Does Competition Influence Airline On-Time Performance?*

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JEL Classification: L13, L93.

December 12, 2001

Abstract

Airlines have attracted congressional scrutiny due to recent mergers, failed mergers, and poor on-time performance. This wave of consolidation has ramifications beyond air fares. We investigate how route competition influences on-time performance. Data obtained from the Bureau of Transportation Statistics include fifty nonstop domestic city-pairs for forty-eight months from 1997 to 2000. The paper analyzes both the frequency and magnitude of flight delays using a three-way fixed effects error component model. We find more competitive routes have worse on-time performance. Other important factors include seasonal effects, airport capacity constraints, the number of scheduled flights, hub originations, and prior month's performance.

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*We are indebted to Bernie Stankus of the Bureau of Transportation Statistics for providing airline on-time performance data. We thank S. Keith Berry, Keith Brown, Anushua Datta, Mark Holmes, Dong Li, and Jun-Byoung Oh for their helpful comments and suggestions. Jim Goodman and Tommy Gore provided excellent research assistance.

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> "Not all flights are treated equally. Planners acknowledge that they try to avoid disrupting trips to and from Washington's National Airport because of the likelihood of congressional passengers or New York's La Guardia airport because those flights carry high-fare, frequent-flying business travelers" (*Wall Street Journal*, 11 September 1996).

1 Introduction

Airline on-time performance has attracted congressional attention since a January 1999 incident at a Detroit airport that left hundreds of passengers stuck in planes on snow covered runways for nearly eight hours. The Senate and House held hearings in 1999 to discuss passenger treatment and a passenger bill of rights. On June 17, 1999 fourteen major domestic airlines agreed to a customer service commitment pledging to improve air travel (*Wall Street Journal*, 18 June 1999). The number one consumer air travel complaint during 2000 was flight problems (i.e., cancellations, delays, and missed connections) an increase of 30 percent from 1999 (Air Travel Consumer Report, February 2001, p 34). In 2001 concerns over flight delays and airline competition due to the recent airline mergers (American Airlines and TWA) and failed mergers (United and US Airways) again led to Congressional hearings which subsequently resulted in legislation of airline operations (Kocher, 2001; Mann, 2001).

The US Department of Transportation's Inspector General Kenneth Mead released report AV-2001-020 to update Congress on airline customer service issues. This report paints a bleak picture of recent air travel performance. Air travelers in 2000 stood a greater than 1 in 4 chance of their flight being delayed, canceled, or diverted. Between 1995 and 2000 the Bureau of Transportation Statistics (BTS) find departure and arrival delays increased 33 percent (1,863,265 to 2,486,103). The FAA reports flight cancellations more than doubled between 1995 and 2000 (91,905 to 187,317). In addition, of the flights arriving late, the average delay exceeded 52 minutes in 2000.

This paper examines the following issue: if an airline X is currently the only airline serving a route and suppose another airline Y enters, does on-time performance improve? More generally, what factors do profit-maximizing airlines consider in determining which flights arrive on-time? This study attempts to answer these questions by investigating how competition influences airline on-time performance.

The BTS attributes flight delays to a variety of factors: severe weather, aircraft maintenance, runway closures, customer service issues, air traffic control decisions, and equipment failures (Air Travel Consumer Report, February 2001). This study examines whether route competition merits inclusion in this set of delay factors. The Air Travel Consumer Report does not identify the cause, only the occurrence of flight delays. The present paper is the first work, to our knowledge, to investigate the relationship between on-time performance and market competition at the route level.

Examining how competition affects airline service quality may be especially relevant given the heightened interest by Congress, recent airline mergers, the bankruptcy of Midway Airlines, airline layoffs and scheduling cutbacks since the September 11th terrorist attacks (*Wall Street Journal*, 26 September 2001). This research may also yield some public policy recommendations regarding whether future airline consolidation will help or hurt airline on-time performance.

2 Previous Work

This study adopts the US DOT definition of “on-time” (i.e., arriving at the destination airport within 15 minutes of the scheduled arrival time). Since the definition of “on-time” arrival is rather arbitrary, the study analyzes both the occurrence of delays (which flights are late?) and the magnitude of delays (how late was the flight?). Passengers may have a different definition of “on-time” that may be more stringent or more forgiving. Hence, average minutes late may provide a better depiction of the factors that cause extended delays.

Researchers have previously investigated how delays impact consumer loyalty in the airline industry. Suzuki (2000) explores the relationship between the rate in which passengers switch carriers due to their previous flight experiences (i.e., whether they have or have not experienced delays). Suzuki finds that passengers with delay experience are more likely to switch carriers which results in greater market share for carriers with better historical on-time performance. This paper examines the relationship between market share and on-time arrivals.

Foreman and Shea (1999) consider the relationship between competition and on-time performance using monthly summary statistics of carrier performance (i.e., 65.3 percent of all Southwest Airlines flights were on-time in December 2000). Whereas, this study uses route level data which provides a lower level of aggregation (i.e., 61.4 percent of Southwest Airlines Los Angeles to Phoenix flights were on-time in December 2000). The level of data aggregation is the foremost distinction between Foreman and Shea and this paper.

Route level data is especially critical for the airline industry since previous research has extensively documented higher fares with greater industry concentration along specific airline routes due to mergers or airport dominance at origination or destination airports.[1] Holding price

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[1] For example, see Borenstein, 1989; Kim and Singal, 1995; and Morrison and Winston 1990.

constant, consumer demand has also been shown to be higher for airlines with large operations from the origination city (Morrison and Winston, 1989). We investigate whether on-time performance improves for flights originating from or destined for hubs. Entry decisions have been examined by Berry (1992) and more recently by Oh and Wiggins (2001) for Southwest Airlines and Fournier and Zuehlke (2001) for medium-size U.S. markets. This study explores how entry and exit influences on-time performance. Baltagi, Griffin, and Vadali (1998) find that the reorganization of route structures after deregulation has enabled airlines to make significant improvements in capacity utilization and cost reductions. This study considers airport capacity constraints at both the origination and destination airports.

3 On-time Performance Data

3.1 The Sample

Airlines that account for at least 1 percent of domestic scheduled passenger revenues are required to submit monthly reports to the BTS. Data appear both on line and in monthly summary format in the Air Travel Consumer Report which lists individual carrier on-time performance by airport.[2] These BTS data cover all nonstop scheduled-service domestic flights by the ten largest or "major" U.S. carriers, which account for more than 85 percent of domestic revenues in 2000 (Air Travel Consumer Report, January 2001). There are 29 U.S. airports in which the ten major carriers are required to report flight operations. All major airlines, however, have chosen to report all domestic operations voluntarily to the BTS. The result is the best source of on-time performance data for the airline industry.

(Place Table I about here)

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[2] We thank the Bureau of Transportation Statistics for providing the data.

The sample includes fifty nonstop domestic city-pair routes (see Table I) from January 1997 to December 2000. These routes include heavy, moderate, and light levels of passenger traffic. Specifically, we select the thirty city-pair routes with the most total passengers flown in 1999.[3] We also randomly select ten moderate size city-pair routes (from 49,550 to 108,160 total passengers in 1999) and ten small city-pair routes (ranging from 14,710 to 20,440 passengers in 1999). Following Borenstein (1990) and Berry (1990), travel from city A to city B is treated as a different market than travel from city B to city A. To be included as an observation, the carrier must offer a minimum of sixteen scheduled flights on a route per month. The result is a sample of 9,545 observations from one hundred routes. Table I also reports the average number of carriers serving the route, percentage of flights arriving on-time, average minutes late, total passengers served in 1999, and nonstop distance between city-pairs. Figure 1 plots the monthly average on-time performance which averaged 75.7 percent during the four year sample period (1997 to 2000). A noticeable decline in performance occurs in 2000, as the average on-time rate ranges from 76 to 78 percent between 1997 and 1999 drops below 72 percent in 2000.

(Place Figure 1 about here)

Table II reports that nearly two-thirds of the sample routes had an average monthly delay of 0 to 15 minutes. Flights that were between 0 and 15 minutes early on average during the month were much less common, comprising just ten percent of the sample. Flights arriving after their scheduled arrival time outnumbered early arrivals in the sample by a 9 to 1 ratio.

(Place Table II about here)

The best performance (80.3 percent) occurs for routes served by a single carrier. The most common number of competitors along a route in the sample is two. On time performance declines

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[3] We over sample the heaviest passenger traffic routes since these routes are typically served by multiple carriers.

with two carriers (75.6 percent) and bottoms out with three carriers at 73.0 percent. The on-time average begins to rise with four, five, and six carriers, yet still remains below the performance of a single carrier. A graph of carriers (on the horizontal) and on-time performance (on the vertical axis) reveals a U shape, with a peak at one carrier and a bottom at three carriers. These data suggest a potential nonlinear relationship exists between carriers and on-time performance.

Spring and *fall* have noticeably better on-time arrival rates than *winter* and *summer* for different reasons. Bad weather may explain the downturn for *winter*, while heavier passenger loads may contribute to *summer* delays. Southwest Airlines CEO Herb Kelleher blames higher load factors for his companies' drop in on-time performance during 1998 and 1999 (Flint, 2000).

The best on-time performance (78 percent) and shortest average delay (7.29 minutes) occurs for carriers offering the fewest number (i.e., one or two) daily scheduled flights on a route. On time arrival rates monotonically decline and delays lengthen as carriers schedule more daily flights on a route. For example, on-time rates fall with three or four daily flights (76.7 percent); decline again for five to six daily flights (76.4 percent), become worse for seven to eight daily flights (74.6 percent) and bottom out at nine to eleven daily flights (72.9 percent on-time and average 12.71 minutes late). Twelve to fifteen flights and sixteen or more flights had slightly better arrival rates of 74.9 percent and 74.3 percent, respectively. On-time performance varied by carrier from a low of 70.3 percent (Alaska) to a high of 81.9 percent (Northwest). We should note that these carriers had the two smallest number of observations of 298 and 354. Southwest reports the best on-time performance of 77.4 percent of the five carriers with more than 500 sample observations.

Carriers entered and exited during the four year sample. There were thirty-three instances of entry on twenty-three routes.[4] Figure 2 compares the on-time performance of the entrant with the existing carriers following entry in period 0. The initial three months the entrant performs

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[4] These numbers differ since more than one carrier entered the same route during the four-year sample period.

worse than the established carriers, while the next three months the entrant registers slightly better performance than its competition. On-time performance for both the entrant and existing carriers appear to move together. Figure 3 compares the average minutes late for the entrant and established carriers. A similar pattern emerges as the entrant initially performs slightly worse than its competition, however, in the later months the entrant experiences shorter delays.

