Sequential Peak-Load Pricing in a Vertical Setting: the case of airports and airlines

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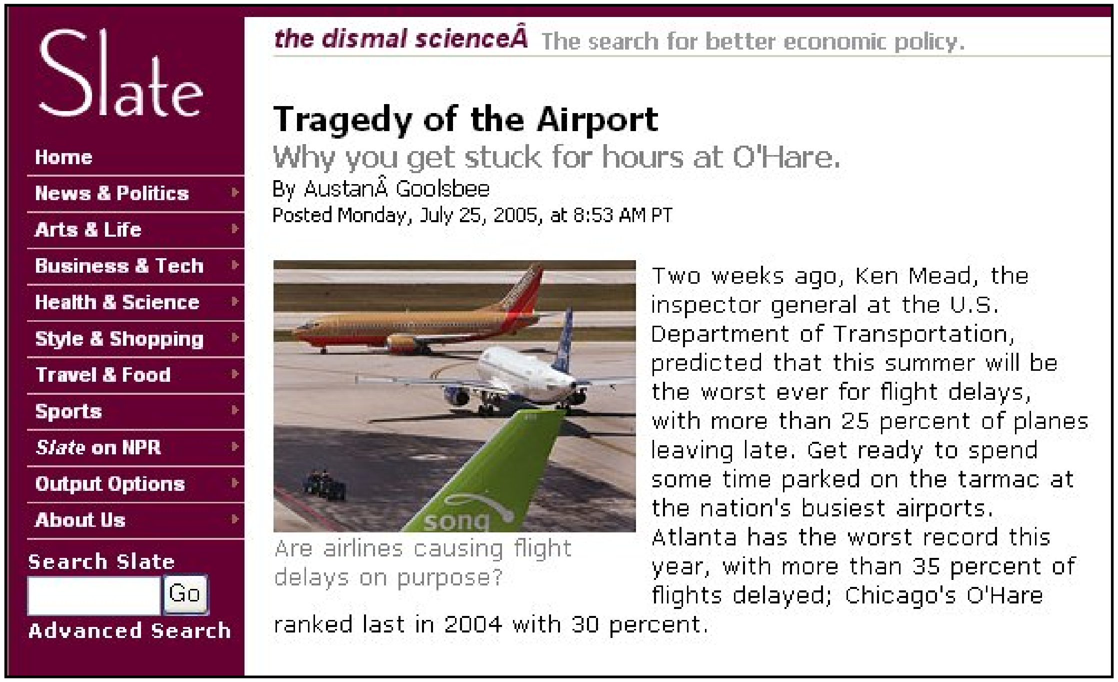
Introduction (1/5)

- The main driver of research on optimal airport pricing has been congestion problems at major airports (early papers: Levine, 1969; Carlin and Park, 1970; Walters, 1973).



the dismal scienceÂ The search for better economic policy.

Tragedy of the Airport

Why you get stuck for hours at O'Hare.

By AustanÂ Goolsbee

Posted Monday, July 25, 2005, at 8:53 AM PT

Are airlines causing flight delays on purpose?

Two weeks ago, Ken Mead, the inspector general at the U.S. Department of Transportation, predicted that this summer will be the worst ever for flight delays, with more than 25 percent of planes leaving late. Get ready to spend some time parked on the tarmac at the nation's busiest airports. Atlanta has the worst record this year, with more than 35 percent of flights delayed; Chicago's O'Hare ranked last in 2004 with 30 percent.

- For some time now economists have called for the use of the price mechanism
- Yet, congestion pricing schemes have not really been implemented

Introduction (2/5)

- Many authors have argued that privatized airports would use peak-load congestion pricing (Poole, 1990; Gillen, 1994; Vasigh and Haririan, 1996)
- Hence, privatization would lead to a better use of existing capacity
- **In this paper we**:
  - Analyze peak-load congestion pricing for a private and a public airport
  - Compare their price levels, prices structures, allocation of passengers to peak and off-peak periods, delays and total social welfare
  - Further, we analyze the case of a private airport that strategically collaborates with the airlines.

