Airport Ownership: Effects on Pricing and Capacity

Leonardo Basso
University of British Columbia

March 2005
Revised: May 2006
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Leonardo J. Basso
Sauder School of Business – The University of British Columbia
basso@sauder.ubc.ca

March 2005
Revised: May 2006

Abstract

It has been argued in the literature that privatized airports would charge more efficient congestion prices and would be more responsive to market incentives for capacity expansions. Furthermore, the privatized airports would not need to be regulated since price elasticities are low, so allocative inefficiencies would be small, and collaboration between airlines and airports, or airlines countervailing power, would solve the problem of airports’ market power. This paper uses a model of vertical relations between airports and airlines to examine, both analytically and numerically, how ownership affects airports prices and capacities. Results show a rather unattractive picture for privatization when compared to first- and second-best public airports. We find that: (i) private airports would be too small in terms of both, traffic and capacity and, despite the fact that they may be less congested, they induce important deadweight losses; (ii) the arguments that airlines countervailing power or increased cooperation between airlines and airports may make regulation unnecessary are most likely overstated; and (iii) things may deteriorate further if privatization is done on an airport by airport basis rather than in a system. We also show that two features of air travel demand that have not been incorporated previously in the literature—demand differentiation and schedule delay cost—play important roles on airports’ preferences regarding the number of airlines using the airport. (JEL L93, H23, L50)

Keywords: Airport privatization, airport congestion pricing, vertical structure

Acknowledgments: I would like to thank Anming Zhang and Tom Ross for many insightful comments and encouragement. I also would like to thank Ralph Winter, David Gillen and seminar participants at The University of British Columbia and the Pan-American Advanced Studies Institute in Transportation Science. This research was partially funded by the Social Science and Humanities Research Council of Canada (SSHRC).
1. **Introduction**

In the last decades, some industry watchers, commentators and economists have argued in favor of the privatization of airports. They have given many reasons; among others, government revenues, financing aspects and private enterprise creativity and drive. On efficiency grounds, which is the focus of the present paper, it has been argued that private airports would charge more efficient congestion and peak-load prices and that they will respond to market incentives for capacity expansions (see e.g. Craig, 1996). These last points are important because, in the literature, congestion is often mentioned as the most important problem major airports face.

In 1987, the three airports in the London area and four other major airports in the UK were privatized. Following the example of the UK, many countries moved –or are moving– towards privatization of some of their public airports (among others, Austria, Denmark, New Zealand, Australia, Mexico and many Asian countries). Out of the concern that the privatized airports would exert market power –they would be local monopolies by having a captive market– most of the newly privatized airports have been subject to economic regulation, either in the form of price caps (as London Heathrow) or rate-of-return (as Flughafen Düsseldorf). Lately, however, many authors have argued that the regulation mechanisms fell short of being optimal; in particular, privatization has not been as successful as expected because the regulation mechanisms would misplace the incentives regarding capacity: price caps would lead to underinvestment while rate-of-return would lead to overinvestment in capacity.\(^1\) Moreover, some authors and government agencies have argued that *ex-ante* regulation could be unnecessary altogether so it should be either completely divested or replaced by *ex-post* price monitoring. Why? Some of the reasons that have been put forward are the following (see e.g. Beesley, 1999; Condie 2000; Forsyth, 1997, 2003; Starkie, 2000, 2001, 2005; Productivity Commission, Australia, 2002; Civil Aviation Authority UK, 2004): (i) airports have low price elasticity of demand so price levels will not have large implications for allocative efficiency; (ii) airlines have countervailing power that will put downward pressure on airport prices; (iii) alternatively, most of the problems would be solved if deeper collaboration between airlines and airports was allowed and encouraged; and (iv) demand complementarities between aviation and concession activities would induce the airport to charge below monopoly prices on the aeronautical side.

\(^1\) For a list of papers that discuss country-specific experiences with regulation see Oum et al. (2004).
(particularly when concession revenues are larger than airside revenues). In fact, the move towards divestment of regulation or the less-stringent price monitoring has already started in some countries (e.g. New Zealand and Australia).

However, as important as this may appear, there have been, to our knowledge, only two papers that have analytically examined what the outcomes of privatization or divestment of regulation may be (Zhang and Zhang, 2003; Oum et al., 2004). And, although there are many analytical papers that examine optimal pricing of public airports, most of the papers that do deal with privatization and divestment of regulation issues are fairly descriptive. Forsyth (2003) acknowledges this: “The shift to price monitoring has been a response to these problems [the problems with regulation], though the content and likely impact of monitoring has yet to be determined”. What this paper does, precisely, is to analyze the effects of airport ownership on prices and capacities using a formal model, since the suggested move towards private unregulated airports is fairly new and hence empirical analyses are not feasible. The idea is to make an analytical examination of some of the assertions that have been put forward in the literature regarding privatization and regulation of airports, and to gain insights about other issues that have yet been discussed.

What makes this paper different from the previous two is the way the airline market enters the picture. Zhang and Zhang (2003) and Oum et al. (2004) essentially abstract from it, assuming that an airport’s demand is a function of a full price –which includes airport charges and congestion costs–, and measuring consumer surplus through the integration of the airport’s demand. In this paper, we formally model the airline market as an oligopoly, which takes airport charges and capacities as given, recognizing that this is a vertical setting: airports provide an input –airport service–, which is necessary for the production of an output –movement– that is sold at a downstream market. Hence, the demand for airports services is a derived demand. Indeed vertical settings similar to the one considered here have been proposed before (Brueckner, 2002; Pels and Verhoef; 2004; Raffarin, 2004), but they have not been used to study issues other than optimal congestion pricing. Optimal capacity or the effects of privatization have not been analyzed (capacity has always been assumed to be fixed).
In this paper we look into private ownership and allow capacity to be a decision variable. We consider both system and individual privatization of airports, and the case of joint maximization of airports’ and airlines’ profits, comparing these cases against both the first-best benchmark and budget constrained public airports. Analytical and numerical results show a rather unattractive picture for privatization when compared to the first-best. First, the idea that low elasticities of demand for airports would induce small allocative inefficiency would be true only if the elasticity was constant, something rather improbable. Observed elasticities from public airports or regulated airports are not evidence that this would be the case in a private unregulated airport; monopolies price in the elastic range of the demand. What is obtained here is that important allocative inefficiencies may well arise. Besides, the low price elasticity argument overlooks the fact that private and socially optimal capacities will be different. When capacity becomes a decision variable of the airport—an idea that dominates the airport privatization and regulation literature—private airports would tend to be fairly small in terms of capacity, which further decreases traffic. Results worsen when privatization is done on an airport by airport basis rather than in a system because when airports are both origin and destinations of trips, their demands are perfect complements and therefore ‘competition’ between airports induces a horizontal double marginalization problem. On the other hand, the maximization of joint profits benchmark shows that the arguments regarding airlines countervailing power or an increased scope for cooperation between airlines and airports are probably overstated. The outcome does improve but still falls far off from the first-best. When privatization is compared against public airports that have a budget constraint, its performance depends on whether public airport are able to use two-part tariffs or not. If they are, the results are essentially unchanged. If they are not, the gap diminishes but remains large.

The airline oligopoly model we use expands on previous work in several ways: airlines’ demands are sensitive to schedule (frequency) delay cost in addition to flight delay caused by congestion at the airport, airlines services are not necessarily perfect substitutes, and the impact of the number of firms on airport demand (a proxy for market structure) is highlighted. Evidently, the idea is to better understand how these three aspects of the downstream market influence the performance of the airport market. It is shown that they have an important role on the incentives an airport has with respect to the dominance by a single airline.
The plan of the paper is as follows: Section 2 contains formal modeling of the downstream airline market. The derived demand for airports is obtained and characterized here. We analyze whether this derived demand carries enough information about the downstream market so that it would be possible to focus only on the airport market, abstracting from what happens downstream. Section 3 uses the results obtained in the previous section to analyze airport pricing, capacity and incentives under private and public ownership. Since most of these analyses rely on comparative statics, Section 4 provides numerical simulations that allow a better assessment of the differences. Section 5 concludes.2

2. The Airline Market

2.1 The airline oligopoly model

The oligopoly model presented here is used to obtain the derived demand for airports and to characterize it. We start by making two simplifying assumptions: First, we abstract from network and route structure decisions by having only two national airports. Second, we assume there is only demand for round trips, not for unidirectional trips.3 Having two airports enable comparisons between system and individual privatization later. The game we analyze is a three stage game: first, airports choose their capacities, $K_h$; second, they choose the charge per flight, $P_h$; finally, airlines choose their quantities. We look for sub-game perfect equilibria through backward induction, so we focus first, in this section, on the Nash equilibria of the airlines’ sub-game. We consider $N$ airlines with identical cost functions, facing differentiated demands in a non-address setting with fixed variety. Thus, differentiation is horizontal and $N$ is exogenous and represents the main airline industry structure indicator in the model. Each firm’s demand is dependent on the vector of full prices,4 $\theta$:  

$$q_i(\theta) = q_i(\theta_i, \theta_{-i})$$

$$\theta_i = t_i + G(\tau_i) + \alpha(D(Q, K_1) + D(Q, K_2))$$

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2 For space reasons, some proofs, derivations and results have been omitted. A supplementary appendix containing these omitted elements is available upon request from the author.

3 These assumptions are consistent with Pels and Verhoef (2004) and are, in fact, a generalization of Brueckner (2002) and Raffarin (2004), who consider a single airport. Zhang and Zhang (2003) and Oum et al. (2004), also consider an airport in isolation.

4 The use of full prices is a common feature of airline and transport economics papers. They are indeed used in the previous airport privatization papers but there they directly determine airport’s demand (e.g. Oum et al. 2004).
where \( q_i \) is the demand faced by airline \( i \), \( \theta_i \) is its full price, \( Q \) is the total number of flights of all airlines, \( t_i \) is the ticket price for the round trip, \( G(\tau_i) \) is schedule delay cost,\(^5\) \( \tau_i \) is the expected gap between passengers’ actual and desired departure time, \( D(Q,K_h) \) represents flight delay because of congestion at airport \( h \) and \( \alpha \) represents the passengers’ value of time. Note that \( \tau_i \) depends on the frequency chosen by airline \( i \); the higher the frequency, the smaller the gap. Thus, schedule delay cost can be written as \( g(Q_i) = G(\tau_i(Q_i)) \) where \( Q_i \) is the number of flights of airline \( i \), \( g'(Q_i) < 0 \) while \( g''(Q_i) \) has no evident sign a priori. The delay function considered is

\[
D^h(Q,K_h) = \frac{Q}{K_h(K_h - Q)}
\]

This convex function of \( Q \) was proposed by the US Federal Aviation Administration (1969) and is further discussed in Horonjeff and McKelvey (1983).\(^6\) \( D^h \) is the total delay of both take-off and landing at airport \( h \), which requires to assume that take-off and landing capacities are equal.

Assuming that demands are linear, symmetric and airlines’ outputs are substitutes:

\[
q_i(\theta) = a - b\theta_i + \sum_{j \neq i}^N e\theta_j
\]

where \( a, b \) and \( e \) are positive. Inverting the system and re-labeling we get

\[
\theta_i = A - B \cdot q_i - \sum_{j \neq i}^N E \cdot q_j
\]

where \( A, B \) and \( E \) are positive. As in Vives (1985), \( A, B \) and \( E \) are assumed to be fixed and \( B>E \), that is, outputs are imperfect substitutes. It is easy to verify that \( B>E \) is equivalent to \( b>(N-1)e \): if all full prices increase by the same amount, the demand for airline \( i \) will decrease (a condition

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\(^5\) Schedule delay cost represents the monetary value of the time between the passenger’s desired departure time and the actual departure time. It was first introduced by Douglas and Miller (1974) and there, it was the addition of two components: frequency delay cost and stochastic delay cost. The former is a cost induced by the fact that flights do not leave at a passengers’ request but have a schedule. Stochastic delay has to do with the probability that a passenger cannot board her desired flight because it was overbooked. Overbooking arises in the presence of stochastic demands, which is not the case here; hence our schedule delay cost corresponds only to frequency delay cost. For more on schedule delay cost, see also Small (1992).

