The Effect of the Internet on On-Time Performance in the Airline Industry

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Abstract

This paper uses flight-level data and measures of Internet penetration in U.S. metropolitan statistical areas between 1997 and 2007 to study the relationship between Internet access and flight on-time performance, which represents a measure of flight quality. We find that on-time performance is substantially worse for flights in which passengers originated in areas with greater Internet access. The magnitude of the effect of the Internet is larger for competitive segments. Our results are driven by longer departure delays and longer flight time, despite airlines' increased flight schedule times. Our results lend support to theoretical search models that suggest that firms engaging in price competition may choose to lower the quality of the goods they offer. We also discuss additional explanations for our findings.

JEL classification: D83; L25; L93

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I. Introduction

Internet access provides consumers with information about product prices and makes it easier for them to compare prices across different merchants. Empirical economic literature has typically found that higher Internet usage leads to lower prices and exacerbates price competition among firms. This change in the competitive landscape is likely to have a negative effect on firms' margins, thereby raising the question of whether and how firms respond to this change in competition.

Our paper aims to address this question by exploring changes in the quality of goods as Internet usage increases. To the best of our knowledge, this is the first empirical study on the relationship between product quality and consumer search. In particular, we examine the relationship between increased Internet usage and on-time performance in the U.S. airline industry. On-time performance is considered a primary quality criterion in air travel – it is a primary reason for consumer air travel complaints,[1] and airlines are quick to announce improvements in this area.[2]

The predicted effect of the Internet on product quality is ambiguous. On the one hand, firms may not find it possible to maintain the same level of product quality when prices are lower. As search costs fall, firms compete vigorously at the observable price dimension, both at the cost of their own profits and at the expense of the less observable and less salient quality measures of their product. On the other hand, increased competition in price might induce firms to compete in other product dimensions. In the case of airlines, this may include quality measures such as on-time performance. Furthermore, passengers might find it easier to compare on-time performance for alternative flights using the Internet, thereby increasing the incentives for airlines to improve their on-time performance.

We use several sources of flight-level data for the years 1997 – 2007. Three main sources of variation in the data are used to identify the effect of the Internet on on-time performance: 1) differences in Internet penetration over time; 2) differences in Internet penetration across geographical locations; and 3) differences in the competition level for segments originating from the same airport on the same day. These sources of variation allow us to (a) estimate differences-in-differences regressions for the marginal effect of Internet penetration on on-time performance and (b) investigate whether the size of these effects varies across market structures. By using a rich set of control variables and fixed effects, we are able to identify the impact of the Internet on

[1] For example, Bowen and Headley (2001) in their "Airline Quality Rating" series devise a quality metric composed mostly of flight delay rates and factors that are exacerbated by delayed flights (e.g., customer complaints, lost baggage). Forbes (2008b) finds a positive relationship between the number of complaints and the number of delays.
[2] See, e.g., United's press release at http://www.united.com/press/detail/0,7056,61642-1,00.html.

flight on-time performance, controlling for unobserved segments, airports, airlines, and time-specific characteristics.

Generally, airlines can improve on-time performance in two distinct ways: they can shorten actual flight time or, alternatively, they can schedule longer flights, also known as schedule padding. Accordingly, we investigate the relationship between Internet penetration and measures of both actual and scheduled flight times.

Our findings indicate that flights with more passengers originating in areas with high Internet penetration had substantially worse on-time performance. This poorer on-time performance is apparent mainly in longer actual flight times, primarily due to longer departure delays.[3] In addition, our estimates indicate that on-time performance worsens in competitive segments as Internet penetration increases. In particular, we find that, *ceteris paribus*, an increase of 0.2 in the share of households with Internet access is associated with longer arrival delays by about two to three minutes, depending on the competitive level of the particular segment. We also find increased flight schedule time for segments where passengers originated in areas with higher Internet penetration. However, this increase did not fully compensate for the increase in actual flight times.

Overall, these findings lend support to theoretical search models that show that product quality deteriorates as search costs and prices fall. Therefore, our findings suggest that airlines choose to save costly resources, such as crew and ground employees, which are needed to ensure on-time performance. Nevertheless, the large estimated effect of the Internet could suggest an additional channel through which the Internet affects airline scheduling and on-time performance. We propose that the rise of on-line distribution channels, where passengers typically sort flights based on price, and the declining role of brick-and-mortar travel agencies, where flights were typically sorted based on schedule time, might further explain the patterns we find. In other words, the Internet has changed the form of competition in the airline industry, shifting it from

[3] Departure delay is the elapsed time between the actual time a plane leaves the gate at the origin airport and its scheduled departure time.

an environment where flights with shorter schedules on a given segment play an important role in selling tickets to an environment where price plays the dominant role in selling tickets.[4]

The paper proceeds as follows. In Section II, we discuss the related literature, and in Section III, we provide some background on the airline industry and discuss potential explanations for the effect of the Internet on on-time performance. In Section IV, we describe our data sources, and in Section V, we present the empirical specification and the results. In Section VI, we discuss our results, and in Section VII, we conclude.

II. The Related Literature

The economic literature on the effect of the Internet focuses on price levels and price dispersion.[5] In particular, several papers consider the impact of the Internet on prices in the airline industry. Clemons, Hann and Hitt (2002) find that prices available from online travel agents are just as dispersed as those available from traditional offline travel agents. Verlinda and Lane (2004) use national data on Internet usage to show that increased Internet usage is associated with greater differences between restricted and unrestricted fares. Sengupta and Wiggins (2007) use a cross-section of airline tickets purchased both online and offline to demonstrate that tickets sold online have lower average prices and that increases in the share of tickets purchased online imply lower *offline* fares and lower price dispersion. Finally, using metropolitan-area Internet access and a differences-in-differences estimation strategy similar to our own, Orlov (2010) examines the impact of Internet access on prices and price dispersion in the airline industry. He shows that increases in Internet access are associated with decreases in airport-pair fares and fare dispersion.

Few papers have empirically examined how firms respond to the increased capability of consumers to compare prices. Ellison and Ellison (2009) illustrate how firms adopt obfuscation strategies that

[4] American Airlines' Capacity Planning MD Don Casey referred to the pre-Internet period: "You had to be on the first (CRS) screen. All the booking came off the first screen. You'd bring your airplanes in as fast as you can and you'd let them go as fast as you can." He also noted that when most tickets are sold online, "It's important still to have competitive elapsed time, because there's a point at which consumers will say no. But it isn't important to have the fastest elapsed time." This was released on ATW online, November 2002, which is available at http://www.nesdb.go.th/specialWork/suvarnabhumi/ceo_talk/No%20Peaking.pdf.

