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Has market concentration fostered on-time performance? A case study of seventy-two U.S. airports

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ABSTRACT

The study compares a multivariate with a quantile regression model to determine whether utilized airport capacity, departure and airborne delays, departure and arrival demand, and market structure explained variations in on-time gate arrivals and arrival delays. In both models, airport departure delays, arrival and departure demand explained variations in the two response variables in prioritized and non-prioritized metroplexes, holding other variables constant. After 2008, the consolidation of the airline industry through mergers coincided with the implementation of NextGen programs, which may have contributed to improvements in on-time performance, especially at prioritized metroplexes where airspace was redesigned.

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1. Introduction

This paper evaluates whether the consolidation of the airline industry and the implementation of NextGen[1] programs after the 2008 recession had a significant impact on two on-time performance metrics (i.e., the percent of on-time gate arrivals and gate arrival delays). This study focused on prioritized versus non-prioritized metroplexes rather than hubs versus non-hubs. Prioritized and non-prioritized metroplexes include a mixture of hub and non-hub airports. As the Federal Aviation Administration (FAA) started to deploy NextGen programs and redesign some airspaces after the 2008 recession, this analysis assumed that selected operational factors, market structure, and airline industry consolidation would have had a more significant effect on on-time performance at prioritized metroplexes where airspace was redesigned. The timeline of airline consolidation is included in Fig. 1 of the appendix.

This study is of interest to aviation analysts because it presents a methodology to assess the influence of both operational factors (the percentage of airport capacity utilized, airport departure and airborne delays, departure and arrival demand) and market structure (Herfindahl-Hirschman index) on two on-time performance metrics. It also contrasts prioritized with non-prioritized metroplexes to evaluate the impact of NextGen programs. On the one hand, a multivariate regression model served to determine whether the effects of the selected independent variables on each on-time performance metrics were robust overall. On the other hand, a quantile regression was used to measure differences in the impact of the selected independent variables at the first, second, and third quantiles of the response variables. A key advantage of quantile regression is that estimates are more robust to outliers than those of an ordinary least squares model.

As part of NextGen, the FAA and the aviation industry agreed to prioritize twelve metroplexes that would yield benefits by 2025. A metroplex represents an airspace where larger commercial and smaller general aviation airports operate in close proximity. The seventy-two sampled airports and their status are listed in Table 3 of the appendix. NextGen programs are designed to improve access of general aviation aircraft into smaller secondary airports, to increase capacity utilization at larger congested airports, and to reduce delays through more direct routing through performance-based navigation. As a portfolio of programs rather than a single program, NextGen supports the transition from the present radar-based, air-traffic-controlled to a satellite-based, air-traffic-managed navigation system in which aircraft can provide position, heading, and airspeed information automatically to controllers and surrounding aircraft. NextGen's satellite-based technologies enable more accurate position information, allowing for closer spacing of

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[1] NextGen is the abbreviation of the Next Generation Air Transportation System.

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aircraft and computer-generated rerouting. This, in turn, is likely to reduce airborne delays, improve traffic flows, and reduce the workload of air traffic controllers who can communicate flight instructions through aircraft's flight management systems (Data Communication).

2. Literature review

In this analysis, actual gate arrival times were compared with the last flight plan filed prior to takeoff instead of published schedules (Rupp et al., 2006) or excess travel time (Mayer and Sinai, 2003). Comparing actual with arrival times filed in flight plans is more likely to reflect airlines' anticipation of actual surface and enroute conditions before leaving the airport. Moreover, flight plans may indicate how airlines are internalizing delays due to poor weather conditions, enroute and airport congestion, as well as traffic management initiatives (TMI) when they estimate flight routing and duration.

Several studies determined that airline schedules were more likely to be padded in order to anticipate airborne and surface delays (Skaltsas, 2011; Morisset and Odoni, 2011; Wu, 2010, 2005; Mayer and Sinai, 2003). Mazzeo (2003) reported that monopoly routes had longer scheduled flight times. Most of the studies that focused on the effect of competition on on-time performance analyzed route-level data for selected months. This study uses yearly data, which are more suited for overall program evaluation and forecast. It does account for the status of airports as hubs as the focus is prioritized versus non-prioritized metroplexes.

On-time performance is one of the key airlines' strategic objectives because it serves to maintain passenger satisfaction and loyalty, and it often represents an effective marketing tool to differentiate one airline from its competitors. Suzuki (2000) argued that on-time performance affected a carrier's market share primarily through the passengers' experience. Airline performance is usually compared with published schedules in government surveys (i.e., the monthly Airline Service Quality Performance report released by the Bureau of Transportation Statistics). On-time performance also supports predictability, which is another concern of airlines because schedule disruptions can be very costly. In a recent study, J.D. Power claimed that "the airline industry is evolving from merely providing transportation to being a hospitality and services business, and the carriers most focused on providing a pleasant experience are being rewarded with higher customer satisfaction and loyalty."[2] It explained that "when the airline provides good service, passengers are generally less critical when there is a departure delay or a late arrival." However, "complaints also increased, and on-time performance declined, when Delta Air Lines (DAL) and Northwest Airlines (NWA) combined during 2009 and 2010," according to CNN Money.[3] The J.D. Power 2015 North America Airline Satisfaction Study included costs and fees, in-flight services, boarding/deplaning/baggage, flight crew, aircraft, check-in, and reservation, but not the percent of on-time gate arrivals and gate arrival delays.