\(^6\) This delay function has been used by Morrison (1987), Zhang and Zhang (1997) and Oum et al. (2004). Pels and Verhoef (2004) and Raffarin (2004) considered delay functions that were linear on the traffic level.
sometimes called *diagonal dominance*). We assume that airlines behave as Cournot oligopolists in that they choose quantities, an assumption that is backed by some empirical evidence (Brander and Zhang, 1990; Oum et al., 1993). In the absence of congestion and schedule delay cost – i.e. when \( \theta_i \equiv t_i \) – and with constant marginal cost, the game is well behaved in that a unique equilibrium exists. Furthermore, market power decreases with the number of firms (Vives, 1985). So, in principle, the model is useful to assess the importance of airline industry structure \( (N) \) on airport pricing.

Three more comments about the demand model are important. First, note that homogeneity in the Cournot competition, the usual case in airline oligopoly models\(^7\), is a special case of our model (it will suffice to replace \( E \) by \( B \) in the results). This enables an assessment of the importance of (horizontal) airline differentiation in airport decisions. Second, we incorporated the schedule delay cost, an important aspect of service quality which has sometimes been considered in pure airline oligopoly models but never in airport markets analysis.\(^8\) Finally, we chose to have \( N \) as an exogenous parameter because airports may have preferences regarding \( N \) that are different than the pure free entry equilibrium, and they may indeed have a sizeable influence in the number of active firms. Airports’ preferred \( N \) under different ownership and pricing schemes is analyzed in Section 3. In any case, the equations that define the free entry \( N \) are easy to identify.

Using (4) and (1), the following system of *inverse demands* faced by the airlines can be obtained:

\[
t^i = A - B \cdot q_i - \sum_{j \neq i}^N E \cdot q_j - g(Q_i) - \alpha(D(Q,K_i) + D(Q,K_j))
\]

This can be simplified though, by recognizing that \( q_i = Q_i \times \text{Aircraft Size} \times \text{Load Factor} \). Here, we assume that the product between aircraft size and load factor, denoted by \( S \), is constant and the same across carriers, making the vertical relation between airports and airlines of the fixed proportions type.\(^9\) Thus

\[
t^i(Q_i,Q_{-i}) = A - SBQ_i - \sum_{j \neq i}^N SEQ_j - g(Q_i) - \alpha(D(Q,K_i) + D(Q,K_j))
\]

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\(^7\) See e.g. Brueckner and Spiller (1991), Oum et al. (1995), Brueckner (2002), and Pels and Verhoef (2004).


\(^9\) This assumption was also made by Brueckner (2002) and Pels and Verhoef (2004). A variable proportions case arise if, before a change in airport charges, airlines decide to change \( S \) (aircraft size, load factor or both).
It can be noted that linear demands in full prices do not lead to *inverse demands* that are linear in output, as \( D \) is not linear and there is no reason to think that \( g \) is.\(^{10}\) In fact, we make now the following useful assumptions regarding schedule delay costs:

(a) The monetary cost of the gap between the actual and desired departure times, \( \tau \), is proportional to its length.

(b) \( \tau \) is inversely proportional to the frequency of flights.

Assumption (a) is similar to what has been already assumed regarding congestion delay costs; (b) is equivalent to say that \( \tau \) is directly proportional to the interval between flights (inverse of the frequency). Hence, under (a) and (b) we get \( g(Q_i) = G(\tau_i(Q_i)) = \gamma \cdot \tau_i(Q_i) = \gamma \cdot \eta \cdot Q_i^{-1} \), where \( \gamma \) is the constant monetary value of a minute of schedule delay and \( \eta \) is a constant.\(^{11}\) Thus, the residual inverse demand is negative and upward-sloping first; it then becomes positive, and then downward sloping, when the linear part of the function starts dominating schedule delay cost. Finally, for higher values of \( Q_i \), congestion starts to kick and \( \tau \) decrease faster than linearly. This particular feature of this demand system is not troublesome though: the main insight is that schedule delay cost put by itself, and regardless of other technological considerations such as a fixed cost, a limit to the number of firms that can be active in the industry: there is a minimum scale of entry. What it does imply is that perfect competition is not consistent with this model.

The final ingredient necessary before analyzing equilibria is costs. Airline costs are

\[
C_A(Q_i, Q_{-i}, P_h, K_h) = Q_i \left[ c + \sum_{h=1,2} (P_h + \beta D(Q, K_h)) \right]
\]

The term in square brackets is the cost per flight, which includes pure operating costs \( c \), airports charges \( P_1 \) and \( P_2 \), and congestion delay costs.\(^{12}\) Using the expression for delay in (2), it can be

\(^{10}\) Pels and Verhoef (2004) obtain linear inverse demands because they assumed a linear delay function and no schedule delay cost.

\(^{11}\) If passengers’ desired departure time is uniformly distributed along the day, then assumption (b) holds and \( \eta = 1/4 \). Note that we are assuming only one period here and not peak and off-peak periods: this is a model of congestion pricing and not peak-load pricing. If we were to assume more than one period (e.g. Zhang and Zhang, 1997), it would still be a reasonable assumption that, within each period, desired departure times are uniformly distributed. The results in this paper extend trivially to the case of many periods as long as demands in each period are independent of each other.

\(^{12}\) Note that here it is assumed that \( c \) does not depend on aircraft size or load factor, which may appear as a strong simplification. Given that \( Q_i \) is directly proportional to \( q_i \), this essentially says that the cost per passenger is fixed,
verified that marginal costs are strictly increasing and larger than average cost (except at $Q_i = 0$). Cost, marginal cost and average cost functions are strictly convex.

Airline $i$'s profits are obtained from (5), (6) and the fact that revenues are $t^i q_i = t^i Q_i S_i$. We get

$$
\phi^i(Q_i, Q_{-i}, P_h, K_h) = \left[ AS - BQ_i S^2 - \sum_{j \neq i} EQ_j S^2 - c - \sum_{h=1,2} P_h \right] Q_i - S Q_i g(Q_i) \\
- (\alpha S + \beta) \sum_{h=1,2} Q_i D(Q, K_h)
$$

(7)

2.2 Equilibrium in the airline market: derived demand for airports and its characteristics

To obtain the derived demand for airports, we need to find the equilibrium of the airline market. Using (7), it can be shown that under assumptions (a) and (b) there exists a unique, interior and symmetric Cournot-Nash equilibrium of the sub-game, as long as $N$ is smaller than the free-entry number of firms which should always hold. Thus, $\partial \phi^i / \partial Q_i = 0$ gives us the unique and symmetric Cournot-Nash equilibrium of the game. Calculating this and imposing symmetry, we obtain the following important equation

$$
\Omega(Q, P_h, K_h, N) = (\alpha S + \beta) \sum_{h=1,2} \left( D_h^i(Q, K_h) + \frac{Q}{N} D_Q^i(Q, K_h) \right) + S \left( g(O) + \frac{Q}{N} g'(\frac{Q}{N}) \right) \\
+ S^2 (2B + (N-1)E) \frac{Q}{N} + c + \sum_{h=1,2} P_h - AS = 0
$$

(8)

Equation (8) implicitly defines a function $Q(P_h, K_h; N)$, which is airports’ demand as a function of airport charges, capacities and airline market structure, $N$ (the implicit function theorem holds). Two observations are worthy to be made: first, under assumptions (a) and (b), something that has been assumed elsewhere (e.g. Brander and Zhang, 1990, Pels and Verhoef, 2004). Alternatively, one could assume that a single aircraft size and load factor prevail, as in Brueckner (2002). Also, the cost function should depend on a vector $w$ of other input prices. That dependence could be modeled through $c(w)$. Since it is assumed that input prices other than airport charges remain constant throughout, vector $w$ will be suppressed for notational simplicity.

13 As for Cournot (or tatonnement) stability, a sufficient condition is that the best reply mapping is a contraction. In homogenous Cournot, it is known that this condition holds for $N$ small. Here, while differentiation $(E<B)$ gives some latitude, congestion works in the opposite direction. In fact, the contraction condition was checked in the numerical application of Section 4 and results indeed show that it holds only for $N=2$. 

8
\(g(x) + xg'(x) = 0\) and the second term would be zero. Second, one can define, without loss of generality, \(P = P_1 + P_2\); if airports were to be priced jointly then an explicit expression of the airports’ inverse demand \(P(Q, K_h; N)\) is obtainable.

We now characterize the demand for airports. We are interested first in learning how airports’ demand changes with \(P_h, K_h\) and \(N\) or, alternatively, how the inverse demand \(P(Q, K_h; N)\) changes with \(Q, K_h\) and \(N\). Consider first changes of \(Q\) with \(N\). If assumptions (a) and (b) hold,

\[
\frac{dQ}{dN} = -\frac{\Omega_N}{\Omega_Q} = \frac{Q}{N} \left( \frac{(\alpha S + \beta) \sum D_Q^h + S^2 (2B - E)}{(\alpha S + \beta) \sum D_Q^h + S^2 (2B - E) + \sum (ND_Q^h + QD_{QQ}^h) + S^2 EN} \right)
\] (9)

It can be checked that \(dQ/dN > 0\), \(d^2Q/dN^2 < 0\) and \(dQ^i/dN < 0\) \(\forall E \in (0, B]\), so total flights increase with \(N\) at a decreasing rate, while each firm’s number of flights decrease. In the absence of congestion, when \(E \to 0\), \(Q^i\) becomes independent of \(N\): each firm has its own turf. With congestion, \(Q^i\) decreases even when substitutability is very low (\(E \to 0\)) because the congestion externality causes marginal costs to increase. Note that, in this section, this and any other examination of changes with respect to \(N\) are valid in the sub-game only: \(P\) and \(K\) are fixed and not functions of \(N\) yet as they will be in the equilibrium of the full dynamic game. All other derivatives are obtained in a similar fashion as above. In summary

\[
\begin{align*}
\frac{\partial P}{\partial Q} &< 0, & \frac{\partial P}{\partial N} > 0, & \frac{\partial^2 P}{\partial Q \partial N} > 0, & \frac{\partial^2 P}{\partial Q^2} < 0, & \frac{\partial Q}{\partial N} > 0, \\
\frac{\partial Q}{\partial P_h} &< 0, & \frac{\partial Q}{\partial K_h} > 0, & \frac{\partial^2 Q}{\partial P_h^2} < 0, & \frac{\partial^2 Q}{\partial P_h \partial K_h} > 0 \\
\frac{\partial P}{\partial K_h} &> 0, & \frac{\partial^2 P}{\partial Q \partial K_h} > 0, & \frac{\partial^2 P}{\partial K_h^2} < 0, & \frac{\partial^2 P}{\partial K_h \partial K_2} = 0, & \frac{\partial^2 P}{\partial K_h \partial N} < 0
\end{align*}
\] (10)

Results in the first two rows of (10) require assumptions (a) and (b) regarding schedule delay cost, while those in the third row do not.\(^{14}\)

