Product Quality Effects of International Airline Alliances, Antitrust Immunity, and Domestic Mergers

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Abstract

Much of the literature on airline cooperation focuses on the price effects of cooperation. A key contribution of our paper is to empirically examine the product quality effects of airline cooperation. Two common types of cooperation among airlines involve international alliances and antitrust immunity (ATI), where ATI allows for more extensive cooperation. Additionally, this paper examines the extent to which domestic mergers affect the quality of international air travel products. The results suggest that increases in the membership of a carrier's alliance or ATI partners and domestic mergers are associated with the carrier's own products having more travel-convenient routing quality. Therefore, a complete welfare evaluation of airline cooperation and mergers should not ignore product quality effects.

Keywords: Product quality; Airline competition; International alliance; Antitrust immunity; Mergers

JEL classification codes: L13; L93; L40

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1. Introduction

The international airline industry has undergone dramatic changes since the early 1990s. There has been a tendency toward increased cooperation among airlines that provide international air travel. This increase in cooperation may in part be due to regulations restricting the ability of carriers to operate flights to various locations in a foreign country beyond the primary airport in the foreign country that the carrier uses to facilitate international air travel. Cooperation between carriers that are based in different countries effectively allows each carrier greater access to potential passengers in locations of a foreign country that the carrier is not permitted to operate its own flights. In other words, each carrier in the partnership is able to leverage its foreign partner's local route network in the foreign country to better access passengers there.

International cooperation among carriers can take various forms. Two common types of cooperation involve international alliances and antitrust immunity (ATI). These two forms of cooperation differ in the extent of cooperation. For instance, international airline alliances allow the carriers in the alliance to codeshare flights. Codesharing allows a carrier to sell tickets for seats on its partner carriers' planes. Consumers can benefit from an alliance since carriers in the alliance may coordinate flight schedules in an attempt to decrease layover times, check baggage through to the final destination, share frequent flier programs and decrease the distance between the carriers' gates at airports. These features of alliances serve to increase the convenience of international travel for consumers. These travel conveniences are especially important to passengers traveling internationally because international air travel, as compared to domestic air travel, is more likely to require that passengers switch operating carriers at some point on their journey. In these cases, the products offered by each of the operating carriers are complementary.

The three international alliances are Star, Skyteam and Oneworld. Subsets of carriers within these alliances do have ATI. ATI permits more extensive cooperation in which carriers can cooperate on setting fares and capacity in addition to the types of cooperation that can occur without ATI.

Much of the existing literature on airline cooperation focuses on the price effects of cooperation, and often infers welfare effects from these price effects. Results from these previous studies overwhelmingly suggest that cooperation can benefit passengers in the form of lower prices.[1] However, it is well-known in economics that, all else equal, consumer welfare is positively related to product quality. A key objective of this paper is to better understand how international cooperation among carriers affects the quality of the cooperating carriers' air travel products. Understanding the product quality effects is important for a complete welfare evaluation of airline cooperation.

Although there is extensive literature examining the price effects of international airline cooperation, there is a paucity of research regarding the effects on air travel product quality. Some of the research regarding air travel product quality has focused on the relationship between competition and the carriers' on-time performance [e.g. Mazzeo (2003), Rupp et al. (2006) and Prince and Simon (2010)]. Likewise, Richard (2003), Brueckner and Luo (2014), Bilotkach (2011) have examined the effects of competition on flight frequency. However, the existing studies that explore these determinants of air travel product quality focus on domestic air travel markets; whereas this study focuses on international air travel markets, and uses a measure of product quality that has not been fully explored by others.

Our study focuses on a measure of quality that is directly related to the travel convenience of the product in terms of the directness of the product's itinerary routing (measured by distance flown) between the passengers' origin and destination. This quality measure is termed routing quality [Chen and Gayle (2014)], and is calculated as the minimum flying distance between an origin/destination, divided by the actual distance flown by passengers using a specific itinerary routing between the origin and destination. As the distance flown by a passenger to reach their destination increases relative to the minimum distance, the lower is the routing quality of the product. The assumption is that, all else equal, passengers prefer the most direct routing to get to their destination.

Cooperation between carriers may require each to rearrange parts of their route network to facilitate network integration. Rearrangement of networks can result in new product offerings and impact the average routing quality of the set of products offered by each carrier in the alliance. Since a given carrier typically needs to accommodate multiple alliance partners, it is not clear a priori that such multi-dimensional network integration necessarily results in a given

[1] Theoretical papers examining the effects of cooperation include, but are not limited to: Bilotkach (2005), Brueckner (2001), Chen and Gayle (2007), Hassin and Shy (2004) and Park (1997). Empirical papers examining the effects of cooperation include, but are not limited to: Brueckner and Whalen (2000), Brueckner (2003), Brueckner et al. (2011), Flores-Fillol and Moner-Colonques (2007), Park and Zhang (2000) and Oum et al. (1996).

carrier offering products of higher routing quality. However, to persuade regulatory authorities to approve formation of the alliance, which is required before the alliance can be implemented, carriers typically make arguments suggesting that the alliance will result in their products having better routing quality. Similar arguments are often made to convince regulatory authorities to grant the carriers ATI.

For instance, in a joint application to the U.S. Department of Transportation (DOT) for ATI in 2007 involving Delta Airlines, Northwest Airlines and four European carriers, the carriers make the claim that 1,466 city-pair combinations will be upgraded to one-stop service and 4,071 city-pair combinations will be upgraded to two-stop service. [2] Additionally, after the approval of this ATI application in 2008, Delta Airlines added nonstop service from Newark, Portland, Minneapolis/St. Paul, Seattle and Memphis among other origins to Amsterdam. Similarly, when an ATI agreement between American Airlines and SN Brussels Airlines ceased in 2009, American Airlines then stopped offering nonstop flights from Los Angeles to Brussels. Although, when SN Brussels was granted ATI with United Airlines in 2009, United Airlines added nonstop service between Los Angeles and Brussels. Note that SN Brussels was granted ATI with United Airlines shortly prior to joining the Star alliance with United Airlines. These are just a handful of examples. However, it is clear that cooperation can induce changes in flight offerings.

Using rigorous econometric analysis this study seeks to be the first to formally establish and document systematic evidence of the relationship between routing quality and international airline cooperation. We estimate reduced-form regression equations that use a difference-in-differences strategy via interaction variables to identify the relationship of interest. The data sample focuses on products offered by the three carriers: United Airlines, Delta Airlines and American Airlines. Each of these carriers is a founding member of their respective alliance, their participation in the alliance has not wavered over time, and any ATI agreement between a U.S. carrier and foreign carrier involves one of these carriers. Additionally, Clougherty (2002) suggests that the effects of domestic mergers on international travel often get overlooked. As such, we also use the data to better understand the impacts of the United/Continental merger and the Delta/Northwest merger on routing quality in international air travel markets. Therefore, this

[2] See U.S. Department of Transportation docket: Joint Application for Approval of and Antitrust Immunity for Alliance Agreements (Public Version), DOT-OST-2007-28644-0001-0001.

paper complements work by Chen and Gayle (2014) who focus on the routing quality impacts of these mergers within U.S. domestic air travel markets.

The results provide strong evidence that cooperation among international carriers is associated with an increase in a carrier's routing quality on average. This is a result that is consistent for alliance and ATI membership for each of the three carriers examined. Moreover, the results indicate that an increase in alliance membership is associated with relative routing quality increases for online, traditional codeshare and virtual codeshare products offered by the carriers.[3] In the case of United Airlines and American Airlines, the greatest relative routing quality increase shows up in the virtual codeshare products offered by these carriers. This suggests that when a carrier gains an alliance member, the carrier is able to utilize the alliance member's network to offer new products with relatively better routing quality. The results regarding the routing quality effects of ATI on a carriers' products are mixed. However, there is evidence that the United/Continental and Delta/Northwest mergers are associated with a relative increase in the routing quality of international air travel products provided by the merging airlines.