(Place Figure 2 and 3 about here)

There were eighteen cases of carriers exiting from sixteen routes. Figure 4 shows the exiting carrier averaged 3.6 percent better on-time performance for the five months immediately before exit than the remaining carriers. Figure 5 also reports a similar trend as the exiting carrier has substantially shorter delays than the remaining competitors during the five months prior to exit. We should also note that immediately following exit, the remaining carriers temporarily suffer a short term drop in on-time performance lasting approximately three months.

(Place Figure 4 and 5 about here)

3.2 Variables

The following variables are obtained or constructed from the BTS data:

- *Percent on-time* is the percentage of flights on route i for carrier j at month t that arrived at the gate no more than 15 minutes after the scheduled arrival time. Specifically, *percent on-time* is the number of on-time flights divided by the number of scheduled flights for each carrier serving the route. Diverted and cancelled flights are counted as late.

- *Percent on-time*$_{t-1}$ is the prior month *percent on-time* on route i for carrier j.

- *Percent on-time*$_{t-12}$ is the prior year *percent on-time* on route i for carrier j.

- *Minutes late* is the average number of minutes that flights for carrier j on route i arrived after the scheduled arrival time. The average *minutes late* calculation excludes diverted and cancelled flights.
- *Winter* equals one for flights in December, January, and February.
- *Spring* equals one during March, April, and May.
- *Summer* equals one for June, July, and August.
- *Distance* is the nonstop flight distance in miles between a city-pair.
- *Origination hub* equals one if the flight originated from carrier j's hub.[5]
- *Destination hub* equals unity for flights destined for carrier j's hub.
- *Scheduled flights* is the number of monthly nonstop scheduled flights by carrier j on route i.
- *Low-fare carrier* equals one if a low fare competitor has more than 10 percent market share on route i.[6]
- *Carriers* is the number of major carriers on route i plus one if a low-fare carrier (other than Southwest[7]) has more than 10 percent market share on route i.
- *Carriers squared* equals *carriers*carriers*.
- *Monopoly* equals one if *carriers* equals one, otherwise zero.
- *Duopoly* equals one if *carriers* equals two, otherwise zero.

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[5] See Appendix Table I for a complete hub listing.

[6] Low-fare carriers include Access Air, Air South, Air Tran, American Trans Air, Carnival, Frontier, Kiwi, National Airlines, Pro Air, Reno, Southwest, Spirit, Sun Country, Vanguard, and Western Pacific.

[7] We exclude Southwest since it is already counted as a major airline.

- *Three carriers* equals one if *carriers* equals three, otherwise zero. (*Four* and *five carriers* are defined likewise).

- *Entry* equals one for established carriers on route i if a carrier has entered route i within the past six months. The entrant and all others equal zero.

- *Exit* equals one for established carriers on route i if a carrier has exited route i within the past six months.

- *Market share* is the number of scheduled flights for carrier j on route i divided by the total number of scheduled flights for all carriers on route i.

- *Herfindahl index* is the sum of the squared market shares for all carriers serving route i.

- *Effective competitors* is the inverse of the Herfindahl index.

- *Effective competitors squared* equals *effective competitors*effective competitors.*

The following variable comes from the FAA *Airport Capacity Benchmark Report 2001*:

- *Capacity* is the number good weather hours that a departure airport has scheduled operations that exceed the capacity benchmarks.[8] This number varies from 0 hours for many of the smaller airports (e.g., Albany, NY, Tucson, AZ, and Miami, FL) and 0.25 for Boston's Logan airport to 8 hours for New York City's La Guardia airport.

Various measures of route competition are considered. These include the number of *carriers* providing nonstop service between the city pair. *Carriers squared* captures potential

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[8] The capacity benchmark developed by the FAA for the nation's busiest 31 airports. The FAA also provides capacity benchmarks during bad weather, however, since we do not have data on the number of "bad weather" days per month at each airport, we opt to use only the good weather capacity measure.

nonlinear competitive effects. *Low-fare carrier* indicates competition from a low-fare carrier with 10 percent or more market share on a route. *Entry* and *exit* capture recent changes in the level of competition on a route. *Herfindahl index* provides a measure of route level industry concentration. Following the suggestion of Adelman (1969) we interpret the inverted Herfindahl index as the number of *effective competitors*.[9] This measure may be preferred to *carriers* since a carrier count makes no distinction between large and small carriers. *Market share* measures the impact of market dominance on the quality of service.

On-time performance can also be influenced by specific route level characteristics independent of market competition. Since volume effects could potentially influence performance, we include the number of monthly *scheduled flights* for carrier j on the route. Carriers might provide better on-time service to *destination hub* since these flights typically involve connections. Longer flights, denoted as *distance* between city-pairs, may allow pilots to "make-up" for flight delays on the ground by flying at faster air speeds. Finally, some estimations include the prior month's performance to determine if a trend exists in on-time arrivals.

3.3 Hypotheses

The director of flight operations control of American Airlines, Art Pappas states his companies' objectives: "we want to minimize customer inconvenience and maximize profits," (*Wall Street Journal*, 11 September 1996, B1). We assume that all carriers have similar objectives. Suppose a carrier offers a morning and an evening flight between city-pair A to B and flights each hour between city-pair A to C. Due to a maintenance issue it must cancel or significantly delay a flight from city A. All else equal, which city-pair is more likely to suffer a cancellation or delay?

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[9] For more discussion on effective competitors in the airline industry at the national level see Morrison and Winston (1995, pp. 8-10).

We expect the carrier to cancel or delay service on the route offering more daily flights (city pair A to C) since this minimizes customer inconvenience as the next available flight is just one hour later. In fact, Table II presents anecdotal evidence that carriers with fewer daily flights provide better service. This leads to our first claim:

Claim 1: (Minimize customer inconvenience) Everything else equal, worse on-time performance occurs on routes with more daily scheduled flights.

Since at a typical hub, a majority of the passengers make connections (Morrison and Winston, 1995, pp. 44), an airline can minimize customer inconvenience (i.e., reissuing tickets for missed connections) by providing better service to flights destined for hubs. This also becomes a profit maximizing issue for evening flights since airlines are responsible for providing overnight food and lodging for passengers missing connections due to a factor within the airline's control. This leads to our second claim:

Claim 2: (Minimize customer inconvenience and maximize profits) All else equal, flights destined for the carrier's hub have better on-time performance.

Suzuki (2000) finds that passengers with delay experience are more likely to switch carriers. Therefore, we expect that carriers will want to retain passengers on more profitable/higher fare routes by providing better service. The converse also holds: we expect worse service on the less profitable routes. While carriers do not provide profitability figures for each route, one measure of a route's profitability does exist: whether the carrier faces competition from a low-fare competitor. Our third claim is as follows:

Claim 3: (Maximize profits) All else equal, worse on-time performance occurs on routes with competition from low-fare carriers.

Airlines compete for customers on two primary fronts: price and schedule. Consider a carrier that is the sole provider of air travel on a route. The monopolist has an incentive to schedule flights farther apart (offering maximum brand differentiation) in order to maximize profits. Now suppose two carriers serve the same route. Hotelling's (1929) model of spatial competition predicts that when a second firm enters the market minimum brand differentiation occurs (i.e., if two sellers can choose where to locate along a line, they will both choose to locate at the midpoint). Hotelling finds no stable equilibrium location when three firms serve the market.

In the airline industry, on routes with two or more carriers (with market shares above 10 percent), the cross-carrier variation in average fares on a route is less than 5 percent (Borenstein and Rose, 1994). Since carriers match each other's prices, the only dimension left to compete on is schedule times. Borenstein and Netz (1999) show that multiple carriers on a route will locate flight departures closer together than will a single firm which operates the same number of flights. Some significant scheduling differentiation also occurs between routes served by two versus three carriers. Carriers have an incentive to increase market share by offering schedules at peak travel times (i.e., lots of 8 am departures). The result is a difficult schedule to meet, given airport capacity constraints occur at peak travel times.

Claim 4: (Maximize profits) All else equal, more competitive routes will have worse on-time performance due to a clustering of flights at peak travel times.

4 Econometric Specification

The BTS data are used in the following model of airline on-time performance:

$$y_{ijt} = x_{ijt}\beta + u_{ijt} \tag{1}$$

where y_{ijt} is a vector of the monthly average *percent on-time* on the ith route (i = 1,..., 100) of the jth carrier (j = 1,..., 10) for the tth month (t = 1,..., 48), x is a vector of route and airline characteristics, and the disturbance is given by:

$$u_{ijt} = \mu_i + \lambda_j + \gamma_t + \nu_{ijt} \tag{2}$$

where μ_i denotes a route-specific effect, λ_j denotes a carrier-specific effect, and γ_t represents a month-specific effect and $\nu_{ijt} \sim IID(0, \sigma^2_\nu)$.[10]

The route specific effects (μ_i) are assumed fixed parameters to be estimated as coefficients of route dummies for each of the 100 routes in the sample. This can be justified since the FAA's Airport Capacity Benchmark Report (2001) indicates airport capacity constraints at departure and arrival airports on each route differ. Secondly, the proportion of business/vacation travelers and hence the profitability of each route also differs. For example, the composition of travelers from Los Angeles to Las Vegas (the number one route in terms of total passengers in 1999) is expected to differ substantially from the second largest route: Los Angeles to New York's JFK.

The carrier-specific effects (λ_j) are assumed fixed and estimated as carrier dummies for each of the ten major carriers in the sample. These carrier-specific characteristics include the age of a carrier's fleet, airplane turnaround times, and scheduled block times. For example, younger aircraft are expected to have fewer equipment failures and hence less frequent delays. Of the major carriers Continental, American, and Southwest have the youngest average fleet age of approximately ten years old, whereas TWA and Northwest have the oldest fleets averaging fourteen and twenty-one years old, respectively.[11] Southwest is known for its industry leading twenty minute plane turnaround and unlike its competitors, Southwest does not artificially stretch its scheduled block times (i.e., the amount of time allocated for a particular flight segment) to

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[10] For additional examples of three-way error component estimations see Davis (2002) and Goldhaber, Brewer, and Anderson (1999).

