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Scarcity, Market Power, and Prices at Slot-constrained Airports

Evidence from Mexico City

Almudena Arcelus, Ryan Booth, Aaron M. Fix, Jee-Yeon K. Lehmann, Federico G. Mantovanelli, and Robert S. Pindyck

Address for correspondence: Aaron M. Fix, Analysis Group, 111 Huntington Avenue, 14th Floor, Boston, MA, 02199, USA (aaron.fix@analysisgroup.com).

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Abstract

Many of the world's major airports are both slot-constrained, meaning that demand for take-offs and landings exceeds airport capacity at certain time periods, and concentrated, meaning that a single airline operates a large share of take-offs and landings. Slot constraints and slot concentration can each lead to higher average fares, but for different reasons that may require different policy prescriptions. In this article, we demonstrate how policy makers can differentiate between the effects of scarcity and concentration on prices, and we apply our methodology to a recent investigation into the allocation of take-off and landing slots at Mexico City's airport.

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1.0 Introduction

Many of the world's major airports are highly congested, with the numbers of take-offs and landings approaching capacity. At some of these airports, take-off and landing slots — authorisations either to take off or to land at a specific time during the day — are used to limit and to coordinate scheduled air traffic. Time periods during which the demand for take-offs and landings exceeds the number of available slots are referred to as 'saturated', and airports with saturated time periods are referred to as 'slot-constrained'. Many slot-constrained airports also exhibit 'slot concentration', meaning that a single airline operates a significant share of slots. For example, Franz Josef Strauss International Airport in Munich (Lufthansa), Charles de Gaulle International Airport in Paris (Air France), and Liberty International Airport in Newark (United Airlines) are all highly congested airports, with a single carrier consistently operating 50 per cent or more of all take-offs and landings.[1]

The effects of slot constraints and slot concentration at congested airports — particularly their potential effects on ticket prices — are of interest to policy makers and airport administrators responsible for allocating slots. Broadly speaking, there are two potential price effects of slot allocation at a slot-constrained airport. First, the impact of the slot *constraint* on ticket prices is theoretically unambiguous: all else being equal, average fares to and from that airport are expected to be higher than they would be in the absence of such a restriction on the supply of flights. Below, we refer to this effect as a *scarcity effect* on price, which is expected to be positive. Second, the impact of slot *concentration* on price is theoretically ambiguous. While a high concentration of take-off and landing slots could allow a dominant airline to exercise market power that can result in higher-than-competitive fares (a market power effect), slot concentration may also facilitate the operation of an airline's hub-and-spoke route network (a network effect), which may reduce cost and lower fares. As a result, what we refer to as a *concentration effect* on price can be positive or negative, depending on the relative magnitudes of the potential market power and network effects.

Another potential effect of concentration is that by facilitating the efficient operation of a hub-and-spoke network, slot concentration may also allow the hub airline to improve the quality of service. This improved quality of service could, at least theoretically, lead to higher fares due to consumers' increased willingness-to-pay. These higher fares, however, would not be the result of an exercise of market power on the part of the dominant airline. If so, the model that we present will tend to overestimate the market power effect of slot concentration.

If the primary goal of a policy is to minimise the effects of congestion on ticket prices, it is important to disentangle scarcity effects from market power effects. This is because the preferred policy prescription for high prices at congested airports will depend on the source of those high prices. For example, a reallocation of slots across carriers may reduce average ticket prices if slot concentration is facilitating the exercise of market power by a dominant carrier, but that same reallocation is unlikely to reduce ticket

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[1] These figures include feeder flights operated by regional affiliates, such as 'United Express' flights operated by Republic Airlines to and from United's hub in Newark. See Starkie (2008).

prices if those higher prices are caused by slot scarcity. In fact, such a reallocation could lead to *higher* prices if the reallocation reduces the efficiency of a hub carrier's network operations, or if the reallocation makes individual carriers less likely to internalise negative congestion externalities caused by their individual demands to operate flights. Such a reallocation could also reduce the hub carrier's service quality if it impedes the operation of the hub-and-spoke network. A better policy prescription might be to expand airport capacity, which could potentially counter the price pressures from slot scarcity as well as from slot concentration, depending on how additional capacity is allocated.

When evaluating policy options, how can we separate the positive price effect of scarcity from the ambiguous price effect of concentration, and estimate the likely magnitude of each effect? In this article, we show how a difference-in-differences estimator can be used to address this question. We apply this methodology to the recent investigation by the Federal Economic Competition Commission of Mexico (Comisión Federal de Competencia Económica, or COFECE) into the allocation of take-off and landing slots at Benito Juarez International Airport in Mexico City (MEX). In July 2017, COFECE recommended changes to the slot allocation system at MEX, due in part to concerns that the current system had led to high concentration and elevated prices. Although we observe elevated prices at MEX relative to prices at other airports in Mexico, we find evidence that these elevated prices resulted from *slot scarcity*, but do not find evidence of a *market power* effect due to *concentration*.