A PricewaterhouseCoopers (PwC) report (2014:4) maintained that "US carriers have measurably improved operating performance over the past five years. These improvements may be attributed in part to the impact of consolidation: As airlines have merged, carriers have removed capacity from the system and increased overall efficiency in their operations." The PwC study concluded that "passengers on average are enjoying increased reliability when flying domestically." Factors such as gate departure and arrival delays, taxi-in and out times at the twenty busiest airports were used to measure on-time performance. In this analysis, airport departure delays measure airport congestion, while airborne delays account for aircraft utilization, flight time predictability, and, to some extent, passenger experience.

The Office of the Inspector General found that market concentration is likely to reduce on-time gate arrivals.[4] Yet, market structure should not be isolated from operational factors. Airports face different constraints (operational factors) and airlines' network strategies (point-to-point versus hubbing). Mayer and Sinai (2003) argued that the relationship between on-time performance and market structure was likely to depend on the hubbing activity of an airport. Using data on all domestic flights by major U.S. carriers from 1988 to 2000, Mayer and Sinai examined network benefits related to hubbing and congestion externalities as two factors that may explain air traffic congestion. In their view, hubbing represented the primary economic contributor to air traffic congestion. It allowed dominant air carriers to add flights without considering their marginal costs on other airlines' increased travel time. The failure of hub carriers to internalize delays further created airport congestion. However, congestion may not only depend on the dominant carrier's hubbing strategy. This study argues that on-time performance also depends on the complexity of the airspace around a large metropolitan area, which makes it difficult for airports to manage demand and capacity.

Mayer and Sinai maintained that, although some of the excess travel time occurred in the air, most of the delays could be attributed to taxi-in and gate arrival delays. This motivated the inclusion of airport departure and airborne delays as two independent variables in the present study. Moreover, hub airports would have more traffic and greater delays than non-hub airports of equivalent size and with equal local demand. However, the implementation of NextGen technologies, procedures, and airspace redesign was assumed to provide an edge to prioritized metroplexes in terms of on-time performance compared with non-prioritized metroplexes.

Based on 2000 data from the Bureau of Transportation Statistics (BTS), Mazzeo (2003) examined whether the lack of competition on particular routes resulted in worse on-time performance. His sample included individual flights between fifty major airports during three months in 2000. He found that the prevalence and duration of flight delays were significantly higher on routes where only one airline provided direct service. He argued that additional competition was correlated with better on-time performance. While weather, congestion, and scheduling decisions contributed significantly to explaining flight delays, they were likely to influence the distribution of flight delays, which makes the use of quantile regression more compelling.

Rupp et al. (2006) maintained that flights to and from hubs were more likely to arrive on time and have shorter average delays than non-hubs. They used fixed instead of random effects to estimate on-time performance. All fixed effects were conditional on the particular route selected. The authors suspected that the better performance of non-hub carriers was due to fewer peak-time departures. However, there was no difference in service quality (on-time performance) between hub and non-hub carriers when flights were destined for hub airports. They founded their analysis on the

[2] See J.D. Power and Associates (May 13, 2015). Airlines: A Transportation or Hospitality Business, Press Release, retrieved at http://www.jdpower.com/press-releases/2015-north-america-airline-satisfaction-study#sthash.qGSCI7lF.dpuf.

[3] US Airways-American Airlines to Merge, CNN Money, February 14, 2013, retrieved at http://money.cnn.com/2013/02/14/news/companies/us-airways-american-airlines-merger/index.html.

[4] U.S. Department of Transportation, Office of the Inspector General. "Reduction in competition increases flight delays and cancellations," Report # CR-2014-040, April 23, 2014.

largest one hundred domestic airport-paired routes and fifty randomly selected small and midsize routes. They used four measures of airline competition, i.e. the number of carriers, effective competition, market share, and monopoly route indicator, as well as other factors such as yield, weather, and number of operations at origin and destination airports. The authors found that more competitive routes have better on-time performance. The shorter delays may be attributed to schedule padding, but also to the type of operations at non-hub airports served mostly by point-to-point carriers. Some studies have suggested that delay propagation, as well as congestion in the enroute and surface environments were more likely to affect point-to-point traffic than hubs (Kondo, 2012; AhmadBeygi et al., 2008). Finally, Rupp et al. associated improved on-time performance with better yield because better service quality enabled carriers to retain passengers.

The reviewed analyses occurred before the implementation of NextGen programs in 2008. They also focused on the concept of hub, that is, an airport used as a transfer point to other destinations in a network (hub and spokes). In this paper, individual flights arriving at the seventy-two airports were aggregated by period and by location, and not by route.

3. The variables and data sources

The sample included all domestic and international flights aggregated by year that arrived at seventy-two U.S. airports during the core operations hours of 07:00 to 21:59 (local time). The 715 observations from calendar year 2005–2014 were divided into two samples (before and after the 2008) and two sub-samples (airports in prioritized versus non-prioritized metroplexes). The year 2008 is part of the pre-recession period. The sample contains large, medium, and small hubs as defined in the National Plan for Integrated Airport System (NPIAS).[5]

The variables were selected on the basis of the lowest value of the Akaike Information Criterion (AIC) among different models. Most of the data originated from the Aviation System Performance Metrics (ASPM) data warehouse, unless otherwise indicated.[6]