[5] Brown and Goolsbee (2002) is a prime example. Ellison and Ellison (2006) provide an insightful survey of the literature.

frustrate consumer search, thereby reducing consumer price sensitivity for certain products. Goldmanis et al. (2010) present evidence from three retail industries, including brick-and-mortar travel agencies, and show that the number of retailers fell as Internet use increased. They also show that larger retailers were typically more likely to survive.[6] Importantly, we are not aware of papers that examine how the Internet affects the quality of products provided by firms. The structure of the airline industry enables us to explore this relationship between the Internet and on-time performance across different market structures.

There are two additional strands of literature related to this paper: the literature on search when the quality of the good is uncertain and the literature on the relationship between quality and market structure. Models of search have shown that prices might be used to signal the quality of goods, where higher prices signal a higher quality of goods (Wolinsky, 1983, Schwartz and Wilde, 1983). Rogerson (1988) compares the equilibria of search models where quality is observable at a cost and prices are either costlessly observable or costly to observe. He shows that prices and quality fall when search costs diminish. Nevertheless, welfare increases because the reduction in prices compensates for the deterioration in product quality.[7] We are not aware of empirical papers that test these search models.[8]

Theoretical papers analyzing the relationship between product quality and the competitive structure offer mixed predictions. Swan (1970) claims that market structure and quality are unrelated.

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[6] Papers examining the effect of the Internet on consumers and focused on non-price attributes include the following: Dana and Orlov (2010) who provide evidence that changes in Internet penetration can explain a large part of the significant increases in airline capacity utilization; Scott Morton (2005) who emphasizes that the Internet can benefit consumers by informing them about product attributes and facilitating more efficient matching. Brynjolfsson, Hu and Smith (2003) who show that the Internet helps consumers to buy hard-to-find books; Ghose, Telang and Krishnan (2005) who show that the Internet increases the resale value of new products; and Ghose, Smith and Telang (2006) who show that the Internet facilitates the market for used books. Finally, Forman, Ghose and Goldfarb (2009) offer evidence that the use of the Internet is associated with lower consumer travel and transportation costs in traditional offline market books, which suggests that lowering transactions costs is a big advantage of online purchases.

[7] During the 1980's, a great debate took place over the potential costs and benefits of allowing price advertising by providers of professional service. The main concern was that allowing price advertising would result in lower quality. See also Chan and Leland (1982).

[8] Lynch and Ariely (2000) do consider the tradeoff between price and quality in e-commerce but treat the quality of goods as fixed.

Schmalensee (1979) argues that the theoretical relationship depends on specific assumptions, and Gal-Or (1983) shows that both prices and product quality might fall as more firms enter a market.

Despite these inconclusive theoretical results on the relationship between product quality and competition, the empirical evidence generally suggests that quality is higher in more competitive environments. Domberger, Hall, and Li (1995) empirically examine the effect of increased competition on the choice of price and quality for cleaning service contracts. Their results show that increased competition pushes prices down while exerting either no effect or a positive effect on quality. Mazzeo (2003) and Rupp, Owens and Plumly (2003) use a cross-section of flights and find that on-time performance is better in more competitive environments, as measured by the Herfindahl Index.[9] Like these papers, we include the same measure of competition. In addition, our panel data and our focus on the effect of the Internet allow us to provide additional evidence on the link between competition and quality. Like previous studies, our findings suggest that quality is lower in less competitive environments. Nevertheless, if we believe that increased Internet access leads to fiercer price competition, then our findings suggest that quality deteriorates as competition intensifies.[10] We find, like Forbes (2008a), that lower prices are correlated with poor on-time performance.

More broadly, the strategic management literature (e.g., Porter, 1980) focuses on firms' strategic decisions to adopt price or non-price strategies. In this paper, we suggest that the Internet has contributed to the observed changes in the strategies of legacy airlines, moving from non-price strategies, in which passengers pay higher prices in return for high-quality products, toward strategies in which airlines mainly compete by setting lower prices.

[9] Other papers examining the relationship between market structure and quality are Prince and Simon (2009) (who show that on-time performance is poorer when airlines engage in multi-market contact), Hoxby (2000) and Domberger and Scherr (1989).

[10] Other papers that look at airlines' actual and scheduled performance typically focus on the incentives of airlines to internalize congestion at the airport. See, for example, Mayer and Sinai (2003b), Brueckner (2002), Morrison and Winston (2007) and Ater (2010). One exception is Forbes and Lederman (2010), who examine how vertical integration decisions affect airlines' operational performance.

III. Industry Background and Motivation

III.1. The Airline Industry, Internet and On-time Performance

The U.S. airline industry has experienced significant changes in the last 15 years as Internet access has increased. On the demand side, less than 0.5% of airfares in the U.S. were sold online in 1996; this figure increased to 50-60% by 2007. On the supply side, airlines have eliminated traditional travel agents' commissions and now rely heavily on online travel agents and their own websites to sell tickets (Berry and Jia, 2010). As Internet penetration across the U.S. has increased, statistics on airlines' on-time performance have become more readily available to passengers from various sources, such as the website of the U.S. Department of Transportation, various online media sources, and even online travel agencies.[11] Nevertheless, these published statistics are imperfect measures of a particular on-time flight performance for two reasons. First, most of these published measures are at the carrier-national level. Second, they represent past on-time performance, which is not necessarily a good predictor of future performance.

In Table 1, we present information on on-time performance for airlines in our sample between 1997 and 2007. In the late 1990s, more than 20% of flights were late to their destination.[12] The economic slowdown of the early 2000s and the 9/11 terrorist attacks that led to capacity cuts are associated with an improvement in on-time performance, which reached its peak in 2003, when roughly only 17% of flights arrived late. After 2003, on-time performance became worse. In 2007, the last year in our sample, almost 27% of flights were considered late.