[11] Fleet age is defined as aircraft in service as of April 15, 2001. Figures are provided by AirClaims and were obtained from http://airtravel.about.com/library/stats/blageairlinehp.htm accessed November 25, 2001.

improve on-time performance (Flint, 2000).

The time-specific effects (γ_t) are also assumed fixed and estimated as time dummies for each month in the sample. Time-specific effects control for seasonal effects such as severe weather during winter and more leisure travelers in the summer. Labor unrest is a common theme for the airline industry during the sample period. For example, TWA and American Airlines both cancelled flights due to strikes in 1996, while flight attendants threatened "chaos" (i.e., organized efforts to call in sick) at United Airlines (*Wall Street Journal*, 24 June 1996). In 1998, airlines began enforcing carry-on baggage limits in an effort to improve on-time performance (*Wall Street Journal*, 11 December 1998). Airline carriers avoided Congressional mandates in 1999 by voluntarily promised to improve customer service (*Wall Street Journal*, 18 June 1999).

Our selection of routes is not a random sample of all routes and thus may not be representative (i.e., we analyze the thirty largest routes along with ten randomly selected medium and small size routes). Therefore, we use fixed effects (or within), instead of random effects, to estimate on-time performance in equation (1). All fixed effects estimations are conditional on the particular routes chosen. Finally, the magnitude of late flights is addressed by using the dependent variable *minutes late* in (1) with the identical set of explanatory variables.

5 Results

5.1 The Occurrence of Flight Delays: Which Flights are Late?

We begin by replicating Foreman and Shea's (1999) on-time performance model using the same set of explanatory variables with route level data instead of carrier level data. The OLS estimations (see model (1) in Table III) reveal a negative coefficient for *carriers* and a positive coefficient for *carriers squared*. These results suggest that additional carriers reduce on-time performance, contrary to Foreman and Shea. Other differences exist between the two studies as we find significantly worse on-time performance for carriers with more *scheduled flights*, while Foreman and Shea report insignificant volume effects. The studies do share some similarities as the following variables: *winter, summer,* and *percent on-time* (lagged one month and one year) are all significant with the same coefficient signs.

(Place Table III about here)

An advantage of route level data is the ability to control for route-specific effects in addition to carrier and month-specific effects. A within estimation of the same set of variables wipes out the time invariant variables (*winter, spring* and *summer*). The results appear in model (2) of Table III. The difference between this estimation and the first model is that the competition variables (*carriers* and *carriers squared*) lose their explanatory power as does the twelve month lagged *percent on-time*.

Table III also presents weighted least squares (WLS) estimation with the weight being the number of monthly scheduled flights.[12] This estimation extends the earlier models by including some variables that are only available at the route level. In addition, some of these explanatory variables are time invariant and hence annihilated by a within transformation. The estimations appear in model (3) indicate that route competition: *carriers* (-) and *carriers squared* (+), regain their statistical significance. The presence of a *low-fare carrier* on a route lowers the average percentage of on-time flights by 0.59 percentage points. This finding lends support to the third claim that carriers provide worse service on less profitable routes (i.e., those with low-fare competition).

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[12] The following WLS regression estimates on time performance: $y_{ijt}\sqrt{n_{ijt}} = x_{ijt}\sqrt{n_{ijt}}\beta + \varepsilon_{ijt}\sqrt{n_{ijt}}$ where n_{ijt} is the number of scheduled flights per month for carrier i on route j at month t.

Appendix Table II presents additional WLS estimations which reveal more frequent (model 10a) and longer delays (models 11 and 11a) occur on routes with competition from a *low-fare carrier.* This appendix also reports higher delay rates for *winter* and *summer* flights (see models 10 and 10a). These delays are attributed to bad weather and higher load capacities, respectively.

Model (3) also includes *capacity,* which measures congestion at the departure airport. The significant -0.21 coefficient indicates that an additional hour (from the sample mean of 1.63 capacity hours) in which operations at the departure airport during good weather exceed capacity, reduces on-time performance by -0.21 percentage points.[13] For example, these results suggest that departing from San Francisco (2.5 hours capacity constraints in good weather) instead of Los Angeles International Airport (1.5 hours capacity constraints) lowers the average rate of on-time arrivals by 0.21 percentage points. The importance of capacity constraints at departure airports is not surprising given that the FAA reports that 75% of all flight delays in 2000 occurred before the flight leaves the ground (US DOT Report AV-2001-020).

Appendix Table II provides more support that *capacity* constraints significantly influence on-time arrival rates (see models 10 and 10a). The remaining variables provide little explanatory power in the estimation: *entry, exit, destination hub, origination hub*, and *distance.* Given that these results (on-time performance declines for more competitive routes) contradicts an earlier study, we consider alternative competitive measures (e.g., effective competitors and market share) to determine if similar results are found.

Since the twelve month lagged dependent variable reduces the sample size by one-fourth and given this variable is insignificant in the within estimation in model (2) of Table III, our estimations include at most a one month lag. The within estimates on Table IV include a measure

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[13] Arrival airport capacities are considered, however, they generate insignificant estimates.

of route competition, changes in route competition during the sample (entry and exit), volume effects, and hub effects. The within transformation wipes away *capacity* and *distance* since these variables do not change during the sample. Models (4), (5), and (6) use different competition proxies as model (4) includes *carriers* and *carriers squared*, model (5) has *effective competitors* and *effective competitors squared*, and model (6) uses *market share*. Models (4a), (5a), and (6a) are identical to their numbered counterparts with one exception, the "a" models include *percent on-time*$_{t-1}$. The one month lagged dependent variable, while highly significant in all estimations, drains the explanatory power of the other variables. Thus separate estimates are provided. We now test the validity of each of the four claims presented in the previous section.

(Place Table IV about here)

We find considerable support for claim 1, as *scheduled flights* registers significant estimates in all six models in Table IV. The negative coefficients confirm our expectation that more scheduled flights contribute to frequent flight delays. The converse also holds: higher arrival rates occur on routes with fewer scheduled flights. We interpret the -0.005 coefficient from model (4) as follows, an additional daily scheduled flight by carrier i on route j reduces on-time performance by -0.005*30 = -0.15 percentage points.

We find no evidence supporting claim 2, as insignificant *destination hub* estimates appear in all models in Table IV. This indicates that flights destined for hubs have neither better nor worse on-time performance than any other flight. On the other hand, flights with an *origination hub* have more frequent flight delays. Since flight delays maybe a function of the aircraft arriving late from the previous flight, we compare the scheduled turnaround time or the number of minutes before the plane's next scheduled (same-day) departure. Turnaround times for two randomly selected city-pair routes appear on Table V. The eleven America West flights from Los Angeles (LAX) to Phoenix (PHX) (on Thursday, November 11th, 1999) were scheduled to spend an average of 57.6 minutes at their PHX hub before departure. In comparison, America West scheduled a much shorter period (40.4 minutes) in LAX (non-hub) for flights from PHX to LAX. America West flights for this city-pair route spend an additional 17.2 minutes at the PHX hub.

This hub effect is not unique to America West as United flights on the LAX-PHX route spend 4.3 minutes longer at United's LAX hub. Table V also shows similar findings for a second route: Chicago (ORD) to Atlanta (ATL). Delta flights on this route are scheduled to spend almost ten more minutes at the ATL hub, while American and United flights on this route spend an average of 12.4 and 18.1 additional minutes, respectively at their ORD hubs. Except for the first morning flights each day, most departing flights rely on earlier same-day flight arrivals. Therefore, longer scheduled turnaround times at hubs should improve the prospect of an on-time departure even for late arriving aircraft. Surprisingly, we find the opposite occurs as *origination hub* flights have lower on-time arrival rates (averaging 1.2 to 2.5 percentage points worse in Table IV). One plausible explanation for longer scheduled turnaround times and subsequent flight delays is that some aircraft services (such as cleaning, refueling, or catering) may only occur at hubs and hence require more preparation time. Because the BTS does not list the cause of the delay, only its occurrence, we can only speculate as to the reason for more frequent hub delays.

As previously discussed, we find Appendix Table II supports claim 3 since routes with competition from a *low-fare carrier* have worse on-time performance. Since *low-fare carrier* is time invariant, it does not appear in the within estimations.

Regardless of how competition is defined: whether it is the number of *carriers*, *effective competitors* or *market share*, Table IV presents clear evidence that more competitive routes have worse on-time performance. *Carriers* (-) and *carriers squared* (+) are significant in both models

(4 and 4a) suggesting that additional carriers lower on-time performance to a limit.[14] Models (5 and 5a) find a similar result as *effective competition* (-) and *effective competition squared* (+) achieve statistical significance in both estimations. Since *effective competition* is the inverse of the *Herfindahl index*, this result indicates that more concentrated routes have better on-time performance. Borenstein and Netz (1999) report a positive correlation between Herfindahl and average differentiation of flight departure times. Concentrated routes with more schedule differentiation have higher on-time arrival rates is consistent with claim 4. *Market share* estimations in models (5) and (5a) provide more evidence of the validity of claim 4 as carriers with greater market share have significantly better on time arrival rates. Specifically, model (5) suggests that a one percentage point increase from the mean market share on route i improves carrier j's on-time performance by 0.058 percentage points.

Since Borenstein and Netz (1999) find higher differentiation of departures for routes served by one carrier compared with two carriers and some evidence that more differentiation occurs between the second and third carriers, we re-estimate models (4) and (4a) using dummy variables for the number of carriers serving the route instead of *carriers* and *carriers squared.* If on-time performance is due to scheduling differentiation we should see significantly different performance for routes served by one versus two carriers and routes served by two versus three carriers. Finally, since routes served by three or more carriers have little scheduling differentiation, we expect little difference in on-time arrival rates between three versus four carrier routes.

Model (12) of the Appendix Table III reports significantly better on-time averages for both *monopoly* and *duopoly* and worse performance for *five carriers* compared with routes served by *six carriers* (the omitted dummy). A test of the coefficient differences reveals that *monopoly*,

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[14] For example, the first-order condition of the partial derivative of *on-time* with respect to *carriers* in Model (4) indicates that the most competition can reduce on-time performance is 6.86 percentage points.

while having a larger coefficient (in absolute value), is not significantly different from *duopoly* at standard significance levels. On-time performance does significantly differ between *duopoly* and *three carriers*. We cannot reject that on-time performance is equivalent for *three* and *four carriers* nor do we reject that *four* and *five carriers* have equivalent coefficients. In sum, we find support for claim 4 since a significant change in on-time arrival rates occurs between *duopoly* and *three carriers* with better on-time performance for *duopoly* routes. On-time performance for routes with *three, four*, and *five carriers* do not significantly differ.