This paper proceeds as follows. Section 2 provides a brief background history of each of the three major international alliances and ATI partnerships with U.S. carriers, defines key concepts, as well as a discussion of the data used in the analysis. Section 3 provides a description of the methodology used, while Section 4 discusses the empirical results. Section 5 concludes the paper.

2. Data

2.1 Background Information on Alliances, ATI Partnerships, and two Domestic Mergers

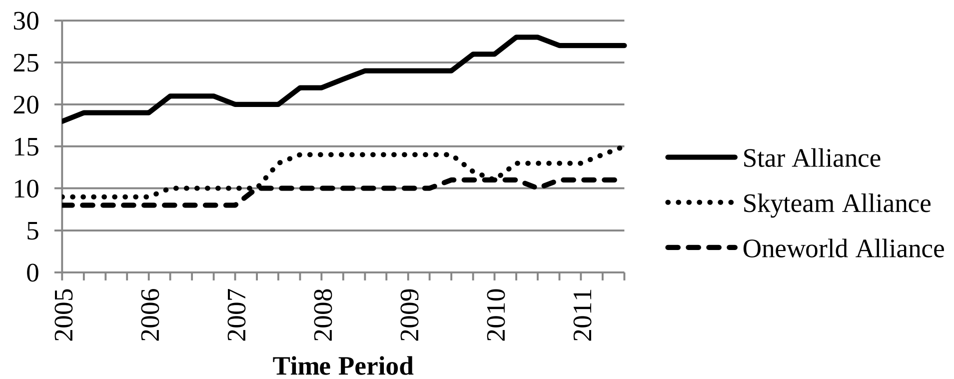
The landscape in the international airline industry has undergone rapid changes over the past 20 years. There are currently three major international alliances: Star, Oneworld and SkyTeam. The first of these alliances to be founded was the Star alliance in 1997. There were five original members which included United Airlines. As of the first quarter of 2005, the alliance had grown to include 18 official members and by the third quarter of 2011 the alliance included 27 official members. The star alliance is the largest international alliance in terms of

[3] In the following section of the paper we define and distinguish between these three types of air travel products.

the number of members. Figure 1 provides a time plot detailing how the size of the alliances has changed from the first quarter of 2005 through the third quarter of 2011.[4]

The next alliance formed was Oneworld in 1999. There were five founding members including American Airlines. The Oneworld alliance has grown to include 11 members as of the third quarter of 2011. SkyTeam was also created in 1999 by Delta Airlines along with three international members. In 2004, Continental Airlines and Northwest Airlines joined the SkyTeam alliance. Continental Airlines was a member of the SkyTeam alliance for five years, before leaving and joining the Star alliance, eventually merging with United Airlines in the second quarter of 2010. From 2005 through the third quarter of 2011, the SkyTeam alliance grew from 9 official members to 15 official members.

Figure 1. Total number of carriers in 3 international alliances by time



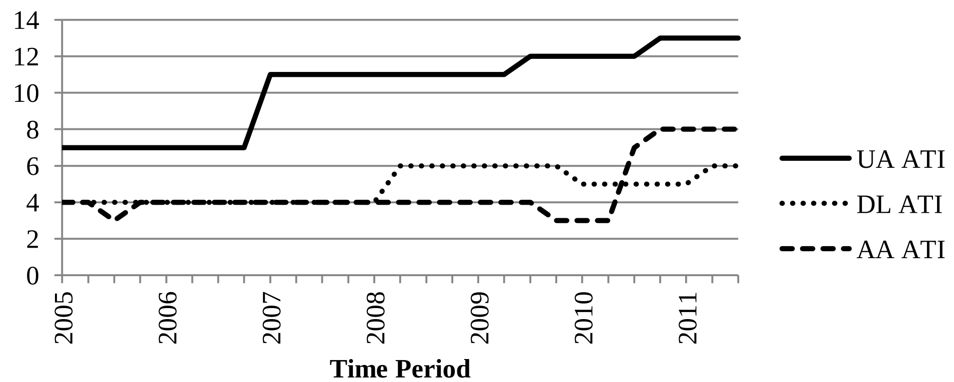
One important aspect to note is the trend in ATI decisions by the DOT. Most ATI rulings in the 1990s consisted of an ATI agreement between only two carriers. However, recently many of these agreements have been extended to include multiple carriers.

The DOT's first ATI approval came in 1993 to Northwest and KLM ATI. In 1996 the DOT granted ATI to Delta and three foreign carriers: Austrian Airlines, Sabena and Swissair. Also in 1996, the DOT granted ATI to United Airlines and Lufthansa. American Airlines was first given ATI with Canadian Airlines in 1996 as well. As of the first quarter of 2005, United Airlines had 7 ATI partners while Delta Airlines and American Airlines each had 4 ATI partners.

[4] Table A1 in the appendix provides a detailed description of how alliance membership for each alliance has changed since each of their inceptions.

Through the third quarter of 2011; however, United Airlines had ATI agreements with 13 carriers, Delta Airlines had ATI agreements with 7 carriers and American Airlines had ATI agreements with 8 carriers. Figure 2 illustrates how the number of ATI partners has evolved over this time span.[5]

Figure 2. Total number of ATI partners with United Airlines, Delta Airlines and American Airlines by time



It is indeed also desirable to study routing quality impacts on products offered by non-US airlines resulting from changes in size of alliance and ATI partnerships to which these non-US airlines belong. Unfortunately, the data to which we have access have limited information on non-US carriers' products and operations. Hence for simplicity our study focuses on routing quality impacts for these three U.S. airlines: United Airlines, Delta Airlines, and American Airlines. An additional reason for focusing on these three U.S. carriers is that each is a founding member of their respective alliance and their participation in the alliance has not changed since their alliances were formed. However, over time other carriers have entered/exited the alliance. Furthermore, each of the aforementioned carriers are the only U.S. carriers to have multiple ATI agreements and the number of ATI partners for each of these carriers has changed over time.

Over the span of the time period analyzed in this study, two domestic mergers took place. On April 14, 2008 Delta Airlines and Northwest Airlines announced their plan to merger. The Department of Justice formally approved the merger on October 29, 2008.[6] On May 2, 2008,

[5] Table A2 in the appendix gives a chronological history of the DOT's granting of ATI to U.S. carriers.
[6] Northwest Airlines remained an official member of the Skyteam alliance until the merger was complete in January 2010. Thus, in the dataset Northwest Airlines is considered an alliance member of Delta Airlines until the first

United Airlines and Continental Airlines announced their plan to merge and the Department of Justice approved the merger on August 27, 2010. There is the potential that these mergers between U.S. national carriers could have routing quality impacts on the merging airlines' international travel products since a merger allows a carrier better direct control over the route network structure of the carrier it merges with.

2.2 Key Definitions

Before describing the variables used in the analysis, it is worth defining a few key concepts. First, a market is defined as an origin, destination and time period combination. For example, Chicago to Paris in the first quarter of 2005 is a different market than Chicago to Paris in the second quarter of 2005. Furthermore, there is a set of products offered by a carrier or carriers in each market. A product is defined by the unique combination of ticketing carrier, operating carrier(s), origin airport, destination airport and sequence of intermediate stop airport(s). The ticketing carrier is the carrier from which a passenger bought the travel ticket for the itinerary, while the operating carrier(s) are the carrier(s) that physically transport the passenger between the origin and destination. Our analysis focuses on products with a single ticketing carrier.