III.2. Motivation

In this section, we briefly summarize alternative channels through which the Internet might affect on-time performance.[13] In particular, we argue that the Internet can have either a negative

[11] Travelocity.com, kayak.com and some airlines' websites report past on-time performance for flights.
[12] A flight is considered late if it arrives 15 minutes or more after its schedule time.
[13] Clearly, multiple factors affect an airline's scheduling decisions and its on-time performance. These include weather, the network structure, the number of available aircraft and their utilization, and aggregate demand and competition. Understanding how each of these factors affects on-time performance is beyond the scope of this paper.

or a positive effect on on-time performance. The main goal of our paper is to study which of the two effects of the Internet is dominant.

There are at least two reasons why the effect of the Internet on on-time performance could be negative.

First, higher Internet usage lowers passengers' search costs and leads airlines to set lower prices (Orlov, 2010). If airlines can credibly transmit verifiable information about prices and cannot do so with respect to quality, then they may enter an "excessive" price competition at the cost of consumer quality. Airlines could avoid taking actions or making investments that would improve on-time performance. For example, allocating fewer crew members and ticket counters would require a longer time for passengers to enplane. Similarly, fewer ground members would require a longer time to carry baggage on board. In addition, airlines may not adopt incentive schemes that encourage employees to achieve better on-time performance. Any of these measures could add substantial costs and are likely to depend on consumer willingness to pay for the flight. Consequently, as prices fall, airlines may choose to offer lower quality. This effect is likely to be larger in more competitive environments.

Second, the major change in the distribution channels that occurred as airline passengers switched from brick-and-mortar travel agencies to online travel agencies may also explain why on-time performance worsened over the years. In the early 1990s, travel agencies sold over 80% of airline tickets (Borenstein, 1992). These agencies received ticket information from computer reservation systems (CRS), computer systems introduced in the 1970s to automate and control ticket distribution. Flights typically appeared in CRSs in an ascending order by their scheduled flight time or scheduled journey time.[14,15] Given that travel agents booked over 80% of flights from the first screen and that the majority of the tickets were sold from the first line, airlines looked for ways to reach the top of travel agents' screens (Guerin-Calvert, 1992). Therefore, airlines had strong incentives to maintain short flights, presumably incurring large operational

[14] See GAO (1995), p.55.
[15] Journey time is the total time needed to reach airport B from airport A. Journey time is different from the scheduled flight time for connecting passengers because it includes scheduled flight times for both segments as well as the layover time between connecting flights.

costs to achieve these efficiencies. These incentives were particularly large in competitive environments. Given that many passengers on monopolistic routes later connect to flights on competitive routes, these incentives are also relevant for monopolistic routes. As Internet penetration increased and more passengers used online travel agencies that were typically sorted according to price, airlines had lower incentives to allocate large resources to improving and maintaining their operational efficiency. Consequently, on-time performance deteriorated.

At the same time, increased Internet usage may also have a positive effect on on-time performance.

This can happen when airlines start competing in quality aspects, such as on-time performance, as prices are driven to be the same. For example, Spiegler (2006) shows that increased price competition could lead to higher product quality.

Furthermore, the fact that passengers can more easily observe and compare on-time performance across carriers on the Internet might further induce airlines to improve on-time performance. Indeed, prior empirical studies of the effects of information on product quality suggest that improved information leads to higher quality. Jin and Leslie (2003) show that policy intervention to improve consumer information led to improved hygienic quality in restaurants. Foreman and Shea (1999) find evidence that average delays decreased after airlines were required to publish on-time performance statistics.

IV. Data

Our data come from several sources. The primary sources of data are the flight-level on-time performance statistics from the U.S. Bureau of Transportation Statistics. This database reports schedule and actual flight information for every flight on each airline with at least 1% of domestic passenger revenues. In particular, the data include measures of departure delays, arrival delays and airtime as well as identifying information on each aircraft and flight.

The second primary data source is the Computer Use and Ownership Supplement to the Consumer Population Survey (CPS). We use the CPS to measure Internet penetration for every major metropolitan area. The survey asks about Internet access at home, school, and business. For each metropolitan area, we compute the percentage of respondents answering "yes" to any of these Internet access questions using sample weights provided by the CPS. The data are available for the years 1997, 1998, 2000, 2001, 2003, and 2007. Table 2 provides descriptive statistics for this variable.

We supplement these data with additional sources. First, we use the Origin and Destination Survey (DB1B) market database. This is a 10% sample of all passenger tickets purchased in each quarter for each year of our sample and includes the airline, the quarter in which the ticket was used, the fare, the number of passengers paying the fare, the origin and destination airports (for the passenger), and the itinerary (the individual flight segments flown). Importantly, the DB1B database identifies the outbound and return portions of round-trip tickets, so we know which airport is the passenger's home airport (and therefore the associated metropolitan area in which he or she is likely to have purchased his or her ticket).[16] We use the DB1B dataset to calculate the metropolitan-area traffic weights to match our Internet penetration variable to our segment data. Simply matching the segment data to the metropolitan area in which the flights' origination airport is located is inadequate. Many passengers are returning home on the return portion of a round-trip ticket, and these passengers are likely to have purchased their ticket in the metropolitan area in which the flight's destination airport is located. Still other passengers are on the second leg of their outbound itinerary (or the first leg of their return itinerary), so the airport at which these passengers began their round-trip travel is neither the airplane's origination nor destination airport. The distinction is important because our hypothesis is that Internet penetration in the metropolitan area where passengers live and purchase their tickets affects on-time performance more than Internet penetration in the metropolitan area in which the flight originates.[17] Specifically, our weighted Internet measure is

[16] Before 1999, Southwest Airlines reported all of its roundtrip ticket sales as two one-way tickets, so we cannot identify the home airport for these Southwest passengers.

[17] The metropolitan-area traffic weights constructed from the DB1B database are equal to a fraction of each airline's passengers flying on each segment that originate their one-way or round-trip itinerary in each metropolitan area. We use the DB1B database to find all of the passengers with itineraries that include the particular airline airport-pair segment and then calculate the percentage of these consumers whose itineraries originated at each airport. A metropolitan-area traffic weight is the sum of the airport weights across all airports located in the metropolitan area. Finally, we compute the traffic-weighted average of the metropolitan area Internet penetration to obtain a measure of Internet penetration that is unique to each airline airport-pair segment. For example, consider a flight from airport A to airport B. Assume that 40 percent of the passengers are flying round trip from A to B (so they are on the outbound portion of their round-trip itinerary), another 35 percent of the passengers are flying round trip from B to A (so they are on the return portion of their round-trip itinerary), another 15 percent of the passengers are flying round trip from airport C to airport B with a stop each way at airport A (so they are on the second segment of the outbound portion

$\mathrm{IP}_{ijt} = \sum_k \omega_{ijkt} \mathrm{I}_k^m \mathrm{IP}_{mt}$, where ω_{ijkt} is the share of all passengers that fly on airline *i*'s flight serving segment *j* in quarter *t* who began the travel itinerary in airport *k*, IP_{mt} is the Internet penetration in metropolitan area *m*, and I_k^m is an indicator that is equal to 1 if airport *k* is located in metropolitan area *m* and 0 otherwise. In addition, we use the DB1B data to derive our airfare control variable.