Market competition changes during the sample are captured by recent *entry* and *exit*. All six models in Table IV indicate that no noticeable change in on-time performance following *entry*. Models (4), (5), and (6) reveal significant improvements in arrival rates (between 1.8 to 2.1 percentage points) for the remaining carriers after *exit*. This result, while consistent with claim 4 (less competition improves on-time performance), is somewhat surprising given airlines' reluctance to change schedules posted six months in advance (Flint, 2000). The inclusion of a one month lagged *percent on-time* in models (4a), (5a), and (6a) drains the explanatory power of *exit*.

5.2 The Magnitude of Flight Delays: How Late was the Flight?

The previous section examined the frequency of flight delays using the dependent variable: *percent on-time* which classifies flights as either on-time or late. As a result, flights twenty minutes late are treated the same as flights arriving an hour and twenty minutes late. This section addresses the factors that cause extended delays. The dependent variable: *minutes late* enables us to quantify, in minutes, each of the relevant flight delay factors. The same set of regressors are included with one exception: $minutes\ late_{t-1}$ replaces $percent\ on\text{-}time_{t-1}$. Table VI presents regression results from estimating equation (1) using the dependent variable: *minutes* *late*. We now analyze each of the four claims.

(Place Table VI about here)

Previously we found more frequent delays occur on routes with more *scheduled flights* (see Table IV). We find additional support for claim 1 as four of the six Table VI estimations reveal significantly longer delays for *scheduled flights*. Specifically, the 0.002 coefficient in model (7) indicates that an additional daily scheduled departure causes 0.06 minute (or about 4 seconds) longer average delay. Results from Table IV and VI combined reveal that routes with more *scheduled flights* have frequent short delays, a finding consistent with the first claim.

Claim 2 asserts better on-time performance on routes destined for hubs. We find some support for this claim as flights with a *destination hub* arrive significantly earlier (on average 42 seconds early) in models (7), (8), and (9). Given our previous findings from Table IV that *destination hub* flights do not have higher on-time arrival rates, we believe that short delays occur for flights destined for hubs. With the inclusion of the lagged dependent variable *destination hub* loses its significance in models (7a), (8a), and (9a). Therefore, Table IV and VI jointly provide only modest support for claim 2. *Origination hub* flights are not associated with extended delays.

The previous section found more frequent flight delays on routes with *low-fare carriers*. Significantly longer delays (from 5.1 to 6.9 minutes) also occur on routes with competition from a *low-fare carrier* (see appendix Table II models (11 and 11a)). The major carriers appear to provide better service on the more profitable routes. We find considerable evidence supporting claim 3 as routes with *low-fare carriers* experience both more frequent and longer delays.

Results from Appendix Table II also suggest *capacity* significantly influences the length of delay. Specifically, an additional hour in which operations at the departure airport exceed *capacity* generates substantially longer delays between 1.1 to 1.7 minutes (see models (11 and

11a). This appendix table also reports longer delays during *summer* and *winter*.

Finally, we find more support for claim 4 as competitive routes have extended delays. Model (7) estimations indicate significant coefficients for *carriers* (+) and *carriers squared* (-). For example, suppose two routes are identical except for the number of carriers: 3.86 instead of 2.86 (sample mean). The average delay would increase by 0.59 minutes (or approximately 35 seconds) on the more competitive route. Now suppose a carrier enters a monopolist's route, model (7) estimates suggest that average minutes late increases by 1.76 minutes, a substantially larger effect which illustrates the nonlinear effects of competition.

Appendix Table III model (13) reports significantly shorter delays for both *monopoly* and *duopoly* while routes with *three, four*, and *five carriers* are not associated with shorter (nor longer) delays. We cannot reject the equivalence of the *monopoly* and *duopoly* coefficients. We can, however, reject the equivalence of *duopoly* and *three carriers* coefficients: as *duopoly* delays are significantly shorter than routes served by *three carriers.* Finally, we find no significant difference in delay length occurs when comparing *three carriers* with *four carriers* and *four carriers* versus *five carriers.* Models (12) and (13) of appendix Table III indicate higher on-time arrival rates and shorter delays for *monopoly* and *duopoly* routes. A significant drop in on-time performance occurs for routes served by *three carriers.* Little change in performance is detected for routes with four or more carriers.

Effective competitors (+) and *effective competitors squared* (-) estimates in Model (8) indicate longer delays on more competitive routes, a result that also supports claim 4. Moreover, model (9) finds an inverse relationship between *market share* (-) and length of delay. Routes with recent *entry* and *exit* are not associated with longer delays. Table VI and appendix Table III therefore provide considerable support for claim 4: on-time performance (measured by both the percentage of on-time arrivals and average minutes late) declines with more competition.

6 Conclusion

It would be audacious to assert that our findings of an inverse relationship between competition and on-time performance are correct while Foreman and Shea are incorrect. We do, however, believe that route level data provide a better depiction of the competitive environment in the airline industry than carrier level data. Using a three way fixed effects error component model we are able to control for route-specific, carrier-specific, and month-specific effects.

We are now able to answer the questions posed in the introduction. Routes served by one and two carriers have higher on-time arrival rates and shorter average delays than routes served by three or more carriers. We attribute this result to more schedule differentiation which occurs for less competitive routes. Additional carriers cluster flight schedules around peak travel times and hence contribute to frequent flight delays. Market competition of a route as measured by *carriers, carriers squared, effective competition, effective competition squared*, and *market share* all yield the same result: more competition brings more frequent and longer flight delays. Evidence is presented that *exit* on a route leads to higher on-time arrival rates for the remaining carriers, yet this does not translate into shorter delays. The effects of recent carrier *entry* are negligible.

Airlines' on-time performance is dictated by two objectives, maximize profits and minimize customer inconvenience. We find evidence of the former as more frequent and longer delays occur on less profitable routes (i.e., routes with competition from a *low-fare carrier*). We find evidence of the latter since carriers with more *scheduled flights* on a route experience more frequent and slightly longer flight delays. This minimizes customer inconvenience since routes with many *scheduled flights* have more alternatives for passengers displaced due to delayed or cancelled flights.

The list of flight delay factors published by the Bureau of Transportation Statistics includes: severe weather, aircraft maintenance, air traffic control decisions and runway closures. We find that *winter* (due to severe weather) flights experience recurrent and longer delays. Departure airports with *capacity* constraints (which include runway closures) have frequent long delays. We suggest that two additional variables be added to this list. Load factors may be causing frequent and extended *summer* delays. Second, we find route competition contributes to the frequency and duration of flight delays. What public policy implications do we infer from this study? The recent wave of airline consolidation and service cutbacks may provide air travelers with a surprising benefit: better on-time performance, particularly on routes which consolidate from three to fewer carriers.

References

Adelman, M.A. 1969. 'Comment on the 'H' Concentration Measure as a Numbers-Equivalent', *Review of Economics and Statistics*, 51, pp. 99-101.

Baltagi, Badi, James M. Griffin and Sharada Vadali. 1998. 'Excess Capacity: A Permanent Characteristic of U.S. Airlines', *Journal of Applied Econometrics*, 13, pp. 645-57.

Berry, Steven T. 1990. 'Airport Presence as Product Differentiation', *American Economic Review Papers and Proceedings,* 80:2, pp. 394-99.

_____. 1992. 'Estimation of a Model of Entry in the Airline Industry', *Econometrica,* 60:4, pp. 889-917.

Borenstein, Severin. 1989. ‘Hubs and High Fares: Dominance and Market Power in the US Airline Industry’, *Rand Journal of Economics,* 20, pp. 344-68.

______. 1990. ‘Airline Mergers, Airport Dominance, and Market Power’, *American Economic Review Papers and Proceedings,* 80:2, pp. 400-04.

Borenstein, Severin and Janet Netz. 1999. ‘Why Do All the Flights Leave at 8 am?: Competition and Departure-time Differentiation in Airline Markets’, *International Journal of Industrial Organization*, 17, pp. 611-40.

Borenstein, Severin and Nancy L. Rose. 1994. ‘Competition and Price Dispersion in the US Airline Industry’, *Journal of Political Economy*, 103, 653-83.

Davis, Peter. 2002. ‘Estimating Multi-way Error Component Models with Unbalanced Data Structures’, *Journal of Econometrics*, 106:1, pp. 67-95.

Flint, Perry. 2000. ‘Back on Schedule’, *Air Transport World*, 37:11, pp. 47-51.

Fournier, Gary M. and Thomas Zuehlke. 2001. ‘New Carrier Entry and Airport Substitution by Travelers: Why Do We have to Drive to Fly?’ Florida State University Department of Economics Working Paper.

Foreman, Stephen Earl and Dennis G. Shea. 1999. ‘Publication of Information and Market Response: The Case of Airline on Time Performance Reports’, *Review of Industrial Organization*, 14, pp. 147-62.

Goldhaber, Dan D, Dominic J. Brewer and Deborah J. Anderson. 1999. ‘A Three-way Error Components Analysis of Educational Productivity’, *Education Economics*, 7:3, pp. 199-208.

Hotelling, Harold. 1929. ‘Stability in Competition’, *Economic Journal*, 39, pp. 41-57.

Kim, E. Han and Vijay Singal. 1993. 'Mergers and Market Power: Evidence from the Airline Industry', *American Economic Review*, 83:3, pp. 549-69.

Kocher, Daniel. 2001. 'Airline Competition, Flight Delays Continue to Worry Congress', *Nation's Cities Weekly*, 24:13, pp. 12.

Mann, Paul. 2001. 'Congress Bearish on Big Carriers', *Aviation Week & Space Technology*, 154:11, pp. 66-67.

Morrison, Steven and Clifford Winston. 1989. 'Enhancing the Performance of the Deregulated Air Transportation System', *Brookings Papers on Economic Activity: Microeconomics,* 1, pp. 61-112.

_____. 1990. 'The Dynamics of Airline Pricing and Competition', *American Economic Review Papers and Proceedings,* 80:2, pp. 389-93.

_____. 1995. *The Evolution of the Airline Industry.* Washington, D.C.: The Brookings Institution.

Oh, Jun-Byoung and Steven N. Wiggins. 2001. 'Determinants of Entry and Successful Market Performance of Upstart Firm: An Empirical Study of the U.S. Domestic Airline Industry', Texas A&M University Department of Economics Working Paper.

