln(S_{0mt}) &= \beta_0 + \beta_1 Price_{jmt} + \beta_2 Origin\ Presence_{jmt} + \beta_3 Nonstop_{jmt} \\ &\quad + \beta_4 Routing\ Quality_{jmt} + \sigma \ln\left(S_{jmt|g}\right) \\ &\quad + \lambda_a + \eta_t + origin_m + dest_m + \xi_{jmt}, \end{aligned} \tag{6}$$

where S_{jmt} is the observed share of product j computed from data by $S_{jmt} = \frac{q_{jmt}}{POP_{mt}}$, in which q_{jmt} is the quantity of product j purchased and POP_{mt} is the potential market size measured by origin city population. $S_{0mt} = 1 - \sum_{j \in J_{mt}} S_{jmt}$ is the observed share of the outside option; $S_{jmt|g}$ is the observed within-group share of product j; and ξ_{jmt} is the structural demand error term.

4.1.1 Instruments

Since $Price_{jmt}$ and $\ln\left(S_{jmt|g}\right)$ are endogenous, we use two-stage least squares (2SLS) to estimate equation (6). We use a product's itinerary flying distance to instrument for its price. As discussed in Gayle (2007 and 2013), Gayle and Thomas (2016) and Gayle and Xie (forthcoming), this instrument is motivated by the fact that a product's price is influenced by the marginal cost of providing the product, and flying distance covered by an air travel product is likely to be correlated with the marginal cost of providing the product.

As in Gayle and Thomas (2016) and Gayle and Yimga (forthcoming), to instrument for within group product share, $\ln\left(S_{jmt|g}\right)$, we use a variable that measures the deviation of a products' routing quality from the mean routing quality of the set of products offered by the airline in the market. Recall that the nested logit demand model we use is constructed based on grouping/nesting products by airlines in a market. This means that a product's within group share is based on how attractive it is to passengers relative to the other products offered by the airline, which is why a product's within group share should be correlated with the deviation of the products' routing quality measure from the mean routing quality of the set of products offered by the airline in the market.[21]

The previous discussion of the instruments suggests why the instruments are likely correlated with the endogenous variables, but to be useful, we need these instrument to be uncorrelated with the shocks to demand captured by ξ_{jmt}. The fact that the menu of products offered by airlines in a market is predetermined at the time of shocks to demand is likely to make our choice of instruments uncorrelated with shocks to demand. Furthermore, as argued in Gayle and Xie (forthcoming), Gayle and Yimga (forthcoming), Gayle and Thomas (2016) and Gayle (2007 and 2013), unlike price and within group product share, 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

[21] In situations where the airline only offers a single product in the market, which implies that this product has a within group share of 1, the deviation of routing quality instrument variable is constructed to take the maximum value of the routing quality measure of 100.

the influence of demand shocks on the menu of products offered and their non-price characteristics. Therefore, a product's itinerary flying distance and its routing quality measure are predetermined during the short-run period of price-setting by airlines and product choice by passengers, which makes these valid non-price product characteristics to use for constructing instruments.

4.2 Reduced-form Routing Quality Equation

We use a reduced-form regression equation of *Routing Quality* to evaluate effects that each of the two mergers have on routing quality of the merged firms. A difference-in-differences strategy is used to identify possible merger effects on routing quality, i.e., we compare pre-post merger periods changes in routing quality of products offered by the firms that merge, relative to changes in routing quality of products offered by non-merging firms over the relevant pre-post merger periods. Recall that the full data set span the period 2005:Q1 to 2013:Q3. We use 2008:Q4 to 2013:Q3 for the DL/NW post-merger period, while 2010:Q4 to 2013:Q3 is used for the CO/UA post-merger period.

We use the following reduced-form specification of the *Routing Quality* equation:

$$\begin{aligned} Routing\ Quality_{jmt} &= \gamma_0 + \gamma_1 Origin\ Presence_{jmt} + \gamma_2 Destination\ Presence_{jmt} \\ &+ \gamma_3 Nonstop\ Flight\ Distance_m + \gamma_4 N\_comp\_connect_{jmt} \\ &+ \gamma_5 N\_comp\_nonstop_{jmt} + \gamma_6 DN_{jmt} + \gamma_7 T_t^{dn} + \gamma_8 T_t^{dn} \times DN_{jmt} \\ &+ \gamma_9 CU_{jmt} + \gamma_{10} T_t^{cu} + \gamma_{11} T_t^{cu} \times CU_{jmt} + \lambda_a + \eta_t + origin_m + dest_m + \mu_{jmt}, \end{aligned} \tag{7}$$

where DN_{jmt} is a zero-one airline-specific dummy variable that takes the value one only for products offered by Delta or Northwest, while T_t^{dn} is a zero-one time period dummy variable that takes a value of one only in the DL/NW post-merger period. Considering the entire time span of the data set, γ_6, which is the coefficient on DN_{jmt}, tells us whether the routing quality of Delta and Northwest products systematically differs from the routing quality of products offered by other airlines. γ_7, which is the coefficient on T_t^{dn}, tells us how routing quality of products offered by airlines other than Delta or Northwest change over the DL/NW pre-post merger periods. On the other hand, γ_8, which is the coefficient on the interaction variable $T_t^{dn} \times DN_{jmt}$, tells us if routing quality of products offered by Delta or Northwest changed differently relative to routing quality changes of products offered by other airlines over the DL/NW pre-post merger periods. Therefore, γ_8 should capture changes in the routing quality of products offered by Delta and Northwest that are associated with the DL/NW merger.

Parameters γ_9, γ_{10} and γ_{11} are interpreted analogously to γ_6, γ_7 and γ_8, but relate to the CO/UA merger. For example, γ_{11} tells us if routing quality of products offered by Continental or United changed differently relative to routing quality changes of products offered by other airlines over the CO/UA pre-post merger periods. Therefore, γ_{11} should capture changes in the routing quality of products offered by Continental and United that are associated with the CO/UA merger.

In the subsequent empirical analysis we do augment the interaction variables, $T_t^{dn} \times DN_{jmt}$ and $T_t^{cu} \times CU_{jmt}$, to investigate how the quality effects of each merger vary across markets with different levels of pre-merger competition intensity between the firms that merge. Therefore, the routing quality equation in (7) can be thought of as a baseline specification, which we meticulously augment to investigate predictions from our theoretical model.

As mentioned in the data section, *N_ comp_ nonstop* measures the number of nonstop products offered by an airline's competitors in the market, while *N_ comp_ connect* measures the number of products that require intermediate stop(s) offered by an airline's competitors in the market. Therefore, these two variables are used to control for the level of product-type-specific competition faced by a given product in a market. We also control for the effect of distance between the origin and destination (*Nonstop Flight Distance*), and also for the size of an airline's presence at the endpoint airports of the market (*Origin Presence* and *Destination Presence*). Note that unobserved airline-specific (λ_a), time period-specific (η_t), origin-specific ($origin_m$), and destination-specific ($dest_m$) effects are controlled for in the reduced-form routing quality regression.

The reduced-form routing quality regression is estimated using ordinary least squares (OLS).