Second, we use the data published by the Official Airline Guide (OAG), which contains a complete set of scheduled non-stop flights for all airlines between all U.S. airports. We use these data to construct several measures of aircraft operations in each airport and at different times throughout the day. Third, we use data from the Bureau of Economics to construct demographic and economic measures at the metropolitan-area level. These measures control for expected and unexpected demand changes that may be spuriously correlated with Internet penetration. We use the traffic weights described above to match these data to the directional-airline segments Finally, we use the T100 (Form 41) database from the Bureau of Transportation Statistics to derive a directional carrier-airport-pair segment load factor variable for each month in our sample.

After matching these datasets, we limit our sample to traffic on one arbitrary Thursday in January, April, July and October in the following years: 1997, 1998, 2000, 2001, 2003 and 2007. In what follows, we present estimation results using nine carriers that were included in the data on on-time performance for all years between 1997 and 2007. The airlines are listed in Table 3. We also limit our analysis to segments between the top 100 airports by the number of passengers. The results are qualitatively similar if we do not constrain the data.[18] This leaves us with 306,108 observations.

V. Estimation and Results

V.1. Estimation

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of their round-trip itinerary), and, finally, that the remaining 10 percent are flying round trip from airport A to airport D with a stop each way at airport B (so they are on the first segment of the outbound portion of their round-trip itinerary). The weighted average Internet penetration for passengers on this particular airline's flight from airport A to airport B is equal to (0.40 + 0.10) IP_A + 0.35 IP_B + 0.15 IP_C, where IP_i denotes the Internet penetration in the metropolitan area in which airport *i* is located..

[18] We also have preliminary results on the effect of the Internet on on-time performance obtained by low-cost carriers. These results, which suggest that there is no effect on low-cost carriers, are consistent with the idea that only legacy carriers faced the tradeoff between lower prices and lower quality. We plan to investigate this issue more in future versions.

To examine the relationship between Internet access and airlines' on-time performance, we estimate the following reduced-form regressions:

$$Y_{fijt} = \beta_I IP_{jt} + \beta_D X_{jt}^D + \beta_C X_{ijt}^C + \beta_{MS} HHI_{ijt} + \beta_{I-MS} IP_{jt} \cdot HHI_{ijt} + \beta_Z Z_{fijt} + FE + \varepsilon_{fijt},$$

where an observation is flight *f* of airline *i* on segment *j* on day *t*, and the dependent variable *Y* is either minutes late or a dummy variable that equals one if the flight arrives 15 minutes or more after its schedule time and zero otherwise.[19] The primary independent variables are the traffic-weighted measures of metropolitan-area Internet penetration measure (IP) and the interaction between this measure and the competition level (IP*HHI).[20] A positive coefficient for the Internet variable would lend support to the argument that delays increased and quality fell, whereas a negative coefficient would suggest that delays diminished and quality improved as the Internet became more available. Because the effect of the Internet is likely to be greater on more competitive routes, we expect the interaction term to have a sign opposite that of the Internet coefficient. The segment HHI is also added as a separate regressor. A positive coefficient on this variable would suggest that on-time performance is better on more competitive routes.

We also add several flight specific control variables (Z). First, we include an aircraft's arrival delay (in minutes) on its previous flight.[21] We expect this variable to be positively correlated with the current flight delay.[22] Second, we include the scheduled time (in minutes) between a given flight's scheduled departure and the aircraft's previous flight schedule arrival times. This measure represents the available scheduled time to prepare an aircraft for its next flight. Longer ground time between subsequent aircraft operations might reduce delays on an aircraft's next flight.[23] Third, we add a counter of the aircraft's flight on a given day. The variable takes the value 1 for the first aircraft's flight on a given day, the value 2 for the second flight on a given day, etc. This variable measures how long each aircraft is in service on a given day. A longer amount of time in service on a

[19] This measure is consistent with the DOT definition of on-time performance.
[20] The HHI measure is derived using the OAG data, based on the number of scheduled flights on a segment.
[21] This variable takes the value zero for the aircraft's first flight on a given day.
[22] Airlines report that late aircraft arrival is a primary cause of flight delays. For example, according to airline reports to the DOT in 2007, more than 8% of flights were late due to late aircraft arrival.
[23] For the first aircraft's flight on a given day, we arbitrarily set the value of this variable to 240.

given day makes it more likely that associated delays will accumulate and lead to a delay on a given flight.

In addition, we use the OAG data to construct various measures of the number of flights that are scheduled to operate at the origin and destination airports at the same hour on the same day. In particular, we include the following measures: the number of flights per day on a given segment; the number of departures and the number of arrivals from/to the flight's origin airport and, separately, the destination airports on that day; the number of departures and arrivals from/to the flight's origin airport within an hour of a given flight's departure from the airport; the number of departures and arrivals from/to the flight's destination airport within an hour of a given flight's arrival at the airport; and HHI at the flight's origin airport and at the flight's destination airport. The airport HHI measures should reflect any potential advantages in handling flight operations and avoiding delays held by airlines that operate in concentrated airports.

The demand controls (X^D) are metropolitan area population and average per capita income. Each of these measures is matched to the segment data using the same weights used above to match the Internet penetration variable to the segment data. These variables are included to control for both short- and long-run variations in demand growth across airline segments and thus are constructed from the MSA data in the same way as Internet penetration.

Finally, we include a variety of fixed effects (FE), which include segment, aircraft type, origin/airline and airline/day. The directional segment fixed effects control for time-invariant metropolitan area, airport, and airport-pair segment characteristics. Including the airline/day fixed effects captures unobservable events that might have different effects on different airlines on the same day. These fixed effects also control for time-varying characteristics that are carrier specific, such as system-wide schedule changes (e.g., ripple effects caused by severe weather conditions in one or more airports) or attitude towards on-time performance. The airport/day fixed effects should capture unobserved events, such as extreme weather effects, that may affect delays at a certain airport.