2.0 Related Literature

The contribution of this study lies at the intersection of the literatures on: (i) congestion and capacity constraints at airports; (ii) concentration at airports and in air travel markets generally; and (iii) competition in the Mexican domestic airline industry specifically.

Previous research has documented that prices tend to be higher at congested airports due to capacity constraints. Morrison and Winston (1990) find that the effect of competition on price is dampened at slot-controlled airports, and Dresner *et al.* (2002) find a positive effect of the existence of airport slot controls on average fares. Ciliberto and Williams (2010) investigate the effect of control of airport gates and subleasing practices on higher prices, and find that limited access to airport facilities partially explains higher prices at hub airports. Other studies have investigated the incentives of hub carriers at congested airports. Brueckner (2002), Mayer and Sinai, (2003), and Ater (2012) show that hub carriers are more likely to internalise the congestion externalities caused by their flight movements than carriers that operate only a small share of slots at congested airports. Kleit and Kobayashi (1996) investigate whether hub carriers take advantage of airport capacity constraints and inefficiently 'hoard' slots at Chicago's O'Hare airport. They do not find evidence of such hoarding, and conclude that the allocation of slots to hub carriers is the result of efficient airport utilisation.

Several studies investigate the effects of airport-level concentration on price, and find evidence consistent with both market power and network effects. For example, Borenstein (1989), and Evans and Kessides (1993), show that airlines charge higher prices on a route when they have a higher share of passengers at the origin and destination airports, although they find conflicting effects of route-level shares on prices. Bamberger and Carlton (2002) find that network effects from the operation of a hub-and-spoke network, as well as service quality, explain a substantial portion of the observed higher fares for travel to and from hub airports. Starkie (2008), and Gillen and Starkie (2016), discuss the importance of a significant presence at slot-constrained airports for the operation of an efficient hub-and-spoke system, as well as the (dis-)incentives of incumbent hub airlines to support capacity expansion at slot-controlled airports when that capacity is likely to be allocated to new entrants.

Finally, Ros (2010, 2011) investigates the determinants of domestic flight prices in Mexico, focusing on the effects of competition from low-cost carriers, and the price 'premium' associated with flights to and from Mexico City. While he documents that prices for flights to and from Mexico City are higher than prices for flights to and from other airports in Mexico, he does not attempt to distinguish between scarcity and concentration effects as potential sources of those price differences.

3.0 Analysis of Slot Scarcity and Concentration at Mexico City Airport

Benito Juarez International Airport in Mexico City (MEX) is the busiest airport in Latin America by passenger traffic.[2] More than half of all domestic flights within Mexico, and about one-third of all international flights into or out of Mexico, either take off or land at MEX. MEX is also highly congested. The International Air Transport Association (IATA) classifies MEX as a 'Level 3 Coordinated Airport', meaning that airlines must be allocated specific take-off and landing times by the airport slot administrator before scheduling flights to or from the airport.[3]

The Mexican domestic aviation industry and the composition of carriers operating at MEX have undergone a significant transformation in the past decade. Of the five domestic air carriers that offered commercial service at MEX 10 years ago, only Aeroméxico and Aeromar remain as of 2018.[4] As the only Mexican airline with sufficient capacity at the time, Aeroméxico was allocated many of the slots at MEX that were made available due to the exit of Aero California, Aviacsa, and Mexicana from 2008 to 2010.[5] In recent years, Aeroméxico has operated around 50 per cent or more of all domestic flights at MEX, with the remaining slots allocated to Aeromar and three newer low-cost carriers: Interjet, Volaris, and VivaAerobus.[6]

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[2] During 2015, the year of our data, São Paulo-Guarulhos International Airport was the busiest airport in Latin America, and MEX was the second busiest, according to statistics published by those airports.

[3] A 'Level 3 Coordinated Airport' is one at which 'the expansion of capacity, in the short term, is highly improbable and congestion is at such a high level that: the demand for facilities exceeds availability during the relevant period; attempts to resolve problems through voluntary schedule changes have failed; and airlines must have been allocated slots before they can operate at that airport'. See IATA's Worldwide Scheduling Guidelines, available at www.euaca.org/up/files/docsWSG/WORLWIDE_SCHEDULING_GUIDELINES/WSG_12th%20Ed.pdf_040309_032834.pdf.

[4] Grupo Aeroméxico is the parent company of both Aeroméxico and Aeroméxico Connect, its regional subsidiary. We refer to Aeroméxico and Aeroméxico Connect collectively as 'Aeroméxico'.

[5] Mexicana was Mexico's oldest airline and flagship carrier when it suspended operations in 2010 in an attempt to restructure under bankruptcy protection. Low-cost carriers Aero California and Aviacsa ended all operations at MEX in 2008 and 2009, respectively.

[6] Interjet began operating at MEX in 2008; Volaris and VivaAerobus began operations at MEX in 2010.