5 Empirical Results

5.1 Estimates from Demand Equation

Recall that price and within-group product shares are endogenous variables in the demand equation. Therefore, OLS estimates of coefficients on these variables will be biased and inconsistent. To get a sense of the importance of using instruments for these endogenous variables, Table 4 reports both OLS and 2SLS estimates of the demand equation. The OLS estimates of the coefficients on *Price* and $\ln\left(S_{jmt|g}\right)$ are very different than the 2SLS estimates, in fact the OLS coefficient estimate on *Price* is positive and therefore contrary to standard demand theory. A formal Wu-Hausman statistical test of exogeneity, reported in Table 4, confirms the endogeneity of *Price* and $\ln\left(S_{jmt|g}\right)$. Simple regressions in which *Price* is regressed on its instrument, and $\ln\left(S_{jmt|g}\right)$ regressed on its instrument produce R-squared values of 0.15 and 0.39 respectively. In addition, the coefficient estimate on the instrument variable in each of these regressions is statistically significant at the 1% level, indicating that the instruments do explain variations in the endogenous variables.[22]

Given the clear need to instrument for *Price* and $\ln\left(S_{jmt|g}\right)$, the remainder of our discussion of the demand estimates focuses on the 2SLS estimates. Furthermore, since all coefficient estimates are statistically significant at conventional levels of statistical significance, the discussion focuses on the relationship between the measured product characteristic and consumer choice behavior that is implied by the sign of the relevant coefficient estimate.

Table 4

Demand Estimation Results

804,242 observations: 2005:Q1 to 2013:Q3

	OLS		**2SLS**	
Variable	Coefficient	Std. Error	Coefficient	Std. Error
Price	0.00025***	0.00003	-0.00897***	0.00007
$\ln(S_{j/g})$	0.50430***	0.00094	0.19455***	0.00236
Origin presence	0.01343***	0.00006	0.01138***	0.00008
Nonstop	1.05856***	0.00416	1.23368***	0.00418
Routing Quality	0.01730***	0.00009	0.02024***	0.00012
Constant	-11.91585***	0.02725	-10.9138***	0.03081
Carrier fixed effects	YES		YES	
Quarter and Year fixed effects	YES		YES	
Origin city fixed effects	YES		YES	
Destination city fixed effects	YES		YES	
R-squared	0.645		0.5432	

Tests of endogeneity

Ho: variables are exogenous

Wu-Hausman: 24092.6*** F(2; 804,075) Prob_Value = 0.000

*** Statistical significance at the 1% level.

As expected, an increase in the product's price reduces the probability that the product will be chosen by a typical consumer. The coefficient estimate on $\ln\left(S_{jmt|g}\right)$, which is an estimate of σ, is closer to zero rather than one. This suggests that although consumers do exhibit some loyalty to airlines, their loyalty is not strong.

The larger the size of an airline's operations at the consumer's origin airport, as measured by the *Origin Presence* variable, the more likely the consumer is to choose one of the products offered

[22] Since there are two endogenous variables and two instruments, the demand equation is exactly identified.

by the airline. This result can be interpreted as capturing a "hub-size" effect on air travel demand. Since airlines typically offer better services at their hub airports, such as frequent and convenient departure times, the positive "hub-size" demand effect is consistent with our expectation.[23]

The positive coefficient estimate on the *Nonstop* dummy variable suggests that passengers prefer products that use a nonstop flight itinerary from the origin to destination. In fact, if we divide the coefficient estimate on the *Nonstop* dummy variable by the coefficient estimate on *Price*, this ratio suggests that consumers are willing to pay up to \$137.57 extra, on average, to obtain a product with a nonstop itinerary in order to avoid products with intermediate stop(s).

The positive coefficient estimate on the *Routing Quality* variable suggests that consumers prefer products with itinerary flight distances as close as possible to the nonstop flight distance between the origin and destination. This provides empirical validation that higher values of our routing quality measure are associated with a more passenger-desirable travel itinerary. In fact, if we divide the coefficient estimate on the *Routing Quality* variable by the coefficient estimate on the *Price* variable, this ratio suggests that consumers are willing to pay up to \$2.23, on average, for each percentage point increase that the nonstop flight distance is of the actual itinerary flight distance.

The demand model yields a mean own-price elasticity of demand estimate of -1.67. Oum, Gillen and Noble (1986) and Brander and Zhang (1990) argue that a reasonable estimate for own-price elasticity of demand in the airline industry lies in the range of -1.2 to -2.0. Therefore, the mean own-price elasticity estimate produced by our demand model appears reasonable.

Last, the demand model yields mean cross-price elasticity of demand estimates of 0.00027 between Delta and Northwest products, and 0.00034 between Continental and United products during their respective pre-merger periods; the former is smaller than the latter, and the difference is statistically significant. Recall that our theoretical model suggests that the intensity of pre-merger competition (as measured by cross-elasticity of demand) between merging firms' products matters for the quality effect of a merger. The empirical analysis in the next subsection verifies this theoretical prediction.

[23] Instead of using the *Origin Presence* variable, we also estimated the demand equation using a dummy variable (*HUB_origin*) for whether or not the origin airport is a hub for the airline offering the product. The qualitative results are robust to using either *Origin Presence* or *HUB_origin* to capture the size of an airline's operations at the origin airport. Since airlines typically have multiple hub airports, and the size of an airline's operations may differ across its hub airports, we favor using *Origin Presence* since it is a continuous variable and therefore better able to capture heterogeneity in the size of an airline's operations across different airports.

5.2 Estimates from Reduced-form Routing Quality Equation

Table 5 reports estimates of the reduced-form routing quality equation. The table provides three columns of coefficient estimates. Coefficient estimates in the first column can be thought of as a baseline specification of the equation (Specification 1), while the other three columns (Specifications 2 and 3) incrementally assess how various factors influence the quality change from each merger.

Table 5
Estimation Results for Reduced-form Routing Quality Regression
804,242 observations: 2005:Q1 to 2013:Q3

	Dependent Variable: *Routing Quality* (in %)		
	Specification 1 OLS	**Specification 2 OLS**	**Specification 3 OLS**
	Coefficient (Robust Std. Error)	Coefficient (Robust Std. Error)	Coefficient (Robust Std. Error)
Variable			
Constant	88.364*** (0.2608)	88.338*** (0.2605)	88.306*** (0.2606)
Origin Presence	0.068*** (0.0007)	0.068*** (0.0007)	0.069*** (0.0007)
Destination Presence	0.066*** (0.0008)	0.065*** (0.0008)	0.066*** (0.0008)
Nonstop Distance (Miles)	0.005*** (0.00004)	0.005*** (0.00004)	0.005*** (0.00004)
N_comp_connect	-0.165*** (0.0029)	-0.168*** (0.0029)	-0.169*** (0.0029)
N_comp_nonstop	0.273*** (0.0094)	0.260*** (0.0094)	0.261*** (0.0094)
MKT_{bm}^{dn}	-	-0.401*** (0.0571)	-0.407*** (0.0571)
DN_{jmt}	-13.419*** (0.2059)	-13.467*** (0.2059)	-13.479*** (0.2061)
T_t^{dn}	-0.801*** (0.0950)	-0.790*** (0.0950)	-0.795*** (0.0950)
$T_t^{dn} \times DN_{jmt}$	-0.345*** (0.0694)	1.239*** (0.1695)	1.235*** (0.1694)
$MKT_{bm}^{dn} \times T_t^{dn} \times DN_{jmt}$	-	-1.797*** (0.1690)	-1.771*** (0.1726)
$E_{bm}^{dn} \times MKT_{bm}^{dn} \times T_t^{dn} \times DN_{jmt}$	-	-	266.357 (192.737)
$(E_{bm}^{dn})^2 \times MKT_{bm}^{dn} \times T_t^{dn} \times DN_{jmt}$	-	-	-130104.300*** (28144.34)
MKT_{bm}^{cu}	-	-1.017*** (0.0465)	-1.021*** (0.0465)
CU_{jmt}	-12.605*** (0.2054)	-12.639*** (0.2054)	-12.646*** (0.2055)
T_t^{cu}	-0.322*** (0.0961)	-0.327*** (0.0960)	-0.333*** (0.0960)
$T_t^{cu} \times CU_{jmt}$	0.177** (0.0821)	5.609*** (0.1834)	5.600*** (0.1834)
$MKT_{bm}^{cu} \times T_t^{cu} \times CU_{jmt}$	-	-6.329*** (0.1879)	-6.104*** (0.1919)
$E_{bm}^{cu} \times MKT_{bm}^{cu} \times T_t^{cu} \times CU_{jmt}$	-	-	-716.357*** (119.673)
$(E_{bm}^{cu})^2 \times MKT_{bm}^{cu} \times T_t^{cu} \times CU_{jmt}$	-	-	58037.38*** (15769.14)
R-squared	0.1639	0.1662	0.1665

*** indicates statistical significance at the 1% level, ** indicates statistical significance at the 5% level, while * indicates statistical significance at the 10% level. Estimation of each regression includes fixed effects for carriers, time periods, origin cities, and destination cities, even though their associated coefficients are not reported in the table. Since dummy variables for the merging carriers, *DN* and *CU*, are separately included in each regression, the carrier fixed effects not reported are among the non-merging airlines. OLS: Ordinary least squares.