Products in which the ticketing carrier is the same as the operating carrier on each trip segment are defined as online products. For example, a product that is ticketed by United Airlines and United Airlines is the sole operating carrier is an online product. However, in some cases the ticketing carrier and operating carrier of a product may differ. Products that have multiple operating carriers are defined as traditional codeshare products. Thus, a consumer travelling on an itinerary that is traditional codeshared is switching carriers at some point along their trip. For instance, a product ticketed by United Airlines with one intermediate stop where United Airlines operates the first segment and Air Canada operates the second segment is a traditional codeshare product. A product that has a single operating carrier that is different from the ticketing carrier is defined as a virtual codeshare product. Thus, a product in which United Airlines is the ticketing carrier, but Air Canada is the sole operating carrier is a virtual codeshare product.

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quarter of 2010. Similarly, Northwest Airlines is also considered an ATI partner of Delta Airlines until the first quarter of 2010.

2.3 Data and Sample Selection

This study is performed using quarterly data from the International Passenger Origin and Destination Survey obtained from the U.S. Department of Transportation. This data is a 10% sample of all itineraries involving an international flight segment, where at least one segment is operated by a U.S. carrier. The time period examined in this study spans from the first quarter of 2005 through the third quarter of 2011. Each observation in the dataset is an itinerary containing information regarding the prices, origin airport, intermediate stop airports, destination airport, distance between each airport, operating carrier for each coupon segment, ticketing carrier for each coupon segment, and the number of passengers that purchased the itinerary at a particular price. One key characteristic of this dataset is that it contains information for each direction of travel (going and returning/coming) on the itinerary. Thus, there is information regarding the going portion of the itinerary (origin to destination) and the coming portion of the itinerary (destination back to origin) for roundtrip itineraries.

In order to properly study the effects of international airline alliance and ATI participation on product quality, the data are restricted to itineraries that meet specific criteria. First, only roundtrip itineraries are used in the analysis. Additionally, itineraries in which there are multiple ticketing carriers are excluded. Itineraries in which the origin airport, destination airport or one of the intermediate airport stops occur more than once for the going portion or coming portion of the itinerary are also excluded. Finally, only itineraries with a price within the range of $100 to $10,000 are examined. The number of itineraries within each quarter of the dataset is extremely large and repeated multiple times. Therefore, repeated itineraries are collapsed into uniquely defined products for each quarter. Thus, each observation in the dataset represents a particular product. The final sample consists of 2,057,144 observations/products spread across 541,978 markets.

In this study we focus on each product's quality of routing between the origin and destination, and we measure routing quality using distance travelled on an itinerary. Routing quality is measured as follows:

$$Routing\_quality_{jmt} = \frac{Min\_dist_m}{Itinerary\_dist_{jmt}} \times 100. \tag{1}$$

Given that information is available for the going and coming portion of an itinerary, one can separately measure the routing quality for the going and coming portions of the itinerary. *Routing_quality_going* is calculated as minimum flying distance between the origin/destination divided by the actual itinerary flying distance for the going portion of the itinerary. Actual flying distance may differ across products due to differences in intermediate stop(s) locations across products. *Routing_quality_coming* is similarly calculated for the coming portion of the itinerary. *Mindist_going* (*Mindist_coming*) is calculated as the minimum distance on the going (coming) portion of a product in a given market.[7] Both routing quality variables are measured in terms of percentage. The highest routing quality product in each market has a measure of 100. Therefore, the routing quality of each product is measured relative to the highest quality product in the market. We also construct a variable, *Routing_quality*, that assigns a unique routing quality value to each product. *Routing_quality* is the mean of *Routing_quality_going* and *Routing_quality_coming*.

Other variables used in the study include a measure of an airline's origin airport presence, *Opres*. *Opres* is calculated as the number of destination airports that a ticketing carrier offers nonstop service to leaving from a given origin airport. *N_comp_nonstop_going* (*N_comp_nonstop_coming*) is defined as the total number of products in a market that do not require an intermediate stop on the going (coming) portion of the itinerary, and these enumerated products are offered by ticketing carriers that are competing with the ticketing carrier of the product for which *N_comp_nonstop_going* (*N_comp_nonstop_coming*) is computed. Analogously, *N_comp_interstop_going* (*N_comp_interstop_coming*) is defined as the total number of products in a market that require an intermediate stop on the going (coming) portion of the itinerary, and these enumerated products are offered by ticketing carriers that are competing with the ticketing carrier of the product for which *N_comp_interstop_going* (*N_comp_interstop_coming*) is computed.

Other key variables in the analysis include codeshare variables. In order to create the codeshare variables regional carriers must be accounted for. Specifically, to facilitate accurate construction of codeshare variables, we follow previous studies and convert regional carriers to

[7] It is important to note that the minimum flying distance between the origin and destination is not always equal to the nonstop flying distance. This is because there is not always a nonstop flight available between an origin and destination. In cases where there is not a nonstop flight available, the minimum distance is calculated using the lowest itinerary distance between the origin and destination.

their respective major carrier. For instance, consider the US domestic regional carrier SkyWest Airlines (OO). The assumption is made that SkyWest Airlines is operating a coupon segment for the US major ticketing carrier that often transport passengers internationally. Therefore, in the sample the ticketing carrier/operating carrier combination, UA/OO, would be transformed to UA/UA and classified as online. This procedure ensures that when an itinerary is classified as having codeshare features, this codesharing is between major carriers, and therefore consistent with the focus of much of the literature on airline codesharing.

Two types of codeshare variables are defined: traditional and virtual. *Traditional_going* (*Traditional_coming*) is a zero-one dummy variable that takes the value one only if there are multiple carriers that operate respective coupon segments on the going (coming) portion of the itinerary. *Virtual_going* (*Virtual_coming*) is a zero-one dummy variable that takes the value one only if there is one carrier that operates each coupon segment on the going (coming) portion of the itinerary, but the sole operating carrier is different than the ticketing carrier.

Dummy variables are created to indicate whether a product is a United Airlines (*UA*), Delta Airlines (*DL*) or American Airlines (*AA*) product. *Star* is a variable indicating the total number of carriers in the Star alliance other than United Airlines for each quarter. In the event that a carrier enters the alliance in a particular quarter, the number of carriers in the alliance increases for that quarter. Similarly, if a carrier exits the alliance in a particular quarter, the number of carriers in the alliance decreases for that quarter. ATI^{UA} is defined as the total number of carriers in each quarter that have ATI agreement with United Airlines. *Skyteam* and ATI^{DL} are analogously defined variables for the Skyteam alliance and ATI agreements that include Delta Airlines. Additionally, *Oneworld* and ATI^{AA} are analogously defined variables for the Oneworld alliance and ATI agreements that include American Airlines.

2.4 Summary Statistics

Table 1 reports summary statistics on each of the variables. The summary statistics in Table 1 for the going portion of all itineraries in the sample indicate that approximately 17% of the products in the sample are traditionally codeshared, and about 2% are virtually codeshared. Therefore, approximately 81% are online products. These statistics are similar when examining the coming portion of itineraries.

The summary statistics in Table 1 show that approximately 17% of the products in the sample are United Airlines products, 24% are Delta Airlines products and 18% are American Airlines products. Furthermore, Table 2 gives a breakdown of the types of products offered by the three carriers. Table 2 indicates that about 23% of United Airlines products are traditionally codeshared and 5% are virtually codeshared. A much larger portion of United Airlines products is codeshared when comparing to Delta Airlines and American Airlines. This could be due to the fact that United Airlines is a member of the largest international alliance and has the most ATI partners. Only about 1% of Delta Airlines' products are virtually codeshared and less than 1% of American Airlines' products are virtually codeshared.