Introduction (3/5)

- Our model is a PLP model, in contrast to the majority of studies that are congestion pricing models (one period, no inter-temporal pricing):

  Morrison (1987), Zhang and Zhang (2003), Pels ad Verhoef (2004), Basso (2005)

- Major innovation: the vertical structure, which gives rise to **sequential PLP**
  - ➢ Airlines face periodic (and interdependent) demands, so they use PLP
  - ➢ This induce a different periodic demand to the airport ➔ the airport will also use PLP!!
  - ➢ Hence, final demand is fluctuating and PLP occurs, sequentially, at two levels.

Introduction (4/5) Related Literature

- **Classical papers on PLP**: Boiteaux (1949, 1960), Steiner (1957), Hirschleifer (1958), Williamson (1966)
- Focus on normative rules for pricing **public** utility’s non-storable service subject to periodic demand
- “New” papers: Panzar (1976), Craven (1971, 1985), Crew and Kleindorfer (1986,1991), Burness and Patrick (1991), Shy (2001)
- However, sequential PLP, be it for public or private utilities, has not yet been analyzed.

Introduction (5/5) Related Literature

- In telecom research:
  - Laffont and Tirole (2000) looked at PLP only at the upstream level (the network access charge)
  - Calzada (2003) considered PLP only at the downstream level
- In airport research
  - PLP primarily at the airport level
    - Morrison and Winston (1989), Arnott, De Palma and Lindsey (1993), Daniel (1995, 2001) [stochastic bottleneck]
  - PLP primarily at the airline level
    - Brueckner (2002, 2005)

Outline

1. Introduction and related literature
2. The model
3. Analysis of the airline market equilibrium
4. Analysis of the airport market: the influence of ownership on peak-load pricing, traffic, delays and welfare
5. Strategic collaboration between airlines and airport
6. Concluding remarks

The model (1/4)

- One congestible airport
- N homogenous air carriers
- Two periods, peak and off-peak (otherwise we have no paper)
- Three-stage game: look for sub-game perfect equilibria

1. Airport Choose P_h , $h \in \{p, o\}$
2. Airlines choose quantities for peak and off-peak
3. Consumers’ decisions

- Continuum of consumers, $\theta \in [\underline{\theta}, \overline{\theta}]$

The model (2/4)

- We consider a discrete choice model: the consumer has to choose between flying in the peak, flying in the off peak, or not flying.
- Periods are vertically differentiated: $B_p(\theta) > B_o(\theta) > B_n(\theta) = 0$
  - This is different than in Brueckner (2002, 2005)
- We assume that both the travel benefit and the conditional indirect utility function are linear. We obtain

$$\overline{V}_h(\theta) = \theta B_h - \alpha D_h - t_h$$

- Consumers will compare these functions to decide
- α is the value of time

The model (3/4)

- It can be proven that, for an interior allocation:

$$\underline{\theta} < \theta^{f} < \theta^{*} < \overline{\theta}$$

- Assumptions:

1. Fixed proportions: S = Aircraft Size × Load Factor, is constant
2. L_h, length of pricing periods, is fixed and exogenous
3. No intra-period demand fluctuation
4. L_o is long enough so that $D(Q_o) = 0$
5. The delay function fulfils $D_p^{'} = \frac{dD}{dQ_p} > 0, \qquad D_p^{''} = \frac{d^2D}{dQ_p^2} \geq 0$

- We these we get:

$$\theta^{*} = \overline{\theta} - Q_p S$$

$$\theta^{f} = \theta^{*} - Q_o S$$

The model (4/4)

- …and airlines' inverse demand functions for each period:

$$t_o(Q_o, Q_p) = B_o\bar{\theta} - B_o S Q_o - B_o S Q_p$$

$$t_p(Q_o, Q_p) = B_p\bar{\theta} - B_o S Q_o - B_p S Q_p - \alpha D(Q_p)$$

- Next, airlines cost functions:

$$c_A^i(Q_h^i, \mathbf{Q}_h^{-i}, P_h) = \sum_{h \in p,o} [c + P_h + \beta D(Q_h)] Q_h^i$$

- With all these, we obtain airlines profit functions, ϕ^i , so we have a well-defined game

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The airline market (1/5)

- Here we solve stage 2: airlines decide number of flights for peak and off-peak, taking airport prices as given.
- Solving the game, and imposing symmetry, we can (implicitly) obtain the **derived demands** for airport:

$$Q_p = Q_p(P_o, P_p; N), \qquad Q_o = Q_o(P_o, P_p; N)$$

- We would like to characterize these derived demands:

➔ Comparative statics

The airline market (2/5)

$$\frac{\partial Q_p}{\partial P_p} < 0, \qquad \frac{\partial Q_p}{\partial P_o} = -\frac{\partial Q_p}{\partial P_p} > 0,$$

$$\frac{\partial Q_o}{\partial P_p} = -\frac{\partial Q_p}{\partial P_p} = \frac{\partial Q_p}{\partial P_o} > 0, \qquad \frac{\partial Q_o}{\partial P_o} = -\frac{\partial Q_p}{\partial P_o} - \frac{N}{B_o S^2 (N+1)} < 0,$$

$$\frac{\partial (Q_o + Q_p)}{\partial P_p} = 0, \qquad \boxed{\frac{\partial (Q_o + Q_p)}{\partial P_o} = -\frac{N}{B_o S^2 (N+1)} < 0}$$

$$\frac{\partial Q_p}{\partial \Delta P_{p-o}} = \frac{\partial Q_p}{\partial P_p} < 0$$

Proposition 1:

- Airport demands are downward sloping in own price
- Peak and off-peak periods are gross substitutes
- For a given off-peak price, the peak price only influences the partition of total traffic: *the fare differential determines the allocation*
- The off-peak price determines the total amount of traffic

The airline market (3/5)

- **Proposition 2**: In the sub-game Cournot equilibrium,

  Peak traffic, off-peak traffic and total traffic increase with N

- Finally, we would like to compare peak and off-peak airfares

Fare <u>differential</u>: oligopoly

$$\Delta t_{p-o}\Big|_{\text{Cournot eq}} = \frac{P_p - P_o}{S} + \frac{\beta}{S} D(Q_p) + \frac{\beta}{S}\frac{Q_p}{N} D'(Q_p) + \alpha \frac{Q_p}{N} D'(Q_p) + Q_p \frac{(B_p - B_o)S}{N}$$

- If airport uses PLP, airlines do as well. But even if the airport does not use PLP, airlines will use it.
- A monopoly airline has the larger fare differential (total d( )/dn)
- Also, $dt_o / dN < 0$ ➔ the lower the *N* the higher the off-peak fare

The airline market (4/5)

Fare differential: SGE max social welfare $\left(CS + \sum_{i=1}^{N} \phi^{i}\right)$

$$\Delta t_{p-o}\Big|_{\substack{\text{efficient}\\ \text{output}}} = \frac{P_p - P_o}{S} + \frac{\beta}{S} D(Q_p) + \frac{\alpha S + \beta}{S} Q_p D'(Q_p)$$

- A monopoly has an airfare differential that is too large…
- …but, highly competitive markets have fare differentials that are too small

The airline market (5/5)

Fare differential: SGE cartel

$$\left(\sum_{i=1}^{N}\phi^{i}\right)$$

$$\Delta t_{p-o}\Big|_{\text{cartel output}} = \frac{P_p - P_o}{S} + \frac{\beta}{S} D(Q_p) + \frac{\alpha S + \beta}{S} Q_p D'(Q_p) + Q_p (B_p - B_o) S$$

- The fare differential of the oligopoly is insufficiently large from the point of view of the cartel
- This ‘*problem*’ worsens the more loose the oligopoly is (large *N*)

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The airport market (1/5)

- Here, we solve stage 1: Airport chooses prices for peak and off-peak, taking into account how airlines and consumers will react
- We first analyze two cases
  - Private Airport
  - Public Airport
- …then, comparisons between them: price levels, price structure, traffic levels and allocation, delay, social welfare

- We are in a perfect information world here
- No differences in efficiency

The airport market (2/5)

- **Private airport**

$$\max \quad \pi(P_o, P_p; N) = P_o Q_o + P_p Q_p - C \cdot (Q_o + Q_p) - rK$$

$$P_o^{\pi} = C + \frac{Q_o S^2 B_o (N+1)}{N} + \frac{Q_p S^2 B_o (N+1)}{N}$$

$$\Delta P_{p-o}^{\pi} = \frac{\alpha S + \beta}{N} Q_p \left[(N+1) D'(Q_p) + Q_p D''(Q_p) \right] + \frac{Q_p (B_p - B_o) S^2 (N+1)}{N}$$

