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A note on optimal airline networks under airport congestion

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HIGHLIGHTS

- Airport congestion is a severe economic problem.
- We examine optimal airline networks under airport congestion.
- Airlines exhibit a preference for hub-and-spoke (HS) configurations.
- Airlines may be inefficiently biased towards HS networks.
- We recommend regulatory tools like congestion pricing or slot constraints.

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ABSTRACT

We extend the monopoly case without congestion in Brueckner (2004) by examining network choice in a duopoly where airport congestion can occur. Airlines prefer hub-and-spoke configurations, even if this implies higher congestion costs. Airlines may be inefficiently biased towards hub-and-spoke networks.

1. Introduction

The deregulation of air transportation allowed carriers to make strategic choices about fares and networks. The success of hub-and-spoke (HS) structures can be explained in terms of the savings carriers made from operating fewer routes and from exploiting economies of traffic density. However, the concentration of traffic favored by HS networks has contributed to an increase in airport congestion causing delays, cancellations, and missed connections, all of which ends up having a detrimental impact on passengers and airlines alike.

Congestion is a severe problem and it is especially worrisome in HS networks.[1] Since network structure is essential to understand the problem of congestion, our main aim is to examine this relationship and assess the eventual detrimental effects of HS networks on social welfare.

We study network choice in a duopoly with schedule competition where congestion can occur. First, we compare the incentives for airlines to operate either HS or fully-connected (FC) networks.

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[1] On the one hand, the magnitude of the problem can be noticed by looking at data over the period 2005–2013 for the top 50 US airports (data from RDC Aviation, Capstat Statistics), which reveals that the percentage of flights suffering a delay longer than 15 min was about 22%. On the other hand, the relationship between HS networks and congestion is empirically shown in Brueckner (2002), which shows that delays are higher in hub airports after controlling for airport size and other airport attributes.

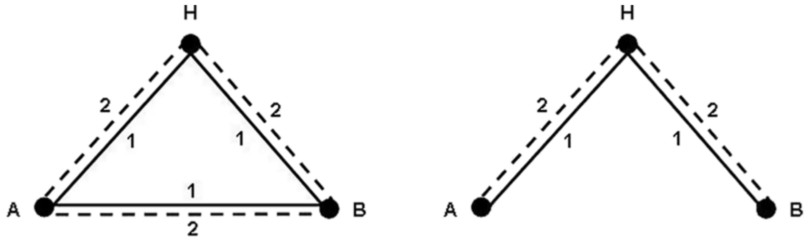

Fig. 1. The FC and HS networks.

We find that airline profits are higher under HS networks without congestion and that this result is typically reinforced in the presence of congestion. Second, we perform a welfare analysis revealing that airlines choose excessive frequencies and that they may be inefficiently biased towards HS networks, especially in a congested environment. Our analysis suggests the need to apply regulatory tools like congestion pricing or slot constraints.

We bring together two strands of the literature: one on airport congestion and another one on airlines' network choice.[2] Brueckner (2004) studies the monopoly case (without congestion) and finds an inefficient bias towards the HS network. He suggests that a model including airline competition should corroborate his result. Our paper fills this gap.

2. Model and equilibrium analysis

We assume the simplest possible network with three cities (A, B, and H), two airlines (1 and 2), and three city-pair markets (AH, BH, and AB). AB can be served either nonstop (FC network) or via hub H (HS network), as shown in Fig. 1.

Passenger population size in each market is normalized to unity and we limit market power by assuming fully-served markets.[3]

The two symmetric networks are compared. Therefore, we do not perform a complete equilibrium analysis since we do not consider the asymmetric case. The reason is twofold: an asymmetric outcome is not likely to arise in equilibrium (with fully-served markets and symmetric carriers),[4] and it would complicate severely the exposition of the results. We are implicitly assuming a coordination game with two symmetric equilibria and our purpose is to develop a focal criterion to select the Pareto-superior equilibrium.

2.1. FC network

Utility for a passenger traveling with carrier 1 is

$$u_1 = \underbrace{y - p_1}_{\text{Consumption}} - \underbrace{\frac{\gamma}{f_1}}_{\text{Expected schedule delay}} - \underbrace{\lambda\,(4f_1 + 4f_2)}_{\text{Congestion damage}} + \underbrace{b + a}_{\text{Travel benefit}}. \quad (1)$$

Consumption equals $y - p_1$, where p_1 is airline 1's fare and y denotes income. The *expected schedule delay* is decreasing with frequency, where $\gamma > 0$ captures the disutility of schedule delay (as Brueckner, 2004). The *congestion damage* depends on the aircraft movements at the origin and destination airports ($2f_1 + 2f_2$ at each airport), where $\lambda \geqslant 0$ captures the disutility of congestion (as Flores-Fillol, 2010). Finally, *travel benefit* includes the gain from travel (b) and the airline brand-loyalty (a),[5] which is uniformly distributed over $[-\alpha/2, \alpha/2]$ and denotes the utility gain from using airline 1 (as Brueckner and Flores-Fillol, 2007). Interestingly, α measures product differentiation.[6] The analysis is presented for carrier 1 (expressions for carrier 2 are derived analogously).