Table 1. Descriptive Statistics
(2005Q1 – 2011Q3)

Variable	Mean	Std. Dev.	Min	Max
Routing_quality_going	93.90	9.29	35.71	100
Routing_quality_coming	93.82	9.38	28.28	100
Routing_quality	93.86	8.62	36.72	100
Opres	26.74	41.14	0	265
Mindist_going	3776.98	2433.80	96	14135
Mindist_coming	3776.37	2432.39	96	14421
N_comp_nonstop_going	0.09	0.81	0	46
N_comp_nonstop_coming	0.09	0.81	0	47
N_comp_interstop_going	7.29	10.94	0	137
N_comp_interstop_coming	7.32	10.94	0	138
Traditional_going	0.17	0.37	0	1
Traditional_coming	0.17	0.38	0	1
Virtual_going	0.02	0.15	0	1
Virtual_coming	0.03	0.16	0	1
UA	0.17	0.38	0	1
Star	22.14	3.18	17	27
ATI^{UA}	10.40	2.24	7	13
DL	0.24	0.43	0	1
Skyteam	11.37	2.26	8	15
ATI^{DL}	5.17	1.11	4	7
AA	0.18	0.38	0	1
Oneworld	8.68	1.22	7	10
ATI^{AA}	4.65	1.67	3	8
Observations	2,057,144			
Markets	541,978			

Table 2. Rate of Product Types by Carrier			
	UA	DL	AA
Traditional_going	0.234	0.126	0.152
Traditional_coming	0.230	0.135	0.155
Virtual_going	0.050	0.013	0.005
Virtual_coming	0.058	0.018	0.006

3. Methodology

The goal is to examine the relationship between the routing quality of United Airlines', Delta Airlines' and American Airlines' products and changes in alliance participation or ATI partners. This is accomplished by estimating the following reduced-form regression where *i* indexes product, *m* indexes the origin/destination combination and *t* indexes the time period:

$$\begin{aligned} Routing\_quality_{imt} = {} & \beta_1 + \beta_2 X_{imt} + \beta_3 UA_{imt} + \beta_4 Star_t + \beta_5 UA_{imt} \times Star_t \\ & + \beta_6 ATI_t^{UA} + \beta_7 UA_{imt} \times ATI_t^{UA} \\ & + \beta_8 T_t^{UA/CO} + \beta_9 UA_{imt} \times T_t^{UA/CO} \\ & + \beta_{10} DL_{imt} + \beta_{11} Skyteam_t + \beta_{12} DL_{imt} \times Skyteam_t \\ & + \beta_{13} ATI_t^{DL} + \beta_{14} DL_{imt} \times ATI_t^{DL} \\ & + \beta_{15} T_t^{DL/NW} + \beta_{16} DL_{imt} \times T_t^{DL/NW} \\ & + \beta_{17} AA_{imt} + \beta_{18} Oneworld_t + \beta_{19} AA_{imt} \times Oneworld_t \\ & + \beta_{20} ATI_t^{AA} + \beta_{21} AA_{imt} \times ATI_t^{AA} \\ & + \alpha_i + \gamma_t + origin_m + dest_m + \varepsilon_{imt}. \end{aligned} \quad (2)$$

X_{imt} is a vector of control variables that are hypothesize to influence a product's routing quality. These controls include: (1) a measure of the origin presence of the ticketing carrier, captured by variable, *Opres*; (2) the minimum distance between the origin and destination, captured by variables, *Mindist_going* and *Mindist_coming*; (3) the number of products that competes with the product in question, captured by variables, *N_comp_nonstop_going*, *N_comp_nonstop_coming*, *N_comp_interstop_going*, and *N_comp_interstop_coming* respectively. The set of variables in (3) control for the level of competition a product faces by type of competing products. Additionally, dummy variables are included in X_{imt} that indicate if the product is traditionally codeshared or virtually codeshared. Operating carrier fixed effects

(α_i), year and quarter fixed effects (γ_t), origin fixed effects ($origin_m$) and destination fixed effects ($dest_m$) are included to control for their unobserved effects on a product's routing quality.

The specification in equation (2) can identify how alliance participation and ATI membership affect routing quality of a carrier's products. This is achieved through a difference-in-differences identification approach through the use of interaction variables. *UA*, *DL* and *AA* are dummy variables indicating if the ticketing carrier is United Airlines, Delta Airlines or American Airlines, respectively. *Star*, *Skyteam* and *Oneworld* are as previously defined. Likewise, ATI^{UA}, ATI^{DL} and ATI^{AA} are as previously defined. The specification in equation (2) implies that the routing quality of products offered by United Airlines, Delta Airlines or American Airlines depends on the number of alliance and ATI partners. Therefore, β_3, β_{10} and β_{17} by themselves capture how the routing quality of products offered by each of these carriers differs from the routing quality of products offered by other carriers on average if the respective carrier had no alliance or ATI partners. The coefficient estimates of the interaction variables then capture how an additional alliance member or ATI partner affects the routing quality of the respective ticketing carrier's products relative to products offered by other carriers.[8]

One of the key variables in this analysis is the interaction variable, $UA \times Star$. The coefficient on this interaction variable, β_5, indicates how, on average, an additional member in the Star alliance affects the routing quality of United Airlines' products relative to the routing quality of non-United products, all else constant. A positive value for β_5 indicates that an additional member in the Star alliance increases the routing quality of United Airlines' products relative to non-United products, while a negative value indicates a relative decrease in routing quality of United Airlines' products. Similarly, β_7, indicates how the routing quality of United Airlines' products change on average relative to non-United products when United receives an additional ATI partner. Note that β_4 and β_6 respectively capture how an additional member in the Star alliance and an additional ATI partner for United Airlines affect the routing quality of other carriers' products on average, all else constant. The total effect of an additional Star

[8] $\partial Routing\_quality/\partial UA = \beta_3 + \beta_5 Star + \beta_7 ATI^{UA} + \beta_9 T^{UA/CO}$. How the routing quality of United's products compare to products of other carriers depends on the number of alliance members (*Star*), ATI partners (ATI^{UA}), and whether the time period is before or after the United/Continental merger. A positive estimate of β_5 indicates that each alliance partner increases the routing quality of United Airlines' products relative to other carriers' products on average, and an analogous interpretation for β_7 in case of United Airlines acquiring an additional ATI partner. A positive estimate of β_9 indicates that the average routing quality of the set of products offered by United has increased relative to the average routing quality of products offered by other carrier's after the merger with Continental.

alliance member can be calculated as $\beta_4 + \beta_5$.[9] This total effect captures the total change in routing quality of United Airlines' products on average with an additional member in the Star alliance. Similarly, the total effect of an additional ATI partner of United can be calculated as $\beta_6 + \beta_7$. β_{11}, β_{12}, β_{13} and β_{14} can be interpreted similarly for Delta Airlines and the Skyteam alliance, while β_{18}, β_{19}, β_{20} and β_{21} can be interpreted similarly for American Airlines and the Oneworld alliance.