Suzuki, Yoshinori. 2000. 'The Relationship between On time Performance and Airline Market Share', *Transportation Research: Part E: Logistics and Transportation Review*, 36:2, pp. 139-54.

US Department of Transportation. 2001. Federal Aviation Administration, *Airport Capacity Benchmark Report 2001*, Washington, D.C.: US Government Printing Office.

US Department of Transportation. 2001. Office of Aviation Enforcement and Proceedings, *Air Travel Consumer Report* (January 2001 and February 2001), Washington, D.C.: US Government Printing Office.

US Department of Transportation. 2001. Office of Inspector General, *Final Report on the Airline Customer Service Commitment*, Report AV-2001-020, Washington, D.C., US Government Printing Office.

Wall Street Journal. 1996. 'United Flight Attendants Warn of 'Chaos'', 24 June, pp. B1.

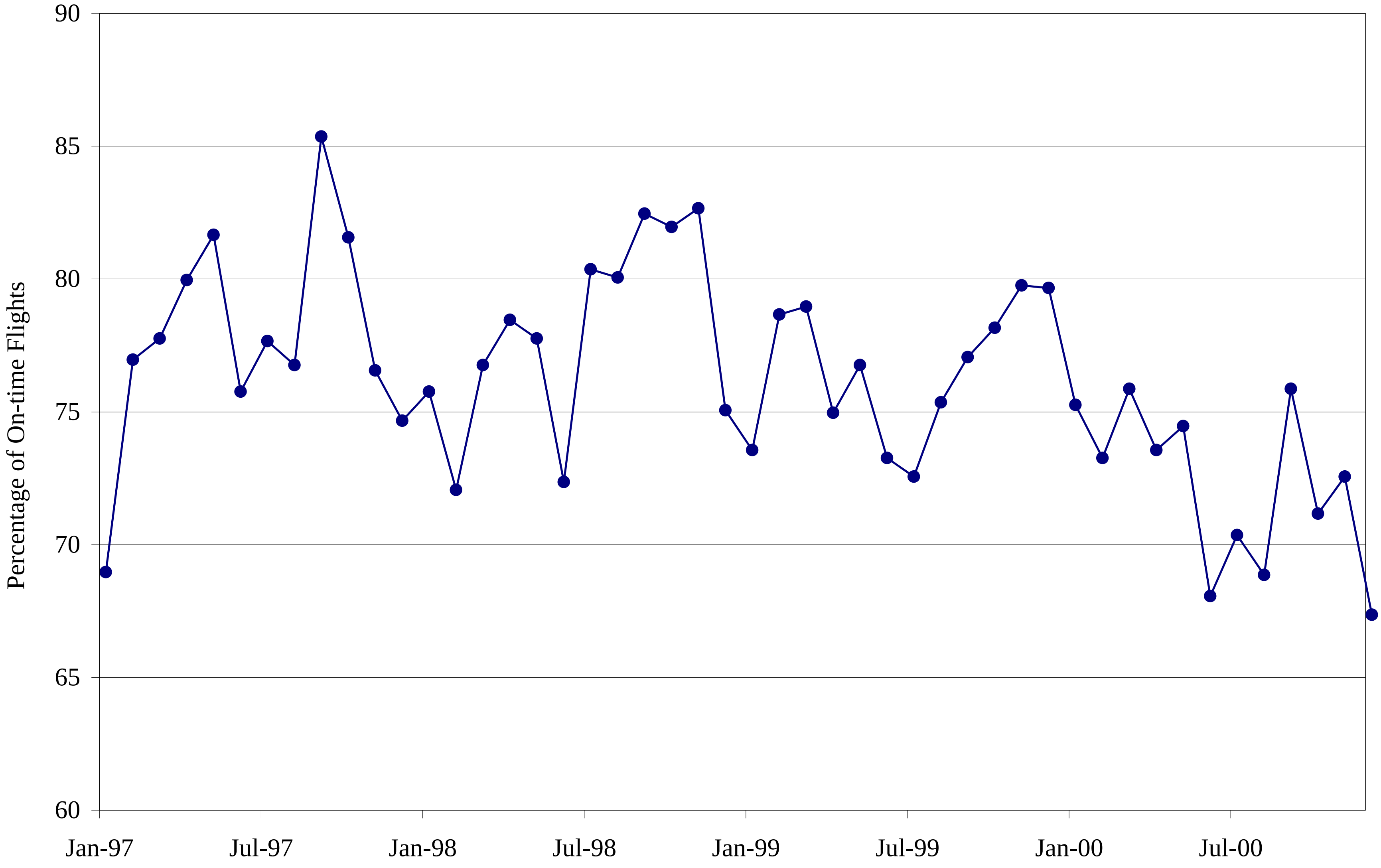
______. 1996. 'The Inexact Science of Keeping an Airline on Schedule', 11 September, pp. B1.

______. 1998. 'Bags Away: A Crackdown on Carry-ons', 11 December, pp. W6.

______. 1999. 'Airlines Promise Measures to Boost Customer Service', 18 June, pp. A6.

______. 2001. 'Airline Workers Decry Use of Clause Excluding Them from Bailout Plan', 26 September.

Figure 1: Monthly Airline On-time Performance from Bureau of Transportation Statistics Data for Major U.S. Carriers on Fifty NonStop Domestic City Pair Routes, January 1997 to December 2000.



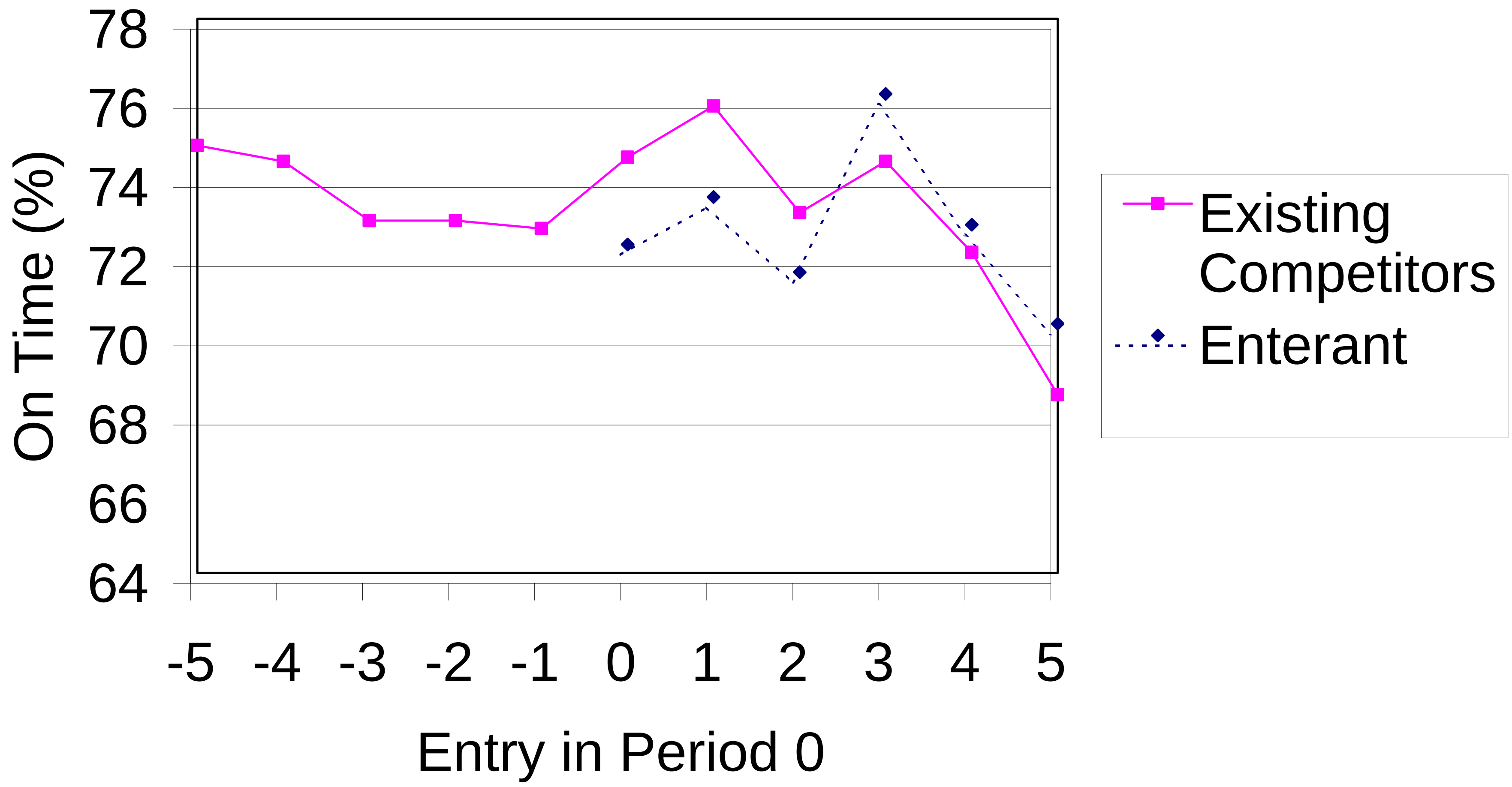
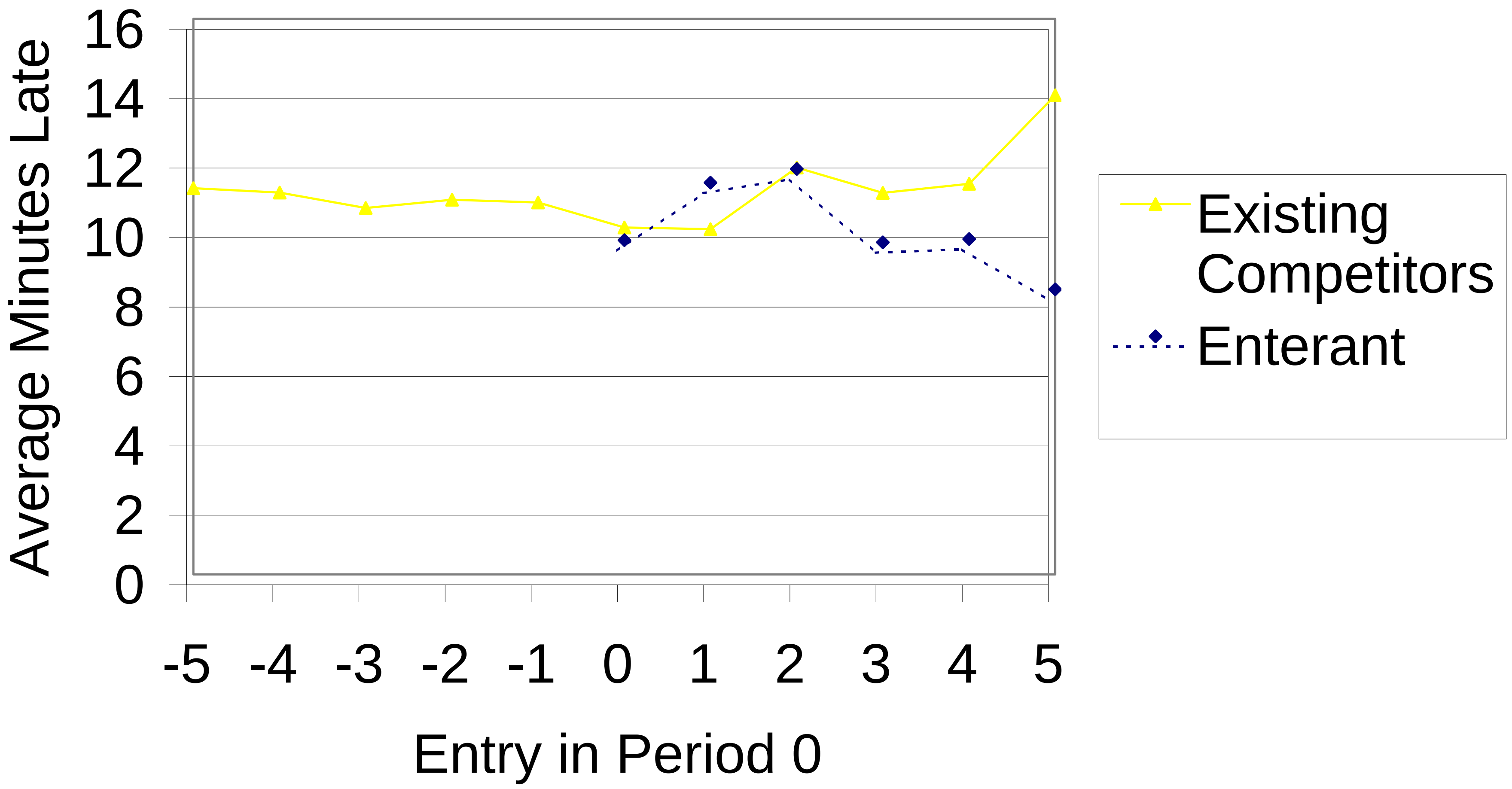


