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Internalization of congestion at US hub airports

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ABSTRACT

I study delays and congestion patterns in US hub airports during periods of high flight volume. I find that these periods are longer when the share of flights operated by the hub airline is greater, and these longer periods exhibit shorter delays. These results lend support to recent theoretical work on congestion, implying that hub-airlines take into account the impact of their scheduling decisions on the congestion that they bear. The results may suggest that congestion management solutions implemented at hub airports dominated by one airline could have only a limited impact on congestion in general.

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1. Introduction

Delays and congestion in the airline industry are a major concern,[1] and policymakers are considering various solutions, such as congestion pricing or restricting the number of flights during high-demand periods in order to reduce congestion.[2] The successful implementation of solutions to congestion depends on understanding the airlines' scheduling decisions, particularly how airlines determine their schedules, given the impact of these decisions on the congestion that they cause and bear.

This paper offers an innovative addition to the empirical literature on the internalization of airport congestion. Internalization by airlines implies that flight operations in airports where one airline operates most of the flights will be organized to generate less congestion than in airports where multiple airlines operate and each airline operates a small share of the flights. Thus, the basic prediction of the theoretical literature on congestion is a negative relationship between concentration and delays: an increase in airport concentration, which moves the airport farther away from the extreme atomistic or competitive case, should lead to less congestion and fewer delays.[3]

Two prior papers, Brueckner (2002) and Mayer and Sinai (2003) offer only mild empirical support for this prediction,[4] while Rupp (2009), who extended Mayer and Sinai's analysis, finds no support for internalizing behavior. Daniel (1995) and Daniel and Harback (2008, 2009) use simulation models to show that the pattern of flight operations at hubs is not consistent with airline attempts to limit self-imposed congestion. Thus, the existing empirical literature provides, at best, mixed evidence for what would seem to be a very natural behavior by airlines: considering self-imposed congestion in scheduling decisions. Given the lack of evidence supporting for internalizing behavior, Brueckner and Van-Dender (2008) builds on Daniel's (1995) idea that hub carriers use flight schedules to preempt

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1 In the US, the total estimated costs of air transportation delays are $9.4 billion annually. Between 2002 and 2004 more than $4.5 billion was spent annually to reduce flight delays; see www.fightgridlocknow.gov/docs/conginitoverview070301.htm. The cost of air delays in 1999 in Europe is estimated between EUR 6.6–11.5 billion; see www.eurocontrol.int/prc/gallery/content/public/Docs/stu2.pdf. On July 13, 2010, a US federal appeals court rejected an airline-industry challenge to Department of Transportation regulations that allow airports to charge airlines more to land their planes at peak times. "Court Upholds Landing-Fee Rule", *Wall Street Journal*, July 13, 2010.

2 Currently, in most US airports the order of flights' arrivals and departures is based on a first-come first-served process. Landing charges are based on aircraft weight, rather than flight time of operation.

3 Theoretical papers that illustrate and develop this point include the following: Brueckner (2002), Brueckner (2005), Pels and Verhoef (2004), Zhang and Zhang (2006), Basso and Zhang (2007), and Brueckner (2009).

4 Brueckner uses 25 observations of aggregate annual data on delays across airports and finds a statistical significant relationship in one out of six specifications. Mayer and Sinai (2003) find a negative relationship between airport concentration and delays only for two out of the five measures they use for delays.

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entry by other carries, and develop a theoretical model that can explain why such evidence was not found (see also Daniel (2009)).

This paper offers a resolution to this puzzle by, in effect, combining elements of the previous approaches. Like Brueckner (2002) and Mayer and Sinai (2003), the paper looks for an effect of airports' competitive structure on the delays. Like Daniel (1995), it studies the details of airport flight schedules to find such an effect. In particular, the paper hypothesizes that a hub airline that internalizes congestion should spread out each of its departure and arrival "banks" (waves of departing and arriving flights) to limit self-imposed congestion. With wider banks, flights will interfere less with one another, reducing delays. This prediction is tested by relating the length of the bank (in minutes) to the extent of bank concentration, measured by the HHI index, which is computed based on the share of flights operated by airlines within a bank. If the bank period contains mostly flights operated by a single airline, then (holding the number of bank flights constant), the bank length should be longer and the operations less congested than in the case, where the bank-concentration measure is lower.

Section 2 includes a simple framework for a hub-carrier scheduling decision, which guides the empirical analysis. This simple framework provides intuitive predictions of internalizing behavior: more concentrated banks are longer and have lower flight density, and longer banks exhibit shorter delays. Furthermore, as the unit cost of queuing rises, the length of the bank period chosen by the hub-carrier increases.