Estimates of the constant term across the regression specifications are approximately 88.3. Therefore, assuming all determinants of routing quality in the regressions are held at zero, the mean routing quality measure across all products in the sample is approximately 88.3. This means that nonstop flight distances between origins and destinations are on average 88.3% of the flight distances associated with product itineraries used by passengers in the sample markets. Of course, this mean routing quality will change with each of the measured routing quality determinants in the regressions. We now examine the impact of each of the measured routing quality determinants.

5.2.1 Impact of Measured Determinants of Routing Quality

Size of an airline's operations at the market endpoint airports, as measured by the *Origin Presence* and *Destination Presence* variables, positively impact routing quality of products offered by the airline in the market. In particular, the relevant coefficient estimates suggest that for each additional city that an airline connects to either endpoints of a market using nonstop service, routing quality of the airline's products within the market will increase by approximately 0.06%.

The positive coefficient estimate on the *Nonstop Flight Distance* variable suggests that products tend to have higher routing quality the longer the nonstop flight distance between a market's origin and destination. For example, assuming all other determinants of routing quality are equal, the routing quality of products in the New York City to Atlanta market (nonstop flight miles of 761) should be lower than routing quality of products in the New York City to Los Angeles market (nonstop flight miles of 2,469).

The sign pattern of the coefficient estimates on variables, *N_ comp_ connect* and *N_ comp_ nonstop*, suggests that a product's routing quality tends to be higher (lower) the larger the number of competing nonstop (intermediate stop(s)) products it faces in the market.[24] A reasonable inference that can be drawn from these results is that an airline contemplating what type of products to enter a market with is more likely to offer products with characteristics closer to the characteristics of competing products in the market. Such non-price product characteristic choice behavior of airlines leads to more intense short-run price competition than if competing airlines chose greater differentiation of non-price product characteristics.

To achieve our ultimate goal of properly identifying merger effects on routing quality, it is

[24] It is reasonable to argue that measures of competition are endogenous in the routing quality regression equation. However, as shown in Gayle and Wu (2013), the endogeneity bias resulting from these measures of competition in the airline industry is negligible.

important to control for the determinants of routing quality discussed above. In addition, given that we will use a difference-in-differences identification strategy, it is also important to control for persistent differences in routing quality across firms. Such controls are especially important if the routing quality of products offered by the firms that merge are persistently different from routing quality of products offered by other firms in the sample. Without controlling for persistent routing quality differences, we may incorrectly attribute measured differences in routing quality to the merger. As such, we now examine potential persistent routing quality differences across the firms that merge relative to other firms in the sample.

5.2.2 Persistent Differences in Routing Quality of Products offered by the Merging Firms

The coefficient estimates on dummy variable DN are approximately -13, suggesting that throughout the time span of the data, assuming all determinants of routing quality in the regressions are held constant, the mean routing quality measure of products offered by Delta and Northwest is 13 points less than the mean routing quality measure across all products in the sample. If all determinants of routing quality in the regressions are held at their sample mean for Delta/Northwest products throughout the time span of the data, then regression coefficient estimates in Specification 1 suggest that the mean routing quality measure of Delta/Northwest products is approximately 85.29.[25] This routing quality measure suggests that nonstop flight distances between origins and destinations are on average only 85.29% of the flight distances associated with Delta/Northwest product itineraries used by passengers.

Analogously, we can use the regression coefficient estimates to compute and interpret routing quality measures for Continental/United products. The coefficient estimates on dummy variable CU are approximately -12, suggesting that throughout the time span of the data, assuming all determinants of routing quality in the regressions are held constant, the mean routing quality measure of products offered by Continental and United is 12 points less than the mean routing quality measure across all products in the sample. If all determinants of routing quality in the

[25] This mean routing quality measure for Delta/Northwest products is computed using the regression equation in Specification 1 as follows:

$$\begin{aligned} \textit{Routing Quality}^{dn} &= 88.364 - 13.419 + 0.068 \times (30.613) + 0.066 \times (30.528) \\ &\quad + 0.005 \times (1415.863) - 0.165 \times (8.98) + 0.273 \times (2.366), \end{aligned}$$

where the numbers in parentheses are means of the regressors for DL/NW products, while the other numbers are the coefficient estimates in Specification 1 of the regression model.

regressions are held at their sample mean for Continental/United products throughout the time span of the data, then regression coefficient estimates in Specification 1 suggest that the mean routing quality measure of Continental/United products is approximately 86.45.[26] Therefore, nonstop flight distances between origins and destinations are on average 86.45% of the flight distances associated with Continental/United product itineraries used by passengers. In summary, the evidence suggests that CO/UA products have slightly higher mean routing quality compared to mean routing quality of DL/NW products.

With the controls on routing quality discussed above in place, as well as fixed effects controls for other airlines, time periods, origin cities, and destination cities, we are now in a position to examine the effect of each merger on routing quality.

5.2.3 Overall Routing Quality Effects of each Merger

The negative coefficient estimate on T^{dn} suggests that the routing quality of products offered by airlines other than Delta or Northwest declined by 0.8% below the sample average over the DL/NW pre-post merger periods, i.e., non-DL/NW itinerary flight distances increased relative to nonstop flight distances by 0.8% over the relevant pre-post merger periods. Interestingly, the negative coefficient estimate on the interaction variable $T^{dn} \times DN$ suggests that routing quality of products offered by the merged Delta/Northwest carrier has an even larger decline of 1.1% ($= 0.801 + 0.345$ based on estimates in Specification 1) over the pre-post merger periods. This suggests that the merger may have precipitated an additional 0.3% decline in the routing quality of DL/NW products relative to the routing quality of products offered by other airlines. In essence, the flight distances associated with DL/NW product itineraries increased over convenient nonstop flight distances by an additional 0.3% due to the merger.

The negative coefficient estimate on T^{cu} suggests that the routing quality of products offered by airlines other than Continental and United declined by 0.32% below the sample average over the CO/UA pre-post merger periods. However, the coefficient estimate on the interaction variable $T^{cu} \times CU$ is positive, but in Specification 1, smaller in absolute terms than the coefficient estimate

[26] This mean routing quality measure for Continental/United products is computed using the regression equation in Specification 1 as follows:

$$\begin{aligned} \textit{Routing Quality}^{cu} &= 88.364 - 12.605 + 0.068 \times (29.391) + 0.066 \times (28.870) \\ &\quad +0.005 \times (1582.71) - 0.165 \times (11.035) + 0.273 \times (2.549), \end{aligned}$$

where the numbers in parentheses are means of the regressors for CO/UA products, while the other numbers are the coefficient estimates in Specification 1 of the regression model.

on T^{cu}. Therefore, based on Specification 1, routing quality of products offered by all carriers declined over the CO/UA pre-post merger periods, but CO/UA products experienced a smaller decline, approximately 0.15% ($= |-0.322 + 0.177|$), due to the merger. This suggests that the merger had a relative increasing impact on routing quality of CO/UA products.