To help identify the potential routing quality impacts of two domestic mergers - United/Continental merger and Delta/Northwest merger - we construct two zero-one time period dummy variables, $T^{UA/CO}$ and $T^{DL/NW}$, respectively. These time period dummy variables that take the value one during post-merger time periods for the respective mergers, i.e., $T^{UA/CO}$ takes the value of one for time periods beyond and including the fourth quarter of 2010, while $T^{DL/NW}$ takes the value of one for time periods beyond and including the fourth quarter of 2008. Therefore, β_8 measures systematic changes in routing quality of non-UA/CO products that occurred subsequent to the UA/CO merger, and β_9 measures how the routing quality of UA products change relative to other carriers' products subsequent to the UA/CO merger.[10] Thus, a positive estimate of β_9 indicates that the merger increased the average routing quality of United's products relative to other carriers' products. The sum of β_8 and β_9 tells one how the total routing quality of United's products changed on average after the merger. Analogous interpretations hold for β_{15} and β_{16} in case of the Delta Airlines and Northwest Airlines merger.

As mentioned previously, one characteristic of the International Passenger Origin and Destination Survey is that it contains information for the going and coming portions of roundtrip

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[9] $\partial Routing\_quality/\partial Star = \beta_4 + \beta_5 UA$. The effect an additional Star alliance member has on routing quality depends on whether the product is a United Airlines product (i.e. the effect depends on whether $UA = 0$ or $UA = 1$). β_4 captures the effect of *Star* when $UA = 0$. $\beta_4 + \beta_5$ captures the effect of *Star* when $UA = 1$. For instance, if the coefficient estimate for this interaction term (β_5) is statistically significant, it means an additional Star Alliance member affects the routing quality of United products differently than products offered by other carriers. So β_5 illustrates how the routing quality of United products change relative to products offered by other carriers. In order to determine whether the overall routing quality of United's products increase or decrease, one must consider the coefficients estimates of both β_4 and β_5.

[10] $\partial Routing\_quality/\partial T^{UA/CO} = \beta_8 + \beta_9 UA$. This partial derivative illustrates that the effect of the United/Continental merger on routing quality depends on whether the product is a United Airlines product (i.e. the effect depends on whether $UA = 0$ or $UA = 1$). β_8 captures the effect of the merger when $UA = 0$. $\beta_8 + \beta_9$ captures the effect of the merger when $UA = 1$. For instance, if the coefficient estimate for the interaction term (β_9) is statistically significant, it means that the merger affects the routing quality of United products differently than products offered by other carriers. So β_9 illustrates how the routing quality of United products change relative to products offered by other carriers as a result of the merger. In order to determine whether the overall routing quality of United's products increase or decrease, one must consider the coefficients estimates of both β_8 and β_9.

itineraries. The method proposed in this study is to separately examine the going and coming portions. In line with this, the reduced-form equation (2) is estimated under three sets of information. Equation (2) is estimated using only the information for the going portion of the itinerary, using only information for the coming portion of the itinerary, and using information from the entire itinerary.

4. Estimation Results

4.1 The Effects of Alliance Membership and ATI on Average Routing Quality

Table 3 reports parameter estimates for equation (2). Regressions are estimated using ordinary least squares (OLS) with robust standard errors. The first column in the table shows estimation results based on information from the going portion of each itinerary, estimates in the second column are based on information from the coming portion of each itinerary, and estimates in the third column are based on information from each complete itinerary. The qualitative results are quite consistent across each column of estimates. For brevity, the following discussion focuses on estimation results based on information from each complete itinerary.

The first point to be made is in regard to the constant term. The constant term of 92.85 indicates that the minimum distance between an origin and destination is on average 92.85% of the itinerary distances actually flown by passengers when all independent variables in the regression have a value of zero. Although, this mean will change as values of the independent variables change. The result regarding origin presence, *Opres*, suggests that each additional airport that a carrier offers nonstop service to from the market's origin airport increases routing quality of the carriers' products in that market by 0.02 percentage points on average. In other words, the mean distance flown by passengers decreases and becomes closer to the minimum distance between the origin and destination.

Table 3. Routing Quality Estimation Results

	Dependent Variable					
	Routing_quality_going		Routing_quality_coming		Routing_quality	
	Coefficient Estimate	Robust Std. Error	Coefficient Estimate	Robust Std. Error	Coefficient Estimate	Robust Std. Error
Opres	0.019***	(0.000)	0.018***	(0.000)	0.020***	(0.000)
Mindist_going	0.003***	(0.000)			0.001***	(0.000)
Mindist_coming			0.003***	(0.000)	0.002***	(0.000)
N_comp_nonstop_going	1.017***	(0.009)			0.534***	(0.008)
N_comp_nonstop_coming			1.012***	(0.009)	0.547***	(0.008)
N_comp_interstop_going	-0.101***	(0.001)			-0.048***	(0.001)
N_comp_interstop_coming			-0.097***	(0.001)	-0.041***	(0.001)
Traditional_going	-0.686***	(0.040)			-0.369***	(0.023)
Traditional_coming			-0.731***	(0.037)	-0.476***	(0.023)
Virtual_going	1.913***	(0.045)			1.271***	(0.038)
Virtual_coming			1.753***	(0.041)	1.268***	(0.035)
UA	-2.735***	(0.142)	-2.720***	(0.144)	-2.931***	(0.131)
Star	-0.024*	(0.014)	-0.018	(0.014)	-0.022*	(0.012)
UA×Star	0.051***	(0.009)	0.046***	(0.009)	0.045***	(0.008)
ATI^{UA}	-0.061	(0.045)	-0.068	(0.046)	-0.042	(0.041)
$UA\times ATI^{UA}$	0.073***	(0.012)	0.067***	(0.012)	0.074***	(0.011)
$T^{UA/CO}$	0.045	(0.070)	0.135*	(0.070)	0.073	(0.063)
$UA\times T^{UA/CO}$	-0.029	(0.048)	0.099**	(0.049)	0.062	(0.044)
DL	-3.672***	(0.110)	-3.484***	(0.111)	-3.456***	(0.103)
Skyteam	-0.054***	(0.010)	-0.056***	(0.010)	-0.050***	(0.009)
DL×Skyteam	0.139***	(0.011)	0.138***	(0.011)	0.121***	(0.010)
ATI^{DL}	0.013	(0.022)	-0.004	(0.022)	-0.003	(0.020)
$DL\times ATI^{DL}$	-0.034	(0.027)	-0.074***	(0.027)	-0.029	(0.025)
$T^{DL/NW}$	-0.021	(0.043)	-0.016	(0.044)	-0.014	(0.040)
$DL\times T^{DL/NW}$	0.496***	(0.040)	0.584***	(0.041)	0.527***	(0.037)
AA	-2.542***	(0.135)	-2.412***	(0.136)	-2.637***	(0.123)
Oneworld	-0.009	(0.022)	-0.019	(0.022)	-0.021	(0.020)
AA×Oneworld	0.155***	(0.015)	0.142***	(0.016)	0.163***	(0.014)
ATI^{AA}	0.006	(0.011)	-0.001	(0.011)	0.004	(0.010)
$AA\times ATI^{AA}$	0.017	(0.011)	0.016	(0.011)	0.018*	(0.010)
Constant	93.347***	(0.666)	93.266***	(0.669)	92.847***	(0.624)
OP Carrier FE	Yes		Yes		Yes	
Time FE	Yes		Yes		Yes	
Origin/Dest FE	Yes		Yes		Yes	
R^2	0.201		0.200		0.227	
Breusch-Pagan (χ^2) test for Heteroskedasticity	593,866.43***		595,256.84***		608,639.31***	
Observations	2,057,144					

Notes: Equations are estimated using ordinary least squares (OLS) with robust standard errors. *** indicates statistical significance at the 1% level, ** indicates statistical significance at the 5% level and * indicates statistical significance at the 10% level.