During the autumn of 2014, COFECE announced an investigation into the slot allocation at MEX. Of primary concern to COFECE was the possibility that the current allocation of slots among airlines was harming consumers through higher prices and harming competition by creating barriers to entry. Although the exact mechanism by which slots have been allocated at MEX is complex, its main principle of operation has been based on 'historical slots' or 'grandfathering'. This is similar to the mechanisms used at other major slot-constrained airports: a slot allocated to and used by an airline in a given year will be allocated to the same airline in the next year.

When COFECE concluded its investigation in July 2017, it recommended changes to the manner in which slots are allocated at MEX, citing several concerns including a high concentration of slots, higher-than-average fares, lower-than-expected increases in seat capacity, and frequent cancellations and delays.[7]

COFECE ordered the airport authority to: (1) publish data on the allocation and the actual use of slots; (2) define clear rules for the allocation, withdrawal, and transfer of slots; (3) prohibit take-offs and landings by airlines not holding a valid slot; (4) enforce the assigned slot schedule; and (5) prohibit any carrier from acquiring additional slots during any given hour in which it already holds at least 35 per cent of slots.[8] While most of the corrective measures were intended to treat problems of transparency, accountability, and enforcement, the '35 per cent rule' was clearly intended to treat a perceived problem of higher prices due to concentration. COFECE's full opinion did not directly discuss the potential effect of scarcity separately from the perceived effect of concentration. In order to evaluate the likely effects of the 35 per cent rule, we need to understand better the relative effects of concentration versus scarcity on prices.

To investigate the determinants of prices at MEX, we estimate a fare equation using a difference-in-differences methodology to disentangle the effects of slot scarcity and concentration. Our approach is explained in detail below. We show that although prices for flights to and from MEX are indeed higher on average than prices for other domestic Mexican flights, this is likely due to a scarcity effect rather than a concentration effect: after accounting for differences between airlines and other route and ticket characteristics, we find that Aeroméxico charges a lower 'premium' for flights in and out of MEX than other domestic airlines, all else being equal.

3.1 Model specification

Our difference-in-differences estimator draws on a common research design in economics that is typically used to isolate the causal effect of a policy or treatment in the presence of unobserved confounding factors.[9] The usual formulation of this methodology involves comparing the outcomes on two groups, before and after a policy change or treatment that affects one group but not the other. In our application of the methodology, we compare the differences in average fares charged by Aeroméxico (the group that is 'treated' by slot concentration at MEX) and other airlines (the 'control group') for itineraries involving

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[7] See Comisión Federal de Competencia Económica (2016).

[8] 'COFECE notifies Mexico City's International Airport (AICM) of measures to regulate slot allocation', COFECE press release, 3 July 2017, available at https://www.cofece.mx/cofece/ingles/images/ingles/press_release/COFECE-036-2017_English.pdf.

[9] For a discussion of the difference-in-differences research design, see Meyer (1995).

Figure 1
Illustration of the Difference-in-Differences Methodology

	Average fares on flights to/from MEX	*Average fares on flights to/from other airports*	*Difference*
Aeroméxico	A	C	$A - C$
Other carriers	B	D	$B - D$ (‘Scarcity effect’)
Difference	$A - B$	$C - D$	$(A - C) \quad (B - D)$ (‘Concentration effect’)

MEX and those not involving MEX, to identify separately the scarcity and concentration effects on prices at MEX.

Figure 1 provides a concrete illustration of our empirical approach. For Aeroméxico and each of the other airlines that operate at MEX and other domestic routes, we compare the average fares on flights to and from MEX (A for Aeroméxico and B for other carriers) to average fares on comparable routes that do not involve MEX (C for Aeroméxico and D for other carriers). The degree to which average prices of flights to and from MEX are higher than average prices of flights on other routes ($A - C$ for Aeroméxico and $B - D$ for other airlines) is the ‘MEX premium’.

The MEX premium for other airlines ($B - D$) is an estimate of the scarcity effect on price. This is because fares charged by the ‘control’ airlines (Aeromar, Interjet, VivaAerobus, and Volaris) with smaller shares of slots at MEX are affected by scarcity at MEX, but not the treatment in our setting: the large share of slots at MEX that has been allocated to Aeroméxico. Aeroméxico’s MEX premium comprises both the scarcity effect and the concentration effect of its large slot share at MEX. Therefore, the *difference* between Aeroméxico’s MEX premium and that of other carriers [$(A - C) - (B - D)$] is an estimate of the effect of slot concentration on price.

Our research design requires two key assumptions. First, our identification strategy requires the assumption that the concentration of slots at the airport does not also affect the fares charged by other airlines on flights to and from that airport — that is, any potential market power that allows a dominant carrier to charge higher fares does not ‘spill over’ to other airlines operating at the same airport or on the same route (a ‘halo’ effect). Empirical evidence from other markets suggests that this is a reasonable assumption. For example, Borenstein (1989) finds that the ‘hub premium’ charged by dominant carriers in the USA does not also appear in the fares of competing airlines operating at the same airport. To the extent that this assumption does not hold in our context, our estimate of the concentration effect can be considered a lower bound; that is, it captures only the direct effect of concentration on price, above and beyond any potential spillover effect.