In summary, coefficient estimates in Specification 1 suggest that, overall, across all markets in the sample, the CO/UA merger is associated with a relative increasing impact on routing quality of their products, but the DL/NW merger is associated with a relative decline in routing quality of DL/NW products. However, as our theoretical model suggests, these quality effects may differ across markets based on certain pre-merger characteristics of a market. We now explore this possibility via model Specifications 2 and 3.

5.2.4 Merger Effects on Routing Quality based on Existence of Pre-merger Competition between Merging Firms

MKT^{dn}_{bm} is a zero-one market-specific dummy variable that takes a value of one only for origin-destination markets in which Delta and Northwest competed prior to their merger. Similarly, MKT^{cu}_{bm} is a zero-one market-specific dummy variable that takes a value of one only for origin-destination markets in which Continental and United competed prior to their merger. These market-specific dummy variables are used in Specification 2 of the regression estimates to investigate whether routing quality merger effects differ in markets where the merging firms competed prior to the merger. Therefore, MKT^{dn}_{bm} and MKT^{cu}_{bm} are discrete indicators of the existence of pre-merger competition between the merging firms, and serve as discrete counterparts to β in the theoretical model, with no pre-merger competition meaning $\beta = 0$.

In our data, Delta and Northwest simultaneously serve 1,730 directional origin-destination combinations prior to their merger, while 735 directional origin-destination combinations are served by either one or the other carrier prior to their merger. However, Continental and United simultaneously serve 1,436 directional origin-destination combinations prior to their merger, while 1,025 directional origin-destination combinations are served by either one or the other carrier prior to their merger.

The merger-specific variables in Specification 2 suggest that the DL/NW and the CO/UA mergers are associated with declines of 1.35% ($= |-0.790 - 1.797 + 1.239|$) and 1.05% ($= |-0.327 - 6.329 + 5.609|$) in routing quality, respectively, of products offered by the merging firms in markets where the merging firms competed with each other prior to their merger. This evidence is based on the sum of the coefficients on T^{dn} and interaction variables, $T^{dn} \times DN$ and $MKT_{bm}^{dn} \times T^{dn} \times DN$, in case of the DL/NW merger, and the sum of the coefficients on T^{cu} and interaction variables, $T^{cu} \times CU$ and $MKT_{bm}^{cu} \times T^{cu} \times CU$, in case of the CO/UA merger. The negative coefficient estimates of -1.797 and -6.329 on the interaction variables, $MKT_{bm}^{dn} \times T^{dn} \times DN$ and $MKT_{bm}^{cu} \times T^{cu} \times CU$, respectively, are the drivers of the evidence of routing quality declines associated with the mergers.

Based on results from our structural demand estimates, we can monetize consumer welfare effects of the routing quality declines associated with the mergers. In particular, recall that our demand estimates suggest that consumers are willing to pay \$2.23, on average, for each percentage point increase that the nonstop flight distance is of the actual itinerary flight distance. Since nonstop flight distance between an origin and destination cannot change, then actual itinerary flight distance must fall towards (increase away from) nonstop flight distance so that nonstop flight distance can account for a larger (smaller) percentage of actual itinerary flight distance. Therefore, in markets that the merging firms competed prior to merger, routing quality effects of the mergers imply that each consumers' utility falls by an average of \$3.01 (= \$2.23 × 1.35) in case of the DL/NW merger, and \$2.34 (= \$2.23 × 1.05) in case of the CO/UA merger.[27] These consumer welfare effects are not trivial considering that many of these markets in our sample have origin city populations close to or greater than a million, e.g. Chicago, Illinois (one of United Airline's hub city).

Specification 2 coefficient estimates on T^{dn}, T^{cu} and the interaction variables, $T^{dn} \times DN$ and $T^{cu} \times CU$, suggest that routing quality of the merging firms' products actually experienced an increase of 0.45% $(= |-0.790 + 1.239|)$ and 5.28% $(= |-0.327 + 5.609|)$ associated with the DL/NW and CO/UA mergers, respectively, in markets where the merging firms did not compete with each other prior to the merger. So each consumer in these markets experienced increases in utility related to routing quality improvements equivalent to \$1.00 (= \$2.23 × 0.45) in case of the DL/NW merger, and \$11.77 (= \$2.23 × 5.28) in case of the CO/UA merger.

5.2.5 Merger Effects on Routing Quality based on Pre-merger Competition Intensity between Merging Firms

To investigate the theoretical prediction that the effect of a merger on product quality depends on the intensity of pre-merger competition (as measured by cross-elasticity of demand) between

[27] This method of computing a welfare effect associated with routing quality changes abstracts from second-order welfare effects that can occur due to routing quality influencing other variables (e.g. price) that in tern affect welfare.

products of the merging firms, we use the demand model that was estimated in the previous section to compute pre-merger cross-price elasticities between Delta and Northwest products, and between Continental and United products. The variable, E_{bm}^{dn}, measures pre-merger cross-price elasticities of demand between Delta and Northwest products, while variable E_{bm}^{cu} measures pre-merger cross-price elasticities of demand between Continental and United products. The elasticities in each of these variables vary across origin-destination markets in which the merging firms competed prior to their respective mergers. A cross-price elasticity between the merging firms' products will only exist in markets where they are competitors prior to the merger. In this section of the empirical analysis, E_{bm}^{dn} and E_{bm}^{cu} serve as continuous indexes of β in the theoretical model.

We use the pre-merger cross-elasticity variables to construct interaction variables: (i) $E_{bm}^{dn} \times MKT_{bm}^{dn} \times T^{dn} \times DN$; (ii) $\left(E_{bm}^{dn}\right)^2 \times MKT_{bm}^{dn} \times T^{dn} \times DN$; (iii) $E_{bm}^{cu} \times MKT_{bm}^{cu} \times T^{cu} \times CU$; and (iv) $(E_{bm}^{cu})^2 \times MKT_{bm}^{cu} \times T^{cu} \times CU$. Specification 3 in Table 5 adds these variables to the routing quality regression.

The Delta/Northwest merger The segment of the regression equation in Specification 3 that relates to routing quality effects of the Delta/Northwest merger in markets where they directly competed prior to the merger is given by:

$$\Delta \textit{Routing Quality}^{dn} = -0.795 + 1.235 - 1.771 - (0)E_{bm}^{dn} - 130104.3\left(E_{bm}^{dn}\right)^2, \tag{8}$$

where dummy variables MKT_{bm}^{dn}, T^{dn} and DN each take the value of 1. Note that the coefficient estimates in equation (8) imply that $\Delta \textit{Routing Quality}^{dn}$ is negative for all permissible values of E_{bm}^{dn}.[28] This suggests that the Delta/Northwest merger decreased routing quality of its products in all markets that the two airlines directly competed in prior to the merger. In addition, routing quality fell by more in markets where the two airlines competed more intensely (higher E_{bm}^{dn}) prior to the merger.