A passenger loyal to 1 (with $a > 0$) will fly with her preferred carrier when $y - p_1 - \gamma/f_1 + b + a > y - p_2 - \gamma/f_2 + b$, i.e., when $a > p_1 - p_2 + \gamma/f_1 - \gamma/f_2 \equiv \widehat{a}$.[7] Then, carrier 1's traffic is

$$q_1 = \int_{\widehat{a}}^{\alpha/2} \frac{1}{\alpha} da = \frac{1}{2} - \frac{1}{\alpha}(p_1 - p_2 + \gamma/f_1 - \gamma/f_2). \quad (2)$$

Carrier 1's total costs on a route are

$$c_1 = f_1 \left[\underbrace{\theta}_{\text{Fixed cost}} + \underbrace{\tau s_1}_{\text{Seat cost}} + \underbrace{\eta\,(4f_1 + 4f_2)}_{\text{Congestion cost}} \right], \quad (3)$$

where τ is the marginal cost per seat, s_1 is carrier 1's aircraft size, and $\eta \geqslant 0$ denotes airlines' congestion damage. As in Brueckner (2004), the cost per seat falls with aircraft size, capturing the presence of economies of traffic density. Frequency, aircraft size, and traffic are related by $s_1 = q_1/f_1$.[8] Therefore (3) can be rewritten as

$$c_1 = \theta f_1 + \tau q_1 + f_1 \eta\,(4f_1 + 4f_2). \quad (4)$$

Airline 1's profit is $\pi_1 = 3\,(p_1 q_1 - c_1)$ and, using (4), it becomes

$$\pi_1 = 3 \left\{ \underbrace{(p_1 - \tau)\, q_1}_{\text{Margin}} - \underbrace{f_1 \left[\theta + 4\eta\,(f_1 + f_2)\right]}_{\text{Congestion and fixed cost}} \right\}. \quad (5)$$

Airlines maximize profits by choosing fares and frequencies. Plugging (2) into (5), $\partial\pi_1/\partial p_1$ and $\partial\pi_1/\partial f_1$ can be computed.[9] From $\partial\pi_1/\partial p_1$, after applying symmetry, we obtain

$$p = \tau + \alpha/2, \quad (6)$$

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2 Studies on airport congestion include, among others, Daniel (1995), Brueckner (2002), Daniel and Harback (2008), and Flores-Fillol (2010). The literature on airlines' network choice includes, among others, Pels et al. (2000), Brueckner (2004), and Flores-Fillol (2009).

3 As in Flores-Fillol (2010), market power only affects the division of a fixed traffic pool. Partially-served markets introduce tractability complications since a reduction in frequency mitigates congestion but raises fares.

4 Flores-Fillol (2009) performs a *full* equilibrium analysis in the absence of congestion. Asymmetric networks only occur in equilibrium when markets are partially served.

5 Without brand loyalty, the airline with the most attractive frequency/fare combination would attract all the passengers.

6 A small (large) α indicates similar (different) products, i.e., a small (large) gain from using an airline.

7 Analogously, the utility of a passenger traveling with carrier 2 is $u_2 = y - p_2 - \frac{\gamma}{f_2} - \lambda\,(4f_1 + 4f_2) + b - a$, with $a < 0$ for passengers loyal to carrier 2 and $a > 0$ for passengers loyal to carrier 1.

8 As such, we assume that all seats are filled. In Fageda and Flores-Fillol (2012), the 100% load factor assumption is relaxed. This distinction is not needed for the purposes of this analysis and, in any case, high load factors are a prerequisite for profitability.

9 $\partial^2\pi_1/\partial p_1^2$ and $\partial^2\pi_1/\partial f_1^2 < 0$ are satisfied by inspection. The positivity condition on the Hessian determinant, which is assumed to hold, requires $p_1 - \tau > \frac{\gamma}{4f_1} - \frac{4\alpha\eta f_1^3}{\gamma}$, i.e., margins have to be sufficiently large.