- ***The Percentage of On-Time Gate Arrivals*** (On-Time Gate Arrivals) is one of the two dependent or response variables. The percentage of on-time gate arrivals refers to the number of flights that arrive at the gate less than 15 min past the estimated time filed in the last flight plan before takeoff. It is expressed as a percent of the total number of domestic and international arrivals that can be matched to their last flight plan before takeoff at their origin airports.
- ***Gate Arrival Delays*** is the second response variable. It is the sum of minutes of gate arrival delays of 1 min or more divided by all arrivals that can be matched to a flight plan before takeoff at their origin airports. Gate arrival delays measure the difference between actual and filed gate-in times, in minutes. The data originate from ARINC[7] (gate-out, gate-in, wheels-on, and wheels-off times or OOOI data) and FAA's Traffic Flow Management System of TFMS (arrival and departure messages).
- ***Herfindahl-Hirschman Index* (HHI)** is a measure of market concentration at arrival airports. The index is computed by squaring the market share of top four air carriers based on the number of scheduled domestic and international arrivals and departures and then summing the resulting numbers. Domestic and international flights arriving at the selected seventy-two airports are part of the index computation. The flights were grouped by seller carrier (i.e., American Airlines) rather than operator carriers (i.e., American Airlines and Envoy as two separate carriers). The HHI varies from close to 0 to 10,000 when a market is controlled by a single firm. The U.S. Department of Justice and the Federal Trade Commission (2010) classify markets in three types:
  - Unconcentrated markets: HHI below 1500.
  - Moderately concentrated markets: HHI between 1500 and 2500.
  - Highly concentrated markets: HHI above 2500.

The sources of schedule data are the Official Airline Guide (OAG) and Innovata[8] retrieved from the ASPM data warehouse.

- ***Airport Departure Delays*** are computed in ASPM as follows:

(Actual wheels-off - gate-out time in the flight plan) + unimpeded taxi-out time. Unimpeded taxi-out times refer to the nominal gate-out-to-wheels-off times. The computation of unimpeded taxi-out times are based on ARINC data and available by season and by carrier for the large air carriers reporting in monthly Airline Service Quality Performance survey.[9] If a flight takes off at 2:45 (actual wheels-off time), departed the gate at 2:20 (gate-out time) and the unimpeded taxi-out time is 20 minutes, then the airport departure delay for that flight would be 45 min.

- ***Arrival Demand*** is estimated for all city pairs whose destination is a sampled airport. Arrival demand starts at the origin airport and it includes the number of aircraft in increments of 15 min between wheels-off time plus estimated time en route. It ends at wheels-on time at the destination airport.
- ***Departure Demand*** is estimated for all city pairs whose origin is one of the sampled airports. The expected departure time (or start of demand) is calculated as the carrier's filed gate departure time plus unimpeded taxi-out time. The end of demand is actual wheels-off time.
- ***Percent Total Capacity Utilized*** is the ratio of actual arrivals plus departures to airport arrival plus departure rates. The arrival and departure rates reflect anticipated operations, weather conditions, traffic management initiatives, and runway configurations at the reporting airport.
- ***Airborne Delays*** are delays incurred in the air, either en route or when holding. Airborne time refers to the period of flight between wheels-off and wheels-on times.
- ***Metroplex*** is a dummy variable coded as ‘1’ if an airport is located in one of the twelve prioritized metroplexes, otherwise ‘0’. For instance, the District of Columbia Metroplex is a prioritized metroplex. It includes large airports such as Washington Dulles International (IAD), Washington Reagan National (DCA), and Baltimore/Washington International Marshall airports (BWI), as well as smaller general aviation airports such as Martin State (MTN) and Frederick Municipal (FDK) airports, among others.
- ***Time Period*** is a dummy variable coded as ‘1’ for the years prior to the 2008 economic recession (2005–2008), otherwise ‘0’ (2009–2014). One of the key impacts of the recession was a

[5] The NPIAS defines the types of airports eligible for funding under the Airport Improvement Program. Large hubs handle 1 percent of the U.S. annual passenger boarding; medium hubs, 0.25 to 1 percent; and small hubs, 0.05 to 0.25 percent.

[6] The website is https://aspm.faa.gov.

[7] The website is http://www.airinc.com.

[8] The websites are respectively http://www.oag.com and http://www.innovata_llc.com.

[9] Large certified carriers hold Certificates of Public Convenience and Necessity issued by the U.S. Department of Transportation authorizing the performance of air transportation with annual operating revenues of $20 million or more.

reduction in air travel demand as per capita disposable income (a key indicator of funds available for leisure travel) declined. Airlines merged to adapt to new market conditions and restore profitability as fuel prices were very volatile. In early 2012, the airline industry went from ten to five carriers through mergers, controlling about 80 percent of the domestic passenger market. The restructuring of the major carriers affected regional affiliates serving mainly secondary airports. As the number of flights declined after the 2008 recession, the average on-time performance at the seventy-two airports increased overall from 77.8 percent (from 2005 to 2008) to 82.3 percent (from 2009 to 2014) based filed flight plans. During the same time period, the average gate arrival delays went down from 11.5 to 9.2 min, according to ASPM.

4. The model specifications and assumptions

4.1. The multivariate multiple regression model

Multivariate regression analysis serves several purposes. First, it allows analysts to determine whether the same set of independent variables may have similar effects on two or more related response variables (on-time arrivals and arrival delays) when analysts cannot control the research setting. Secondly, it ensures that there is some degree of robustness of the findings.

Given m responses $Y_1, Y_2, \ldots, Y_2$ and the same set of r predictors $X_1, X_2, \ldots, X_r$ on each sample unit, each response is part of a different regression model such that

$$Y_1 = \beta_{01} + \beta_{11}X_1 + \ldots + \beta_{r1}X_r + \varepsilon_1 \tag{1}$$

$$Y_2 = \beta_{02} + \beta_{12}X_1 + \ldots + \beta_{r2}X_r + \varepsilon_2 \tag{2}$$

$$Y_p = \beta_{0p} + \beta_{1p}X_1 + \ldots + \beta_{rp}X_r + \varepsilon_p \tag{3}$$

In the model, $\varepsilon = (\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_p)'$ has expectation 0 and variance matrix $\Sigma_{p\times p}$. The errors associated with different responses on the same sample unit may have different variances and may be correlated.