\(^{14}\) Regarding how market power (air tickets) change with \(N\), the result by Vives (1985) that \(d^t/dN < 0\) when \(E \in (0, B]\) is the normal case here, but the opposite case may also arise. The intuition is: when \(N\) increases, prices tend
Having characterized the shape of the demand function, we can now compute the surpluses (in sub-game equilibrium) of airlines and passengers. Passenger surplus is given by

\[ PS = \int_{\theta(P,K,N)} \sum_{i} q_i(\theta) d\theta \]. Since \( \partial q_i / \partial \theta_j = \partial q_j / \partial \theta_i \), the line integral has a solution that is path independent (\( PS \) is equal to both Hicksian measures). Using a linear integration path, straightforward calculations lead to

\[ PS(P_h, K_h, N) = (B + (N - 1)E)S^2Q(P_h, K_h, N)^2 / 2N \] (11)

The aggregate (equilibrium) profit for carriers, \( \Phi \), is easily obtainable from an individual carrier’s profit (7) and the imposition of symmetry, that is, \( Q_i = Q(P, K_h, N) / N \). We obtain:

\[ \Phi(P, K_h, N) = QS\left[ A - \frac{QS}{N} (B + (N - 1)E) - g\left( \frac{Q}{N} \right) - \alpha \sum D(Q, K_h) \right] - \left[ c + P + \beta \sum D(Q, K_h) \right] \] (12)

We can now look at how much information about the downstream market is captured by the derived demand for airports. This is important because of the following: the airline market model was useful to derive and characterize the demand for airports (equations 8 and 10). It would be simple if we could directly use this demand function to fully analyze the airports markets, because this function may be estimated only with airport level information. In the private airports case, we will indeed use this demand function to setup the maximization of profits problem. Things are less obvious with the maximization of social welfare case, though. What is needed is a measure of consumer surplus. But as it is clear from this vertical setting, consumers of airports are both final consumers (passengers) and airlines. What we need then is a measure of the sum of
to go down because of two effects: \( Q \) increase, so substitutability will put downward pressure on prices, and demands shift inwards because of increased congestion. Marginal costs of each firm go up though, because of congestion, which makes \( Q \) decrease, putting upward pressure on prices. When \( E \) is close to zero and if \( B \) is large enough (i.e. substitutability is weak), the first effect is not important, while the third effect may dominate the second, resulting in prices that actually increase with \( N \) (this is confirmed by numerical simulations). With no externalities and no substitutability, a change in \( N \) does not affect a firm’s marginal cost or demand: \( N \) does not affect prices.

It can be checked that, when there is no congestion, \( dCS / dN > 0 \quad \forall \ E \in (0, B] \). But, as with \( \ell \), when there is congestion and substitutability is small, the opposite case may occur. However, the somewhat strange case \( dCS / dN < 0 \) is not necessarily tied to increasing prices because, as \( N \) increase, not only quantities and prices changes but demands shift as well due to increased congestion. Thus, although prices may be smaller (larger), the area under the demand curves may have decreased (increased).
passenger surplus and airlines profits. What has been assumed in previous papers about privatization, where the airline market is not formally incorporated (Zhang and Zhang, 1997; Oum et al. 2004), is that the airport demand does carry enough information so that its integration gives consumer surplus. We investigate now under which conditions this is true.

In Zhang and Zhang (1997) and Oum et al. (2004), the demand for the airport, $Q$, is assumed to be dependent on a full price $\rho$, which includes flight delay costs and the airport charge. They argue that, under perfect competition, the airport charge would be passed entirely to consumers. Using the notation of this paper, the demand for the airport would be $Q \equiv Q(\rho)$, where:

$$\rho = \sum_{h=1,2} P_h + (\alpha S + \beta) \sum_{h=1,2} D^h(Q, K_h) \equiv P + (\alpha S + \beta) \sum_{h} D^h$$  \hspace{1cm} (13)

Indeed, $Q(\rho)$ defines a fixed-point rather than a closed form demand. Other charges to passengers, such as the flight ticket, are assumed to be exogenous as far as the airport is concerned. However, when one considers the full vertical structure and the associated subgame equilibrium, $Q^i(P_h, K_h; N) = Q(P_h, K_h; N)/N$, both delays (equation (2)) and ticket prices (equation (5)) will directly depend on airport charges and capacities, which are the decision variables of the airports. So, the first question is, is it reasonable to use the full price idea at the airport, rather than at the airline market? A clearer picture can be obtained by looking at equation (8). Using (13) to form $\rho$, and abstracting from schedule delay cost effects (i.e., making $g=0$), so that we can take $N \to \infty$, (8) can be written as:

$$QS^2 \left( \frac{2B}{N} + \frac{(N-1)}{N} E \right) + \rho + c - AS + (\alpha S + \beta) \frac{Q}{N} \sum_{h} D^h = 0$$  \hspace{1cm} (14)

Hence, in general, $Q$ would not depend only on $\rho$ but also on $D_Q$ and $N$; the (implicit) demand for airports should be $Q \equiv Q(\rho, D_Q, N)$. However, in the perfect competition case, that is when $N \to \infty$, (14) leads to $Q(N \to \infty) = \frac{AS - c - \rho}{S^2 E}$, which implies that $Q(\rho, D_Q, N \to \infty) \equiv Q(\rho)$. Thus, under perfect competition, a full price as defined by $\rho$, can in fact be used directly at the airport market level. It does summarize well the equilibrium of the downstream market.
Next, what has been (implicitly) assumed previously is that the integration of the airport demand with respect to the full price would capture the consumer surplus. Let us study this, using the general (implicit) demand function \( Q = Q(\rho, D_Q, N) \). We are thus interested in unveiling how

\[
\int_\rho^\infty Q(\rho, D_Q, N) \, d\rho
\]  

(15)

is related to airlines profits and passenger surplus. For this consider the aggregate (equilibrium) profit for carriers, \( \Phi \), in equation (12). Regrouping terms to form \( \rho \), and assuming away schedule delay effects, we obtain that:

\[
\Phi(Q, \rho) = QS \left[ A - \frac{Qs}{N} \left( B + (N - 1)E \right) \right] - Q[e + \rho]
\]  

(16)

Consider now the total derivative of \( \Phi \) with respect to \( \rho \). Using (16) the following results

\[
\frac{d\Phi}{d\rho} = -Q(\rho, D_Q, N) - \frac{(N - 1)ES^2Q}{N} \frac{\partial Q}{\partial \rho} - (\alpha S + \beta) \frac{Q}{N} \sum_h D_Q^h \frac{\partial Q}{\partial \rho}
\]  

(17)

Reordering, integrating from \( \rho \) to \( \infty \), and using equation (14) we finally get\(^{16}\)

\[
\int_\rho^\infty Q(\rho, D_Q, N) \, d\rho = \Phi + PS - \frac{BS^2Q^2}{2N} - \frac{1}{N} (\alpha S + \beta) \int_\rho^\infty \sum_h D_Q^h \, d\rho
\]  

(18)

From equation (18) it is obviously clear that integration of the airports demand with respect to the full price, will deliver a correct measure of consumer surplus if and only if the airline market is perfectly competitive \((N \to \infty)\), which was in fact the maintained assumption of Zhang and Zhang (2003) and Oum et al. (2004). Hence, we have provided theoretical support for their modeling. When the airline market is imperfectly competitive though, the integral of \( Q \) with respect to \( \rho \), does not capture airlines profits plus passenger surplus because market power

\(^{16}\) Here, we used the fact that \( Q(\rho = \infty, D_Q, N) = 0 \) and therefore \( \Phi(\rho = \infty, D_Q, N) = 0 \).
induces losses of consumer surplus and partial internalization of congestion (third and fourth terms in equation 18 respectively).\textsuperscript{17}

The main conclusion of the previous analysis is that to fully analyze airport markets, one cannot abstract from the airline market if competition is imperfect there. Formal modeling is required to adequately set up the social welfare maximization problem. The simplest way to do this is by considering directly the three actors involved, although one could also add the missing terms to the integral of airport’s demand. At the practice level, the conclusion is bad news for managers of public airports or airport regulation authorities: even in a setting of complete information, optimal pricing and capacity require detailed knowledge about the market structure and demand of the airline market; information on costs and demand for airports alone is not enough. This unquestionably complicates the problem. Thus, fully modeling the vertical setting stands as a more correct way to study airport markets in general and the effects of airport ownership on prices and capacities in particular. The latter, which would have been new in any case, has now a stronger \textit{raison d’être}.

3. **The Airports Market**

3.1 \textit{General Features}

In this Section, we look at the first two stages of the game –airports’ capacities and prices– taking as known the equilibrium in the third stage. We compare prices and capacities of private airports against first-best ‘public’ airports that maximize social welfare, but later address the problem of budget adequacy of public airports. We assume that both public and private airports impose per-flight charges, although this may not be a reflection of actual practice. The point is that we would like to shed light on what are the differences induced by ownership and not by failure to implement the right policies.\textsuperscript{18} It is further assumed that both type of airports have the

\textsuperscript{17} Jacobsen (1979) and Quirmbach (1984) are the classic references on the relation between input market surplus and the downstream market. Basso (2005) synthesize and generalize their results. Among other things, he shows that, in a case like this, the integral of the input demand with respect to $P$ –as opposed to $\rho$– would never adequately capture downstream firms’ profits plus final consumer surplus, not even under perfect competition.

\textsuperscript{18} Many airports actually have weight-based charges, but this has been starkly criticized on efficiency grounds by economists for at least three decades (e.g. Carlin and Park, 1970). And while in public airports efficient prices – which we show are not simply marginal cost– have certainly not been the norm (see discussions in Morrison, 1987, and Borenstein, 1992), private airports have not really moved to congestion pricing either (Forsyth, 2003; Starkie, 2005). Per-flight charges have been assumed in every analytical airport pricing paper we are aware of.
same cost structure, despite arguments by some authors that public airports would not be as cost efficient as private ones (e.g. Condie, 2000). This assumption however, has some empirical support: Oum et al. (2004) found no significant differences between private and public airports in productivity terms. Overall, the idea is to understand the differences in a stylized benchmark model, leaving for future research the analysis of whether the alleged inefficiencies of public airports, if unsolvable, are important enough to make differences small.

As explained in the introduction, it has been argued that concession revenues would put downward pressure on airside charges of private airports, making regulation less needed (Condie, 2000; Starkie, 2001; Forsyth, 2003). We do not consider concession revenues here though, first, because probably the demand for concession services is not a Marshallian demand but a derived one, just as in the aeronautical side. Hence, when analyzing the public case, we would need to device a way to adequately consider the surpluses of all actors involved: profits of the companies that run the concessions and final consumers. Modeling and incorporating this would increase the complexity of the model while obscuring the insights we look for. The second reason to abstract from the concession revenues issue is that the outcome of incorporating them is probably known. Zhang and Zhang (2003) find that, while airside private prices diminish as expected, they decrease less than prices in a public airport that also has concessions. The intuition is simple: a private airport cares only about the profits from the concession activities while a public airport, maximizing social welfare, cares about consumer surplus as well. Consequently, the decrease in prices is stronger in the public case: concession revenues actually increase the gap between private and public airside charges. And while Zhang and Zhang modeled this without considering the vertical feature of the problem, it is very likely that their insight goes through. We see the confirmation of this, though, as future work.