Second, our research design requires the assumption that any potential scarcity effect on price is similar across all airlines. In reality, the scarcity effect on price is likely to be greater for products for which demand is less price-elastic. Given that airlines sell differentiated products, this second assumption may not hold in practice. However, any difference in the price elasticity of demand between different airlines' offerings is likely mitigated in our application by the fact that we use data on the lowest available fare. We are not comparing, for example, a price that a business traveller is likely to pay on Aeroméxico with the price that a leisure traveller is likely to pay on another airline. To the degree that the price elasticity of demand differs among airlines, it is likely that demand for Aeroméxico is less price elastic than demand for other airlines. As Mexico's flag carrier, Aeroméxico likely has the most well-known brand. By comparison, the newer low-cost carriers likely cater to the most price-sensitive leisure travellers. If so, then the scarcity effect at MEX would be higher for Aeroméxico than for other carriers, meaning that the difference-in-differences estimate would tend to overstate the positive effect of slot concentration on price.

With these considerations in mind, we implement the difference-in-differences methodology using an ordinary least squares (OLS) model that accounts for differences in observable route and itinerary characteristics that are likely to influence fares. Specifically, we estimate the following fare equation:

$$P = \alpha_0 + \beta_1 AMX + \beta_2 MEX + \beta_3 AMX * MEX + \beta_4 \Delta_{Route} + \beta_5 \Delta_{Ticket} + \varepsilon, \qquad (1)$$

where P is the natural logarithm of the nominal fare in pesos for a non-stop domestic itinerary, for a given carrier and departure date; AMX is an indicator variable equal to one if the carrier is Aeroméxico, and zero otherwise; and MEX is an indicator variable equal to one if the itinerary involves MEX, and zero otherwise. $AMX*MEX$, the interaction between AMX and MEX, is an indicator variable equal to one if the carrier is Aeroméxico *and* the itinerary involves MEX. We also include controls for other route (Δ_{Route}) and ticket (Δ_{Ticket}) characteristics that may impact ticket prices. These characteristics, which are described in greater detail in Section 3.2, include among others the geometric mean of the population of the origin and destination city, and per capita income of the origin and destination city, tourist city indicators for the origin or destination city, travel distance and length, and the day of the week of the flight.

As illustrated in Figure 2, the coefficient β_1 in our model is an estimate of the average difference in the price charged by Aeroméxico versus the price charged by other carriers on routes not involving MEX, net of any exogenous differences in ticket and route characteristics. A positive and statistically significant estimate of β_1 would imply that fares on Aeroméxico tend to be higher on average than fares on other airlines, even on routes that are not directly impacted by conditions at MEX. In other words, β_1 measures the Aeroméxico premium that may be attributed to such factors as brand effects or the value of amenities offered. The coefficient β_2 estimates the average difference in price for a flight on non-Aeroméxico carriers to or from MEX relative to flights that do not involve MEX. A positive and statistically significant estimate of β_2 would suggest that fares for travel to and from MEX tend to be higher on average than fares for travel to and from other airports, irrespective of the airline. In other words, β_2 is an estimate of the scarcity effect on prices at MEX, which we expect to be positive.

Finally, β_3 provides an estimate of the degree to which Aeroméxico charges higher prices for travel to and from MEX, after netting out any differences in average prices between carriers and accounting for the effect of slot scarcity at MEX. That is, β_3 is the

Figure 2
Interpretation of Coefficients in Fare Regression

	Fares on flights to/from MEX	*Fares on flights to/from other Airports*	*Difference*
Aeroméxico	$\alpha_0 + \beta_1 + \beta_2 + \beta_3$	$\alpha_0 + \beta_1$	$\beta_2 + \beta_3$
Other carriers	$\alpha_0 + \beta_2$	α_0	β_2 ('Scarcity effect')
Difference	$\beta_1 + \beta_3$	β_1	β_3 ('Concentration effect')

Note: Model coefficients are estimated controlling for other route and ticket characteristics. See equation (1) for model specification.

difference-in-differences estimate that measures the slot concentration effect. The expected sign of β_3 is theoretically ambiguous, and depends on the relative magnitudes of the market power effect (which leads to higher prices) and the network effect (which leads to lower prices because of greater efficiency). A positive estimate of β_3 would suggest that the market power effect from Aeroméxico's significant allocation of slots dominates at MEX, while a negative estimate of β_3 would suggest that network effects from the operation of Aeroméxico's hub-and-spoke network dominate.

3.2 Data

We construct our dependent variable using information from Infare — a leading supplier of airfare data — on advertised prices for non-stop round-trip itineraries during the summer and autumn of 2015.[10] For each travel date, we identify the lowest advertised price associated with each domestic itinerary offered by Aeromar, Aeroméxico, Interjet, VivaAerobus, and Volaris. From these same data, we construct a set of the ticket-attribute variables, Δ_{Ticket}, including the number of days until departure, an indicator for Saturday night stayovers, the number of days between the departure and return date, and indicators for the calendar month, day of the week, and hour of the day when each flight departs.