The multivariate multiple regression model can be formulated as

$$Y_{n\times p} = X_{n(r+1)}\beta_{(r+1)p} + \varepsilon_{n\times p} \tag{4}$$

with $E(\varepsilon_{(i)}) = 0$, $Cov(\varepsilon_{(i)}, \varepsilon_{(k)}) = \sigma_{ik}\mathbf{I}$, and $i, k = 1, 2, \ldots, p$. Given n equations and p independent variables (including the intercept), the parameter estimates are derived from the n x p matrix such that

$$\mathbf{B} = (\mathbf{X}'\mathbf{W}\mathbf{X})^{-1}\mathbf{X}'\mathbf{W}\mathbf{Y} \tag{5}$$

where **Y** is an n x p matrix of dependent variables **X** an n x p matrix of independent variables. **W** is a weighting matrix to **I** if no weight is specified. The residual covariance matrix can be defined as

$$\mathbf{R} = \{\mathbf{Y}'\mathbf{W}\mathbf{Y} - \mathbf{B}'(\mathbf{X}'\mathbf{W}\mathbf{X})\mathbf{B}\}/(n - p) \tag{6}$$

The estimated covariance matrix of the estimates is $\mathbf{R} \otimes (\mathbf{X}'\mathbf{W}\mathbf{X})^{-1}$.

4.2. The quantile regression model

As a semi-parametric model, quantile regression does not rely on the normality assumption of the error terms and it is more robust to outliers, heteroskedasticity, and model misspecifications. It reduces the number of models necessary to convey differences by level at different percentiles of the distribution of on-time gate arrivals and gate arrival delays. A key assumption is that quantile regression provides a better predictive relationship between the mean of the response variable and the predictive factors at different percentiles. In other words, the independent variables may not provide accurate information on the relationship between the percentage of on-time gate arrivals and gate arrival delays, and the independent variables since the variance of the residuals may not be homogeneous. For instance, above-average delays at times of adverse weather conditions, airport and airspace congestion, and/or airborne delays are likely to skew the distribution of delays.

Based on Koenker and Bassett (1978) and Koenker (2005), a linear model for the τ^{th} quantile is characterized as

$$Y_i = X_i^T\beta_T + \varepsilon_i \tag{7}$$

where the τ^{th} quantile of ε_i is zero.

Given

$$Q\tau(Y|X) = X^\tau\beta^\tau \tag{8}$$

the estimator of β^τ is

$$\widehat{\beta} = \text{argmin}_{\beta\in R^p}\sum_{i=1}^{n} pT(y_i - x_iT\beta) \tag{9}$$

Therefore, the regression quantile is

$$\widehat{Q}_T(Y|X) = X^\tau \beta^\tau \tag{10}$$

5. The model outcomes

5.1. The multivariate regression model

In Table 1, shaded estimates are not significant at a 95 percent level.

The interpretation of the multivariate regression estimates and statistics is similar to that of a multiple regression model. The coefficients of determination R^2 indicate that all models explained a high proportion of variations in the two response variables. The Breusch-Pagan test of independence determines whether the residuals from two equations, by period and by location, are independent. Since the p-values were less than $\alpha = 0.05$, we conclude that the residuals were not independent at a 95 percent level..

The intercepts were all significant at a 95 percent level. In the post-recession samples, on-time performance improved: The percent of on-time gate arrivals increased, while the average minutes of gate arrival delays decreased, holding other variables constant. Consistency in the on-time performance outcomes—when actual arrivals were compared with flight plan data—suggests that flight time predictability improved at all locations after 2008.

In both samples, airport departure delays and arrival demand had a negative effect on on-time gate arrivals, whereas airport departure delays and arrival demand had a positive impact on gate arrival delays, holding other factors constant. Airport departure delays had the highest negative impact on on-time gate arrivals and the highest positive effect on gate arrival delays, before and after the recession. For instance, at non-prioritized metroplexes, the pre-recession coefficient of −1.2265 represents the mean decline in the percent on-time gate arrivals for 1-min increase in airport departure delays from 07:00 to 21:59 local time, holding other variables constant. The post-recession coefficient was slightly higher (−1.2509). Considering airport location and period, there was not a

Table 1
Estimates of the multivariate regression model.

	After recession				Before recession			
	Non-prioritized metroplex		Prioritized metroplex		Non-prioritized metroplex		Prioritized metroplex	
	On-time arrivals	Arrival delays	On-time arrivals	Arrival delays	On-time arrivals	Arrival delays	On-time arrivals	Arrival delays
Airport departure delays	−1.2265	0.7182	−1.3162	0.7262	−1.2509	0.7211	−1.3343	0.7430
Airborne delays	0.1561	−0.0579	0.4450	−0.1897	0.8781	−0.2525	0.5983	−0.3354
Departure demand	0.0001	−0.0001	0.0001	−0.0001	0.0001	−0.0001	0.0001	0.0000
Arrival demand	−0.0001	0.0001	−0.0001	0.0001	−0.0001	0.0001	0.0000	0.0000
Percent capacity utilized	0.0376	−0.0195	0.0563	−0.0289	−0.0211	0.0020	0.0351	−0.0172
HHI	0.0005	−0.0002	0.0005	−0.0003	0.0002	−0.0001	0.0003	−0.0001
Intercept	90.1910	3.6338	90.4372	3.7608	87.8663	4.2839	88.3887	4.5323
n	295		209		123		88	
R^2	0.8065	0.8759	0.7745	0.8344	0.8771	0.9215	0.7467	0.7660
Breusch-Pagan test of independence: Pr=	0.0000		0.0000		0.0000		0.0000	

Not significant (95 percent).

significant change in the magnitude and sign of the estimates for airport departure delays. The magnitude of the HHI estimate at airports in non-prioritized metroplexes increased, which may be explained by the presence of hubs and focus cities in the non-prioritized metroplex group.