Given that E_{bm}^{dn} has a mean of 0.00027, a minimum value of 1.60e-07, and a maximum value of 0.0098, equation (8) implies that routing quality of DL/NW products declined by a mean of 1.34%, a minimum of 1.33%, and a maximum of 13.83% across markets in which Delta and Northwest competed prior to their merger. So there exists a market in which a typical consumer experienced a decline in utility equivalent to \$30.84 (= \$2.23 × 13.83), due to routing quality declines associated

[28] Variable E_{bm}^{dn} can only take positive values since it measures cross-elasticities. Note also that in equation (8) we set equal to zero the coefficient on E_{bm}^{dn} since its coefficient estimate in the regression is not statistically different from zero at conventional levels of statistical significance.

with the DL/NW merger. In fact, Atlanta to Washington, DC; Atlanta to Philadelphia; and Atlanta to San Francisco; are examples of markets in the sample in which E_{bm}^{dn} is greater than 0.008, which implies that a typical consumer in these markets experienced a decline in utility greater than \$21.54 ($\approx$ \$2.23 $\times$ 9.66) due to routing quality declines associated with the DL/NW merger.

Interpreting the Delta/Northwest results in the context of our theoretical model suggest that the negative competitive incentive effect of the merger dominates the positive coordination effect in all markets that the two airlines competed in prior to the merger. Note however that the coefficient on $T^{dn} \times DN$ in Specification 3 remains positive, suggesting that the positive coordination effect remains the key driver of merger quality effects in markets where Delta and Northwest did not directly compete prior to the merger.

The Continental/United merger The segment of the regression equation in Specification 3 that relates to quality effects of the Continental/United merger in markets where they directly competed prior to the merger is given by:

$$\Delta Routing\ Quality^{cu} = -0.333 + 5.600 - 6.104 - 716.357E_{bm}^{cu} + 58037.38\,(E_{bm}^{cu})^2\,, \qquad (9)$$

where dummy variables MKT_{bm}^{cu}, T^{cu} and CU each take the value of 1. Note that the coefficient estimate on $(E_{bm}^{cu})^2$ in equation (9) is positive, while the coefficient on E_{bm}^{cu} is negative. This sign pattern of the coefficients in equation (9) suggests an interesting result for the Continental/United merger: the effect of the merger on routing quality varies in a U-shaped manner with pre-merger competition intensity (measured by cross-elasticity) between the two airlines, where the minimum turning point in the U-shaped relationship occurs at a cross-elasticity of 0.0062 ($= 716.357/(2 \times 58037.38)$). Specifically, the merger appears to have decreased routing quality more in markets where the pre-merger cross-elasticities between the two airlines' products are higher, up to an intermediate pre-merger cross-elasticity of 0.0062. Markets with pre-merger cross-elasticity between CO and UA of 0.0062, experienced the largest decline in routing quality of 3.05%, which yields a decline in a typical consumer's utility equivalent to \$6.80 (= \$2.23 $\times$ 3.05). Examples of origin-destination markets in our sample in which our demand model generates pre-merger cross-elasticity between CO and UA of between 0.005 and 0.0065 include: (i) Las Vegas, Nevada to Cleveland, Ohio; (ii) Denver, Colorado to Houston, Texas; and (iii) San Francisco, California to Houston, Texas. However, the decrease in routing quality of Continental/United products becomes smaller with pre-merger cross-elasticity higher than this intermediate cross-elasticity level.

Note that equation (9) can be used to show that routing quality decreased in markets where E_{bm}^{cu} is less than 0.0134, but increased in markets where E_{bm}^{cu} is greater than 0.0134, thus exhibiting a U-shaped relationship across markets between routing quality changes and pre-merger competition intensity. In other words, the coefficient estimates in equation (9) provide evidence suggesting that the Continental/United merger increased routing quality of their products in markets where pre-merger cross-elasticity between the two airlines' products are greater than 0.0134. Examples of origin-destination markets in our sample in which our demand model generates pre-merger cross-elasticity between CO and UA that is greater than 0.0134 include: (i) Norfolk, Virginia to Raleigh, North Carolina; and (ii) Tampa, Florida to New York City/Newark. In these markets pre-merger competition intensity between Continental and United is sufficiently high such that the positive coordination effect of the merger on product quality again dominates the negative competitive incentive effect. A rationale for such merger quality effects is, even though competitive pressure motivates firms to improve product quality, the diminished profit under competition, especially when competition intensity goes beyond certain point, can reduce the incentive for costly quality provision. Thus when competition intensity is sufficiently high prior to a merger, the coordination effect can again be the dominant driver of quality changes, resulting in quality improvements when firms merge.

Last, the coefficient on $T^{cu} \times CU$ in Specification 3 remains positive, suggesting that the positive coordination effect remains the key driver of merger quality effects in markets where Continental and United did not compete prior to their merger.

5.2.6 Some Robustness checks of Empirical Results

Proper interpretation of the difference-in-differences identification strategy used above to analyze the impact of each merger on product quality depends on trends in the merging airline's product quality relative to non-merging airlines prior to the merger. For example, the cleanest interpretation of the difference-in-differences merger effects exists when the merging airlines have trends in product routing quality that are statistically similar to non-merging airlines prior to merger. In such a situation, if the merging airlines' product quality begin to deviate from non-merging airlines' product quality subsequent to the merger, then it is reasonable to attribute such post-merger deviation to the impact of the merger. However, as we discuss below, there may still be room to interpret difference-in-differences merger impacts in situations where merging and non-merging airlines have different trends in product quality prior to merger.

To assess pre-merger trends in routing quality prior to each merger, we estimate the following regression during the relevant pre-merger periods:

$$\begin{aligned} Routing\ Quality_{jmt} &= \alpha_0 + \alpha_1 Time\ Trend_t + \alpha_2 Time\ Trend_t \times Merging\_\ Carrier\_A_{jmt} \\ &\quad + \alpha_3 Time\ Trend_t \times Merging\_\ Carrier\_B_{jmt} + \lambda_a + origin_m + dest_m + \mu_{jmt}, \end{aligned} \tag{10}$$

where $Time\ Trend_t$ is a time trend variable; $Merging\_\ Carrier\_A_{jmt}$ is a zero-one dummy variable that takes the value one only for products owned by carrier "A"; and $Merging\_\ Carrier\_B_{jmt}$ is an analogously defined dummy variable for carrier B, where carriers A and B are the two distinct carriers that merge. For example, if carrier A represents Delta airlines, then carrier B represents Northwest airlines. As previously defined, λ_a, $origin_m$ and $dest_m$ are fixed effects for airlines, market origins and market destinations, respectively; while μ_{jmt} is a mean-zero unobserved random error term. In equation (10), α_1 is a parameter that measures the average slope of routing quality trend of non-merging airlines during pre-merger periods, while α_2 and α_3 are parameters that measure the average slopes of routing quality trends of the two merging airlines respectively, prior to their merger. It is expected that the estimates of α_2 and α_3 are statistically indistinguishable from zero in the event that merging airlines have trends in routing quality that are sufficiently similar to non-merging airlines prior to merger.

Table 6 reports estimation results of equation (10). The first column of estimates focus on markets in which DL and NW services overlapped prior to their merger. Since the coefficient estimate on the *Time Trend* variable is statistically insignificant, then we can conclude that routing quality of products offered by airlines other than DL or NW in these markets was neither increasing nor decreasing prior to the DL/NW merger. However, the coefficient estimates on the interaction variables, $Time\ Trend_t \times\ DL$ and $Time\ Trend_t \times\ NW$ are positive and statistically significant at conventional levels of statistical significance, suggesting that both DL and NW separately experienced relative increases in routing quality of their products in these markets during periods prior to the merger. Recall that our difference-in-differences estimates in Table 5 suggest that, across the pre-post merger periods, DL/NW experienced a relative decline in routing quality of their products in markets where these two airlines had overlapping services prior to merging. Attributing to the merger the difference-in-differences results in these markets is reinforced by the fact that results in Table 6 suggest that DL and NW products were experiencing a relative increase in routing quality in said markets prior to their merger.