We construct a set of route-specific characteristics, Δ_{Route}, using data collected from the US Department of Transportation's Bureau of Transportation Statistics, the Mexican Secretary of the Interior (*Secretaría de Gobernación*), the Mexican National Institute of

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[10] Data on prices were collected on two occasions in June 2015 from the websites of each carrier offering commercial passenger air travel service within Mexico. Prices for seven-day round-trip itineraries were collected on 4 June, for departure dates between 4 June and 1 July, or during the first full week of July, August, September, and October 2015. Prices for two-day round-trip itineraries were collected on 8 June, for departure dates between 8 June and 12 July, or during the first full week of August, September, and October 2015.

Table 1
Summary Statistics

Variable	*Description*	*Mean*	*Std. dev.*	*Min.*	*Max.*
AMX	Itinerary is operated by Aeroméxico	0.57	0.49	0.00	1.00
MEX	Itinerary is to/from MEX	0.86	0.34	0.00	1.00
AMX*MEX	Interaction between AMX and MEX	0.52	0.50	0.00	1.00
DIST	Direct flight distance (km/100)	17.06	9.73	4.06	64.79
DAYStoDEP	Number of days to departure date	46.71	41.00	0.00	130.00
P	Price for lowest available fare	3,949	1,614	703	12,390
POP	Population (millions, geometric mean)	5.34	2.87	0.33	9.45
INCOME	Income per capita ('000 pesos, geometric mean)	241.06	67.03	91.22	743.26
MI	Marginalisation index (geometric mean)	3.94	0.53	2.80	7.15
TOURIST	Origin or destination is a tourist city	0.24	0.43	0.00	1.00
SAT	Itinerary includes Saturday night	0.64	0.48	0.00	1.00
LENGTH	Number of days between departure and return	4.55	2.50	2.00	7.00

Notes: The main regression sample contains 557,097 observations. The POP, INCOME, and MI variables are calculated as the geometric mean of the values at the origin and the destination cities in the itinerary.

Statistics and Geography (*Instituto Nacional de Estadística y Geografía*), the United Nations, and the Organization for Economic Co-operation and Development (OECD). Route-specific variables include the total distance in kilometres flown on the itinerary (and its square) and, for each origin and destination city, the geometric mean of the population (in millions) of the origin and destination city, the geometric mean of per capita income of the origin and destination city, the geometric mean of an index of economic marginalisation at the origin and destination, and an indicator variable equal to one if the destination city is a tourist destination.

Summary statistics for the variables included in the regression analysis are presented in Table 1. More than half of the non-stop round-trip itineraries in our sample are operated by Aeroméxico, and 86 per cent of them are either to or from MEX. The average advertised fare is approximately $3,950 MXN (about $200 USD in 2015), the average itinerary is about five days long, and about 64 per cent of trips include a Saturday night stay.

3.3 Results

We estimate our model on a sample that includes all non-stop round-trip itineraries between 4 June 2015 and 11 October 2015. Table 2 reports our main results. The different columns in Table 2 evaluate the sensitivity of our results to the inclusion of fixed effects that account for the timing of outbound and inbound departures: outbound and inbound departure's day of the week; the outbound departure's month; and the outbound and inbound departure's time of the day. Column (1) reports estimates from the model without any of these fixed effects. Column (2) adds fixed effects for outbound and inbound departures' day of the week; column (3) additionally includes fixed effects for the outbound departure's month; and column (4) additionally includes the outbound and inbound departures' time of day. Column (4) is our preferred specification, and we discuss results from this specification in detail below. Notably, while the incremental introduction of these fixed

Table 2
Main Results

Variable	*(1)*	*(2)*	*(3)*	*(4)*
AMX	0.544***	0.545***	0.547***	0.561***
	(0.003)	(0.003)	(0.000)	(0.003)
MEX	0.189***	0.190***	0.191***	0.193***
	(0.002)	(0.002)	(0.002)	(0.002)
AMX*MEX	−0.082***	−0.084***	−0.085***	−0.099***
	(0.003)	(0.003)	(0.003)	(0.003)
POP	−0.057***	−0.057***	−0.057***	−0.056***
	(0.000)	(0.000)	(0.000)	(0.000)
INCOME	−0.000***	−0.000***	−0.000***	−0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
MI	−0.078***	−0.080***	−0.080***	−0.084***
	(0.002)	(0.002)	(0.002)	(0.002)
TOURIST	−0.036***	−0.039***	−0.041***	−0.046***
	(0.001)	(0.001)	(0.001)	(0.001)
DIST	0.010***	0.010***	0.010***	0.011***
	(0.000)	(0.000)	(0.000)	(0.000)
DIST^{2}	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
DAYStoDEP	−0.003***	−0.003***	−0.010***	−0.010***
	(0.000)	(0.000)	(0.000)	(0.000)
DAYStoDEP^{2}	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
LENGTH	−0.009***	−0.014***	−0.011***	−0.005*
	(0.000)	(0.003)	(0.003)	(0.003)
SAT	0.046***	0.082***	0.079***	0.034*
	(0.001)	(0.023)	(0.022)	(0.018)
Constant	8.359***	8.423***	8.486***	8.712***
	(0.008)	(0.009)	(0.009)	(0.035)
Outbound departure day of week	No	Yes	Yes	Yes
Inbound departure day of week	No	Yes	Yes	Yes
Departure month	No	No	Yes	Yes
Outbound departure hour	No	No	No	Yes
Inbound departure hour	No	No	No	Yes
Observations	557,097	557,097	557,097	557,097
Adjusted R-squared	0.536	0.544	0.553	0.564