Before the recession, the percent of total airport capacity utilized and the concentration index of airports not located in prioritized metroplexes did not explain variations in the response variables (p-value $> \alpha = 0.05$). The standard deviation of utilized capacity was less than 10 percent at most of the airports in non-prioritized metroplexes, except at Nashville (BNA), Cincinnati (CVG), and Saint Paul/Minneapolis (MSP). As for the HHI, the highest standard deviations were observed at airports where a carrier either increased its service such as Southwest at Islip (ISP) and Milwaukee (MKE) or where the dominant carrier scaled down its scheduled operations such as Delta at CVG.

After the recession, the estimate for airborne delays at non-prioritized metroplex airports was not significant. Airborne delays are likely to increase when air traffic control implements traffic management initiatives (i.e., miles or minutes in trail, airspace flow programs, and rerouting), resorts to vectoring, and holding. According to OPSNET data, the total number of airborne delays in the post-recession sample declined 76.7 percent at non-prioritized metroplexes versus 26.4 percent at prioritized metroplexes.[10] However, during the same period, the number of traffic management initiatives increased 37.7 percent at prioritized metroplex airports compared with 10.8 percent at non-prioritized metroplex airports.

6. The quantile regression model

Table 2 provides the pseudo-R^2 values, the number of observations, and the estimates at the 25th, 50th, and 75th percentiles of the conditional distribution of the percent on-time gate arrivals and gate departure delays in minutes, by period and by location.

The quantile models indicated a better fit in the case of non-prioritized metroplex airports, both before and after the 2008 economic recession. As a measure of goodness of fit, the pseudo R^2 is computed as follows:

$$1 - \frac{\textit{sum of weighted deviations about estimated quantile}}{\textit{sum of weighted deviations about raw quantile}} \qquad (11)$$

As in the case of the multivariate multiple regression, airport departure delays had the strongest negative impact on on-time gate arrivals and the highest negative impact on gate arrival delays at all locations in both samples. However, contrary to the multivariate model, there was no clear pattern in the significance of the independent variables. All the variables were significant only in the case of the 50th percentile for on-time gate arrivals at prioritized metroplexes.

In the pre-recession sample, market structure did not have any significant impact on on-time performance at both prioritized and non-prioritized metroplex airports. However, in the post-recession sample, the impact of HHI on on-time performance was consistent across all quantiles, regardless of the location. Market structure had a negative impact on the percent on-time gate arrivals and a negative impact on the average minutes of gate arrival delays, holding other variables constant. The consolidation of airline networks resulted in a reduction of scheduled operations. This, in turn, led to improvements in on-time performance, especially where airspace was redesigned.

It is also important to note that the estimates for arrival and departure demand were identical at all quantiles for prioritized and non-prioritized metroplex airports. However, airspace redesign, the implementation of precision approaches and departures, time-based flow management, and wake vortex re-categorization may have contributed to improvements in utilized capacity at prioritized metroplex airports, especially at peak times and in poor weather conditions. This implies that the hub carriers may have, not only taken advantage of their dominant position to control on-time gate arrivals and gate departure delays as predicted in the literature review, but they may also have capitalized on latest NextGen technologies to increase operational efficiency. After the implementation of wake recat, "average taxi-out time [at ATL] declined 6 percent from 18.8 min to 17.6 min. Time in the TRACON [Terminal Radar Approach Control [11]facilities] airspace for arrivals decreased 38 s or 4.4 percent," according to the FAA.

7. Final remarks

This paper compared on-time performance before and after the 2008 recession at prioritized and non-prioritized metroplexes. The percent of on-time gate arrivals and gate arrival delays represented the two response variables that characterized on-time performance. The analysis compared the estimates of a multivariate model with those of a quantile model to ensure the robustness of the outcomes. The present analysis focused on metroplexes instead

[10] The URL is https://aspm.faa.gov/opsnet/sys/main.asp.

[11] Federal Aviation Administration, NextGen Performance Snapshots, "NextGen Stirs Up Efficiency in its Wake," retrieved at https://www.faa.gov/nextgen/snapshots/stories/?slide=41.

Table 2
Estimates of quantile regression models.