For some specifications, we also include as regressors the mean airfare and average load factors on a certain segment. The mean airfare variable provides a direct test of our hypothesis that lower prices might have a negative or positive effect on on-time performance. Finally, we expect that average load factors, which measure how full an airline's flights are, would have a positive effect on delays given that more passengers enplane for each aircraft.

After estimating these regressions using the delay measures as dependent variables, we estimate similar equations using an actual flight time,[24] a flight departure delay and a scheduled flight time as dependent variables.[25]

Table 4 lists descriptive statistics for each of the variables in our analysis. The variables are mainly in levels, but we include four of the control variables (fare, load factors, income per capita and population) in logs. We experimented with the functional form, and the final specification was the best fit for the data.

V.2. Results

V.2.1 Arrival delays and on-time performance

Table 5 shows our estimation results for on-time performance, measured as the difference in minutes between a flight's actual time of arrival and its scheduled time of arrival at its destination. The regression in Column 1 includes only the Internet penetration variable and aircraft and segment fixed effects and finds a positive and statistically significant relationship between Internet penetration and on-time performance.

In Column 2, we add the carrier/day and origin/carrier fixed effects, the three variables for a given flight’s position relative to the previous flight on the same aircraft and the traffic-weighted metropolitan area population and average per capita income control variables. Importantly, the carrier/day and origin/carrier fixed effects control for unobservable factors such as aggregate or

[24] Actual flight time is measured from scheduled departure time to arrival time.
[25] In the regression where the schedule departure is the dependent variable, we do not include an aircraft’s previous flight arrival delay as a control variable.

seasonal changes in the number of flights arriving on time. The coefficient of Internet penetration increases from roughly 3.7 to 13.9, showing that an increase in weighted average Internet penetration for a flight's passengers of 0.1 (which is half of the standard deviation for this variable) is associated with a longer arrival delay of nearly 1.4 minutes. The coefficients of other variables support our expectations: a longer arrival delay for the previous flight on the same aircraft is associated with a longer delay for the given flight, and a longer scheduled time between a given flight's departure and the arrival of the previous flight on the same aircraft is associated with a shorter arrival delay for the given flight. Finally, a flight that takes place later in the day (i.e., a higher level of the FLIGHT IN DAY variable) is associated with a longer arrival delay.

In Column 3, we add our competition measure – the segment HHI and its interaction with our measure of Internet penetration. The HHI coefficient is positive and statistically significant and suggests that on-time performance is better in more competitive markets. This finding is consistent with the results in Mazzeo (2002) and Rupp, Owens and Plumly (2003). The negative and significant coefficient of the interaction term (-5.4) indicates that the effect of increased Internet access on delays is larger on competitive routes. The coefficient of the Internet variable increases to 16.6. This implies that on highly competitive routes, Internet access that is higher by 0.1 is associated with arrival delays lasting nearly 1.7 minutes longer. For monopolistic routes, the same increase in Internet penetration is associated with arrival delays lasting 1.1 minutes longer. In column 4, we add the entire set of congestion controls, and the main coefficients of interest are qualitatively similar.

Other (non-reported) coefficients typically have the expected signs. For example, the coefficient of the number of flights that are scheduled to depart from the same origin airport in the same hour is positive and significant. The same is true for the destination airport. The total daily number of flights operating at the origin and destination airports is insignificant. The concentration level at the origin airport is negatively correlated with on-time performance, suggesting that airlines at concentrated airports can better handle their operations and avoid delays. Interestingly, income per capita has a positive and significant coefficient.

Overall, these results suggest that on-time performance worsens as more passengers gain Internet access, especially on competitive routes, as measured by our HHI variable. However, this measure might not entirely reflect the level of competition, especially when search costs fall. In particular, Orlov's (2010) findings suggest that higher Internet penetration leads to lower prices regardless of changes in carrier market shares. Furthermore, our measure of Internet penetration might be correlated with other changes in the airline industry. In particular, Dana and Orlov (2010) find that load factors increased more in areas with higher Internet penetration. Higher load factors could have a direct effect on delays, simply because more passengers need to enplane (see Ramdas and Williams (2008) for a similar argument.)

Therefore, to further explore how airfares and load factors affect our results, we add as additional regressors the log of mean carrier airfare for each segment in each quarter[26] as well as the log of a carrier average load factor for each segment in each month. The results are shown in Column 5. Consistent with our previous results, the airfare coefficient is negative and significant, suggesting that delays increased more when prices fell. This finding strengthens our main result that carriers facing stronger price competition choose to degrade their product quality, as measured by on-time performance. The load factor variable is positive and significant, confirming our expectation that delays are affected by the number of passengers on each plane. Notably, the coefficient of the Internet variable, falling from 16.3 to 15, is still positive and highly significant.

Both the airfare and the load factors variables are potentially endogenous. For example, if a flight on a certain route is more likely to be late and passengers take that into account when they purchase their airfares, then our airfare coefficient is potentially biased. Although the set of fixed effects that we use may control for this endogeneity problem, we adopt an instrumental variable approach to show that the results are unchanged. Specifically, we instrument the airfare using the airline’s average segment fare on all other segments of a similar length (we divide segments by length into five quintiles) and the airline’s rivals’ average fare on the reverse segment. The instruments for load factor are constructed similarly. As shown in Column 6, the results are qualitatively similar when we control for the endogeneity of airfares and load factors.

[26] The DB1B reports quarterly airfares at the route level, but our flight level delay measures are at the segment level. To derive the segment airfare measure, we divide that airfare by the relative distance of each segment out of the total route distance flown.

In Table 6, we repeat the analysis using as the dependent variable a dummy variable that equals one if the flight arrives more than 15 minutes after its scheduled arrival time and zero otherwise. This definition of a delayed flight is the DOT's definition and is used to calculate statistics for carrier on-time performance. The results are qualitatively similar to the results in Table 5. For example, in Column 4, the coefficient of the Internet variable is 0.101, and the coefficient of the Internet and HHI interaction is -0.078. Therefore, our interpretation is that if passengers originate from an area where Internet access increases by 0.5, then a flight from that airport is almost 5% more likely to be late in highly competitive markets, whereas it is only 0.6% more likely to be delayed in monopolistic markets.