Table 6
Estimation Results for Pre-trends Analysis during Pre-merger periods

	Dependent Variable: *Routing Quality* (in %)			
	Markets in which DL & NW Services Overlapped prior to merger	**Markets in which DL & NW Services did not Overlap prior to merger**	**Markets in which CO & UA Services Overlapped prior to merger**	**Markets in which CO & UA Services did not Overlap prior to merger**
	Pre-merger period: 2005:Q1 to 2008:Q3		Pre-merger period: 2005:Q1 to 2010:Q3	
	Coefficient (Robust Std. Error)	Coefficient (Robust Std. Error)	Coefficient (Robust Std. Error)	Coefficient (Robust Std. Error)
Variable				
Constant	96.113*** (0.4943)	86.249*** (0.6343)	93.482*** (0.3976)	89.102*** (0.5805)
Time Trend	-0.006 (0.006)	0.0191* (0.0104)	-0.013*** (0.0031)	-0.043*** (0.0057)
Time Trend × DL	0.126*** (0.0153)	0.222*** (0.0361)	-	-
Time Trend × NW	0.117*** (0.0166)	0.1802 (0.1238)	-	-
Time Trend × CO	-	-	-0.0019 (0.0108)	0.156*** (0.0341)
Time Trend × UA	-	-	0.043*** (0.0083)	0.156*** (0.0235)
Carrier fixed effects	YES			
Origin city fixed effects	YES			
Destination city fixed effects	YES			
R-squared	0.1449	0.1867	0.1384	0.1477
Number of observations	278,522	79,639	397,980	149,901

Regressions are estimated using ordinary least squares. *** indicates statistical significance at the 1% level, while * indicates statistical significance at the 10% level. Estimation of each regression includes fixed effects for carriers, origin cities, and destination cities, even though their associated coefficients are not reported in the table.

The second column of estimates in Table 6 focus on markets in which DL and NW services do not overlap prior to their merger. Since the coefficient estimate on the *Time Trend* variable is positive and statistically significant, then we can conclude that routing quality of products offered by airlines other than DL or NW in these markets was increasing prior to the DL/NW merger. The coefficient estimate on the interaction variable, $Time\ Trend_t \times\ DL$ is positive and statistically significant at conventional levels of statistical significance, suggesting that DL experienced a relative increase in routing quality of its products in these markets during periods prior to the merger. However, the coefficient estimate on the interaction variable, $Time\ Trend_t \times\ NW$ is statistically insignificant, suggesting that NW did not experience a relative increase in routing quality of its products in these markets during periods prior to the merger. Recall that our difference-in-differences estimates in Table 5 suggest that, across the pre-post merger periods, DL/NW experienced a relative increase in routing quality of their products in markets where the services of these two airlines did not overlap prior to merging. It is now more difficult to attribute to the merger the relative increase in routing quality of DL/NW products in these markets since the relative pre-post merger increase may simply be reflecting trends in routing quality that preceded the merger.

The third column of estimates in Table 6 focus on markets in which CO and UA services overlapped prior to their merger. Since the coefficient estimate on the *Time Trend* variable is negative and statistically significant, then we can conclude that routing quality of products offered by airlines other than CO or UA in these markets was decreasing prior to the CO/UA merger. The coefficient estimate on the interaction variable, $Time\ Trend_t \times\ CO$ is statistically insignificant at conventional levels of statistical significance, suggesting that the routing quality of CO products did not have a statistically different trend than the routing quality of products offered by non-merging airlines in these markets during periods prior to the merger. However, the coefficient estimate on the interaction variable, $Time\ Trend_t \times\ UA$ is positive, statistically significant, and larger in absolute terms compared to the coefficient estimate on *Time Trend*, suggesting that in contrast to non-merging airlines, UA did experience a relative increase in routing quality of its products in these markets during periods prior to the merger. Recall that our difference-in-differences estimates in Table 5 suggest that, across the pre-post merger periods, CO/UA experienced a relative decrease in routing quality of their products in markets where the services of these two airlines overlapped prior to merging. Attributing to the merger the difference-in-differences results in these markets is reinforced by the fact that results in Table 6 suggest that UA products were experiencing a relative increase in routing quality in said markets prior to their merger.

The fourth column of estimates in Table 6 focus on markets in which CO and UA services do not overlap prior to their merger. Since the coefficient estimate on the *Time Trend* variable is negative and statistically significant, then we can conclude that routing quality of products offered by airlines other than CO or UA in these markets was decreasing prior to the CO/UA merger. The coefficient estimates on the interaction variables, $Time\ Trend_t \times\ CO$ and $Time\ Trend_t \times\ UA$ are each positive, statistically significant, and larger in absolute terms compared to the coefficient estimate on *Time Trend,* suggesting that in contrast to non-merging airlines, CO and UA did experience a relative increase in routing quality of their products in these markets during periods prior to the merger. Recall that our difference-in-differences estimates in Table 5 suggest that, across the pre-post merger periods, CO/UA experienced a relative increase in routing quality of their products in markets where the services of these two airlines did not overlap prior to merging. It is now more difficult to attribute to the merger the relative increase in routing quality of CO/UA products in these markets since the relative pre-post merger increase may simply be reflecting trends in routing quality that preceded the merger.

Applying a Synthetic Control Method Having statistically examined pre-merger trends in routing quality of products offered by merging airlines (treatment group) and non-merging airlines (control group), it is clear that there exists markets in which pre-merger trends across merging and non-merging airlines reinforce attributing difference-in-differences impacts to the merger, as well as markets in which such attribution is more difficult to make. Specifically, we found that it is more difficult to attribute difference-in-differences impacts to the mergers in markets where the merging airlines services do not overlap prior to their merger. Attribution of difference-in-differences impacts to the merger is most credible when treatment and control airlines have trends in product routing quality that are statistically similar prior to merger. However, it is often difficult to pick a set of control airlines to achieve such a pre-trend criterion. Fortunately, recent developments in econometric techniques provide a data-driven procedure to construct synthetic control units (synthetic non-merging airlines) based on a convex combination of comparison non-merging airlines that approximates the characteristics of merging airlines. Details on the econometric foundation of the synthetic control method are found in Abadie and Gardeazabal (2003); Abadie, Diamond, and Hainmueller (2010); and Abadie, Diamond, and Hainmueller (2015).

Figure 4, Figure 5, Figure 6 and Figure 7 provide a graphical illustration of results from applying the synthetic control method. Figure 4 and Figure 5 focus on markets in which the merging firms' services do not overlap prior to merger, while Figure 6 and Figure 7 focus on markets in which the merging firms' services do overlap prior to merger. In each figure, routing quality is measured on the vertical axis, while time period is measured on the horizontal axis. Since the data are quarterly, then the time period measure on the horizontal axis is the count of quarters beginning in 2005:Q1. As such, the DL/NW merger that was legally implemented in 2008:Q4 corresponds to time period 16 on the horizontal axis, while the CO/UA merger that was legally implemented in 2010:Q4 corresponds to time period 24 on the horizontal axis. The vertical dashed line in each figure represents the time period in which the relevant merger was legally implemented.

The synthetic control method optimally constructs the synthetic control airline based on a convex combination of characteristics of non-merging airlines such that the synthetic airline best approximates pre-merger routing quality trend of the merging airlines. The characteristics used to match synthetic and merging airlines are the continuous right-hand-side regressor variables in Table 5, as well as mean routing quality at various points of the relevant pre-merger period. The appendix provides tables showing pre-merger match on these characteristics between synthetic and merging airlines. In figures 4 through 7, the solid line time series plot represents the mean routing quality across products offered by the merging airlines, while the dashed line time series plot represents the predicted routing quality of the synthetic control airline. The synthetic control airline's time series plot of routing quality provides a counterfactual prediction of how the merging airlines' mean routing quality would behave had the merger not occurred.