	After recession				Before recession			
	Non-prioritized metroplex		Prioritized metroplex		Non-prioritized metroplex		Prioritized metroplex	
	On-time arrivals	Arrival delays	On-time arrivals	Arrival delays	On-time arrivals	Arrival delays	On-time arrivals	Arrival delays
n	295		209		123		88	
25th Percentile								
Airport departure delays	-1.3917	0.6213	-1.5087	0.6198	-1.3188	0.6845	-1.2348	0.5532
Airborne delays	-0.0505	-0.1192	0.4630	-0.0561	0.5786	-0.3905	0.8098	-0.3938
Departure demand	0.0001	-0.0001	0.0001	-0.0001	0.0001	-0.0001	0.0001	0.0000
Arrival demand	-0.0001	0.0001	-0.0001	0.0001	-0.0001	0.0000	-0.0001	0.0000
Percent capacity utilized	0.0346	-0.0268	0.0611	-0.0221	-0.0271	0.0063	0.0365	0.0059
HHI	0.0005	-0.0002	0.0005	-0.0003	0.0000	-0.0001	0.0003	0.0000
Intercept	91.2949	3.9942	90.9758	3.8057	88.5115	4.2044	85.8263	5.0241
Pseudo R^2	0.5662	0.5901	0.5486	0.5301	0.6570	0.6711	0.5507	0.3910
50th Percentile								
Airport Departure Delays	-1.1706	0.7476	-1.2035	0.7059	-1.2388	0.7251	-1.1332	0.6433
Airborne Delays	0.2365	-0.1935	0.4999	-0.1531	1.0307	-0.3622	0.8323	-0.3996
Departure Demand	0.0001	-0.0001	0.0001	-0.0001	0.0001	-0.0001	0.0001	0.0000
Arrival Demand	-0.0001	0.0001	-0.0001	0.0001	-0.0001	0.0001	-0.0001	0.0000
Percent Capacity Utilized	0.0107	-0.0040	0.0504	-0.0327	-0.0452	-0.0001	0.0130	-0.0087
HHI	0.0005	-0.0002	0.0005	-0.0003	0.0002	-0.0001	0.0001	-0.0001
Intercept	90.2690	3.3232	90.1798	3.9625	88.0074	4.5886	86.8143	5.3495
Pseudo R^2	0.5174	0.6162	0.4898	0.5564	0.6128	0.6927	0.4777	0.4915
75th Percentile								
Airport Departure Delays	-1.0434	0.7797	-1.1087	0.8057	-1.1673	0.7456	-1.3116	0.6900
Airborne Delays	0.4587	0.0546	0.2129	-0.3275	0.9656	0.0076	0.3961	-0.5075
Departure Demand	0.0001	-0.0001	0.0001	-0.0001	0.0001	-0.0001	0.0001	0.0000
Arrival Demand	-0.0001	0.0001	-0.0001	0.0001	-0.0001	0.0001	0.0000	0.0000
Percent Capacity Utilized	0.0287	-0.0082	0.0568	-0.0293	-0.0198	0.0086	0.0293	-0.0209
HHI	0.0005	-0.0002	0.0006	-0.0002	0.0002	-0.0001	0.0001	-0.0001
Intercept	89.8279	3.1799	90.0961	3.7509	88.6445	3.7392	91.0132	5.9437
Pseudo R^2	0.5192	0.6912	0.4774	0.6107	0.6134	0.7576	0.4375	0.5978

Not significant (95 percent).

of hubs to test the hypothesis that on-time performance depends not only on market power characterized by hubbing, but also on the complexity of the airspace and the use of NextGen technologies to improve on-time performance.

This study is original because it considers the effects of market power and other operational factors on two on-time performance metrics, before and after the 2008 recession when the airline industry consolidated and NextGen programs started to be implemented. Previous studies focused on route analysis and on the behavior of airlines at their hub(s). To measure delays, they relied on excess time flown or schedules instead of the last flight plan before takeoff as in the present study. Improvements in the two on-time performance metrics based on flight plan data reflect airlines' capabilities to better anticipate events that preclude punctuality. This has some important ramifications for airline and airport operations, as well as for passengers. Flight predictability may result in reduced fuel burn, both on the ground and enroute. Secondly, it helps airports cope with arrival and departure demand and manage capacity utilization, especially at peak times and in reduced weather conditions. Finally, improvements in on-time arrivals based on flight plans may lead to greater passenger satisfaction when they arrive earlier at the gate than scheduled.

The implementation of NextGen program coincided with the consolidation of the airline industry. The results of the study indicate that the introduction of NextGen programs and airspace redesign contributed to an improvement in on-time performance, especially at prioritized metroplexes. The FAA started to deploy NextGen technologies after 2008 and to redesign some airspaces at selected locations in order to improve flight efficiency and predictability, airport capacity utilization at congested airports, and access of general aviation into metroplexes.

As predicted in previous studies, the degree of market concentration had significant impacts on-time performance. In the pre-recession sample, the Herfindahl-Hirschman index estimates were not significant at the 25th, 50th, and 75th percentiles for prioritized and non-prioritized metroplex airports because the airline industry included more competitors. After the 2008 recession, higher concentration explained more variations in the two response variables in both the multivariate and quantile models, holding other factors constant.

Aviation analysts and regulators should also consider that improvements in on-time performance were related to airport departure delays and the significance of demand management. Before the recession, air traffic control resorted mainly to traffic management initiatives to manage demand, to improve capacity utilization, and to reduce gate arrival delays. With NextGen, demand management tools such as virtual queues, wake vortex recategorization, and time-based flow management can be best exploited through redesigned approach and departure procedures at metroplexes. As more airspaces are redesigned, pilots and air traffic controllers utilize NextGen procedures, and aircraft are equipped with avionics to take advantage of satellite-based navigation, there may not be a significant difference between the on-time performance of hub and point-to-point carriers. Market power will likely depend to a greater extent on carriers' ability to exploit the benefits of NextGen technologies than mere control of a greater share of an airport's departures and arrivals. As fewer airlines compete, operational predictability, on-time performance, and passenger satisfaction will differentiate airlines' level of service and influence passengers' choice.

Note

This article does not reflect the official opinion of the Federal Aviation Administration.