In the next set of results, we attempt to identify whether the change in on-time airline performance comes from increased actual flight time or, alternatively, whether airlines shorten flight schedule time in competitive markets.

V.2.2 Actual flight measures

In Table 7, we repeat our analysis using the actual flight time of operation as the dependent variable. We compute this measure as the time between a scheduled flight departure time and the actual arrival time.[27] In all of the regressions, the coefficients of the Internet penetration variables are statistically significant and larger than the corresponding coefficients in Table 5. These results suggest that on-time performance on Internet routes worsens because the actual time of flights is longer. Next, we explore whether the increased actual time comes from longer departure delays. In Table 8, we present the results of regression in which the departure delay, the elapsed time between actual departure time and schedule departure time, is used as the dependent variable. The results show that departure delays are significantly higher for flights where passengers are likely to have purchased their flights on the Internet, and this increase is higher on competitive routes. The magnitude of the coefficients in Table 6 is smaller than that in Table 7, where the total actual flight time is the dependent variable, amounting to roughly 60% of the magnitude of the corresponding variable. This latter finding is potentially important because airlines often have more control over delays occurring on the ground. The fact that most of the effect of the Internet accrues before departure strengthens our interpretation that airlines choose to avoid costly actions that would reduce delays.

V.2.3 Scheduled flight measures

Airlines can improve on-time performance by padding scheduled flight time, thereby reducing the likelihood that a flight will arrive late. However, airlines may find it costly to pad flights if some passengers choose their flights based on flight schedule time. Also, Mayer and Sinai (2003a) claim that airlines might avoid padding in an effort to minimize labor costs, which are partially determined based on the scheduled flight time or the actual flight time, whichever is longer. In addition, setting longer flight schedules might lead to lower aircraft utilization.

In Table 9, we report the results using a scheduled flight time as the dependent variable. The Internet coefficient in Column 1 equals 8.6 and is highly significant, suggesting that airlines did schedule longer flights as Internet access became more available. However, the magnitude of the

[27] This measure is the same as that used by Mayer and Sinai (2003b).

Internet variable drops somewhat once we add more variables and control for unobservable factors using fixed effects. This implies that U.S. airlines padded their flights over the years but have not done so specifically on routes where more passengers had Internet access. In fact, the negative and significant coefficient of the Internet*HHI interaction term suggests that on monopolistic segments, airlines slightly shortened their scheduled flight time as the Internet became more accessible. Nevertheless, the magnitudes of the Internet variables in these regressions are substantially smaller than the corresponding magnitudes of the coefficients in the regressions using actual time as a dependent variable.

VI. *Discussion*

The U.S. airline industry went through major turmoil in the early 2000s. Four major airlines entered bankruptcy, and all legacy carriers reported a large reduction in profits. One of the factors driving these losses was the change in passengers' purchasing habits as the Internet became the primary distribution channel for purchasing airfares. The rapid expansion of low-cost carriers, whose market share of domestic origin-destination passengers has increased steadily over the past decade, also contributed to the major airlines' difficulties in maintaining their traditional business.

Consequently, in the search for ways to reduce costs, legacy carriers considered abandoning their traditional business model based on the presumption that passengers will pay higher prices for better service in favor of a business model where prices are lower. Our findings suggest that the response by major airlines involved not only price cuts but also reductions in the quality provided to consumers, especially in more competitive environments. We believe, however, that the change in airlines' on-time performance was driven not only by price and quality substitution patterns but also by the change in the distribution channel used to purchase airfares. While traditional travel agencies used reservation systems sorted by departure and elapsed flight time, online travel agencies (e.g., Expedia, Orbitz) are typically sorted by price. Consequently, the need to maintain short schedules and operations diminished.

Finally, our findings can help to explain the increase in the share of direct flight passengers from the late 1990s to 2007 (Berry and Jia, 2010). If passengers realize that delays are more likely and that flight time will probably increase, then they may have a stronger preference for direct flights over connecting flights.

VII. *Conclusion*

Theoretical search models typically predict that prices will fall as search costs diminish. Given that Internet access lowers consumers' search costs, the empirical literature focuses on its effect on price levels and price distributions. Indeed, there is strong evidence that prices in the airline industry have fallen as more passengers use online travel agencies to purchase tickets.

In this paper, we extend the literature by examining the relationship between lower search costs and product quality. In particular, we use flight-level data and measures of Internet access between 1997 and 2007 to estimate the effect of Internet access on on-time flight performance. We provide empirical evidence that airlines' on-time performance worsens as more passengers gain Internet access. We also find that on-time performance deteriorates in more competitive segments and in segments where prices fall. Our findings, together with previous findings that suggest prices have fallen as Internet usage increases, suggest that the effect of the Internet on welfare is ambiguous. Explicitly measuring the effect of the Internet on consumer and total welfare is left for future research.

We propose two mechanisms that may have contributed to the deterioration of on-time performance. First, Internet penetration leads to fiercer price competition, which in turn mitigates airlines' incentives to provide good on-time performance. This mechanism is consistent with the predictions of search models that argue that competition in prices might lead to lower quality. The second mechanism is that the Internet changes the way airlines sell and distribute airfares, fundamentally shifting their focus from traditional travel agencies to on-line travel agencies. Because the computer reservation systems used by traditional travel agencies typically sort flights based on short schedules, airline operations are organized to reduce travel time. This changed as more passengers began using the Internet, where flights are typically sorted by price.

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Table 1. On-Time Performance over Time

Year	Nr Carriers	Average Departure Delay	Average Arrival Delay	% On Time	% Delayed	% Cancelled
1997	9	8.29	7.59	76.4%	21.6%	1.8%
1998	9	9.02	7.59	75.7%	21.4%	2.7%
1999	9	9.40	8.37	74.4%	22.5%	2.8%
2000	9	11.39	10.56	70.7%	25.7%	3.4%
2001	9	8.09	5.39	76.0%	20.2%	3.6%
2002	9	5.53	3.10	80.8%	17.9%	1.1%
2003	9	4.80	3.03	81.8%	16.8%	1.2%
2004	9	7.86	6.67	76.9%	21.6%	1.4%
2005	9	9.09	7.30	75.5%	22.8%	1.5%
2006	8	9.67	7.77	74.4%	24.2%	1.2%
2007	8	11.36	9.82	71.3%	26.8%	1.7%

Source: U.S. Bureau of Transportation Statistics.