Notes: The dependent variable is the natural logarithm of the advertised fare. Robust standard errors are reported in parentheses. Asterisks ***, **, and * indicate statistical significance at 1 per cent, 5 per cent, and 10 per cent, respectively. Aeroméxico includes Aeroméxico Connect.

effects modestly improves the model's fit as evidenced by the increased adjusted R-squared, the coefficients on our key variables of interest — AMX, MEX, and $AMX*MEX$ — remain stable across different specifications, in terms of both their magnitude and their statistical significance.

Our estimate of β_1, the coefficient associated with the indicator variable AMX, is positive and statistically significant, indicating that flights operated by Aeroméxico are about 75 per cent (or about \$1,861 MXN) more expensive than flights operated by other carriers on routes not involving MEX, all else being equal.[11] This Aeroméxico price premium may be explained by differences in airline-specific product characteristics and amenities, differences in costs between airlines, or other factors. As we discuss in more detail below, the Aeroméxico price premium is not explained by a systematic difference in the degree of route competition faced by Aeroméxico and other carriers. On average, Aeroméxico operates on more competitive routes, as measured by the number of carriers serving those routes.

Our estimate of β_2, the coefficient associated with the indicator variable *MEX*, indicates that itineraries to or from MEX are on average 21 per cent (or about \$527 MXN) more expensive than comparable itineraries not involving MEX for carriers that are not Aeroméxico ($e^{0.193} - 1 = 0.213$). This MEX premium includes the potential *scarcity effect* due to saturation conditions at MEX, but it may also include other factors that influence fares on routes involving MEX, including the fact that Mexico City is a common destination for business travellers who are less price sensitive than leisure travellers.

Our difference-in-differences estimate of β_3 — the coefficient of interest associated with the interaction term *AMX*MEX* — is negative, indicating that Aeroméxico charges a lower MEX premium than other carriers. This is true in both percentage and monetary terms. While other carriers charge fares that are about 21 per cent (\$527 MXN) higher for flights to and from MEX relative to their fares on other routes, Aeroméxico charges fares that are about 10 per cent (\$427 MXN) higher for flights to and from MEX relative to its fares on other routes ($e^{0.193-0.099} - 1 = 0.099$). The fact that Aeroméxico charges less for flights to and from MEX than other airlines, relative to fares on other routes, indicates that the overall slot concentration effect associated with Aeroméxico's large share of slots at MEX is negative. This result suggests that a cost-reducing network effect dominates any potential anti-competitive market power effect on Aeroméxico's fares at MEX.

We conduct several robustness checks to our main model. First, we investigate whether our estimate of β_2 — the 'MEX premium' for other carriers — is driven by a difference in route-level competition between routes involving MEX and routes not involving MEX. In Table 3, we estimate our preferred model with the addition of two alternative controls for competition at the route level. In column (1), we reproduce our results from Table 2, column (4). In column (2), we include a measure of market concentration, the Herfindahl-Hirschman Index (HHI) on each route. A higher HHI indicates a lower level of competition, and we would expect the variable to have a positive estimated effect on price. In column (3), we include a variable that measures the number of carriers operating on each route. A higher number of carriers indicates a higher level of competition, and we would expect this variable to have a negative estimated effect on price. We find that each of these alternative control variables enters with the expected sign, and strengthens the primary result. That is, we find that Aeroméxico charges an even lower 'MEX premium', relative to other carriers, after controlling for route-level competition.

A potential concern with including these controls for route-level competition on the right-hand side of the regression is endogeneity — that is, high demand for travel between

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[11] Because the dependent variable is the natural logarithm of the advertised fare, it is necessary to undo the logarithmic transformation in order to calculate the estimated percentage effect ($e^{0.561} - 1 = 0.752$).