Appendix

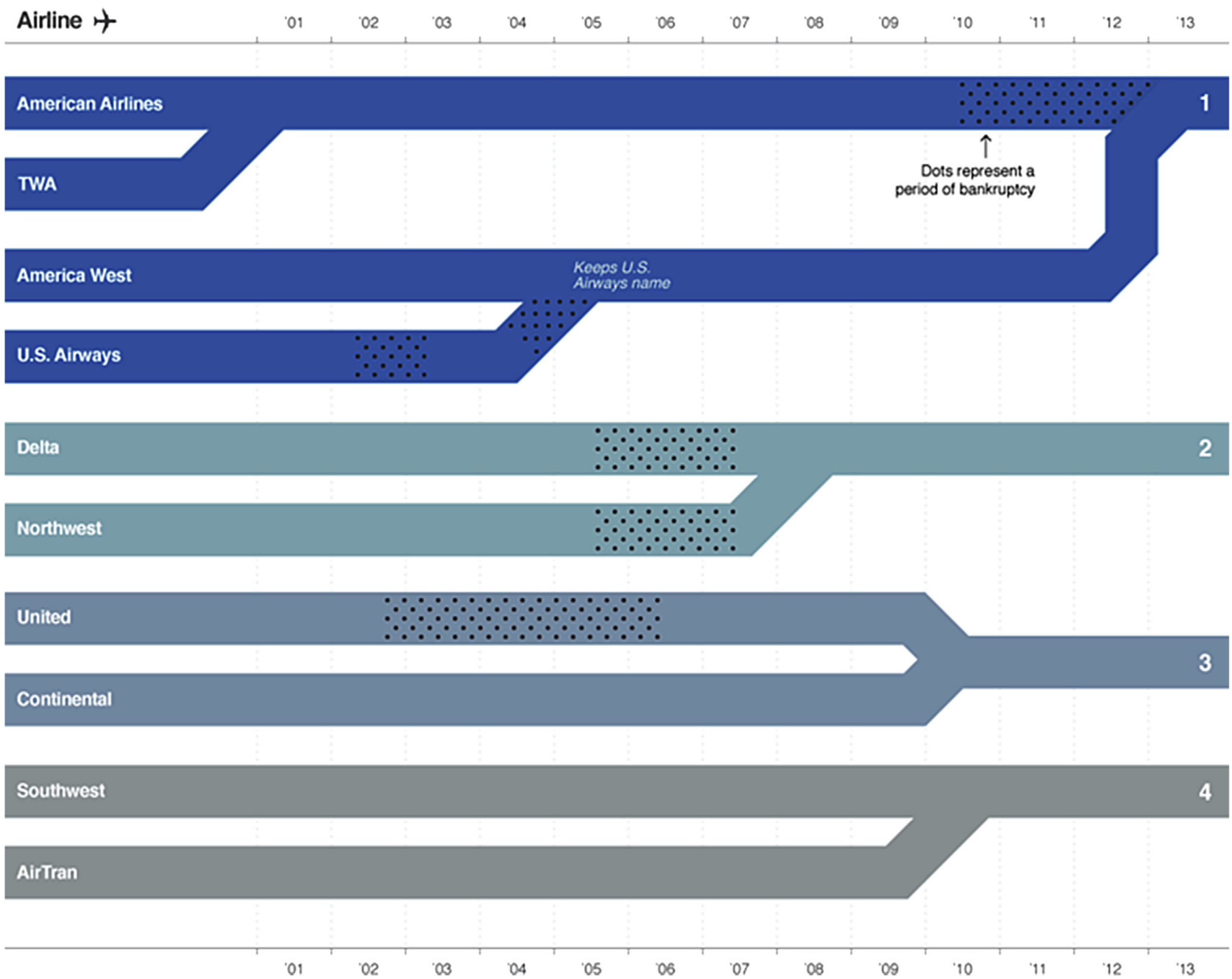

Fig. 1. The Timeline of the U.S. Airline Mergers.
Source, Source: CNN Money (http://money.cnn.com/infographic/news/companies/airline-merger).

Table 3
The Hirschman-Herfindahl Indexes by Sampled Airport.

Airport	Prioritized metroplex	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average before recession	Average after recession
ABQ	N	2101	2152	2276	2683	2748	2707	2804	3003	2868	2844	2303	2829
ANC	N	2073	2076	2046	2019	2234	2281	2311	2407	2422	2045	2054	2283
ATL	Y	5780	5618	5549	5544	5959	6127	6068	5985	6071	6295	5623	6084
AUS	N	1935	1960	1665	1727	1899	1789	1819	2137	2152	2070	1822	1978
BDL	N	1153	1228	1209	1170	1180	1550	1265	1525	1463	1362	1190	1391
BHM	N	2026	1767	1575	1899	1938	2377	2287	2345	2147	2082	1817	2196
BNA	N	2055	2125	2127	2278	2108	2139	2277	2390	2459	2531	2146	2317
BOS	N	1460	1365	1454	1405	1310	1310	1220	1460	1527	1580	1421	1401
BUF	N	1219	1322	1379	1374	1377	1403	1095	1393	1410	1291	1324	1328
BUR	N	3685	3777	3845	4060	4258	4142	4044	4514	4596	4298	3842	4309
BWI	Y	2365	2625	3085	3086	2889	2982	3138	3390	3614	4523	2790	3423
CLE	Y	4407	4758	4952	5203	4700	4650	4753	3761	5423	3747	4830	4506
CLT	Y	7289	7310	7249	7418	7637	7757	8239	7758	7225	8008	7317	7771
CVG	N	8410	7769	7559	7273	7140	6240	5402	4819	4536	4037	7753	5362
DAL	Y	8423	6864	6792	7538	8379	8695	8304	8080	8226	8021	7404	8284
DAY	N	1185	1081	1075	1061	1167	1397	1067	1839	1951	2035	1101	1576
DCA	Y	2489	2565	2691	2739	2639	2853	1805	3172	3144	3096	2621	2785
DEN	Y	3469	3442	3277	3003	2903	2882	2565	2713	2974	3158	3298	2866

(continued on next page)

Table 3 (*continued*)