Proposition 3:

- The private airport charges more than the uninternalized congestion of each carrier.
- The private airport uses PLP, in that $P_p > P_o$, for all values of *N*.
- Further, the off-peak price is above marginal cost

The airport market (3/5)

- **Public airport**

$$\max_{P_o, P_p, K} SW = \underbrace{P_o Q_o + P_p Q_p - C(Q_o + Q_p) - rK}_{\pi} + CS + \Phi$$

$$P_o^W = C - \frac{Q_o S^2 B_o}{N} - \frac{Q_p S^2 B_o}{N}$$

$$\Delta P_{p-o}^W = \frac{N-1}{N}(\alpha S + \beta) Q_p D'(Q_p) - \frac{Q_p S^2 (B_p - B_o)}{N}$$

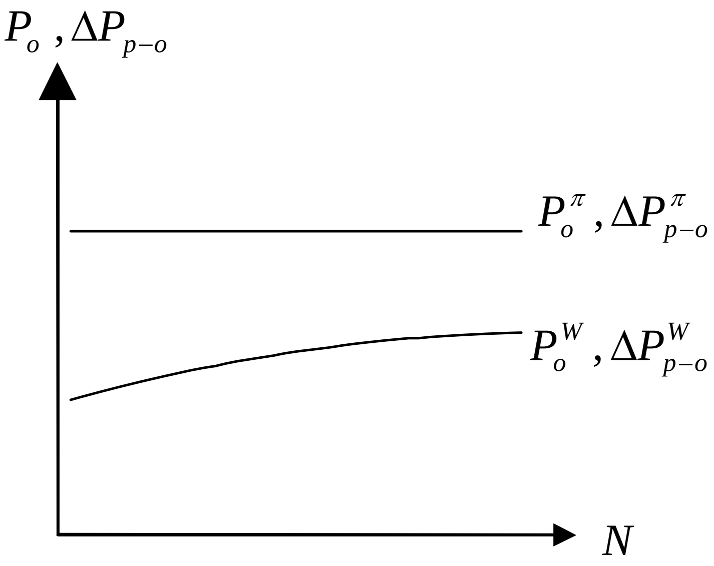
- Subsidy to induce right amount of total traffic
- Induces the right allocation to periods by choosing a price differential that will induce the optimal fare differential
- The airport price differential may be negative! Lower peak-price
- The peak airfare, however, will be always larger
- Looking only at the toll in the congested period is not first best!

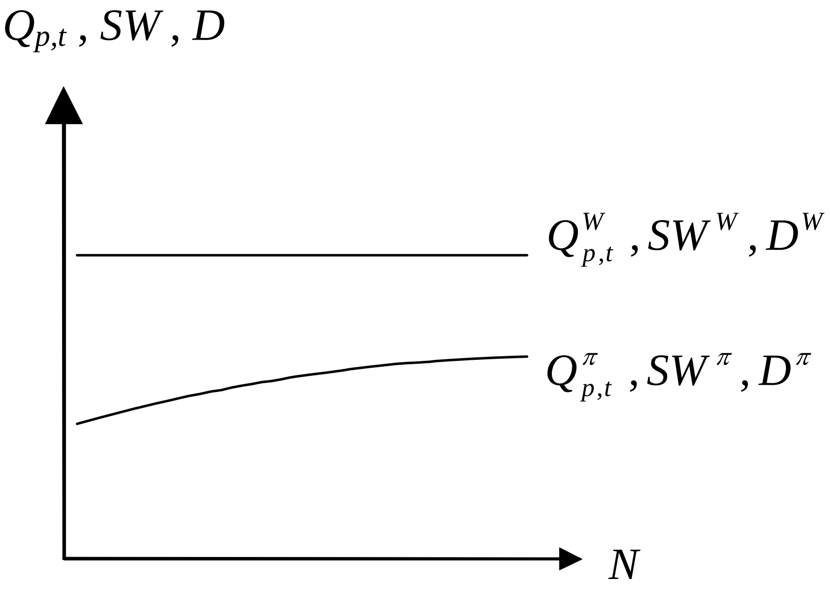
The airport market (4/5)