The estimates regarding *Mindist_going* and *Mindist_coming* indicate that the greater the distance between an origin and destination, the greater the routing quality for products in the market on average. The number of competing products a given product faces in a market also impacts the product's routing quality. A given product's routing quality tends to be higher the greater the number of competing products with nonstop service (going or coming) it faces. In contrast, a given product's routing quality tends to be lower the greater the number of competing products with interstop service (going or coming) it faces.

The results indicating the effects of codesharing also provide interesting results. A product can be online, traditionally codeshared or virtually codeshared. The results indicate that products where the going or coming portion are traditionally codeshared have lower routing quality than online products on average. Specifically, the going (coming) portion of itineraries that are traditionally codeshared have routing quality that is on average 0.37 percentage points (0.48 points) lower than routing quality of online itineraries. Perhaps this result is primarily driven by the fact that traditional codeshared products require intermediate stop(s) to facilitate a change of operating carrier, while some online products do not have an intermediate stop.

On the other hand, products in which the going or coming portion of the itinerary are virtually codeshared have higher routing quality than online products on average. Routing quality for products where the going (coming) itinerary portion is virtually codeshared is on average 1.27 percentage points (1.27 percentage points) higher than if the itinerary portion was online. This result suggests that ticketing carriers of virtual codeshare products tend to practice this type of codesharing with operating carriers that offer online products with higher routing quality than the ticketing carriers' own online products.

The key variables in this analysis are the variables involving the carriers United Airlines, Delta Airlines and American Airlines as well as the variables regarding membership changes in their respective alliance and ATI agreement. The coefficient estimate on *UA* suggests that in the absence of UA having any alliance members or ATI partners, and prior to merging with Continental Airlines, the mean routing quality for products offered by United Airlines is estimated to be 2.93 percentage points lower than the mean routing quality of products offered by other airlines. Analogous estimates of the mean routing quality of Delta Airlines' and American Airlines' products are about 3.46 and 2.64 percentage points lower than the mean routing quality of products offered by other airlines, respectively. However, the positive coefficient estimates on the interaction terms $UA \times Star$ and $UA \times ATI^{UA}$ indicate that as the Star alliance expands or United Airlines gains an additional ATI partner, the routing quality of United Airlines' products increases relative to the routing quality of other carriers' products.

The coefficient estimate on *Star* indicates that an additional member in the Star alliance is associated with lower routing quality of non-United Airlines products by 0.02 percentage points, and the coefficient estimate for *Skyteam* indicates that the routing quality of non-Delta Airlines products decreases by 0.05 percentage points on average with each additional member of the Skyteam alliance.

The coefficient estimates on the interaction term, $UA \times Star$, indicates that each additional member in the Star alliance increases the routing quality of United Airline's products relative to other carriers' products by 0.05 percentage points on average. Table 3.1 provides estimates of the total effect of alliance membership and ATI partnerships. The estimates regarding the total effect of an additional Star alliance member (-0.022+0.045) provide some evidence that on average the routing quality of United Airlines' products increase with each additional Star alliance member. The coefficient estimate for $UA \times ATI^{UA}$ indicates that each additional ATI partner for United Airlines increases the relative routing quality of United Airlines' products by 0.07 percentage points on average.

The results suggest that each additional member in the Skyteam alliance increases the routing quality of Delta Airlines' products relative other carriers' products on average by 0.12 percentage points. The total effect of an additional Skyteam member indicates an average increase in routing quality of Delta Airline's products of about 0.07 percentage points. It is important to note there is evidence that ATI partnerships involving Delta Airlines are associated with lower routing quality for Delta Airlines' products by 0.08 percentage points on average for the coming portion of itineraries. Although, this result is mixed among the three specifications.

Each additional member in the Oneworld alliance, and each additional ATI partner, increase the routing quality of American Airlines' products relative to other carriers' products by 0.16 percentage points and 0.02 percentage points on average, respectively. The total effect of an additional Oneworld member or ATI partner for American Airlines is associated with an increase in routing quality of about 0.14 percentage points and 0.02 percentage points on average, respectively.

The results concerning United Airlines, Delta Airlines, and American Airlines suggest that an additional alliance partner has a larger impact on the routing quality of their products than an ATI partner.

The estimates in Table 3 provide evidence that domestic mergers also had a significant impact on routing quality. The coefficient estimates on $T_t^{UA/CO}$ and $UA_{imt} \times T_t^{UA/CO}$ are not statistically significant on their own when the specification involves the entire itinerary. However, these coefficient estimates are statistically significant for the specification involving the coming portion of itineraries. The coefficient estimates indicate that, post United/Continental merger, the routing quality of United Airlines' products relative to other carriers' products increased by 0.10 percentage points on average. The total effect of the merger on the routing quality for United Airlines' products is shown in Table 3.1. The results indicate the merger increased the routing quality of United Airlines' products by 0.13 percentage points on average.

There is evidence that the Delta/Northwest merger increased routing quality of Delta Airlines' products relative to other carriers' products by 0.53 percentage points on average. The total effect on the routing quality for Delta Airlines' products resulting from the merger is an increase of 0.51 percentage points on average.

Table 3.1 Total Effects of Alliance Membership and ATI Partnerships

	Dependent Variable					
	Routing_quality_going		Routing_quality_coming		Routing_quality	
Total Effect	Estimate	F-Statistic	Estimate	F-Statistic	Estimate	F-Statistic
Star ($\beta_4 + \beta_5$)	0.026*	2.92	0.028*	3.28	0.023*	2.81
ATI^{UA} ($\beta_6 + \beta_7$)	0.012	0.07	0.000	0.00	0.032	0.57
$T^{UA/CO}$ ($\beta_8 + \beta_9$)	0.016	0.04	0.234***	8.49	0.134*	3.47
Skyteam ($\beta_{11} + \beta_{12}$)	0.085***	46.35	0.082***	42.29	0.071***	37.74
ATI^{DL} ($\beta_{13} + \beta_{14}$)	-0.021	0.52	-0.079***	7.44	-0.032	1.47
$T^{DL/NW}$ ($\beta_{15} + \beta_{16}$)	0.475***	85.72	0.569***	120.67	0.513***	117.08
Oneworld ($\beta_{18} + \beta_{19}$)	0.146***	32.31	0.124***	22.87	0.142***	37.27
ATI^{AA} ($\beta_{20} + \beta_{21}$)	0.023	2.64	0.015	1.05	0.021*	2.76

*** indicates statistical significance at the 1% level, ** indicates statistical significance at the 5% level and * indicates statistical significance at the 10% level. The results test whether the linear combination of the respective variables are statistically different from 0.

4.1 The Effects on Average Routing Quality by Product Type

The key results shown in Table 3 indicate that domestic mergers, as well as more extensive international cooperation between airlines, either in the form of alliance or ATI membership increase, are associated with relative increases in the merging or cooperating airlines' product quality. Equation (2) can be modified to identify changes in relative routing quality by types of products when there is: (i) an additional alliance member; (ii) an additional ATI partner; or (iii) a domestic merger. The routing quality effects by product type are identified by the coefficient estimates on three-way interaction variables included in the regressions. For example, the coefficient estimates on three-way interaction variables, *UA×Star×online*, *UA×Star×traditional*, and *UA×Star×virtual*, identify the extent to which increases in membership of the Star alliance influence routing quality of United Airline's online, traditional codeshare, and virtual codeshare products relative to other carriers' products respectively. Analogous three-way interaction variables in the cases of the other two alliances (Skyteam and Oneworld) and carriers (Delta Airlines and American Airlines) are included in the regressions to identify analogous relative routing quality effects by product types.

An increase in the routing quality of a carrier's online products suggests that the carrier's rearrangement of its own network resulted in new routing to more conveniently transport passengers between their origin and destination. An increase in the routing quality of a carrier's codeshare products suggests that an expansion in alliance members/ATI partners resulted in new higher quality routing options that require using its partner carriers' networks.