Airport	Prioritized metroplex	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average before recession	Average after recession
DFW	Y	7012	7156	7226	7383	7464	7479	7356	7214	7106	7072	7194	7282
DTW	Y	6451	6090	5939	6174	6328	6026	6879	6728	6662	6331	6164	6492
EWR	N	4743	5149	5329	5472	5500	5506	5109	3901	5475	5269	5173	5127
FLL	Y	857	771	800	859	933	968	985	905	918	1142	822	975
HNL	N	1432	1373	1377	1559	2119	2255	2281	2393	2243	2514	1435	2301
HOU	Y	7015	7193	7381	7533	7171	7263	7001	7177	7391	7783	7281	7298
HPN	N	1269	1164	1055	984	1277	1462	1285	1597	1811	1745	1118	1530
IAD	Y	3323	4744	4730	5009	5246	5273	5374	5649	5590	5446	4452	5430
IAH	Y	7536	8007	8048	8088	7827	7688	7668	5337	7367	7232	7920	7187
IND	N	1274	1356	1345	1279	1239	1473	1484	1760	1852	1888	1313	1616
ISP	N	4092	5949	6397	6895	7704	7450	7277	6232	5256	5681	5833	6600
JAX	N	1238	1133	1043	1048	1158	1413	1434	1467	1359	1363	1116	1366
JFK	N	1691	1796	2035	1965	2023	2044	2055	1951	1888	1879	1872	1973
LAS	Y	2087	2132	1980	2320	2363	2366	2186	2229	2279	2234	2130	2276
LAX	Y	2047	2076	1866	1790	1824	1800	1703	1825	1833	1761	1945	1791
LGA	N	1989	1992	1976	1942	1894	2064	1691	2278	2692	2639	1975	2210
LGB	Y	4613	4800	4605	4202	4981	4970	4731	5072	4956	5050	4555	4960
MCI	N	1153	1271	1210	1183	1218	1436	1521	1905	2119	2203	1204	1734
MCO	Y	1234	1164	1153	1138	1156	1178	1240	1151	1007	1236	1172	1161
MDW	N	4425	5082	5392	6674	6652	7057	7446	7572	7429	7612	5393	7295
MEM	N	6293	6325	6344	6512	6384	5972	6779	5933	4246	2218	6369	5255
MHT	N	1934	2116	2196	2501	2648	2522	2173	2664	2659	2754	2187	2570
MIA	Y	3717	3846	3975	4331	4760	4988	4987	5210	5266	5222	3967	5072
MKE	N	3365	3851	3994	3192	2277	1631	1591	1434	1684	1913	3601	1755
MSP	N	6498	6178	6174	6348	6084	5712	6507	5890	5557	5777	6300	5921
MSY	N	1458	1232	1127	1270	1372	1533	1709	1865	1949	2042	1272	1745
OAK	Y	3957	4189	4222	5107	5898	5792	5650	5189	5265	5257	4369	5509
OGG	N	1450	1739	1450	1438	1819	1701	1411	1731	2187	2473	1519	1887
OMA	N	1228	1245	1168	1230	1352	1538	1701	1975	2089	2097	1218	1792
ONT	Y	2803	2811	2333	2506	2924	3000	3121	3225	3322	3086	2613	3113
ORD	N	3907	3974	3915	3847	3845	3885	3763	3839	3903	3843	3911	3846
PBI	Y	1422	1421	1353	1301	1142	1323	1314	1392	1455	1441	1374	1345
PDX	N	3066	2999	3058	2872	2374	2323	2438	2574	2729	2897	2999	2556
PHL	N	5050	4950	4977	5082	5243	5587	5709	6124	5903	6460	5015	5838
PHX	N	3438	3275	2542	3403	3411	3488	2384	3560	3391	3511	3165	3291
PIT	N	4551	3721	2868	1644	1277	1344	1011	1661	1636	1729	3196	1443
PSP	Y	2040	2384	2294	2297	2586	2570	2405	2407	2295	2194	2254	2410
PVD	N	1547	1815	1865	2013	2184	2185	1796	2313	2225	2309	1810	2169
RDU	Y	1596	1598	1440	1456	1501	1550	1507	1662	1638	1772	1523	1605
RSW	N	833	630	576	686	684	843	971	993	934	1034	681	910
SAN	Y	1752	1801	1704	1856	2037	2117	2093	2056	1939	1944	1778	2031
SAT	N	1795	1789	1607	1626	1867	1858	1848	2010	2023	2143	1704	1958
SDF	N	1224	1212	1157	1166	1194	1555	1243	1721	1816	1674	1190	1534
SEA	N	3678	3791	3657	3226	3234	3349	3447	3642	3659	3554	3588	3481
SFO	Y	3488	3691	3364	2823	2738	2732	2726	3107	3153	3061	3342	2920
SJC	Y	2354	2370	2399	2585	2833	3123	3249	3289	3006	2915	2427	3069
SJU	N	2497	2557	2849	2477	1943	1944	1621	1400	1208	1318	2595	1572
SLC	N	6513	6090	6095	5825	5971	6343	6066	5885	5959	5594	6131	5970
SMF	N	2912	2803	2468	2667	3087	2979	2806	2830	2968	2942	2713	2935
SNA	Y	1203	1308	1345	1436	1555	1758	1845	2033	2101	2205	1323	1916
STL	N	3684	3531	3009	2597	2206	1807	1833	1999	2065	2074	3205	1997
SWF	N	1997	3411	1750	1959	2010	3387	2993	3470	3321	3322	2279	3084
TPA	Y	1313	1329	1457	1516	1467	1603	1617	1512	1264	1471	1404	1489
TUS	N	1308	1454	1047	1228	1516	1597	1686	2003	1946	1881	1259	1772

Source: OAG, Innovata.

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