Figure 2: Monthly On Time Performance for the Sample Routes with Entry (n=33).

Figure 3: Monthly Average Minutes Late for the Sample Routes with Entry (n=33).



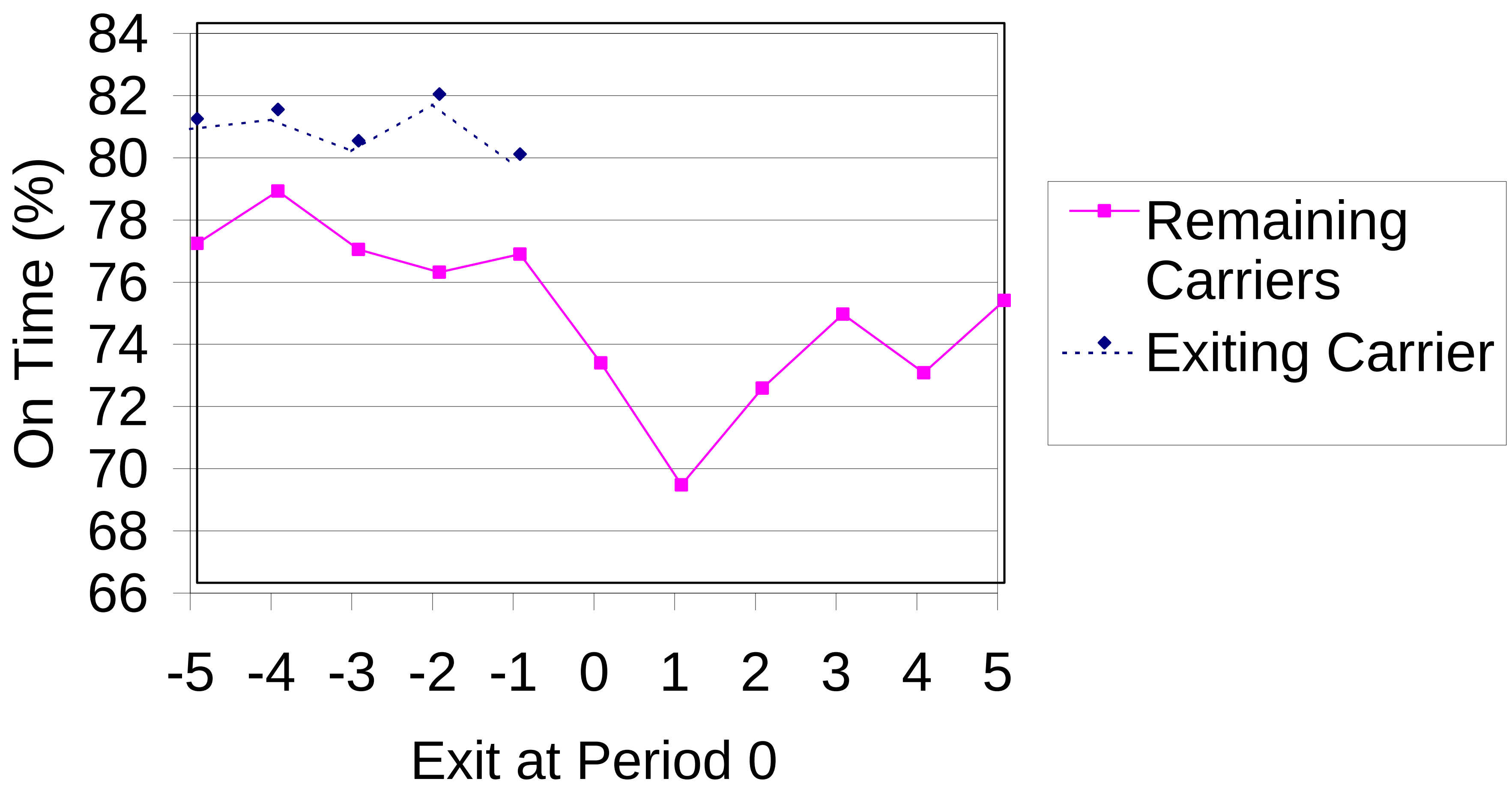


Figure 4: Monthly On Time Performance for the Sample Routes with Exit (n=18).

Figure 5: Monthly Average Minutes Late for the Sample Routes with Exit (n=18).

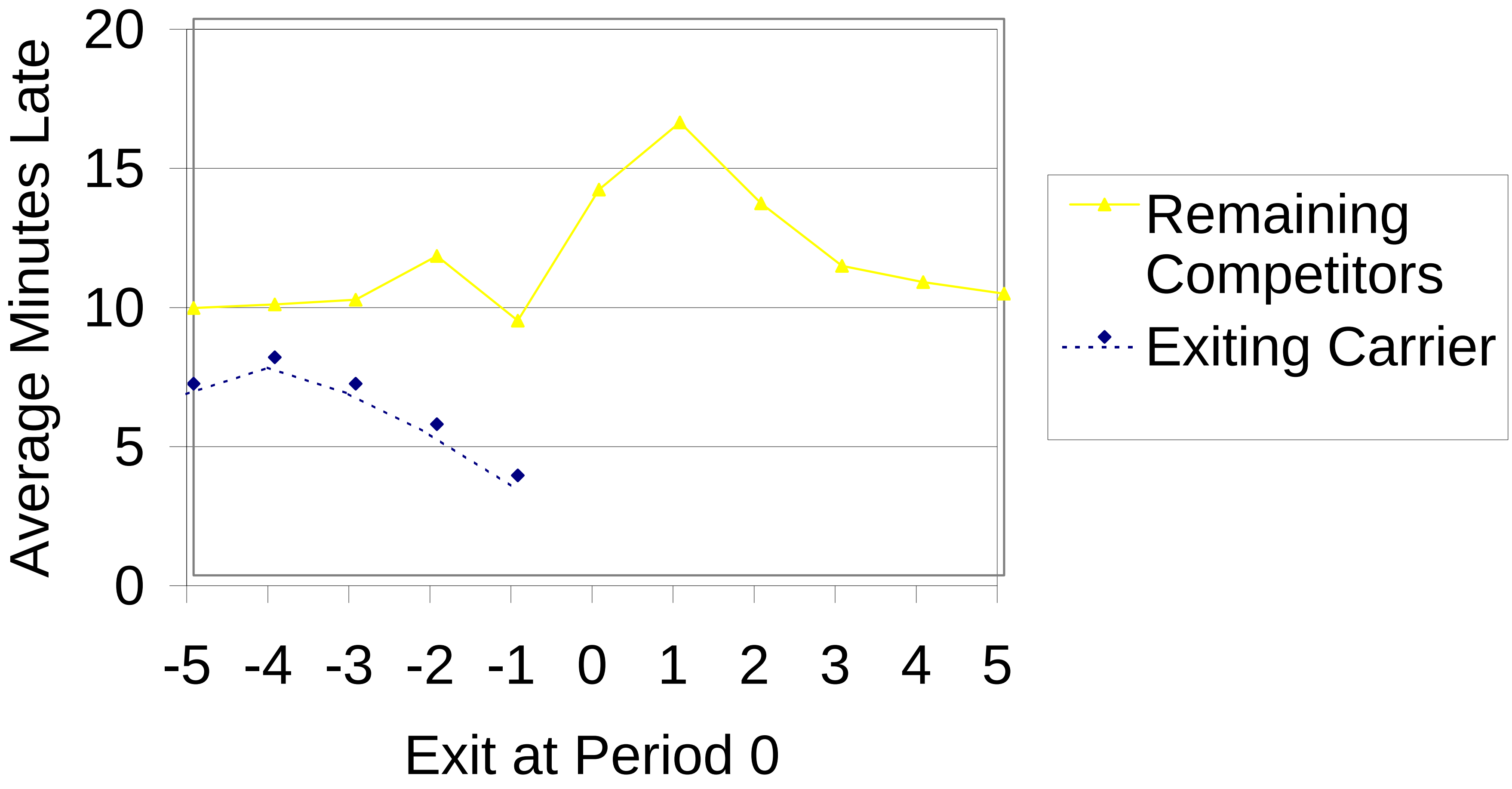


Table I: Descriptive Statistics for the Fifty Nonstop City Pairs from January 1997 to December 2000[1]