3.2 System of Private Airports

We examine first the decisions of a System of Private Airports (SPA): pricing and capacity decisions at both airports are made by a single entity which maximizes profits. This is truly a monopoly situation quite comparable to the analysis of an airport in isolation (the most common case in the airport pricing literature). \( Q(P_h, K_h, N) \) represents the demand for both airports as a function of prices, capacities and the (exogenously given) number of airlines. Decision variables
are \( Q, P \) (which is the sum of \( P_1 \) and \( P_2 \)), \( K_1 \) and \( K_2 \), but \( Q \) and \( P \) are related through the demand function. We use \( P \) and \( K_h \) as decision variables – i.e. we use the inverse demand function \( P(Q, K_h; N) \) – but obviously results do not vary if we choose otherwise. In this setup, the three-stage game is identical to a two-stage game where \( Q \) and \( K_h \) are chosen simultaneously. As it is usual in the literature, it is assumed that an airport costs are given by \( C(Q) + rK \), where, \( C \) are operating costs and the second term capital costs. The problem the SPA faces is given by

\[
\max_{Q, K_1, K_2} \pi(Q, K_h; N) = P(Q, K_h; N)Q - 2C(Q) - (K_1 + K_2)r
\]

where \( \pi \) is the sum of profits of both airports. First-order conditions lead to the following pricing and capacity rules:

\[
P = 2C + \frac{P}{\varepsilon_p} \tag{20}
\]

\[
Q \frac{\partial P}{\partial K_h} = r, \quad h = 1, 2 \tag{21}
\]

where \( \varepsilon_p \) is the (positive) price elasticity of airports’ demand. As for second-order conditions, it cannot be proved that they hold globally but simulation show that they do hold for a large range of parameter values, particularly for the numerical applications in section 4. A necessary condition though, is that \( C \) is not too concave.\(^{19}\) It is also easy to prove that at the optimum, \( K_1 = K_2 = K \). Equation (20) is the familiar market failure in which monopolies set price above marginal cost. Equation (21) shows that private airports increase capacity until the marginal revenue of doing so equals the marginal cost of providing that extra capacity (recall that it was found that the marginal value of capacity, \( \frac{\partial P}{\partial K_h} \), is positive). The monopoly system of airports only cares about the last or marginal consumer: increasing capacity by \( \Delta K \) allow the airport to charge an extra \( \Delta P \), without loosing the marginal consumer (recall that a consumer lost for the airport is equivalent to a change in the equilibrium quantity in the downstream market). The extra charge however can be passed to all inframarginal consumers. What is important to note is that the

\(^{19}\) Evidence suggests that airports’ operational economies of scale are exhausted at fairly small amounts of traffic (e.g. Doganis, 1992).
marginal revenue perceived by the airport is not necessarily a measure of the social benefit of an increase in capacity (Spence, 1975).

Interesting as well, is to see how optimal $Q$, $P$ and $K_h$ change with $N$. Unfortunately, comparative statics are not definitive: derivatives cannot be signed a priori so we will need to wait until the numerical simulation to have a better idea (the same goes for final outcomes in the airline market of course). What it is easy to show, however, is that as $N$ increases, profits increases. To see this, simply differentiate profits evaluated at optimal $Q$ and $K$ with respect to $N$ and apply the envelope theorem:

$$d\pi/dN = \pi_QQ_{SPA} + \sum\pi_{K_h}K_{SPA} + \pi_N = \pi_N = Q_{SPA}P_N > 0.$$ 

### 3.3 System of Public Airports

Consider now a system of public airports that maximizes social welfare. This case will be denoted by $W$. According to the discussion in Section 2, with imperfect competition in the airline market, the social welfare ($SW$) function is not simply the integral of airports’ demand plus airports’ profits. The correct $SW$ function can be obtained by directly adding passenger surplus (11), total airlines profits in the sub-game equilibrium (12)–, and airports profits: $SW = PS + \Phi + \pi$, that is,

$$\max_{Q,K_1,K_2} SW(Q,K_1;N) = P(Q,K_1;N)Q - 2C(Q) - (K_1 + K_2)\gamma + \frac{(B + (N-1)E)S^2Q^2}{2N}$$

$$+ QS\left[ A - \frac{QS}{N}(B + (N-1)E) - g\left(\frac{Q}{N}\right) - \alpha \sum D^h \right] - Q[c + P + \beta \sum D^h]$$

First-order conditions lead to

$$P = 2C^* + \frac{(N-1)}{N}(\alpha S + \beta)\sum_h D_h^h - \frac{BS^2Q}{N}$$

$$- Q(\alpha S + \beta)\frac{\partial D(Q,K_h)}{\partial K_h} = r, \quad h = 1,2$$

Again, second-order conditions do not hold globally but do in the numerical simulation, at the optimum $K_1 = K_2 = K$, and results do not change if $P$ and $K_h$ were taken as the decision variables.
As advanced, we do not impose a budget constraint here, so budget adequacy is not ensured. The discussion about this issue is delayed for Section 3.5.

The public airports’ total charge has three components: marginal cost, a charge that increases price and is equal to the uninternalized congestion of each carrier, and a term that decreases price, which countervails airlines’ market power. In fact, this system of public airports’ manage to induce the outcome of social welfare maximization in the airline market: if one directly maximizes social welfare in the airline market, the equation that describe the final (symmetric) outcome is, precisely, $\Omega(Q, P, K_h, N) + ((N - 1) / N)(\alpha S + \beta)Q\sum_b D^b_Q - BS^2 Q / N = 0$. As can be seen, whether the final charge will be above or below marginal cost depends on whether the congestion effect or the market power effect dominates. For the monopoly airline case, congestion is perfectly internalized and the airports charge will be below marginal cost (and probably below zero). The third term in fact amounts to subsidize firms with market power in order to increase social welfare by diminishing allocative inefficiency. The implicit assumption is, evidently, that there is no other mechanism in place to control this market power. Note that if $K$ is fixed, the market power effect decreases as $N$ grows while the congestion effect increases. When $K$ is not fixed, this is expectable but not clear cut, because $K$ will change with $N$ as well. In fact, the signs of $dQ^w / dN$, $dK^w / dN$ and $dP^w / dN$ cannot be determined a priori.

The congestion term was first found by Brueckner (2002). Pels and Verhoef (2004) later pointed out that the market power term was also needed (Brueckner acknowledged this, though, by stating that if market power was strong, the pure congestion charge may actually be harmful). There are some differences between Pels and Verhoef’s result and the result here, however: (i) in Pels and Verhoef’s model (and in Brueckner’s), a regulator would charge a toll equal to the second and third terms in (23). Here, it is the public airport that distorts marginal cost pricing by an amount equal to that toll; (ii) they only considered a duopoly in a homogenous Cournot setting while here there are $N$ firms in a differentiated Cournot setting; (iii) they assumed a delay function that was linear in traffic while here it is not; (iv) they assumed a fixed capacity while here capacity is not fixed. Hence, it can be seen that their main insight regarding price expands to a more general case.
As for capacity, public airports will add capacity until the costs of doing so equate the benefits in saved delays to passengers and airlines. Clearly, this capacity decision is different from the decision (a system of) private airports make, as they care about extra revenues and not extra social benefits (Spence, 1975, provided this insight). This result differs from what was obtained by Oum et al. (2004) as they found that private and public airports followed the same capacity rule, and hence it was concluded that private airports set capacity levels efficiently for the traffic they induced through pricing. The divergence is caused by the fact that their set-up only holds for a perfectly competitive airline market, as discussed in Section 2.3. In effect, if one replace in the private airport capacity rule, (21), the marginal value of capacity by its full expression, i.e.

\[
\frac{\partial P}{\partial K_h} = -(\alpha S + \beta)\left(\frac{Q}{N}D_{hK}^h + D_K^h\right),
\]

one can see that, if \(N \rightarrow \infty\), then the capacity rules (21) and (24) do coincide.

How does social welfare change with \(N\)? Differentiating \(SW\) evaluated at optimal \(Q\) and \(K\) with respect to \(N\), and applying the envelope theorem we get:

\[
\frac{dSW}{dN} = \frac{\partial SW}{\partial dN} = \frac{(B - E)S^2Q^2}{2N^2} + Sg\left(\frac{Q}{N}\right)\frac{Q^2}{N^2}.
\]

The first term on the right hand side is non-negative while the second is negative. It can be seen that when differentiation is weak, (25) may be negative implying that it would be better, in a social welfare sense, to have one airline. This may appear surprising but the explanation is simple: with both market power and the congestion externality controlled, as it is the case here, a monopoly airline provides a higher frequency than each airline in oligopoly, thus diminishing schedule delay cost, which increases demand. When differentiation is strong, (25) would probably become positive. In that case, the expansion of demand generated by a new firm will overweight the increased schedule delay cost due to reduced frequencies. The notable thing is that, in this model, with ‘enough homogeneity’ a monopoly airline is optimal but there is no need to regulate it: the public airports system would subsidize the airline to induce the optimal quantity (but there is still the issue of budget adequacy). These results were not obtainable in Pels and Verhoef’s model because they only considered a homogenous duopoly and no schedule
delay cost. Brueckner did considered $N$ firms, but (25) would have always been zero in his case because his model featured homogeneity and no schedule delay cost.

We compare now the system of private airports and the system of public airports. Regarding price, we know the SPA price will be above marginal cost; the W price may be above or below marginal cost depending on whether the congestion effect or the market power effect dominates. May it happen that private airports charge less than public airports, actually inducing more traffic? The problem is that comparisons are complex because quantity (prices) and capacities are chosen simultaneously. A way to make comparisons feasible is to assume first fixed capacity.

**Proposition 1**: For a given $K$, the system of private airports will induce fewer flights than the system of public airports or, equivalently, it will charge a higher price.

*Proof*: See the appendix.

Proposition 1 indicates that it will never happen that the congestion effect leads to public airports that have smaller traffic than private airports; allocative inefficiency will always be in the form of restricted output. As explained in Section 1, it has been argued that this inefficiency would not be too important because the price elasticity of airports’ demand is low. So, even if the price increases importantly, the actual quantity would not decrease as much. This assertion cannot be confirmed or negated with proposition 1, but something can be said even at this point: observed price elasticities are not necessarily good forecasts of the value the price elasticity will attain under other circumstances. The contention would be true only if the price elasticity of airports demand is constant, something rather unlikely. For example, the efficient pricing rule in (23) has probably not been implemented in any airport, so we can hardly know what price elasticity value it would induce. More importantly, monopolies price in the elastic range of the demand. Thus, while it may be true that the price elasticity is low under the current pricing system (say, pure marginal cost, which as seen is *not* the efficient price), the system of private airports would price so to get into the elastic range of the demand, something that may indeed induce important allocative inefficiency. This issue will be further discussed under the light of the numerical simulation.
The reasoning regarding the price elasticity and the allocative inefficiency, also fails to take into account that a private airport would choose a different capacity than a public airport would. How can capacity decisions be compared? Various cases can be distinguished. First, quantity and capacity are defined simultaneously in a system of equations. We could therefore compare actual capacities and quantities. A more interesting question is, what distortions, if any, arise on the capacity side when the (well known) monopoly pricing distortion is taken into account. How would the SPA capacity compare to constrained social welfare maximization where monopoly pricing is taken as given? Is the distortion in capacity a mere byproduct of monopoly pricing? To analyze these two cases, we first examine the transposed of proposition 1, i.e. what happens with $K$ when $Q$ is given (e.g. the airline market is frequency regulated). In these analyzes, the reader will find strong similarities with Spence (1975) examination of the provision of quality by a monopolist. Indeed, under the current modeling, $K$ can be seen as a measure of quality. Spence’s proposition 1 states that, if $\frac{\partial^2 P}{\partial Q \partial K} > 0$, then a monopoly would oversupply capacity. However, Spence’s insights –although pervasive– do not apply here directly even though we are in a case in which the above derivative is indeed positive (see 10). The problem is that in this case, the firm that has to choose quality provides an input to a downstream oligopoly and not a final product. Moreover, in the downstream (final) market, there are externalities in both production and consumption. Hence, a new proof is required.20

**Proposition 2:** For a given $Q$, the system of private (SPA) airports will oversupply capacity with respect to the system of public airports (W).