Note: Includes airlines that reported on-time performance statistics throughout the whole time period; the airlines are listed in Table 3. America West merged with US Airways in 2005.

Table 2. Internet Penetration across Metropolitan Statistical Areas (N=243)

Year	Mean	Std. Dev.	Min	Max
1997	0.194	0.074	0.043	0.489
1998	0.411	0.118	0.094	0.723
2000	0.555	0.110	0.207	0.836
2001	0.662	0.102	0.225	0.911
2003	0.698	0.100	0.323	0.923
2007	0.763	0.085	0.415	0.970

Source: Computer Use and Ownership Supplement to the Consumer Population Survey.

Table 3. Differences across Airlines

	Average Scheduled Flight Time (mins)	Average Arrival Delay (mins)	Average Departure Delay (mins)
Alaska Airlines	136.9	10.7	9.9
American Airlines	159.7	11.7	10.8
Continental Airlines	133.3	10.0	9.5
Delta Airlines	135.7	9.5	9.1
Northwest Airlines	91.9	7.9	10.5
Southwest Airlines	151.6	12.4	12.8
United Airlines	136.9	10.7	9.9
US Airways	163.9	7.5	9.2

Notes: Each cell contains average values over each airline's directional segments in the sample over 28 days in 28 quarters. US Airways merged with America West in 2005; both airlines are treated as US Airways.

Table 4. Descriptive Statistics (306108 observations)

Variable	Mean	Std. Dev.	Min	Max
SCHEDULED FLIGHT TIME	131.8	70.8	30.0	660.0
ARRIVAL DELAY	9.6	31.2	-65.0	358.0
DUMMY FOR ARRIVAL DELAY > 15 MIN	0.2	0.4	0.0	1.0
DEPARTURE DELAY	10.1	27.9	-50.0	360.0
TOTAL ACTUAL TIME	141.4	77.2	3.0	832.0
INTERNET	0.6	0.2	0.1	0.9
Demand Variables:				
LOG (INCOME PER CAPITA)	10.4	0.1	9.6	10.8
LOG (POPULATION)	15.1	0.6	11.7	16.7
Market Structure and Additional Variables:				
HHI	0.686	0.272	0.063	1.000
LATE ARRIVAL	6.2	26.0	-65.0	1083.0
SCHEDULED BUFFER	98.3	93.8	0.0	1406.0
FLIGHT IN DAY	3.3	2.1	1.0	14.0
FARE	140.6	70.1	2.08	659.0
LOAD FACTOR	0.688	0.116	0.075	0.980
NR DEPARTURES PER HOUR, ORIGIN ARPT	32.5	23.9	1.0	122.0
NR DEPARTURES PER HOUR, DEST ARPT	28.1	22.7	0.0	122.0
NR ARRIVALS PER HOUR, DEST ARPT	31.5	24.2	1.0	171.0
NR ARRIVALS PER HOUR, ORIGIN ARPT	28.4	22.4	0.0	171.0

Table 5. Regression Results: Arrival Delays

Dependent Variable:	ARRIVAL DELAY, mins					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	OLS	OLS	IV
INTERNET	3.668***	13.87***	16.63***	16.29***	15.03***	14.90***
	(.608)	(3.180)	(3.360)	(3.282)	(3.219)	(3.244)
HHI			2.272**	2.208*	2.382**	2.589**
			(1.071)	(1.162)	(1.149)	(1.149)
INTERNET * HHI			-5.376***	-4.974***	-4.747***	-4.856***
			(1.689)	(1.657)	(1.635)	(1.635)
LATE ARRIVAL		.553***	.553***	.552***	.552***	.552***
		(.009)	(.009)	(.009)	(.009)	(.009)
SCHEDULED BUFFER		-.015***	-.015***	-.013***	-.013***	-.013***
		(.001)	(.001)	(.001)	(.001)	(.001)
FLIGHT IN DAY		.575***	.577***	.466***	.466***	.470***
		(.041)	(.041)	(.042)	(.042)	(.042)
LOG (AVG. FARE)					-3.664***	-4.226***
					(.701)	(.795)
LOG (LOAD FACTOR)					2.780***	2.530***
					(.576)	(.724)
Segment Fixed Effects	Y	Y	Y	Y	Y	Y
Aircraft Fixed Effects	Y	Y	Y	Y	Y	Y
Demographic Controls (X^D)	N	Y	Y	Y	Y	Y
Additional Controls	N	N	N	Y	Y	Y
Carrier/Day Fixed Effects	N	Y	Y	Y	Y	Y
Origin/Carrier Fixed Effects	N	Y	Y	Y	Y	Y
Observations	306,108	306,108	306,108	306,108	306,108	305,615

Notes: Standard errors are in parentheses. Stars denote the significance level of coefficients: *** - 1 percent, ** - 5 percent, * - 10 percent. Standard errors are clustered within a segment. Additional control variables are described in the text.

Table 6. Regression Results: Arrival Delays > 15 mins

Dependent Variable:	Dummy: ARRIVAL DELAY > 15 min					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	OLS	OLS	IV
INTERNET	.024***	.066	.107**	.101**	.093**	.091*
	(.0081)	(.045)	(.047)	(.046)	(.046)	(.046)
HHI			.054***	.050***	.050***	.051***
			(.015)	(.016)	(.016)	(.016)
INTERNET * HHI			-.085***	-.078***	-.076***	-.076***
			(.023)	(.023)	(.023)	(.023)
LATE ARRIVAL		.005***	.005***	.005***	.005***	.005***
		(.000)	(.000)	(.000)	(.000)	(.000)
SCHEDULED BUFFER		-.0002***	-.0002***	-.0002***	-.0002***	-.0002***
		(.000)	(.000)	(.000)	(.000)	(.000)
FLIGHT IN DAY		.0171***	.0171***	.0157***	.0157***	.0158***
		(.001)	(.001)	(.001)	(.001)	(.001)
LOG (AVG. FARE)					-.0215**	-.0224**
					(.008)	(.010)
LOG (LOAD FACTOR)					.0384***	.0351***
					(.008)	(.010)
Segment Fixed Effects	Y	Y	Y	Y	Y	Y
Aircraft Fixed Effects	Y	Y	Y	Y	Y	Y
Demographic Controls (X^D)	N	Y	Y	Y	Y	Y
Additional Controls	N	N	N	Y	Y	Y
Carrier/Day Fixed Effects	N	Y	Y	Y	Y	Y
Origin/Carrier Fixed Effects	N	Y	Y	Y	Y	Y
Observations	306,108	306,108	306,108	306,108	306,108	305,615

Notes: Standard errors are in parentheses. Stars denote the significance level of coefficients: *** - 1 percent, ** - 5 percent, * - 10 percent. Standard errors are clustered within a segment. Additional control variables are described in the text.