Origination	Destination	Average Carriers	Average On-time[1] Percent	Average Minutes Late	1999 Total Passengers	Nonstop Distance
Las Vegas (LAS)	Los Angeles (LAX)	5.27	76.3%	9.04	1,936,920	236
Los Angeles (LAX)	New York City (JFK)	5.00	75.6%	4.26	1,831,860	2,475
Boston (BOS)	New York City (LGA)	1.22	82.1%	3.91	1,733,620	185
Los Angeles (LAX)	San Francisco (SFO)	5.11	69.9%	12.68	1,663,860	337
New York City (LGA)	Washington, DC (DCA)	1.22	84.6%	2.72	1,536,980	214
Los Angeles (LAX)	Oakland (OAK)	2.18	76.3%	9.58	1,471,510	337
Los Angeles (LAX)	Phoenix (PHX)	3.63	73.7%	10.79	1,307,010	370
New York City (JFK)	San Francisco (SFO)	5.00	74.4%	5.24	1,289,100	2,586
Honolulu (HNL)	Los Angeles (LAX)	6.00	77.6%	5.59	1,258,300	2,556
Newark (EWR)	Orlando (MCO)	2.00	73.7%	11.18	1,220,190	938
Dallas-Love (DAL)	Houston-Hobby (HOU)	1.00	81.3%	8.35	1,215,620	239
Atlanta (ATL)	New York City (LGA)	2.00	70.8%	15.07	1,182,510	761
Chicago (ORD)	New York City (LGA)	2.00	72.7%	14.99	1,157,540	733
Los Angeles (LAX)	San Jose (SJC)	2.43	74.7%	11.24	1,147,780	308
Los Angeles (LAX)	Newark (EWR)	3.00	74.1%	13.21	1,145,320	2,454
Atlanta (ATL)	Chicago (ORD)	3.00	73.1%	14.81	1,098,510	606
Los Angeles (LAX)	Seattle (SEA)	3.30	73.0%	10.95	1,094,410	954
Atlanta (ATL)	Newark (EWR)	2.00	73.5%	15.70	1,051,060	745
San Diego (SAN)	San Francisco (SFO)	1.96	72.9%	16.39	1,049,380	447
Las Vegas (LAS)	Phoenix (PHX)	2.60	74.4%	11.79	1,043,180	256
Atlanta (ATL)	Dallas (DFW)	2.00	76.9%	11.45	1,014,630	732
Fort Lauderdale (FLL)	Newark (EWR)	3.07	70.6%	18.66	1,013,110	1,065
Chicago (ORD)	Los Angeles (LAX)	2.00	76.5%	11.85	1,002,550	1,745
Fort Lauderdale (FLL)	New York City (LGA)	3.18	68.2%	17.77	962,410	1,076
Chicago (ORD)	Newark (EWR)	3.00	74.5%	15.97	952,080	719
Atlanta (ATL)	Washington, DC (IAD)	3.38	73.3%	13.46	939,260	533
Newark (EWR)	Las Vegas (LAS)	2.00	72.9%	13.94	938,730	2,565
San Jose (SJC)	Santa Ana (SNA)	1.66	83.6%	6.43	899,900	342
Boston (BOS)	Washington, DC (IAD)	1.94	78.6%	11.94	879,150	413
San Francisco (SFO)	Seattle (SEA)	2.00	67.9%	17.26	860,500	678
Birmingham (BHM)	Tampa Bay (TPA)	1.00	80.5%	9.11	108,160	460
Albuquerque (ABQ)	Atlanta (ATL)	1.00	75.5%	7.20	76,610	1,269
Miami (MIA)	Seattle (SEA)	1.00	83.5%	0.36	99,710	2,724
Dallas (DFW)	Tucson (TUS)	2.00	82.6%	5.34	98,850	813
Denver (DEN)	Tucson (TUS)	1.00	78.8%	9.83	96,490	639
Albany (ALB)	Atlanta (ATL)	1.00	69.9%	12.35	93,310	852
Louisville (SDF)	St. Louis (STL)	2.00	81.7%	7.72	92,520	254
Alberquere (ABQ)	Houston (IAH)	1.00	86.8%	3.53	90,160	744
Nashville (BNA)	Washington, DC (DCA)	1.00	78.8%	6.61	89,450	562
Colorado Springs (COS)	Phoenix (PHX)	1.00	72.7%	11.64	83,590	551
Cincinnati (CVG)	Pittsburg (PIT)	1.29	81.0%	2.77	49,550	256
Eagle, CO (EGE)	San Francisco (SFO)	1.00	69.9%	15.94	20,440	847
Grand Forks, ND (GFK)	Minneapolis (MSP)	1.00	81.1%	3.85	18,810	284
Cincinnati (CVG)	Syracuse (SYR)	1.00	81.3%	3.97	17,490	527
Albuquerque (ABQ)	St. Louis (STL)	2.00	78.7%	7.53	61,500	934
Memphis (MEM)	Oklahoma City (OKC)	1.00	89.7%	3.05	17,380	432
Billings, MT (BIL)	Salt Lake City (SLC)	1.00	81.5%	6.29	16,900	387
Cincinnati (CVG)	Tucson (TUS)	1.00	77.9%	6.05	16,660	1,548
Phoenix (PHX)	Tucson (TUS)	3.00	78.8%	8.25	16,320	110
Pasco, WA (PSC)	Salt Lake City (SLC)	1.00	85.8%	4.08	14,710	521
Average		2.86	75.7%	10.18	741,512	846

[1] On-time average is the percentage of monthly flights that arrived at the gate no more than 15 minutes after the scheduled arrival time.

Table II: On-time Performance Statistics for the Major Carriers[1] on 100 Domestic Nonstop Routes, January 1997 to Decemeber 2000.

Average Monthly Delay per Carrier by Route	Considered On Time?	Observations	Average Minutes Late	Standard Deviation (minutes)
15+ minutes early	Yes	38	-20.23	6.31
0 to 15 minutes early	Yes	926	-4.13	3.59
0 to 15 minutes late	Yes	6,212	8.06	3.90
15 to 30 minutes late	No	2,105	19.98	3.91
30+ minutes late	No	270	35.79	6.07
Total	75.7%	9,545	10.18	9.05

Carriers per route	Average On-time[2] Percent	Observations	Average Minutes Late	Standard Deviation (minutes)
1 Carrier	80.3%	1,880	6.38	7.88
2 Carriers	75.6%	2,918	11.77	7.55
3 Carriers	73.0%	2,168	13.70	7.84
4 Carriers	74.5%	620	11.48	7.71
5 Carriers	73.7%	1,136	7.09	10.14
6 Carriers	76.6%	823	7.25	12.65
Performance by Season				
Spring	76.8%	2,371	9.68	8.27
Summer	73.9%	2,380	12.49	9.87
Fall	78.3%	2,406	7.92	8.23
Winter	73.9%	2,388	10.66	9.11
Scheduled Flights per Carrier per route				
1 - 2 Daily Flights	78.0%	1,872	7.29	11.68
3 - 4 Daily Flights	76.7%	1,892	8.80	9.06
5 - 6 Daily Flights	76.4%	1,260	10.31	8.59
7 - 8 Daily Flights	74.6%	1,089	11.02	8.10
9 - 11 Daily Flights	72.9%	1,017	12.71	7.68
12 - 15 Daily Flights	74.9%	1,186	12.55	7.01
16+ Daily Flights	74.3%	1,270	11.47	6.63
Performance by Year				
1997	77.4%	2,350	8.77	7.36
1998	77.6%	2,322	9.13	9.32
1999	76.2%	2,393	9.81	8.84
2000	71.9%	2,480	12.87	9.85

[1] Major carriers include all U.S. carriers with at least one percent of total domestic scheduled-service passengers revenue.

[2] On-time average is the percentage of monthly flights that arrived at the gate no more than 15 minutes after the scheduled arrival time.

Table III: Models (1) & (2) Replicate Foreman and Shea's Percentage of Ontime Flights for 100 Domestic Nonstop Routes, January 1997 to December 2000.

Model	(1)	(2)	(3)
Method	OLS	Within	WLS
Constant	32.60***	–	33.46***
	(1.251)		(1.342)
Carriers	-2.996***	-1.744	-2.973***
	(0.340)	(1.075)	(0.366)
Carriers Squared	0.405***	0.165	0.360***
	(0.049)	(0.135)	(0.052)
Scheduled Flights	-0.003***	-0.005***	-0.003***
	(0.001)	(0.001)	(0.001)
Winter	-2.951***	–	-2.297***
	(0.308)		(0.281)
Spring	-1.031***	–	-0.551**
	(0.303)		(0.276)
Summer	-2.680***	–	-2.324***
	(0.306)		(0.277)
Percent On-time$_{t-1}$	0.543***	0.447***	0.523***
	(0.010)	(0.011)	(0.010)
Percent On-time$_{t-12}$	0.109***	0.007	0.125***
	(0.011)	(0.008)	(0.011)
Low-Fare Carrier	–	–	-0.585**
			(0.255)
Entry	–	–	-0.701*
			(0.423)
Exit	–	–	0.654
			(0.490)
Destination Hub	–	–	-0.096
			(0.242)
Origination Hub	–	–	-0.552
			(0.237)
Capacity	–	–	-0.212***
			(0.052)
Distance	–	–	0.0001
			(0.002)
Carrier-Specific Effects?	No	Yes	No
Month-Specific Effects?	No	Yes	No
Route-Specific Effects?	No	Yes	No
Observations	6,924	6,924	6,924
Adjusted R^2	0.406	0.208	0.425

Note: *** significant at 1%; ** significant at 5%; * significant at 10%. Standard errors are in parentheses.

The within transformation wipes out the time invariant variables: winter, spring, and summer.

The weighted least squares estimate (WLS) uses the number of monthly scheduled flights as its weight.

Table IV: Three-way Error Component Fixed Effects Model of the Percentage of Ontime Flights for 100 Domestic Nonstop Routes, January 1997 to December 2000.