The estimation results from this modified specification are shown in Table 4. Separate regressions are estimated using information from the going portion of itineraries and information from the coming portion of the itineraries, respectively. One reason it makes sense to estimate separate regressions for the going and coming portions of itineraries is that each portion of an itinerary is either online, traditionally codeshared or virtually codeshared, but it is not always the case that the going portion is the same type as the coming portion.

First, consider the results of alliance membership. The results indicate that an increase in membership in the Star alliance increases the routing quality for each type of product offered by United Airlines relative to competitors' products. Specifically, each additional member in the Star alliance increases the relative routing quality of United Airlines' online products by approximately 0.02%, traditional codeshare products by 0.11% and virtual codeshare products by 0.13% on average. Similarly, an increase in membership of the Oneworld alliance increases the relative routing quality for each type of product offered by American Airlines. Each additional member in the Oneworld Alliance increases American Airlines' routing quality relative to competitors' products for online, traditional codeshare, and virtual codeshare products by about 0.13%, 0.21%, and 1.18% on average, respectively.

In the case of Delta Airlines, an additional Skyteam member increases the relative routing quality of Delta Airlines' online products by about 0.15% on average. Furthermore, there is evidence that an additional Skyteam member increases the relative routing quality of Delta Airlines' traditional and virtual codeshare products by 0.06% and 0.10% on average.[11]

Collectively, these results suggest that an increase in alliance membership is accompanied with higher relative routing quality for each type of product a carrier can offer. In the cases of United Airlines and American Airlines, the types of products that experience the largest increase in relative routing quality are virtually codeshared products. This suggests that the greater the number of alliance members, the greater the number of flights in which other alliance members can sell to conveniently transport passengers. In the case of Delta Airlines, the types of products that experience the largest increase in relative routing quality are online products. The results regarding alliance membership and a carrier's online products suggest that increases in the membership of a carrier's alliance incentivize that carrier to rearrange its own network to accommodate the partner carriers' network, and this network rearrangement tends to result in products with higher routing quality.

Next, consider the effects of ATI. The results regarding the effects of ATI on routing quality of the different product types are mixed. With regard to United Airlines, each additional ATI partner increases relative routing quality of United Airlines' online products, but not the relative routing quality of its codeshare products. More precisely, each additional ATI partner increases relative routing quality for United Airlines' online products by about 0.10% on average. With respect to Delta Airlines, each additional ATI partner decreases the relative routing quality of Delta Airlines' online products by 0.07%, but increases with traditional codeshare and virtual codeshare products respectively by 0.26% and 0.70% on average. Finally, the results suggest that an additional ATI partner with American Airlines increases relative routing quality of American Airlines' online products by about 0.04% on average. However, an additional ATI partner decreases relative routing quality for traditional and virtual codeshare products by 0.05% and 1.28% on average, respectively.

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[11] Note that the coefficient indicating the effect of Skyteam alliance membership on the routing quality of Delta Airlines' traditional codeshare products is not statistically significant on the coming portion of itineraries, and the effect on virtual codeshare products is not statistically significant on the going portion of itineraries.

Table 4. Routing Quality Estimation Results for Various Types of Products

	Dependent Variable			
	Routing_quality_going		Routing_quality_coming	
	Coefficient Estimate	Robust Std. Error	Coefficient Estimate	Robust Std. Error
Opres	0.019***	(0.000)	0.018***	(0.000)
Mindist_going	0.003***	(0.000)		
Mindist_coming			0.003***	(0.000)
N_comp_nonstop_going	1.020***	(0.009)		
N_comp_nonstop_coming			1.014***	(0.009)
N_comp_interstop_going	-0.101***	(0.001)		
N_comp_interstop_coming			-0.097***	(0.001)
Traditional_going	-0.760***	(0.046)		
Traditional_coming			-0.789***	(0.043)
Virtual_going	1.229***	(0.068)		
Virtual_coming			1.244***	(0.066)
UA	-2.909***	(0.145)	-2.799***	(0.147)
Star	-0.025*	(0.014)	-0.019	(0.014)
UA×Stars×online	0.024***	(0.009)	0.020**	(0.010)
UA×Star×traditional	0.113***	(0.012)	0.111***	(0.012)
UA×Star×virtual	0.129***	(0.021)	0.088***	(0.021)
ATI^{UA}	-0.062	(0.045)	-0.067	(0.046)
UA×ATI^{UA}×online	0.101***	(0.014)	0.096***	(0.015)
UA×ATI^{UA}×traditional	-0.015	(0.021)	-0.028	(0.021)
UA×ATI^{UA}×virtual	0.047	(0.041)	0.087**	(0.041)
$T^{UA/CO}$	0.046	(0.070)	0.137*	(0.070)
UA×$T^{UA/CO}$×online	0.057	(0.055)	0.251***	(0.057)
UA×$T^{UA/CO}$×traditional	-0.094	(0.078)	-0.054	(0.080)
UA×$T^{UA/CO}$×virtual	-1.252***	(0.151)	-1.234***	(0.139)
DL	-3.935***	(0.112)	-3.729***	(0.114)
Skyteam	-0.056***	(0.010)	-0.057***	(0.010)
DL×Skyteam×online	0.151***	(0.011)	0.160***	(0.012)
DL×Skyteam×traditional	0.064***	(0.022)	-0.003	(0.022)
DL×Skyteam×virtual	0.045	(0.052)	0.104**	(0.048)
ATI^{DL}	0.014	(0.022)	-0.003	(0.022)
DL×ATI^{DL}×online	-0.073**	(0.028)	-0.133***	(0.029)
DL×ATI^{DL}×traditional	0.255***	(0.053)	0.353***	(0.053)
DL×ATI^{DL}×virtual	0.704***	(0.122)	0.547***	(0.116)
$T^{DL/NW}$	-0.020	(0.043)	-0.016	(0.044)
DL×$T^{DL/NW}$×online	0.596***	(0.042)	0.698***	(0.042)
DL×$T^{DL/NW}$×traditional	-0.246***	(0.075)	-0.074	(0.077)
DL×$T^{DL/NW}$×virtual	-1.813***	(0.172)	-2.096***	(0.163)

Notes: Test of heteroskedasticity conducted with Breusch-Pagan test. Equations are estimated using ordinary least squares (OLS) with robust standard errors. *** indicates statistical significance at the 1% level, ** indicates statistical significance at the 5% level and * indicates statistical significance at the 10% level.

Table 4 Continued				
AA	-2.782***	(0.140)	-2.530***	(0.139)
Oneworld	-0.006	(0.022)	-0.018	(0.022)
AA×Oneworld×online	0.133***	(0.016)	0.128***	(0.016)
AA×Oneworld×traditional	0.207***	(0.019)	0.160***	(0.019)
AA×Oneworld×virtual	1.179***	(0.059)	0.996***	(0.050)
ATI^{AA}	0.006	(0.011)	-0.002	(0.011)
AA×ATI^{AA}×online	0.036***	(0.012)	0.034***	(0.012)
AA×ATI^{AA}×traditional	-0.053***	(0.018)	-0.047**	(0.018)
AA×ATI^{AA}×virtual	-1.281***	(0.089)	-1.095***	(0.074)
Constant	93.658***	(0.672)	93.494***	(0.672)
OP Carrier FE	Yes		Yes	
Time FE	Yes		Yes	
Origin/Dest FE	Yes		Yes	
R^2	0.201		0.200	
Breusch-Pagan (χ^2)	594,367.56***		595,480.32***	
Observations	2,057,144			

Notes: Test of heteroskedasticity conducted with Breusch-Pagan test. Equations are estimated using ordinary least squares (OLS) with robust standard errors. *** indicates statistical significance at the 1% level, ** indicates statistical significance at the 5% level and * indicates statistical significance at the 10% level.