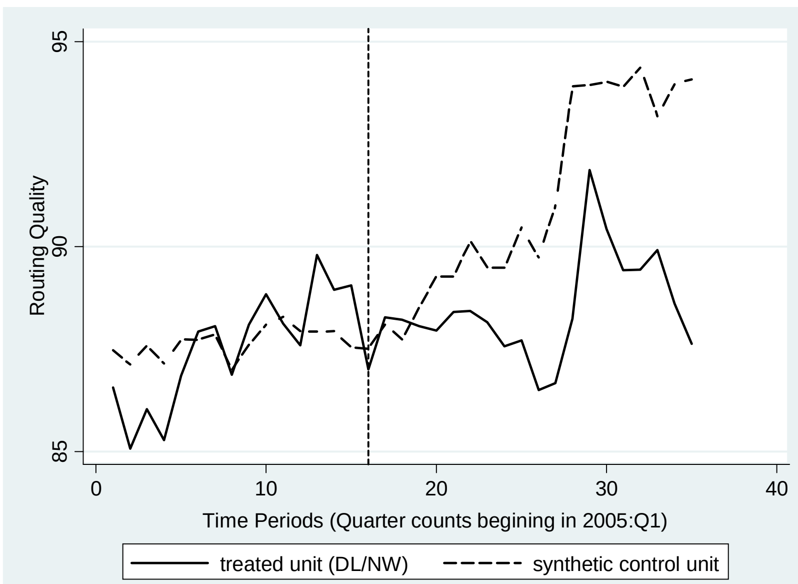

Figure 4: Trends in Routing Quality of DL/NW and Synthetic Control Unit in markets that DL and NW services do not overlap prior to merger.

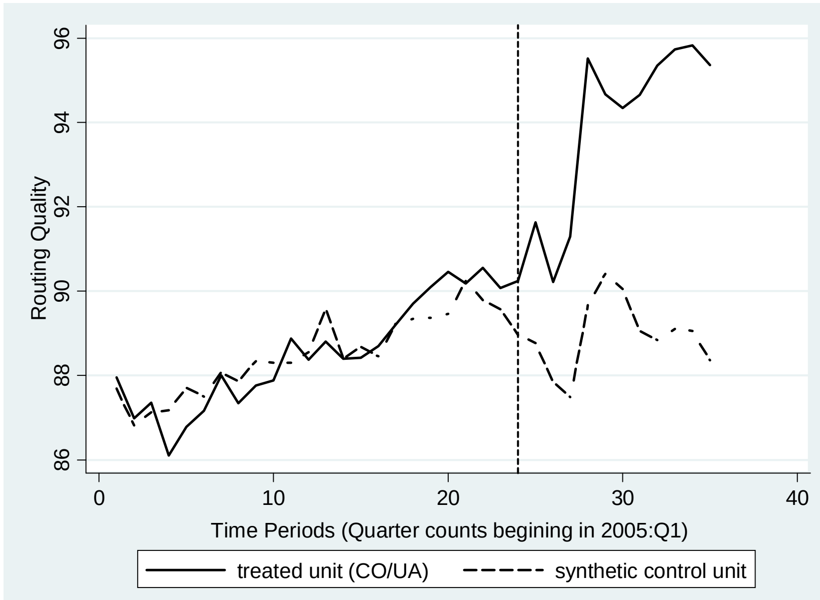

Figure 5: Trends in Routing Quality of CO/UA and Synthetic Control Unit in markets that CO and UA services do not overlap prior to merger.

Figure 4 illustrates the predicted impact of the DL/NW merger in markets that DL and NW services do not overlap prior to them merging. The figure suggests that the merger is associated with a decline in routing quality of DL/NW products in these markets since the solid line time series plot falls below the dashed line time series plot during the post-merger period. This predicted merger impact in non-overlap DL/NW markets is not consistent with the corresponding difference-in-differences result suggested in Table 5.

Figure 5 illustrates the predicted impact of the CO/UA merger in markets that CO and UA services do not overlap prior to them merging. The figure suggests that the CO/UA merger is associated with an increase in routing quality of CO/UA products in these markets since the solid line time series plot lies above the dashed line time series plot during the post-merger period. This predicted merger impact in non-overlap CO/UA markets is consistent with the corresponding difference-in-differences result suggested in Table 5. The figure also suggests that the actual improvement in routing quality began a couple quarters prior to legal implementation of the merger.

Figure 6 illustrates the predicted impact of the DL/NW merger in markets that DL and NW services overlapped prior to them merging. The figure suggests that the merger is associated with a decline in routing quality of DL/NW products in these markets since the solid line time series plot falls below the dashed line time series plot during the post-merger period. This predicted merger impact in overlap DL/NW markets is consistent with the corresponding difference-in-differences

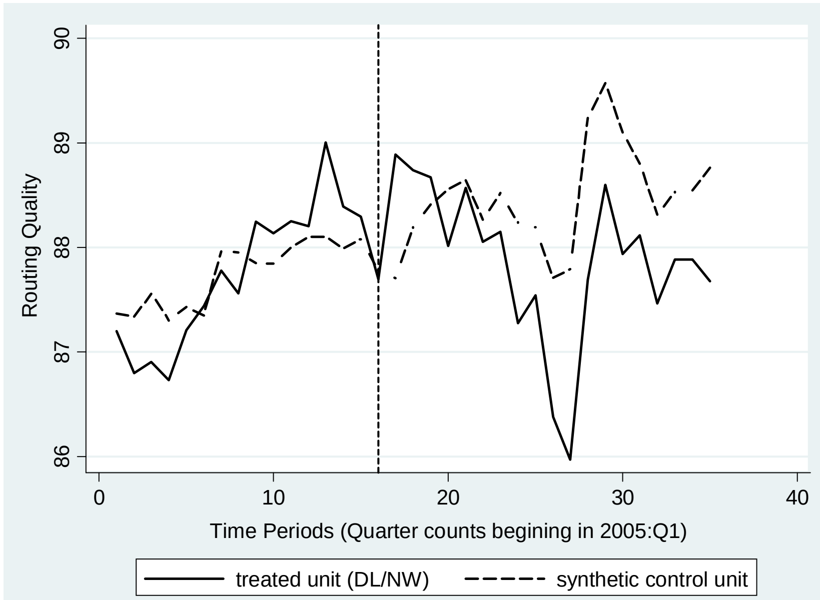

Figure 6: Trends in Routing Quality of DL/NW and Synthetic Control Unit in markets that DL and NW services overlapped prior to merger.

result suggested in Table 5. The figure also suggests that the actual decline in routing quality began a couple quarters subsequent to legal implementation of the merger.

Figure 7 illustrates the predicted impact of the CO/UA merger in markets that CO and UA services overlapped prior to them merging. The figure suggests that the CO/UA merger is associated with an increase in routing quality of CO/UA products in these markets since the solid line time series plot lies above the dashed line time series plot during the post-merger period. The difference-in-differences regression analysis previously discussed, which considers pre-merger competition intensity between merging firms, revealed that in case of the CO/UA merger there exists markets in which pre-merger competition can be sufficiently high such that the merger results in improved routing quality of the merging carriers' products. Even though the synthetic control method does not consider pre-merger competition intensity between merging firms, it also reveals the possibility that the CO/UA merger may have improved routing quality of the merging carriers' products in markets that these carriers competed in prior to merging.