In my empirical analysis, I follow this framework and provide evidence consistent with each of the implications of the framework. First, I examine, for both arriving and departing banks, how the scheduled length of the bank period varies with the bank concentration level. I account for the potential endogeneity of the bank concentration measure by using the number of destinations offered by non-hub carriers from the hub-airport. The validity of the instrument is discussed in Section 4. I find that an increase of one standard deviation in bank concentration is associated with increases of 7 and 7.2 min in the length of departing and arriving banks, respectively. I also find that arriving banks are longer than departing banks. The difference between arriving and departing banks is consistent with the unit cost of queuing being higher during arriving banks. This is because during arriving banks, when airplanes are waiting to land their queuing cost is higher compared to departure banks where waiting occurs on the ground. Consequently, airlines have a greater incentive to avoid congestion during arriving banks compared to departing banks by choosing longer bank periods.

In the second step of the empirical analysis, I verify that an increase in the length of a departing or arriving bank length indeed reduces delays for the flights in that bank. In departing queues, the measure of delay is based on the flight taxi-out time: the elapsed time from leaving the airport gate to wheels off the runway. In arriving queues, the measure of flight delay is the sum of airtime delay – based on flight airtime between takeoff at the airport of origin and landing at the hub airport – and another measure based on taxi-in time. Specifically, for airtime delay I use the fastest hub-bound flight airtime in each origin airport-hub-airport pair as a benchmark, and then subtract this benchmark from each actual flight airtime to obtain the arriving queue delay for each particular flight. My estimates show that longer banks are associated with shorter flight delays in both arriving and departing queues. The changes in the lengths of departing and arriving banks (7 and 7.2 min, respectively) mentioned above translate, on average, into decreases of roughly 0.5 min in the delays in departing banks and 1 min in arriving banks for each flight.

Fig. 1 shows that there is a strong positive relationship between an airport's overall concentration and the average concentration of departing banks at that airport. Because hub-carriers predominantly operate during bank periods, the banks are more concentrated than the airport overall. Taken together, the findings in this paper suggest that greater hub airport concentration raises bank concentration, which implies longer banks and shorter delays. The negative empirical relationship between airport concentration and delays can also be shown in Figs. 2 and 3, where I plot the relationship between the airport concentration level and the arrival and departure delay measures during bank periods.

The remainder of the paper is organized as follows. Section 2 describes the theoretical framework, which guides the empirical estimation and derives testable implications. In Section 3, I describe the data, provide descriptive statistics, and explain how the variables used in the empirical estimation were constructed. Section 4 includes the estimation results of the bank length and bank density regressions, as well as the regressions using the different delay measures as dependent variables. Section 5 concludes the paper.

2. Economics of hub airports and theoretical framework

Following the airline industry deregulation in 1978, airlines accelerated the development of their hub-and-spoke systems. The hub and spoke network structure generally increases the available flight options for passengers traveling to and from hub airports and facilitates more convenient service on routes for which the demand is not sufficient to support frequent nonstop service at relatively low prices. Operating cost economies arise from the increased density of operations, allowing the airline to offer more frequent service on a segment while maintaining high load factors.

Longer travel times and layover times at the hub airport are the costs of a hub system. To minimize those costs, hub-and-spoke networks schedule arrivals and departures at their hubs in banks of flights. Arrival banks consist of hub-bound flights from spoke cities, which land at approximately the same time. At the hub, connecting passengers then change aircraft, and the aircraft from which they disembark prepares for its next operation. Departure banks consist of flights to spoke cities that depart at approximately the same time.

2.1. Theoretical framework

Because runway capacity constraints at hub airports prevent all bank flights from departing or arriving concurrently, hub-carriers schedule their bank flights over a period of time. By choosing a longer bank period, the hub-carrier can reduce congestion costs while increasing connecting passengers' layover time. Thus, in setting the lengths of bank periods, hub-carriers face a basic trade-off between congestion costs and layover/ground time costs. These latter costs include customers' lower willingness to pay for flights that include long connections, as well as the costs associated with lower utilization of the airline's fleet of aircraft.

Airlines bear the externalized cost of congestion during bank periods because flights inflict delay/congestion costs on other flights scheduled around the same time. The closer in time the airplanes are operated, the higher the congestion costs inflicted. Consequently, an airline that operates multiple airplanes during a bank period will benefit from scheduling one flight at a different time from the other flights more than a carrier that operates one airplane during that bank period. In computing congestion costs, the hub-carrier considers the cost that each airplane inflicts on other hub-carrier airplanes. A carrier operating a single flight during a bank does not take into account any impact on other flights' cost of congestion. Consequently, controlling for the number of bank flights, we expect that when several airlines operate during the banks, the banks will be shorter and will generate longer

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