*Proof:* See the appendix.

As for actual capacities and quantities, from proposition 2 it is clear that, if for a given capacity the output restriction of the system of private airports is not too important, i.e. $Q^{SPA}(K) \approx Q^{W}(K)$ (these denote quantity rules for given $K$), then private airports’ capacities

20 Something else that is worth noting is what is required to obtain the positive sign of the cross derivative of $P$. According to Spence, one way such a result may arise is consumers’ heterogeneity; they would differ in their marginal willingness to pay for quality. A positive sign for the derivative shows that the marginal willingness to pay for quality of the marginal consumer is higher than for the average consumer. Here, however, things are different; both passengers and airlines are identical—they all care in the same way about congestion and therefore about capacity—, but the marginal consumer is not defined directly by differences in willingness to pay but by an equilibrium in the downstream market.
will be higher than the W ones. If the output restriction is severe, \( Q^{SPA}(K) \ll Q^W(K) \), then the result is reversed. The low price elasticity reasoning then is also important here because it has a counterpart in terms of capacity.

To analyze optimal social welfare capacities under monopoly pricing, consider the following constrained \( SW \) function, \( \tilde{SW}(K) \equiv SW(Q^{SPA}(K)) \), and maximize it with respect to \( K \) (recall that \( K_1=K_2=K \)). How does the second constrained social welfare capacity, \( \tilde{K}^W \), compare to \( K^{SPA} \)?

Differentiating and evaluating at \( K^{SPA} \) we get

\[
\frac{d\tilde{SW}}{dK}\Bigg|_{K^{SPA}} = \frac{\partial SW}{\partial Q}\Bigg|_{Q^{SPA}(K^{SPA}),K^{SPA}} \cdot \frac{\partial Q^{SPA}(K)}{\partial K}\Bigg|_{K^{SPA}} + \frac{\partial SW}{\partial K}\Bigg|_{Q^{SPA}(K^{SPA}),K^{SPA}}
\]

(26)

We are interested on the sign of (26). If it is positive, then constrained social welfare capacities are larger than the SPA ones. The first derivative on the right hand side is always positive by proposition 1; the second one also is. The third derivative can be rewritten as

\[
\frac{\partial SW}{\partial K}\Big|_{Q^{SPA}(K^{SPA}),K^{SPA}} - \frac{\partial Q^{SPA}}{\partial K}\Big|_{K^{SPA}} = \frac{\partial Q^{SPA}}{\partial K}\Big|_{K^{SPA}} + \frac{\partial SW}{\partial K}\Big|_{Q^{SPA}(K^{SPA}),K^{SPA}}
\]

showing that it is negative by virtue of proposition 2. Therefore, the sign of (26) is not determined a priori: we cannot say whether \( \tilde{K}^W \) is below or above \( K^{SPA} \). However, if \( Q^{SPA}(K) \approx Q^W(K) \), then \( K^{SPA} > \tilde{K}^W \) because the first derivative on the right hand side of (26) would be close to zero by first-order condition in the (unrestricted) max \( SW \) case, and (26) would be negative (of course, we would also have \( K_h^{SPA} > K_h^W \)). So, if it was true that private airports induce small allocative inefficiencies, this would mean that private capacities would be too large, even in a second best sense. If \( Q^{SPA}(K) \ll Q^W(K) \), then the positive terms in (26) are more likely to dominate the negative one, and \( \tilde{K}^W \) may be above \( K^{SPA} \): if the system of private airports restrict output severely, and therefore has smaller capacities, the public airports, when forced to price as the private system, would increase its capacity departing from \( K^{SPA} \), as this directly benefits the other two parties, airlines and passengers. Overall, we can only say that, probably, the monopoly

\[21\] We have that \( \partial Q^{SPA}(K) / \partial K = -\pi_{QK} / \pi_{QQ} \), but \( \pi_{QK} = P_{QK} Q + P_k > 0 \) (see equation 10) and \( \pi_{QQ} < 0 \).
of private airports does induce distortions in capacity, which are in addition to pricing distortions. But whether this distortion is under or overinvestment can be unveiled only through numerical simulation, which is done in Section 4.

3.4 **Maximization of Joint Profits: Airlines and Airports**

There are at least two reasons why it is interesting to look at this case. First, it has been argued that regulation may be unnecessary—in that airport charges may be kept down and capacity investments may be more efficient—if, on one hand, airlines were allowed to have a stake at the airport or if deeper collaboration between airlines and airports was allowed and encouraged, or, on the other hand, if airlines had enough countervailing power (Beesley, 1999; Condie 2000; Forsyth, 1997, 2003; Starkie, 2000, 2001, 2005; Productivity Commission, 2002; Civil Aviation Authority UK, 2004). The maximization of joint profits emerge then as an obvious way to analyze these assertions. It would be the best that can be achieved if collaboration was allowed, while countervailing power would have an effect only on the division of profits. There might be a myriad of implementation problems though, as recognized in the literature (e.g. Condie, 2000; Starkie, 2005). We do not intend to model these problems here but, instead, to use the maximization of joint profits as a benchmark. If the outcome of the benchmark is deemed acceptable, then it can be later discussed how actual implementation would deviate from it.\(^2\) A second reason why it is interesting to look at the maximization of joint profits is because through a simple pricing scheme—two part tariffs—, that outcome is obtained in a non-cooperative fashion. With two-part tariffs, airports not only charge a per-flight price but they also charge a fixed-fee to each airline. Airlines then compete as in section 2 but with this fee added to the cost function, which does not affect their quantity decisions but only whether they operate or not. The outcome is exactly that of maximization of the sum of profits: the system of private airports tries to maximize profits of the chain and then captures airlines’ profits through the fixed fee. This is well-known in the vertical control literature and is somewhat surprising that almost no author has mentioned it (the only exception we are aware of is Borenstein, 1992). The difference with the usual setting is that here the upstream company has a quality (capacity) that matters.

\(^2\) For a discussion about potential strategic coalitions between airlines and airports, see Albers et al. (2005).
This case is denoted JP, for joint profits. Using airlines’ aggregate profit in (12), we set up the problem as:

\[
\max_{Q,K_1,K_2} \pi + \Phi = P(Q,K_h;N)Q - 2C(Q) - (K_1 + K_2)r \\
+ QS \left[ A - \frac{QS}{N} (B + (N-1)E) - g\left(\frac{Q}{N}\right) - \sum_h D_h^h \right] - Qc + P + \beta \sum D_h^h
\]

(27)

First-order conditions yield

\[
P = 2C' + \frac{(N-1)}{N} (\alpha S + \beta)Q \sum_h D_h^h + \frac{(N-1)ES^2Q}{N} - Q(\alpha S + \beta) \frac{\partial D(Q,K_h)}{\partial K_h} = r, \quad h = 1,2
\]

(28)

(29)

Again, second-order conditions do not hold globally and \(K_1=K_2=K\) at the optimum. The price charged by the system of private airports—the variable part in the case of a two-part tariff—, has three components, each one related to a different externality. First, it has marginal cost to avoid the vertical double marginalization problem—a vertical externality to the vertical structure—, which arises in the SPA case. Second, it adds a charge equal to the uninternalized congestion cost of each carrier, a horizontal externality. Third, it adds a term to fight the business-stealing effect, a horizontal externality typical of oligopoly: firms do not take into account profits lost by competitors when expanding their output. The first two components are on line with maximization of social welfare while the third moves in the opposite direction; it destroys competition downstream instead of attacking airlines’ market power. The final outcome is indeed that of cooperation between competitors in the airline market.

This result, which has not been obtained in the airport pricing literature before, has different intuitions depending on why the maximization of joint profits was the relevant case. With two-part tariffs, the private airports use the variable price to destroy competition downstream in order to maximize the profits of airlines, which are later captured through the fixed fee. The process is known: the fixed fee allows the marginal price to act only as an aligner of incentives, relieving it from the duty of transferring surplus as well. When the max joint profits case arises because of collaboration between airlines and airports, what happens is that airlines would like to collude in
order to increase profits, but fail to do so because of the incentives to defect on any possible agreement. What they manage to do here, however, is to ‘capture’ an input provider to run the cartel for them. By increasing the price of the input, the input provider induces the collusion level of output. Here, the price increase takes into account both, the congestion externality and the business-stealing effect. Note that with \( N=1 \), there is no business-stealing effect and congestion is perfectly internalized by the monopolist; consequently, the last two terms vanish. Also, if airlines were completely differentiated, i.e. \( E=0 \), there would not exist the business-stealing effect but congestion would still need to be internalized. The upstream firm is rewarded with part of the profits, which is where bargaining power enters the picture.\(^{23}\) Now, despite the fact that the result is as if airlines collude, this is not necessarily worse for social welfare than a system of private airports charging linear prices as in SPA because, here, two other harmful externalities are dealt with, the vertical double marginalization and the congestion externality. The final outcome is indeed closer to the public case as shown below. As for capacity decisions, it can be seen that the rule is the same as in the public case. This happens because this is the capacity that maximizes downstream profits as well (for a given \( Q \)).

The signs of \( dQ^{jp}/dN \) and \( dK^{jp}/dN \) cannot be determined a priori but we can know how, in equilibrium, joint profits change with \( N \). For this, differentiate \( \pi + \Phi \), evaluated at optimal \( Q \) and \( K \), with respect to \( N \) and apply the envelope theorem:

\[
\frac{d(\pi + \Phi)}{dN} = \frac{(B - E)S^2}{N^2} + Sg(\frac{Q}{N})\frac{Q^2}{N^2} \tag{30}
\]

The analysis is similar to the social welfare case. When substitutability is weak, (30) may be negative so joint profits would be maximized with a monopoly airline: airports would have an incentive to let a single airline dominate. This may be facilitated if airlines and airports are encouraged to collaborate, as the airports may try to deal with only one airline and, together,

\(^{23}\) This idea of an upstream firm running the cartel for the downstream firms has been discussed in the vertical control literature and, particularly, in the input joint-venture case. For example, Shapiro and Willig (1990) conjecture that input joint-ventures can facilitate collusion and push a market toward the monopoly outcome. Chen and Ross (2003) formalize this. If airport provision was seen as an input joint-venture by the airlines, our results show two things in addition to what Chen and Ross found. First, that if there are externalities, the input price is, additionally, used to force their internalization by downstream competitors. Second, that when marginal costs are not constant downstream, the outcome is not as in monopoly or a downstream merger, but as in a cartel.
foreclose entry to other airlines. In the two-part tariff case, the airport would extract all the profits of the monopoly airline through the fixed fee. What is remarkable is that for the SPA case, the larger the \( N \) the better, irrespective of the degree of substitutability. This was Borenstein’s (1992, p.68) insight: he was critic about privatization of airports because, among other things, “without competition from other airports, an operator’s profits would probably be maximized by permitting dominance of the airport by a single carrier and then extracting the carrier’s rents with high facility fees”. His comment is supported by these results but, in this model, airport domination by a single airline is not necessarily harmful. Social welfare may actually increase because, for \( N>1 \), it is still true that the congestion externality is internalized and that there is no competition, as with monopoly. But a monopoly will offer a frequency even higher than the frequency offered by each airline in the coordinated case, reducing schedule delay cost.

When airports are relatively indifferent between \( N=1 \) or higher, the implementation problems mentioned before may play a role. In the case of collaboration between airport and airlines, it may be easier for the airports to coordinate actions with only one airline, but it may be also true that this could increase the airline’s countervailing power. With two-part tariffs, however, airports may still prefer to let a single airline dominate even if (30) is slightly positive because the pricing rule becomes simpler: (i) airports do not need to estimate the second and third terms of the pricing rule (something indeed difficult); (ii) they would need to worry about assessing the right fixed fee for only one firm. This shows that recognizing the scope for vertical control in airport pricing is important. Two-part tariff is the simplest form of vertical control and even this pricing mechanism has important and rather unexplored consequences on the airline market.