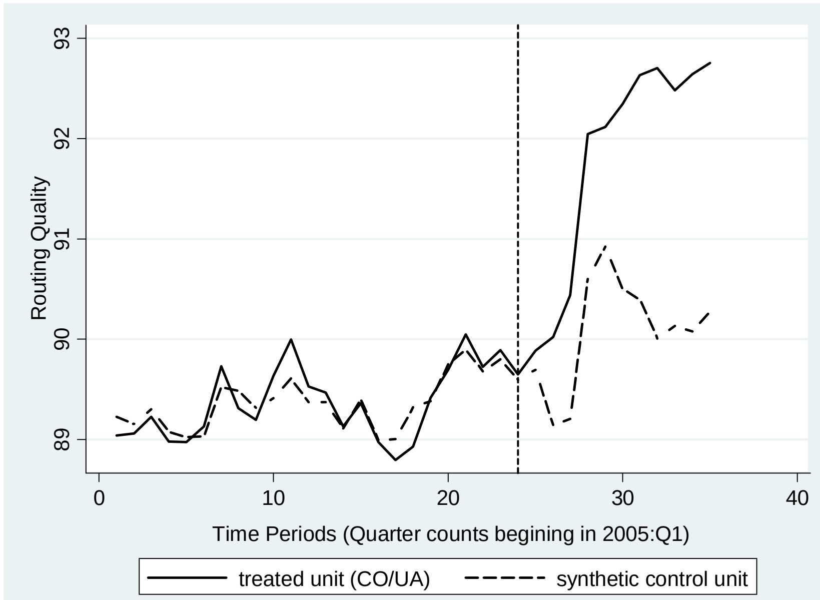

Figure 7: Trends in Routing Quality of CO/UA and Synthetic Control Unit in markets that CO and UA services overlapped prior to merger.

5.2.7 Summary of Empirical Results that are Consistent with Theoretical Predictions

In summary, much of the empirical results, taken together across both mergers, are consistent with the theoretical predictions. Evidence from a difference-in-differences regression analysis suggests that each merger increased routing quality of the merging firms' products - 0.45% and 5.28% for the DL/NW and CO/UA merger respectively - in markets where the merging firms did not compete prior to their merger. In these markets, due to the merging firms' quality improvements, a typical consumer is estimated to experience an increase in utility equivalent to \$1.00 and \$11.77 for the DL/NW and CO/UA mergers, respectively.

In contrast, evidence from the difference-in-differences regression analysis suggests each merger decreased routing quality of the merging firms' products in markets where they competed prior to their merger, and the magnitude of the quality reductions differed across mergers, depending (non-monotonically in the case of CO/UA) on their competition intensity prior to the merger. For the DL/NW merger, routing quality of the merging firms declined by a mean of 1.34%, a minimum of 1.33%, and a maximum of 13.83% across such markets. These quality declines are estimated to yield utility decreases of a consumer in these markets ranging from a minimum of \$2.97 to as high as \$30.84. For the CO/UA merger, the largest decline in routing quality is 3.05%, which yields a decline in a typical consumer's utility equivalent to \$6.80.

6 Conclusion

Departing from the extant economics literature on horizontal mergers that focuses on their price effects, this paper has investigated how mergers affect the merging firms' product quality. Consistent with the theoretical predictions, the empirical analysis of two recent airline mergers finds evidence suggesting that: (1) each merger is associated with a quality *increase* in markets where the merging firms did not compete prior to their merger, but with a quality *decrease* in markets where they did; and (2) the quality change across markets from the Continental/United merger exhibited a U-shaped curve as the pre-merger competition intensity increased.

Our results further indicate that the consumer gains or losses from the quality changes associated with mergers can be substantial. This suggests that the standard practice in merger reviews that consider mainly the price effects may lead to substantial under- or over-estimate of a merger's consumer benefit or harm. It would thus be desirable to explicitly incorporate product quality considerations into merger review, and the insights from this paper may help stimulate further research and policy discussions towards this direction.

Appendix

Table A1
Pre-merger comparison on various characteristics between synthetic and merging airlines across markets in which DL and NW services do not overlap prior to merger

	Mean Values	
Variables	Airlines that Merge (DL & NW)	Synthetic Airline
Origin Presence	32.02	21.68
Destination Presence	28.92	20.80
Nonstop Distance (Miles)	1074.64	1133.01
N_comp_connect	3.49	5.05
N_comp_nonstop	1.59	1.81
Routing Quality (period 15)	89.05	87.54
Routing Quality (period 14)	88.95	87.94
Routing Quality (period 12)	87.59	87.94
Routing Quality (period 10)	88.84	88.09
Routing Quality (period 8)	86.87	87.00
Routing Quality (period 6)	87.93	87.72
Routing Quality (period 4)	85.28	87.15
Routing Quality (period 2)	85.07	87.12

Notes: DL/NW Post-merger period begins in period 16.

Table A2
Pre-merger comparison on various characteristics between synthetic and merging airlines across markets in which CO and UA services do not overlap prior to merger

	Mean Values	
Variables	Airlines that Merge (CO & UA)	Synthetic Airline
Origin Presence	24.46	25.92
Destination Presence	24.45	25.49
Nonstop Distance (Miles)	882.95	847.83
N_comp_connect	4.13	3.48
N_comp_nonstop	2.14	2.01
Routing Quality (period 22)	90.55	89.79
Routing Quality (period 18)	89.70	89.34
Routing Quality (period 15)	88.43	88.69
Routing Quality (period 12)	88.38	88.56
Routing Quality (period 10)	87.89	88.31
Routing Quality (period 8)	87.35	87.87
Routing Quality (period 6)	87.17	87.51
Routing Quality (period 4)	86.10	87.18
Routing Quality (period 2)	86.99	86.83

Notes: CO/UA Post-merger period begins in period 24.

Table A3
Pre-merger comparison on various characteristics between synthetic and merging airlines across markets in which DL and NW services overlapped prior to merger

	Mean Values	
Variables	Airlines that Merge (DL & NW)	Synthetic Airline
Origin Presence	26.23	25.07
Destination Presence	26.36	25.04
Nonstop Distance (Miles)	1456.82	1442.58
N_comp_connect	10.34	11.26
N_comp_nonstop	2.42	2.69
Routing Quality (period 15)	88.29	88.08
Routing Quality (period 14)	88.39	87.99
Routing Quality (period 12)	88.20	88.10
Routing Quality (period 10)	88.13	87.84
Routing Quality (period 8)	87.56	87.95
Routing Quality (period 6)	87.44	87.35
Routing Quality (period 4)	86.73	87.30
Routing Quality (period 2)	86.80	87.34

Notes: DL/NW Post-merger period begins in period 16.

Table A4
Pre-merger comparison on various characteristics between synthetic and merging airlines across markets in which CO and UA services overlapped prior to merger

	Mean Values	
Variables	Airlines that Merge (CO & UA)	Synthetic Airline
Origin Presence	24.60	23.03
Destination Presence	24.11	23.08
Nonstop Distance (Miles)	1694.10	1520.93
N_comp_connect	12.63	11.91
N_comp_nonstop	2.62	2.78
Routing Quality (period 22)	89.73	89.68
Routing Quality (period 18)	88.93	89.32
Routing Quality (period 15)	89.36	89.41
Routing Quality (period 12)	89.53	89.37
Routing Quality (period 10)	89.63	89.41
Routing Quality (period 8)	89.31	89.49
Routing Quality (period 6)	89.13	89.03
Routing Quality (period 4)	88.98	89.08
Routing Quality (period 2)	89.06	89.16

Notes: CO/UA Post-merger period begins in period 24.

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