Table 7. Regression Results: Actual Elapsed Time

Dependent Variable:	TOTAL ACTUAL TIME, mins					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	OLS	OLS	IV
INTERNET	12.28***	15.55***	20.18***	19.40***	17.71***	17.32***
	(.644)	(3.507)	(3.727)	(3.572)	(3.480)	(3.503)
HHI			4.20***	4.19***	4.52***	4.70***
			(1.188)	(1.241)	(1.222)	(1.221)
INTERNET * HHI			-9.102***	-8.484***	-8.248***	-8.320***
			(1.851)	(1.761)	(1.727)	(1.726)
LATE ARRIVAL		.556***	.555***	.554***	.554***	.553***
		(.009)	(.009)	(.009)	(.009)	(.009)
SCHEDULED BUFFER		-.0195***	-.0195***	-.0152***	-.0152***	-.0152***
		(.001)	(.001)	(.001)	(.001)	(.001)
FLIGHT IN DAY		.435***	.439***	.398***	.398***	.402***
		(.047)	(.047)	(.047)	(.047)	(.047)
LOG (AVG. FARE)					-5.206***	-5.790***
					(.753)	(.856)
LOG (LOAD FACTOR)					1.584**	1.803**
					(.635)	(.801)
Segment Fixed Effects	Y	Y	Y	Y	Y	Y
Aircraft Fixed Effects	Y	Y	Y	Y	Y	Y
Demographic Controls (X^D)	N	Y	Y	Y	Y	Y
Additional Controls	N	N	N	Y	Y	Y
Carrier/Day Fixed Effects	N	Y	Y	Y	Y	Y
Origin/Carrier Fixed Effects	N	Y	Y	Y	Y	Y
Observations	306,108	306,108	306,108	306,108	306,108	305,615

Notes: Standard errors are in parentheses. Stars denote the significance level of coefficients: *** - 1 percent, ** - 5 percent, * - 10 percent. Standard errors are clustered within a segment. Additional control variables are described in the text.

Table 8. Regression Results: Departure Delays

Dependent Variable:	DEPARTURE DELAY, mins					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	OLS	OLS	IV
INTERNET	4.419***	8.314***	11.20***	10.28***	9.118***	8.896***
	(.477)	(2.380)	(2.499)	(2.479)	(2.425)	(2.444)
HHI			3.067***	2.351***	2.473***	2.635***
			(.761)	(.840)	(.824)	(.823)
INTERNET * HHI			-5.769***	-4.984***	-4.743***	-4.813***
			(1.209)	(1.190)	(1.167)	(1.166)
LATE ARRIVAL		.562***	.562***	.561***	.561***	.560***
		(.009)	(.009)	(.009)	(.009)	(.009)
SCHEDULED BUFFER		-.0176***	-.0175***	-.0152***	-.0152***	-.0153***
		(.001)	(.001)	(.001)	(.001)	(.001)
FLIGHT IN DAY		.554***	.556***	.420***	.420***	.424***
		(.039)	(.039)	(.040)	(.040)	(.040)
LOG (AVG. FARE)					-3.274***	-3.707***
					(.540)	(.607)
LOG (LOAD FACTOR)					3.523***	3.460***
					(.448)	(.572)
Segment Fixed Effects	Y	Y	Y	Y	Y	Y
Aircraft Fixed Effects	Y	Y	Y	Y	Y	Y
Demographic Controls (X^D)	N	Y	Y	Y	Y	Y
Additional Controls	N	N	N	Y	Y	Y
Carrier/Day Fixed Effects	N	Y	Y	Y	Y	Y
Origin/Carrier Fixed Effects	N	Y	Y	Y	Y	Y
Observations	306,108	306,108	306,108	306,108	306,108	305,615

Notes: Standard errors are in parentheses. Stars denote the significance level of coefficients: *** - 1 percent, ** - 5 percent, * - 10 percent. Standard errors are clustered within a segment. Additional control variables are described in the text.

Table 9. Regression Results: Scheduled Time

Dependent Variable:	SCHEDULED FLIGHT TIME, mins					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	OLS	OLS	IV
INTERNET	8.607***	1.699	3.573***	3.141***	2.697***	2.507**
	(.187)	(1.056)	(1.120)	(1.051)	(1.027)	(1.032)
HHI			1.937***	1.990***	2.140***	2.119***
			(.368)	(.372)	(.370)	(.372)
INTERNET * HHI			-3.738***	-3.520***	-3.511***	-3.475***
			(.528)	(.498)	(.492)	(.492)
SCHEDULED BUFFER		-.004***	-.004***	-.002***	-.002***	-.002***
		(.000)	(.000)	(.000)	(.000)	(.000)
FLIGHT IN DAY		-.133***	-.132***	-.0638***	-.0631***	-.0632***
		(.0178)	(.0178)	(.0155)	(.0155)	(.0155)
LOG (AVG. FARE)					-1.545***	-1.571***
					(.226)	(.247)
LOG (LOAD FACTOR)					-1.192***	-.716**
					(.246)	(.305)
Segment Fixed Effects	Y	Y	Y	Y	Y	Y
Aircraft Fixed Effects	Y	Y	Y	Y	Y	Y
Demographic Controls (X^D)	N	Y	Y	Y	Y	Y
Additional Controls	N	N	N	Y	Y	Y
Carrier/Day Fixed Effects	N	Y	Y	Y	Y	Y
Origin/Carrier Fixed Effects	N	Y	Y	Y	Y	Y
Observations	306,108	306,108	306,108	306,108	306,108	305,615

Notes: Standard errors are in parentheses. Stars denote the significance level of coefficients: *** - 1 percent, ** - 5 percent, * - 10 percent. Standard errors are clustered within a segment. Additional control variables are described in the text.