We can now turn to comparisons. They are summarized through the following propositions:

**Proposition 3**: For a given \( K \) the JP airports will: (i) induce fewer flights than the W ones (ii) Induce more flights than the SPA ones

*Proof*: Part (i) is direct because \( P^{JP} (K) > P^W (K) \) and \( \partial Q / \partial P < 0 \). The proof of (ii) is analogous to the proof of proposition 1 (in the appendix).
Thus, for a given capacity, JP airports induce a smaller allocative inefficiency than SPA airports, showing that the proposal of increased collaboration is an improvement. How strong this allocative inefficiency would be cannot be unveiled until a parameterization is chosen; however, it can be easily pictured that it may not be small since in this case competition downstream is absent while in the public case, market power downstream is controlled.

**Proposition 4**: For a given $Q$, the JP airports will: (i) have the same capacity as W airports (ii) Have less capacity than SPA airports.

*Proof*: (i) is direct as they have the same capacity rule. (ii) follows from proposition 2 and (i). □

**Proposition 5**: As for actual capacities and quantities, JP airports will induce fewer flights and will have smaller capacities than W airports.

This result is evident given the previous propositions and the proof is straightforward so it is omitted. As before, whether actual JP capacities are below or above SPA capacities will depend on whether the output restriction of SPA airports, with respect to JP, is severe or not.

Next, it has been argued before that a capacity rule such as the one JP airports follow would be efficient because it is identical to the public one so, for a given $Q$, capacity will be set efficiently (Oum et al. 2004). The question we ask now is different: do JP airports induce distortions in capacity that go beyond what is induced only by pricing? To analyze this we look for constrained optimal capacities, by maximizing social welfare subject to the restriction of JP pricing. It can be shown that (the proof is similar to the case of W and SPA so it is omitted).

**Proposition 6**: The JP airports undersupply capacity with respect to optimal social welfare capacities under JP pricing (despite having the same capacity rule).

3.5  *On the budget adequacy of public airports*

The comparison between private and first-best public airports is very useful as a benchmark, yet budget adequacy of public airports is evidently important for policy making. The issue of budget adequacy was explicitly considered by Zhang and Zhang (1997) and Oum et al. (2004), but in
models that only looked at the airport market, with social welfare functions that are valid only if the airline market is perfectly competitive. On the other hand, in the airport pricing literature that takes into account the vertical relation between airports and airlines, airports profits are usually not considered in the social welfare function; only passengers’ surplus and airlines profits are included. For example, Brueckner (2002) and Pels and Verhoef (2004) were interested in the toll that some airport authority has to charge to make efficient use of installed capacity, so whether revenues would cover costs or not was not examined.

As is evident from the analysis of first-best practice in Section 3.3, when \( N \) is small it is very likely that public airports would run a deficit because, in this case, it would be optimal for airports to subsidize the airlines (the market power effect dominates the congestion effect). Pels and Verhoef argued that when subsidies are optimal but unfeasible, it would be optimal to set the toll to zero, which in this model is equivalent to airports charging marginal cost. However, the analysis of the joint maximization of airports’ and airlines’ profits in the previous Section contained an important lesson: budget adequacy of public airports may be achievable through a fixed fee. Since lump-sum transfers will not affect airlines’ marginal decisions, the airports may use the efficient pricing and capacity rules –which may include actually paying airlines to land–, and then collect the money necessary to cover their expenses through a monthly facility fee. This would be a sort of Loeb-Magat mechanism, which has also been suggested for the access problem to telecommunications networks (Laffont and Tirole, 2000). Yet, as appealing as the mechanism may be, there is still no guarantee that two-part tariffs would enable cost recovery, because airlines may not make enough money to actually cover the airports’ expenses. To be sure that this would be the case, the restriction \( \pi \geq \Phi \geq 0 \) would need to be included. The cost recovery two-part tariff pricing and capacity rules, case that we denote by CRT, are easy to obtain. The capacity rule would be the same as in W and the JP cases (equations 24 and 29), while the pricing rule is:

\[
P^{\text{CRT}} = \frac{\mu}{1 + \mu} p_w + \frac{1}{1 + \mu} p^w
\]

\[
= 2C' + \frac{(N - 1)}{N} (\alpha S + \beta) \sum_h D_h^k + \frac{S^2 Q (\mu(N - 1)E - \mu B)}{(1 + \mu)N}
\]

(31)
Where $\mu \geq 0$ is the Lagrange multiplier of the restriction, which captures the severity of the constraint. Here, $\mu$ balances the charge between the efficient first-best price and the JP price, enabling the airlines to make enough money to cover the airport costs through the fixed fee.

But, what if two-part tariffs are unfeasible? Note that setting the toll to zero, that is charging marginal cost, would not be enough to cover airports costs even if the marginal cost function is flat, because the airport has to pay for the capacity (see Zhang and Zhang, 1997). In this case, the less efficient alternative of Ramsey-Boiteaux pricing is called for. Formally, to ensure cost recovery using a linear price, the restriction that has to be considered is $\pi \geq 0$. This case, which we denote by CRL, is characterized by the following pricing and capacity rules:

$$
P^{CRL} = 2C^+ \frac{\lambda}{1 + \lambda} P^{SPA} + \frac{1}{1 + \lambda} P^w
$$

$$
= 2C^+ \frac{\lambda}{1 + \lambda} \frac{P}{\varepsilon_P} + \frac{1}{1 + \lambda} \left( \frac{(N - 1)}{N} (\alpha S + \beta) Q \sum_h D^h_0 - \frac{BS^2 Q}{N} \right)
$$

$$
= \frac{Q(\alpha S + \beta)}{1 + \lambda} \frac{\partial D(Q, K_h)}{\partial K_h} + \frac{\lambda}{1 + \lambda} Q \frac{\partial P}{\partial K_h} = r, \quad h = 1, 2
$$

Where $\lambda \geq 0$ is the Lagrange multiplier of the restriction and, obviously, $\lambda \geq \mu$.

3.6 Independent Private Airports

So far, there has been no apparent need to have two airports in the model. We have them because in many cases the idea is to privatize airports independently and not in a system, and we would like to know what the outcome of this may be. However, there are some aspects here that were not present before and that need to be defined. First, do airports choose prices or quantities? This made no difference before but now it does. Given that airports’ direct demands are $Q^1(P_1, P_2, K_1, K_2) = Q^2(P_1, P_2, K_1, K_2) = Q(P_1 + P_2, K_1, K_2)$, we take prices as tactical variables, so airports behave as Bertrand oligopolists with complement products. Second, are capacities and prices chosen simultaneously or sequentially, $K_h$ first and then $P_h$? The first case is usually called open-loop, the second closed-loop. In the closed-loop, the overall game has three stages as originally defined; in the open loop it has two. Let us look first at linear prices in the open-loop.
case. We denote this case IPA, for independent private airports. Airports choose $P_h$ and $K_h$ simultaneously in a non-cooperative game. Each airport’s program is

$$\max_{P_h, K_h} \pi^h = Q_h(P_1, P_2, K_1, K_2)P_h - C(Q_h) - K_h r, \quad h = 1, 2$$  \hspace{1cm} (34)$$

A necessary condition for existence of equilibria is that $C$ is not too concave, something that has been assumed throughout. If this is the case, it can be shown that prices are strategic substitutes. We look for symmetric equilibrium. Interest lies on the sum of airport charges, $P$, rather than individual charges. First-order conditions and imposition of symmetry leads to

$$P = 2C + 2 \frac{P}{\varepsilon_P} \hspace{1cm} (35)$$

$$Q \frac{\partial P}{\partial K_h} = r, \quad h = 1, 2$$  \hspace{1cm} (36)$$

(35) is to be compared with the SPA case in (20); clearly $P_{IPA} > P_{SPA}$. This was expected: it is the result of the horizontal double marginalization problem that arises in oligopoly when outputs are complements. In these cases, competition is harmful for social welfare. Capacity rules are the same but obviously actual capacities will be different. Hence, independent private airports induce fewer flights and have smaller capacities than a system of private airports. From propositions 1 to 4, we have that:

- For given $K$, $Q^W(K) > Q^{JP}(K) > Q^{SPA}(K) > Q^{IPA}(K)$.
- For given $Q$, we will have that, $K^{JP}(Q) = K^W(Q) < K^{SPA}(Q) = K^{IPA}(Q)$.
- For actual capacities and prices, $Q^W > Q^{TPT}$, $Q^{SPA} > Q^{IPA}$, $K^{JP} < K^W$ and $K^{IPA} < K^{SPA}$.

In the closed-loop game, where airports first choose capacities (simultaneously) and then prices, airports over-invest in capacity par rapport to the open loop. Qualitatively (a full derivation is in the appendix), what happens is that, in the three stage game, investment in capacity makes an airport tough: it leads to an own price increase, which hurts the other airport. Since in addition prices are strategic substitutes, increasing capacity increases own profits. Using the terminology of Fudenberg and Tirole (1984), airports over-invest in capacity following top-dog strategies. This leads to higher prices than in the open loop, but the overall effect on traffic is unclear.
What if the independent private airports collaborate with the airlines? In this case, the relevant problem is each airport maximizing its profit plus the profits of airlines, given that the other airport is doing the same. The outcome of this is the same as if airports, individually, charge two part tariffs (in an open-loop setting). We denote this case IJP. Solving the game, we get the following pricing and capacity rules

\[
P = 2C + 2 \frac{(N-1)}{N} (\alpha S + \beta) Q \left( \sum_h D_Q^h + 2 (N-1) \frac{ES^2 Q}{N} \right) + \frac{Q(\alpha S + \beta) \frac{\partial D(Q, K_h)}{\partial K_h}}{h = 1,2}
\]

Jointly, individual airports using two part tariffs or collaborating with airlines charge more than a system of private airports using a two-part tariff or collaborating with airlines (except when \(N=1\)). The horizontal double marginalization also arises here: each airport tries to correct externalities on their own and, as a result, they jointly overcharge for congestion and the business stealing effect. Capacity rules on the other hand are as in JP, therefore comparisons between this case and the JP case is analogous to the comparison between JP and W. Finally, whether there is over or under-investment in the close-loop cases cannot be determined analytically.

4. Numerical Simulations

The need for numerical simulations arises from three facts. First, since the move towards unregulated private airports is only a proposed move, which has not been implemented at a large scale, there is no real data to conduct an empirical analysis. Second, in this model, comparative statics and analytical comparisons were not conclusive in all cases. For example, it was not possible to know how \(Q, K\) and \(P\) change with \(N\), or how SPA actual capacities and prices compare to W ones. And third, even when analytical results were obtainable, they were necessarily qualitative. For example, JP capacities and prices are below W ones, but by how much? We resort to simulation to shed light on these types of questions. We use the parameter values in table 1.
Table 1: Parameter values for the numerical simulation

<table>
<thead>
<tr>
<th>Demand</th>
<th>Airlines</th>
<th>Airports</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>40 A</td>
<td>2000 S</td>
</tr>
<tr>
<td>$\beta$</td>
<td>3000 B</td>
<td>0.15 N</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>4 E</td>
<td>0.13 c</td>
</tr>
</tbody>
</table>

For the schedule delay cost, it is assumed that (a) and (b) in section 2 hold, so that the schedule delay cost function is only defined by $\gamma$ and $\eta$; we impose $\eta$ equal to one.\(^\text{24}\) We consider a constant airport operational marginal cost, implying that economies of scale (if any) arise from the presence of fixed costs. We do not define a value for these so that airports’ profits below are net of the fixed costs. It is not our intention to portray real aviation cases with these parameters but, rather, to obtain insights about what are the consequences of different ownership and pricing schemes; in fact, a two airports system is rarely the usual case. We did try, however, to be as reasonable as possible with the parameterization, by drawing data and values from other studies.\(^\text{25}\) Relative comparisons between results are probably more enlightening that the individual results by themselves, although previous results in the literature (discussed below) confirm the plausibility of the parameterization.