The results regarding the United/Continental and Delta/Northwest mergers are interesting. The estimates indicate that each of the carriers, United Airlines and Delta Airlines, experienced relative routing quality increases for their online products, but relative routing quality decreases for their virtual codeshare products. This result may be evidence that after the respective mergers, the new online international air travel products that United Airlines and Delta Airlines are able to offer based on better control and leveraging of the route network of the carriers they merged with, are of relatively higher routing quality compared to pre-merger routing quality of their online products.

5. Conclusion

A key objective of this study is to examine how the routing quality of products a carrier offers is affected by expansions in the numbers of the carrier's alliance and ATI partners. The study also examines the impacts that two domestic mergers have on the routing quality of international air travel products provided by the merging airlines. Prior research regarding alliance membership and ATI has focused on the price effects. However, it is also important to understand how cooperation affects product quality. The empirical results are obtained by estimating reduced-form product quality regressions, which are specified using a difference-in-differences approach for identifying relevant quality effects.

The results give strong evidence indicating that cooperation among international carriers is associated with an increase in routing quality of a carrier's products on average. This result holds for expansions in alliance membership for each of the three carriers examined: United Airlines, Delta Airlines and American Airlines. Furthermore, the results suggest that increases in alliance membership are associated with relative routing quality increases for each type of product the carrier offers (online, traditional codeshare and virtual codeshare) with virtual codeshare products experiencing the greatest relative routing quality increase for United Airlines and American Airlines. The results regarding the impact of ATI on routing quality of codeshare products are mixed among the three carriers. Furthermore, the United/Continental and Delta/Northwest domestic mergers appear to have increased the routing quality for passengers travelling internationally with United Airlines and Delta Airlines.

Much of the literature to date has focused on the price effects of airline cooperation and mergers, and have used these price effects to infer associated welfare effects. It is well-known in economics that, all else equal, consumer welfare is positively related to product quality. This research formally provides evidence of product quality effects associated with airline cooperation and mergers, which implies that a complete welfare evaluation of these strategic choices of airlines should not ignore product quality effects.

This paper leaves unanswered the question of whether product quality is worse for itineraries involving nonaligned carriers than for alliance itineraries. Future work may consider answering this question.

Appendix

Table A1. Chronological History of Alliance Participation by Alliance			
Alliance	**Carriers**	**Dates beginning**	**Dates ended**
Star	**United Airlines**, Air Canada, Lufthansa, SAS and Thai Airways	5/1997	
	VARIG Brazilian Airlines	10/1997	
	Ansett Australia, Air New Zealand and ANA	3/1999	
	Austrian Airlines Group[1]	3/2000	
	Singapore Airlines	4/2000	
	British Midland and Mexicana Airlines	7/2000	
	Ansett Australia		3/2002
	Asiana Airlines	3/2003	
	Spanair	4/2003	
	LOT Polish Airlines	10/2003	
	Mexicana Airlines		3/2004
	US Airways	5/2004	
	Adria Airways and Croatia Airlines	11/2004	
	TAP Portugal	5/2005	
	South African Airways and Swiss Int. Air Lines	4/2006	
	VARIG Brazilian Airlines		1/2007
	Air China and Shanghai Airlines	12/2007	
	Turkish Airlines	4/2008	
	EGYPTAIR	7/2008	
	Continental[2]	10/2009	
	SN Brussels Airlines	12/2009	
	TAM	5/2010	
	Aegean Airlines	6/2010	
	Shanghai Airlines		10/2010

1. Austrian Airlines, Tyrolean and Lauda Air compose the Austrian Airlines Group.
2. United Airlines and Continental announce their plan to merge in May, 2010. The merger was approved by the Department of Justice in August, 2010.

Table A1 Cont. Chronological History of Alliance Participation by Alliance			
Alliance	**Carriers**	**Dates beginning**	**Dates ended**
Oneworld	**American Airlines**, British Airways, Cathay Pacific, Canadian Airlines and Qantas	2/1999	
	Finnair and Iberia	9/1999	
	Canadian Airlines		6/2000
	Air Lingus and LAN Airlines[3]	6/2000	
	Air Lingus		4/2007
	Japan Airlines, Malev and Royal Jordanian	4/2007	
	Mexicana Airlines	11/2009	8/2010
	S7 Airlines	11/2010	
SkyTeam	**Delta Airlines**, Air France, Aeromexico and Korean Air	6/1999	
	Czech Airlines	3/2001	
	Alitalia	7/2001	
	Continental, **Northwest** and KLM[4]	9/2004	
	Aeroflot	4/2006	
	Air Europa, Copa Airlines and Kenya Airlines	9/2007	
	China Southern Airlines	11/2007	
	Continental and Copa Airlines		10/2009
	Northwest[5]		1/2010
	Vietnam Airlines and TAROM Romanian Air	6/2010	
	China Eastern	6/2011	
	China Airlines	9/2011	

3. LAN-Chile, LAN-Peru, LAN-Argentina and LAN-Ecuador compose LAN Airlines and began offering Oneworld services in 2000, 2002, 2007 and 2007, respectively.
4. Northwest and KLM were alliance partners since 1993.
5. Delta and Northwest announced their plan to merge in April, 2008. The merger was approved by the Department of Justice in October, 2008. However, Northwest continued to operate under the Northwest brand until January, 2010.

Table A2. Chronological History of ATI by U.S. Carrier			
U.S. Carriers	**ATI partners**	**ATI approval**	**ATI close-out**
Northwest	KLM	1/1993	
	KLM and Alitalia[+]	12/1999	10/2001
United Airlines	Lufthansa	5/1996	
	Lufthansa and SAS[+]	11/1996	
	Air Canada	9/1997	
	Austrian Airlines, Lufthansa and SAS[+]	1/2001	
	Air New Zealand	4/2001	
	Copa Airlines	5/2001	
	Asiana	5/2003	
	Austrian Airlines, Lufthansa, Air Canada, SAS, British Midland, LOT, Swiss International Air Lines and TAP [+, 1]	2/2007	
	Austrian Airlines, Lufthansa, Air Canada, SAS, British Midland, LOT, Swiss International Air Lines and TAP, SN Brussels Airlines[+1]	7/2009	
	ANA	11/2010	
Delta Airlines	Austrian Airlines, Sabena and Swissair	6/1996	5/2007[2]
	Air France, Alitalia, Czech Airlines	1/2002	
	Korean Air, Air France, Alitalia and Czech Airlines[+]	6/2002	
	Virgin Australia	6/2011	
	Korean Air, Air France, KLM, Alitalia, Czech Airlines and **Northwest**[+]	5/2008	
American Airlines	Canadian Airlines	7/1996	5/2007[3]
	LAN-Chile	9/1999	
	Swissair	5/2000	11/2001
	Sabena	5/2000	3/2002
	Finnair	7/2002	
	Swiss International Air Lines	11/2002	8/2005
	SN Brussels	4/2004	10/2009
	LAN-Chile and LAN-Peru[+]	10/2005	
	British Airways, Iberia, Finnair and Royal Jordanian[+]	7/2010	
	Japan Airlines	11/2010	

+ indicates an expansion of previous ATI decisions.
1. British Midland did not operate in the alliance beyond 4/2012
2. Although not officially closed until 2007, this alliance was only active until 8/2000
3. Although not officially closed until 2007, this alliance was only active until 6/2000

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