Table 3

Robustness Check: Controlling for the Degree of Competition at the Route Level

Variable	*(1)* *Main model*	*(2)* *Route HHI*	*(3)* *No. of carriers*
AMX	0.561***	0.596***	0.605***
	(0.003)	(0.003)	(0.003)
MEX	0.193***	0.248***	0.177***
	(0.002)	(0.002)	(0.002)
AMX*MEX	−0.099***	−0.136***	−0.144***
	(0.003)	(0.003)	(0.003)
Degree of concentration on route (HHI/10,000)		0.511***	
		(0.004)	
Number of carriers on route			−0.107***
			(0.001)
Route level controls	Yes	Yes	Yes
Ticket level controls	Yes	Yes	Yes
Outbound departure day of week	Yes	Yes	Yes
Inbound departure day of week	Yes	Yes	Yes
Departure month	Yes	Yes	Yes
Outbound departure hour	Yes	Yes	Yes
Inbound departure hour	Yes	Yes	Yes
Observations	557,097	555,115	555,115
Adjusted R-squared	0.564	0.586	0.585

Notes: The dependent variable is the natural logarithm of the advertised fare. Regression includes a constant term (not reported). Robust standard errors are reported in parentheses. Asterisks ***, **, and * indicate statistical significance at 1 per cent, 5 per cent, and 10 per cent, respectively. Aeroméxico includes Aeroméxico Connect. The degree of concentration is measured by the route-specific Herfindahl-Hirschman Index (HHI), calculated using 2014 data from IATA. The number of operating carriers in each route is calculated using the same data source. The number of observations differs slightly from Table 2 because IATA does not provide data for some routes. Also included in the regression (but not reported) are the route- and ticket-level controls shown in Table 2.

two airports would be expected to have a positive effect on price, and may also lead more carriers to operate on a route, resulting in a lower HHI. This endogeneity is likely not a concern for our primary result, as: (a) the result is robust to the exclusion of these route-competition variables; (b) other demand controls included in the model likely mitigate the effect of this endogeneity; and (c) the route-competition variables are highly significant with the expected sign.

Because the lowest available price on a flight typically increases as the date of departure approaches, some of the observed differences in price between airlines and routes may be due to differences in the airlines' yield management practices.[12] In Table 4, we estimate our preferred model with two alternative sample restrictions which remove prices that are very close to the date of departure. In column (1), we reproduce our results from

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[12] Yield management refers to the process by which airlines allocate available capacity on a flight between different fare classes in response to demand as the flight date approaches. Because airlines' yield management systems differ, the lowest available price for a given route may be very different between two carriers, even on the same day, due to differences between fare classes.

Table 4
Robustness Check: Sample Restrictions

Variable	*(1)* *Full sample*	*(2)* *Excluding first two weeks*	*(3)* *July–October only*
AMX	0.561^{***}	0.568^{***}	0.587^{***}
	(0.003)	(0.003)	(0.004)
MEX	0.193^{***}	0.183^{***}	0.195^{***}
	(0.002)	(0.003)	(0.003)
AMX*MEX	-0.099^{***}	-0.085^{***}	-0.103^{***}
	(0.003)	(0.003)	(0.004)
Route-level controls	Yes	Yes	Yes
Ticket-level controls	Yes	Yes	Yes
Outbound departure day of week	Yes	Yes	Yes
Inbound departure day of week	Yes	Yes	Yes
Departure month	Yes	Yes	Yes
Outbound departure hour	Yes	Yes	Yes
Inbound departure hour	Yes	Yes	Yes
Observations	557,097	424,321	269,594
Adjusted R-squared	0.564	0.559	0.555

Notes: The dependent variable is the logarithm of the advertised fare. Regression includes a constant term (not reported). Robust standard errors are reported in parentheses. Asterisks ***, **, and * indicate statistical significance at 1 per cent, 5 per cent, and 10 per cent, respectively. Aeroméxico includes Aeroméxico Connect.

Table 2, column (4). In column (2), we exclude tickets for travel during the first two weeks of our sample, and in column (3), we exclude tickets for travel during June entirely.[13] The exclusion of tickets for travel within the first two weeks of our sample allows us to test whether our results are driven by fares available to less price-sensitive travellers who tend to purchase tickets on relatively short notice without advance purchase discounts. The exclusion of tickets for travel during June allows us to test whether our results are driven by fares offered on flights that may be close to reaching seating capacity at the time that we observe the advertised fare. In both alternative sample restrictions, the coefficient on our key variables of interest — AMX, MEX, and $AMX*MEX$ — are statistically significant and similar in sign and magnitude to our baseline specification.

Finally, Table 5 presents the results from adding a trend aimed at capturing any price effects associated with the time of the day at which the fares were retrieved from the carrier's website. Carriers monitor their flights constantly to analyse booking patterns and change the number of seats available at each fare level in real time. For example, if the demand for a specific route is higher than expected, a carrier may decide to reduce the number of seats available for the lower fare levels. On the other hand, if demand is lower than

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[13] On 4 June 2015, Infare retrieved information on ticket prices for seven-day non-stop, round-trip itineraries occurring over the period 4 June–11 October 2015. On 8 June 2015, Infare retrieved information on ticket prices for two-day non-stop, round-trip itineraries occurring over the period 8 June–11 October 2015. By limiting the sample to travel occurring from July to October, we are excluding prices for tickets that have been purchased less than a month before the departure date.