Table 2 summarizes some of the results obtained. It has both, variable-capacity and fixed-capacity cases; the latter, in order to better see whether the argument that says that allocative inefficiency would be small with privatization holds or not. When capacity is fixed, it was set at

\(^\text{24}\) As explained in footnote 11, if passengers’ desired departure time is uniformly distributed along the day, then assumption (b) holds and $\eta=1/4$. We chose a larger $\eta$ because we wanted to capture the fact that, in some cases, passengers cannot take the scheduled flight they would like to since they are already sold out. Taking $\eta=1/4$ or $\eta=1$ though, will analytically only affect the value of the air ticket $t$, not $P$, $Q$ or $K$.

\(^\text{25}\) The values of some of the parameter may be justified as follows: For $\alpha$, Morrison and Winston (1989, p. 90) empirically found a value of $\$45.55$ an hour in 1988 dollars; for $\gamma$, they found a value of $\$2.98$ an hour in 1983 dollars (p. 66). For $\beta$, Morrison (1987, p. 51 footnote 20), finds that the hourly extra cost for an aircraft due to delays is approximately $\$1,700$ (resulting from $3,484 - 18*100$) in 1980 dollars. For $S$, recall that it reflects the product between aircraft size and load factor. In North America, the average plane size in 2000 was 159 (see Swan 2002, table 2); considering in addition an average load factor of 65% (see Oum and Yu, 1997, p.33) we obtain a value for $S$ of 103.35. Regarding airlines’ operational per flight cost $c$, Brander and Zhang (1990) proposed the following formula for the marginal cost per passenger in a direct connection: $cpm(D/AFL)^{\theta} D$; where $cpm$ is the cost per passenger-mile, $D$ is the origin-destination distance, $AFL$ is the average flight length of the airline and $\theta$ is the cost sensitivity to distance. The following were the average values for American and United Airlines in the period 1981-1988 (see Oum et al., 1993): $cpm=\$0.12/pax/mile$, $AFL=775$ miles and $\theta=-0.43$. If we use $AFL=800$, $cpm=\$0.20$ and $D=1000$ (e.g. Chicago-Austin), and multiply the result by 2S to reflect the operational cost of a return flight, we obtain a value for $c$ of $\$36,340$. 

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the socially optimal level but choosing it otherwise does not change the qualitative conclusions. When airports are independent (IPA and IJP cases), results are for open-loop games. Social welfare is presented in terms of percentages rather than dollars. Second order conditions hold in all cases. As reading directly from table 2 is a rather difficult task, we highlight below what we deem are the main insights gained from the numerical simulation.

1. In the system of private airports (SPA) case, both $Q$ and $K$ increases with $N$; delays also increase. Airports charges, $P$, almost do not change, leading to a $t$ that decreases with $N$ because of increased competition downstream. Airports profits increase with $N$ as analytically showed, but social welfare also does. $P$ is fairly large in all cases and way above marginal cost. This, however, is on line with a previous result: Morrison and Winston (1989) found that the difference between the monopoly and the efficient per-passenger landing fee was $498.4. Multiplying this by $S=100$ lead to a difference of $49,840$ dollars per flight. Since they did not formally considered the airline market, their results are valid for perfect competition in the airline market. In our case, the difference between SPA and W when $N=10$ is $43,505$ per landing (recall that $P$ is the sum of charges at both airports), which is comparable to theirs.26

2. For public airports (W), $Q$ and $K$ increase with $N$ but delays decrease, as opposed to the SPA case. $P$ increases with $N$: as $N$ grows, the congestion effect starts dominating the market power effect. When $N=1$, congestion is perfectly internalized by the airline without the need for correction from the part of the airports, and market power is at its ceiling; the need for subsidy is hence at its maximum, as is evident from the negative and large value of $P$. The charge increases with $N$ and for $N$ large enough subsidies are no longer required. Subsidies required when $N$ is small may appear large but are consistent with Pels and Verhoef (2004) results.27 It can also be seen that $SW$ increases with $N$: differentiation dominates the schedule delay cost effect in equation (25). When homogeneity is increased (not shown), the result reverses as explained. Finally, air tickets decrease marginally with $N$, due to increased schedule delay costs because of depressed frequencies.

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26 This, despite the fact that they used a different delay function (theirs was estimated and homogenous of degree one on $Q$ and $K$), and that their airport’s demand was actually estimated.

27 In the monopoly airline case, they obtained a toll (congestion plus market power components in the pricing rule 21) which was negative and equal to $340,000, and an air ticket of $1,393. Here, the subsidy equals $130,263 (marginal cost was deducted to obtain their toll) and the air ticket is $608.14.
<table>
<thead>
<tr>
<th>N</th>
<th>Type</th>
<th>Q</th>
<th>K</th>
<th>P</th>
<th>D</th>
<th>t</th>
<th>PS</th>
<th>Φ</th>
<th>π</th>
<th>π + Φ</th>
<th>SW</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPA</td>
<td>21.92</td>
<td>31.21</td>
<td>93,629</td>
<td>0.076</td>
<td>1,665</td>
<td>360,368</td>
<td>798,224</td>
<td>1,340,397</td>
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</tr>
<tr>
<td>W</td>
<td>92.18</td>
<td>100.18</td>
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<td>0.115</td>
<td>608</td>
<td>6,372,189</td>
<td>14,599,332</td>
<td>-14,748,019</td>
<td>-148,686</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>JP</td>
<td>45.85</td>
<td>51.48</td>
<td>4,000</td>
<td>0.158</td>
<td>1,300</td>
<td>1,576,519</td>
<td>4,080,700</td>
<td>-1,029,579</td>
<td>3,051,121</td>
<td>74.36</td>
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</tr>
<tr>
<td>1</td>
<td>CRL</td>
<td>42.92</td>
<td>53.71</td>
<td>29,024</td>
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<td>1,350</td>
<td>1,381,798</td>
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</tr>
<tr>
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<td>99.05</td>
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<td>6,222,620</td>
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<tr>
<td>IPA</td>
<td>11.62</td>
<td>17.78</td>
<td>123,352</td>
<td>0.106</td>
<td>1,817</td>
<td>101,304</td>
<td>252,124</td>
<td>822,021</td>
<td>1,283,695</td>
<td>22.25</td>
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</tr>
<tr>
<td>IJP</td>
<td>11.62</td>
<td>17.78</td>
<td>123,352</td>
<td>0.106</td>
<td>1,817</td>
<td>101,304</td>
<td>252,124</td>
<td>822,021</td>
<td>1,283,695</td>
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<tr>
<td>SPA</td>
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<td>608</td>
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<tr>
<td>JP</td>
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<tr>
<td>3</td>
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<td>26,867</td>
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<tr>
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<td>100.08</td>
<td>108.42</td>
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<tr>
<td>IPA</td>
<td>19.80</td>
<td>26.23</td>
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<td>0.117</td>
<td>1,719</td>
<td>267,820</td>
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<td>1,518,049</td>
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<tr>
<td>IJP</td>
<td>34.34</td>
<td>39.21</td>
<td>90,607</td>
<td>0.180</td>
<td>1,516</td>
<td>805,821</td>
<td>820,940</td>
<td>2,189,990</td>
<td>3,010,930</td>
<td>55.76</td>
<td></td>
</tr>
</tbody>
</table>

Fixed capacity (at the socially optimal level)

| SPA | 46.41 | 54.67 | 93,389 | 0.103 | 1,378 | 1,421,451 | 363,240 | 3,055,011 | 3,418,251 | 68.27 |
| W | 104.83 | 113.37 | 6,379 | 0.108 | 607 | 7,252,401 | 1,855,122 | -2,017,987 | -162,865 | 100.00 |
| JP | 52.16 | 58.17 | 83,218 | 0.149 | 1,299 | 1,795,457 | 509,499 | 2,968,472 | 3,477,971 | 74.38 |
| 10 | CRL | 91.84 | 100.71 | 25,934 | 0.103 | 779 | 5,566,250 | 1,410,818 | 0 | 1,410,818 | 98.41 |
| CRT | 103.64 | 112.13 | 8,121 | 0.109 | 623 | 7,088,606 | 1,815,514 | -1,815,514 | 0 | 99.99 |
| IPA | 25.87 | 31.67 | 122,926 | 0.141 | 1,646 | 441,640 | 124,213 | 2,054,761 | 2,567,223 | 42.44 |
| IJP | 31.16 | 35.79 | 113,528 | 0.188 | 1,572 | 640,840 | 205,027 | 2,697,114 | 2,902,142 | 49.97 |


3. Regarding the JP case, $Q$ and $K$ increase with $N$ while delays decrease. $P$ increases with $N$: as $N$ grows, both the uninternalized congestion and the business stealing effects are more important, and they are not countervailed by changes in capacity. When $N=1$, the monopoly airline perfectly internalizes congestion and it obviously produces at the profit maximizing level so there is no need for corrections from the part of the airports: $P$ is thus equal to marginal cost. Air fares decrease marginally with $N$, due to increased schedule costs because of depressed frequencies (recall that competition is destroyed in this case). Joint profits increase with $N$: differentiation dominates the schedule delay cost effect in equation (30). When homogeneity is increased though, the result reverses so it would be better for the airports to let a single airline dominate. This is not harmful for society however as social welfare actually increases (results not shown).

4. It can be seen that actual SPA capacities and quantity are way below social welfare ones. We are therefore in the case in which the SPA output restriction is severe: $Q^{SPA}(K) << Q^W(K)$, implying that $K^{SPA} < K^W$. This is confirmed by the fixed-capacity simulations. The main insight here is that the allocative inefficiency of private airports, if capacity is exogenously decided, is by no mean small, leading to important dead-weight losses. The argument was that price elasticities of demand are low, but the problem with that assertion is that it assumed the elasticity is constant. Observed elasticities however, are not the elasticities that would arise under private (unregulated) ownership, or with the efficient prices derived in (23) because efficient prices have not been the rule. In fact, it is true that the price elasticity of demand when $P$ is equal to the linear cost-recovery price is fairly low (around 0.14 in absolute value) but, still, allocative inefficiency is very strong. Traffic is even smaller when the private airports can choose capacities. But since there is less waste of resources, social welfare is higher when capacity is a decision variable.

5. Comparisons between the SPA and the JP cases were not analytically simple. We can now see that, in general, JP airports are less harmful for social welfare than SPA airports. They induce higher joint profits and consumer surplus –and therefore SW–, more traffic, higher capacities and smaller airfares. The differences decrease with $N$ though, because in the JP case competition downstream is destroyed for every $N$ while in SPA it is not. These findings support the idea that collaboration between airlines and a system of private airports leads to a better outcome. There are two important things to note however. First, the same outcome is
obtained through vertical control by the airports; two-part tariffs are enough in this case. Second, and more importantly, JP airports’ traffic and capacities, while higher than the SPA ones, still fall way off optimal ones, which reflects in large deadweight losses. It would be adventurous, to say the least, to conclude that with privatization and collaboration—or strategic agreements—between airlines and airports, regulation becomes unnecessary. If anything, the outcome is closer to private unregulated airports rather than optimal ones.