Model	(4)	(5)	(6)	(4a)	(5a)	(6a)
Carriers	-5.302***	–	–	-2.561***	–	–
	(0.925)			(0.832)		
Carriers Squared	0.608***	–	–	0.319***	–	–
	(0.112)			(0.101)		
Effective Competitors	–	-5.839***	–	–	-3.351***	–
		(1.316)			(1.177)	
Effective Comp. Sqd.	–	1.058***			0.719***	
		(0.271)			(0.241)	
Market Share	–	–	5.822***	–	–	2.875***
			(0.961)			(0.865)
Percent Ontime$_{t-1}$	–	–	–	0.460***	0.461***	0.460***
				(0.009)	(0.009)	(0.009)
Entry	0.110	0.065	0.036	-0.436	-0.421	-0.352
	(0.564)	(0.539)	(0.526)	(0.501)	(0.477)	(0.467)
Exit	2.055***	1.942***	1.826***	0.951	0.902	0.772
	(0.608)	(0.601)	(0.596)	(0.540)	(0.533)	(0.529)
Scheduled Flights	-0.005***	-0.005***	-0.011***	-0.003***	-0.003***	-0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Destination Hub	0.341	0.336	0.140	-0.173	0.173	0.069
	(0.393)	(0.393)	(0.394)	(0.351)	(0.351)	(0.352)
Origination Hub	-2.249***	-2.255***	-2.464***	-1.173***	-1.172***	-1.285***
	(0.393)	(0.394)	(0.395)	(0.352)	(0.352)	(0.354)
Observations	9,545	9,545	9,545	9,338	9,338	9,338
Adjusted R^2	0.02	0.02	0.02	0.23	0.23	0.23

Note: *** significant at 1%; ** significant at 5%; * significant at 10%. Standard errors are in parentheses.

Table V: Scheduled Flight Turnaround Times[1] (as of November 11, 1999) for Two Sample City-Pairs[2].

Carrier	n	Origination	Destination	Average Turnaround Time at Destination (in minutes)	Additional Time Scheduled at Hub (in minutes)
America West	11	Los Angeles (LAX)	Phoenix* (PHX)	57.64	17.21
Southwest	17	Los Angeles (LAX)	Phoenix* (PHX)	26.18	--[3]
United	6	Los Angeles (LAX)	Phoenix (PHX)	26.17	--
America West	14	Phoenix (PHX)	Los Angeles (LAX)	40.43	--
Southwest	19	Phoenix (PHX)	Los Angeles* (LAX)	29.21	--
United	7	Phoenix (PHX)	Los Angeles* (LAX)	30.43	4.26
American	4	Chicago (ORD)	Atlanta (ATL)	45.25	--
Delta	12	Chicago (ORD)	Atlanta* (ATL)	72.58	9.58
United	5	Chicago (ORD)	Atlanta (ATL)	46.20	--
American	5	Atlanta (ATL)	Chicago* (ORD)	57.60	12.35
Delta	13	Atlanta (ATL)	Chicago (ORD)	63.00	--
United	7	Atlanta (ATL)	Chicago* (ORD)	64.29	18.09

*Denotes destination is a hub.

[1] Turnaround time is the number of minutes before the plane's next scheduled (same-day) departure.

[2] Turnaround time data are obtained from http://www.bts.gov/ntda/oai/DetailedStatistics/ accessed December 8, 2001.

[3] Since Southwest has hubs at both LAX and PHX, the additional hub time is not calculated.

Table VI: Three-way Error Component Fixed Effects Model for the Average Minutes Late for 100 Domestic Nonstop Routes, January 1997 to December 2000.

Model	(7)	(8)	(9)	(7a)	(8a)	(9a)
Carriers	2.707***	–	–	1.322**	–	–
	(0.697)			(0.632)		
Carriers Squared	-0.315***	–	–	-0.158**	–	–
	(0.085)			(0.077)		
Effective Competitors	–	2.847***	–	–	1.468	–
		(0.991)			(0.895)	
Effective Comp. Sqd.	–	-0.530***			-0.321*	
		(0.204)			(0.184)	
Market Share	–	–	-2.633***	–	–	-1.343**
			(0.724)			(0.656)
Minutes Late$_{t-1}$	–	–	–	0.444***	0.444***	0.443***
				(0.009)	(0.009)	(0.009)
Entry	-0.045	-0.020	-0.007	0.397	0.436	0.394
	(0.425)	(0.406)	(0.396)	(0.379)	(0.362)	(0.353)
Exit	-0.507	-0.443	-0.377	-0.206	-0.192	-0.131
	(0.458)	(0.406)	(0.449)	(0.408)	(0.403)	(0.400)
Scheduled Flights	0.002**	0.002**	0.004***	0.001	0.001	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Destination Hub	-0.731**	-0.729**	-0.640**	-0.393	-0.396	-0.347
	(0.296)	(0.296)	(0.297)	(0.266)	(0.266)	(0.267)
Origination Hub	0.186	0.188	0.283	0.061	0.059	0.111
	(0.296)	(0.297)	(0.298)	(0.266)	(0.266)	(0.268)
Observations	9,545	9,545	9,545	9,317	9,317	9,317
Adjusted R^2	0.00	0.00	0.00	0.20	0.20	0.20

Note: *** significant at 1%; ** significant at 5%; * significant at 10%. Standard errors are in parentheses.

Appendix Table I: Hub Listing*

Airline	Hub Location
Alaska	Anchorage (ANC)
Alaska	Portland, OR (PDX)
Alaska	Seattle (SEA)
America West	Columbus, OH (CMH)
America West	Las Vegas (LAS)
America West	Phoenix (PHX)
American	Chicago (ORD)
American	Dallas (DFW)
American	Los Angeles (LAX)
American	Miami (MIA)
American	New York City (JFK)
American	San Francisco (SFO)
Continental	Cleveland (CLE)
Continental	Houston (IAH)
Continental	Newark (EWR)
Delta	Atlanta (ATL)
Delta	Cincinnati (CVG)
Delta	Dallas (DFW)
Delta	Salt Lake City (SLC)
Northwest	Detroit (DTW)
Northwest	Memphis (MEM)
Northwest	Minneapolis (MSP)
Southwest	Baltimore (BWI)
Southwest	Chicago-Midway (MDW)
Southwest	Dallas-Love (DAL)
Southwest	Houston-Hobby (HOU)
Southwest	Las Vegas (LAS)
Southwest	Los Angeles (LAX)
Southwest	Oakland (OAK)
Southwest	Phoenix (PHX)
TWA	Los Angeles (LAX)
TWA	New York City (JFK)
TWA	St. Louis (STL)
United	Chicago (ORD)
United	Denver (DEN)
United	Los Angeles (LAX)
United	San Francisco (SFO)
United	Washington, DC (DCA)
US Airways	Baltimore (BWI)
US Airways	Charlotte (CLT)
US Airways	Philadelphia (PHL)
US Airways	Pittsburg (PIT)

*Hub information was obtained from corporate profile information posted on each companies' web site. For Southwest, we define a hub as any city with more than 100 daily departures.

Appendix Table II: WLS Estimates of Ontime Performance for 100 Domestic Nonstop Routes, January 1997 to December 2000

Model Dependent Variable	(10) Percent Ontime	(10a) Percent Ontime	(11) Minutes Late	(11a) Minutes Late
Constant	87.03***	48.94***	1.695	-1.092***
	(2.941)	(2.780)	(2.120)	(1.961)
Carriers	-2.540***	-1.074	0.652	0.349
	(0.731)	(0.663)	(0.527)	(0.489)
Carriers Squared	0.286***	0.135*	-0.013	-0.008
	(0.087)	(0.079)	(0.063)	(0.058)
Low-Fare Carrier	-2.461	-6.057**	5.121**	6.892***
	(3.449)	(2.939)	(2.487)	(2.160)
Percent Ontime$_{t-1}$	–	0.447***	–	0.405***
		(0.009)		(0.010)
Entry	-0.540	-1.017***	-0.392	0.198
	(0.433)	(0.389)	(0.312)	(0.286)
Exit	1.592***	0.581	-0.304	-0.082
	(0.505)	(0.453)	(0.364)	(0.333)
Scheduled Flights	-0.003***	-0.001*	0.001**	0.001
	(0.001)	(0.001)	(0.0006)	(0.001)
Winter	-3.067***	-7.969***	1.564***	0.091
	(0.830)	(0.745)	(0.598)	(0.546)
Spring	0.199	-0.586	0.244	1.471***
	(0.812)	(0.730)	(0.585)	(0.534)
Summer	-4.176***	-7.372***	2.875***	7.207***
	(0.809)	(0.727)	(0.583)	(0.534)
Destination Hub	-0.375	-0.220	-0.342	-0.179
	(0.351)	(0.317)	(0.253)	(0.234)
Origination Hub	-2.989***	-1.642***	0.479*	0.274
	(0.352)	(0.319)	(0.253)	(0.234)
Capacity	-1.300***	-0.840***	1.749***	1.133***
	(0.300)	(0.272)	(0.216)	(0.200)
Distance	0.001	0.001	-0.004***	-0.002*
	(0.002)	(0.001)	(0.001)	(0.001)
Observations	9,545	9,338	9,545	9,317
Adjusted R^2	0.426	0.538	0.454	0.545

Note: *** significant at 1%; ** significant at 5%; * significant at 10%. Standard errors are in parentheses.

All models contain carrier, monthly, and route dummies.

Appendix Table III: Three-way Error Component Fixed Effects Model for Ontime Performance on 100 Domestic Nonstop Routes, January 1997 to December 2000.

Model	(12)	(13)
Dependent variable	Percent Ontime	Minutes Late
Monopoly	7.546***	-3.688***
	(1.754)	(1.324)
Duopoly	3.358**	-2.744***
	(1.512)	(1.142)
Three Carriers	-1.317	0.071
	(1.188)	(0.897)
Four Carriers	1.111	-0.402
	(0.944)	(0.713)
Five Carriers	-1.930**	0.470
	(0.798)	(0.602)
Entry	0.431	-0.228
	(0.562)	(0.424)
Exit	2.967***	-0.757
	(0.627)	(0.474)
Scheduled Flights	-0.006***	0.002**
	(0.001)	(0.001)
Destination Hub	0.495	-0.752**
	(0.393)	(0.297)
Origination Hub	-2.093***	0.164
	(0.394)	(0.297)
Observations	9,545	9,545
Adjusted R^2	0.02	0.00

Note: *** significant at 1%; ** significant at 5%; * significant at 10%. Standard errors are in parentheses.