- **Proposition 5:** Comparisons between public and private ownership

(i) $P_o^W < P_o^\pi$ (iii) $Q_p^W > Q_p^\pi$ (v) $D_p^W > D_p^\pi$

(ii) $\Delta P_{p-o}^W < \Delta P_{p-o}^\pi$ (iv) $Q_t^W > Q_t^\pi$ (vi) $SW^W > SW^\pi$





The airport market (5/5)

- A simulation showed that:

$$SW^{\pi}(N=1)=49\% \qquad SW^{\pi}(N=3)=65\%$$

$$SW^{\pi}(N=5)=69\% \qquad SW^{\pi}(N=50)=77\%$$

- The N is important. Preferred N of the private airport?

$$\left|\frac{d\pi}{dN}\right|_{P_o^{\pi},P_p^{\pi}}=\left|\frac{\partial\pi}{\partial N}\right|_{P_o^{\pi},P_p^{\pi}}=\left(P_o^{\pi}-C\right)\frac{\partial Q_o}{\partial N}+\left(P_p^{\pi}-C\right)\frac{\partial Q_p}{\partial N}>0$$

- The private airport prefers a large N

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Strategic collaboration between airlines and airport (1/1)

- **Airport-Airline Joint Profit Maximization... Why?**

$$\max_{P_o, P_p, K} \pi + \Phi$$

$$P_o^{JP} = C + \frac{Q_o S^2 B_o (N-1)}{N} + \frac{Q_p S^2 B_o (N-1)}{N}$$

$$\Delta P_{p-o}^{JP} = \frac{N-1}{N} (\alpha S + \beta) Q_p D'(Q_p) + \frac{Q_p S^2 (B_p - B_o)(N-1)}{N}$$

- Sets P_o above marginal cost to induce a profit maximizing traffic contraction for airlines
- Induces the cartel allocation to periods by choosing a price differential that will induce the cartel fare differential
- ➔ Airline competition is destroyed
- When N =1 the airport does not use peak-load pricing
- Middle of the road case: $SW^{JP} = 78\%$

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Summary and Comments

- privatization would not induce efficient peak-load pricing schemes as it has been argued
    - private airport always has an incentive to use PLP
    - would induce insufficient total traffic and insufficient peak traffic
- Public airports may choose a peak price smaller than the off-peak price
    - However, this would be efficient
    - Passengers would pay higher peak airfares anyways
- Airports that collaborate with airlines are more efficient but still far off from the first best
    - Airline competition is destroyed
    - If monopoly airline, the airport will not use PLP
- This sequential PLP setting is relevant for many other transportation cases and industries (telecom in particular)

Thanks!

Questions?

The airline market (1/4)

- **Proposition A. 1**: Conditions that guarantee interior solutions (allocation)

(i) If $(P_p - P_o)/S < \bar{\theta}(B_p - B_o)$, then the peak period is used, that is $\theta^* < \bar{\theta}$.

(ii) If $\underline{\theta} B_o < (c + P_o)/S$, then some consumers will not fly, that is $\theta^f > \underline{\theta}$.

(iii) If $\bar{\theta}$ is large enough, then the off-peak period is used, that is $\theta^* > \theta^f$.

Calculation of consumer surplus

$$CS = \int_{\theta^*}^{\bar{\theta}} \left[\theta B_p - \alpha D(Q_p, K) - t_p(Q_p, Q_o)\right] f(\theta) d\theta + \int_{\theta^f}^{\theta^*} \left[\theta B_o - t_o(Q_p, Q_o)\right] f(\theta) d\theta$$

$$CS = \frac{(\bar{\theta} - \theta^*)(\bar{\theta} + \theta^*)}{2} B_p - (B_p \bar{\theta} - B_o S Q_o - B_p S Q_p)(\bar{\theta} - \theta^*)$$
$$+ \frac{(\theta^* - \theta^f)(\theta^* + \theta^f)}{2} B_o - (B_o \bar{\theta} - B_o S Q_o - B_o S Q_p)(\theta^* - \theta^f)$$

$$CS = \frac{S^2}{2}\left(B_o Q_o^2 + 2 B_o Q_o Q_p + B_p Q_p^2\right)$$