Table 5

Robustness Check: Timing of When Price Was Scraped from Carrier's Website

Variable	*(1)* *Full sample*	*(2)* *Excluding first two weeks*	*(3)* *July–October only*
AMX	0.561***	0.570***	0.591***
	(0.003)	(0.003)	(0.004)
MEX	0.193***	0.183***	0.194***
	(0.002)	(0.003)	(0.003)
AMX*MEX	−0.099***	−0.084***	−0.098***
	(0.003)	(0.003)	(0.004)
Time Trend	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)
Route-level controls	Yes	Yes	Yes
Ticket-level controls	Yes	Yes	Yes
Outbound departure day of week-fixed effects	Yes	Yes	Yes
Inbound departure day of week-fixed effects	Yes	Yes	Yes
Departure month-fixed effects	Yes	Yes	Yes
Outbound departure hour-fixed effects	Yes	Yes	Yes
Inbound departure hour-fixed effects	Yes	Yes	Yes
Observations	557,097	424,321	269,594
Adjusted R-squared	0.564	0.559	0.556

Notes: The dependent variable is the natural logarithm of the advertised fare. Regression includes a constant term (not reported). Robust standard errors are reported in parentheses. Asterisks ***, **, and * indicate statistical significance at 1 per cent, 5 per cent, and 10 per cent, respectively. Aeroméxico includes Aeroméxico Connect.

expected, a carrier may decide to offer more seats at the lower fare levels. These changes may occur not only on a daily basis, but also at multiple times during the same day. To take these effects into account, we include in our model a trend variable equal to the total number of minutes that had elapsed in the day at the time the fare was retrieved.[14] As shown in Table 5, fares retrieved later in the day are, on average, higher than fares retrieved earlier in the day. Importantly, even after adding this control, the coefficients on the variables *AMX*, *MEX*, and *AMX*MEX* are still positive, statistically significant, and of similar magnitude to the baseline specification.

We also conducted additional sensitivity checks: (1) using fares on one-way itineraries instead of round-trip itineraries; and (2) replacing the natural logarithm of the ticket price with the natural logarithm of the ticket price per kilometre as the dependent variable.[15] Our results are robust to these changes.

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[14] So, for example, if the first fare was retrieved at 1 a.m. and the second fare (for the same itinerary and carrier) was retrieved at 1:40 a.m., the trend variable would be equal to zero for the first observation, and equal to 40 for the second observation.

[15] These results are available upon request.

4.0 Summary and Conclusion

In this paper, we demonstrate how a difference-in-differences framework can be used to identify separately two different price effects of slot constraints and allocation mechanisms at congested airports: a scarcity effect and a concentration effect. The data required to conduct such an analysis are available to regulators in most countries with congested airports, and they are publicly available in the USA.

We have applied this methodology to Benito Juarez International Airport in Mexico City, which is the busiest and the only slot-controlled airport in Mexico. We find a positive and significant scarcity effect on price. In other words, the constraint on the supply of flights due to inadequate airport capacity has the expected effect on price: all airlines charge more for flights to and from Mexico City than for flights on other routes. We also find a negative and significant concentration effect on price; that is, the carrier that is allocated the highest share of slots actually charges a lower premium for flights to and from Mexico City than for flights to and from other airports.

Our research design relies on two key assumptions: (1) that concentration of slots allocated to the dominant carrier at the airport does not also affect the fares charged by other airlines on flights to and from that airport (a 'halo' effect); and (2) any potential scarcity effect on price is similar across all airlines. While it is possible that one or both of these assumptions may not hold at a given airport, there is evidence from prior research that suggest that they are not unreasonable assumptions. With regard to the first assumption, past empirical evidence from other markets suggests that the 'hub premium' charged by dominant carriers in the USA does not appear in the fares of competing airlines operating at the same airport (Borenstein, 1989). However, to the extent that this is not true, our estimate of the concentration effect is a kind of lower bound estimate of the potential concentration effect. With regard to the second assumption, any differences in the price elasticity of demand for the offering of different airlines will likely be mitigated by our choice to use data on the lowest available fare. Furthermore, to the extent that price elasticity of demand differs among airlines, it is likely that demand for Aeroméxico — a premium product catering to business travellers — is less price elastic than demand for other airlines. In this case, the scarcity effect at MEX would be higher for Aeroméxico than for other carriers, meaning that our difference-in-differences estimate would tend to overstate the positive effect of slot concentration on price. To the extent that both of these assumptions do not hold, it is unclear what the net direction of the bias would be on the estimate of the concentration effect.

Results from the empirical methodology outlined in this paper can provide valuable insight into the potential impact of different slot allocation mechanism designs and planned expansions in airport capacity. In particular, when higher prices are observed at slot-constrained airports with a dominant carrier, it is critical to understand whether the higher prices are the result of the scarcity of slots or the result of slot concentration. The ability to distinguish between these two effects has important implications for regulators and airport authorities, as they weigh different policy prescriptions for high prices at congested airports. Finally, given that substantial differences exist among major airports in different countries and the carriers that serve them, it is important to conduct the analysis separately for each airport, rather than to make generalisations from the findings at one airport.

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