6. What about budget adequacy of public airports? As expected, public airports charging linear prices (W cases) would run deficits and, although these diminish as the number of airlines increase, they are still sizeable when \( N = 10 \). In section 3.5 we argued that, perhaps, two-part tariff would solve the problem. The simulation however shows that this is not the case: airlines do not make enough profits. Hence, the cost-recovery cases gain importance. It can be seen that cost-recovery two part tariff (CRT) falls extremely close to the first best, showing that if two part-tariffs are feasible, even when one considers budget adequacy, privatization induces important deadweight losses. If two-part tariffs are unfeasible, then the relevant cases to be compared are SPA and CRL. Obviously the performance of private unregulated airports is better here, but they still induce about half the traffic they should, generating deadweight losses of about 30 to 40%.

7. When comparing delays, it can be seen that in almost all cases, SPA airports have the smallest delays. This issues a warning: congestion has been one of the main drivers of research in this area and proponents of privatization have argued that private airports would charge efficient congestion and peak load prices and would respond to market incentives for expansion. If one measures the result of privatization only by its effects on congestion, privatization may appear as a better idea than it actually is. Despite the smaller delays, we have seen that the private airports themselves would be substantially smaller both in terms of traffic and capacity. More importantly, social welfare would be substantially smaller. JP airports on the other hand, would have larger delays than the public airports.

8. When airports are privatized individually (IPA and IJP cases), the horizontal double marginalization problems visibly arise. Independent private airports charging linear prices (IPA), while still performing better than public airports congestion wise, are very small and induce the larger airfare and the smaller social welfare. For individual airports collaborating with airlines—or charging a two-part tariff—, something stranger happens: as \( N \) increases, the
double-charging problem worsens: total airport charges increase with $N$ faster than in the system case, making traffic and capacities actually get smaller as the number of airlines increase (resulting in important reductions of social welfare as $N$ grows).

9. Regarding constrained social welfare capacities (results not shown in table 2), when $N=3$, if public airports are forced to price as SPA, they will increase capacity from 45.5 to 59.1, which will lead to a traffic of 41.2 instead of 36.1. It will still be far away from the first-best capacity though, which was 109.6. Hence, SPA does induce an extra distortion: given that their restriction of output is severe, they undersupply capacity with respect to the second best.  

10. Finally, the insights do not qualitatively change with changes in the value of the parameters, although some numbers do. Specifically, different values for the demand parameters ($A$, $B$ and $E$) and for $r$ and for $C'$ were tried, since for these parameters there was less external information. It was found that the impact of changes in $r$ and $C'$ are quite small, while demand parameters impact on the levels but not on the order of the results. For example, taking $A=5,000$ and $B=1$, as in Pels and Verhoef (2004), and then taking $E=0.8$ and $N=3$, SPA traffic decreases from 36 to 18 and SPA capacity decreases from 45 to 24, while $W$ traffic decreases from 101 to 50 and $W$ capacity decreases from 110 to 56.

5. **Final Comments**

Privatization of airports has been argued for on the grounds that private airports would implement more efficient congestion and peak-load prices, and would have better incentives to invest in capacity. Privatized airports have been subject to economic regulation though, out of the concern that they would exert market power. But it has been argued that regulation may be unnecessary because a private unregulated airport would not induce large allocative inefficiencies since price elasticities are low, because potential collaboration between airlines and airports –or, alternatively, airlines countervailing power– would put downward pressure on market power, and because concession revenues would induce the airports to charge less on the aeronautical side. The aim of this paper was to build an analytical model where these ideas could be tested and other insights gained, since most of the literature on airport privatization has been essentially descriptive and empirical analysis are unfeasible because of absence of real data.
A vertical setting was used to analyze airport privatization, both analytically and numerically. In the model, airports are input providers for the downstream airline market, in which airlines take airport prices and capacities as given. Our airline oligopoly model expanded on previous models on three aspects: it featured demand differentiation, schedule delay cost was included in the full price perceived by passengers, and had a particular emphasis on the importance of the number of airlines in the market. It was shown that these aspects have an important role on the incentives an airport has with respect to the dominance by a single airline. At the airport level, the results showed a rather unattractive picture for privatization when compared to both the first- and second best. First, the idea that low price elasticities of demand for airports would induce small allocative inefficiency failed to take into account the fact that observed elasticities may be poor forecasters of elasticities in other settings, and that capacity would be chosen by a private airport in a different way than a public airport. Our results showed that private airports would be much smaller than efficient public airports in terms of both traffic and capacities, which was reflected in important deadweight losses. Second, the arguments that airlines countervailing power or increased cooperation between airlines and airports may make regulation unnecessary are, most likely, overstated. The benchmark of maximization of joint profits showed, on one hand, that airports exerting vertical control on airlines (two-part tariffs in this model is enough) leads to the same outcome. More importantly, while the vertical double-marginalization problem is solved and the incentives for investment in capacities are better aligned, competition at the airline level is destroyed. So, while the outcome is indeed better in terms of traffic, capacities and social welfare, it is still closer to the pure private case than to the public one. It seems bold to conclude from here then, that regulation is unnecessary, especially because any implementation problem, which would only worsen the outcome, was assumed away. The analysis of budget adequacy showed that two-part tariffs alone may not be enough to avoid deficit of public airports. However, cost recovery two-part tariffs fell very close to the first-best. In the event that two-part tariffs were unfeasible, we found that a cost recovery linear price (i.e. a Ramsey price) would still lead to a superior outcome. Finally, it was shown that things deteriorate further when privatization is done on an airport by airport basis rather than in a system, because airports’ demand complementarities induce horizontal double marginalization problems. These arise with simple linear prices, two-part tariffs, and when airports strategically collaborate with airlines.
We note that our model and its results apply to many other cases such as other transportation terminal (seaports; container terminals), railroad tracks and any vertical setting where upstream quality (here measured by capacity) matters, although we resorted to a number of simplifications to preserve tractability. A few that could be relaxed in future research are: the fixed-proportions assumption, absence of concession revenues, continuous capacity and a single demand period (several independent periods is a trivial expansion so the relevant case to study would be interdependent periods). Another important simplification was assuming (round trip) travel between only two airports (notwithstanding that the literature usually focuses on a single airport’s decisions). It allowed us to abstract from airlines’ route structure choices, an endogenous decision which is central for cost minimization and strategic aspects of competition (See Oum et al, 1995; Jara-Díaz and Basso, 2003). The assumption has a direct effect on the analysis of privatization: the two airports in this paper do not face any kind of competition. In fact, we presented what can be seen as the worst case scenario, social welfare wise, for private airports: the two airports have demands that are perfect complements. Real competition between airports can emerge in two ways though. First, there may be Geographic Competition; airports in the same city area –such as the three San Francisco Bay area airports– compete for consumers in the same origin. Second, there may be competition for connecting passengers. When there is a network of airports (three or more distinct origin-destinations pairs), airlines can partly offset airports’ market power through routing, something that would be taken into account by private airports when making decisions. Modeling these two types of competition seems to us the most important directions for future research, albeit they are complex ones. In our opinion, only with results from such models at hand, we will have a better and more complete picture about the economic effects of privatization and how we should go about regulation.

REFERENCES


**Appendix**

- **Proof of proposition 1**

  From (22), we can write

  \[
  SW(Q, K_h; N) = \pi + \frac{(B + (N - 1)E)S^2Q^2}{2N} \\
  + QS\left[ A - \frac{QS}{N} (B + (N - 1)E) - g\left(\frac{Q}{N}\right) - \alpha \sum D^k \right] - Q[c + P + \beta \sum D^k]
  \]

  We differentiate this with respect to \(Q\) and evaluate the resulting expression at \(Q_{SPA}(K)\), the optimal private quantity for the given \(K\), which makes the term \(\partial \pi / \partial Q\) nil. Using equation (8) to replace \(A g'(\frac{Q}{N})\frac{Q}{N} + g(\frac{Q}{N})\), we obtain:
\[
\frac{\partial SW}{\partial Q} \bigg|_{Q^{SPA}(K)} = -P_\varrho Q + \frac{BS^2 Q}{N} - \frac{(N-1)}{N} (\alpha S + \beta) Q \sum_k D^k \bigg|_{Q^{SPA}(K)}.
\]
Replacing
\[
P_\varrho = (\alpha S + \beta) \sum_k \left( \frac{N-1}{N} D^k + \frac{Q}{N} D^k \right) + \frac{S^2 (2B + (N-1)E)}{N},
\]
we finally get
\[
\frac{\partial SW}{\partial Q} \bigg|_{Q^{SPA}(K)} = \frac{Q}{N} (\alpha S + \beta) \sum_k (2D^k + QD^k) + \frac{S^2 Q (2B + (N-1)E)}{N} > 0,
\]
which shows that the SPA induces fewer flights. The equivalence follows from the decreasing monotonicity of \(P\) with respect to \(Q\).

- **Proof of proposition 2**

Expression (22) for \(SW\) leads to
\[
\frac{\partial SW}{\partial K_1} \bigg|_{K^{SPA}(Q)} = -Q (\alpha S + \beta) D_{K_1} - QP_{K_1}.
\]
Replacing
\[
\frac{\partial P}{\partial K_1} = -(\alpha S + \beta) \left( \frac{Q}{N} D^l_{K_1} + D^l_{K_1} \right),
\]
it is finally obtained that
\[
\frac{\partial SW}{\partial K_1} \bigg|_{K^{SPA}(Q)} = Q^2 (\alpha S + \beta) D_{QK_1} / N < 0.
\]

- **Analysis of the close-loop game when airports are private and independent**

Airports first choose capacities (simultaneously) and then prices. Over or underinvestment in capacity will be par rapport to the open-loop. From the profit functions in (34), and noting that
\[
\frac{\partial Q^h(P_1, P_2)}{\partial P_1 \partial P_2} = \frac{\partial^2 Q(P_1 + P_2)}{\partial P^2},
\]
is then easy to obtain that
\[
\frac{\partial^2 \pi^h}{\partial P_h \partial P_k} = (P_h - C') \frac{\partial^2 Q}{\partial P^2} + \frac{\partial Q}{\partial P} - \left( \frac{\partial^2 Q}{\partial P^2} \right)^2 C'' \quad (A.1)
\]
\[
\frac{\partial^2 \pi^h}{\partial P^2} = (P_h - C') \frac{\partial^2 Q}{\partial P^2} + 2 \frac{\partial Q}{\partial P} - \left( \frac{\partial^2 Q}{\partial P^2} \right)^2 C'' \quad (A.2)
\]
(A.2) being negative is a necessary condition for existence in the open-loop case. If this is true, then (A.1) is negative as well, but also \(\frac{\partial^2 \pi^h}{\partial P^2} + \left| \frac{\partial^2 \pi^h}{\partial P_h \partial P_k} \right| < 0\). Hence, the best reply mapping is a contraction and therefore there is a unique, symmetric and stable Nash equilibrium.
in the second stage, which is denoted by $\hat{P}_h(K_1, K_2)$. To know whether capacities are going to be smaller or larger than in the open-loop game, we look at the first stage:

$$\frac{d\pi^h}{dK_h} = \frac{\partial \pi^h}{\partial K_h} + \frac{\partial \pi^h}{\partial P_h} \frac{\partial \hat{P}_h}{\partial K_h} + \frac{\partial \pi^h}{\partial P_k} \frac{\partial \hat{P}_k}{\partial K_h}.$$ Evaluating this at the open-loop capacity makes the first term on the right hand side vanish. The second term is zero by the envelope theorem. Thus

$$\frac{d\pi^h}{dK_h} \bigg|_{K_h^{OL}} = \frac{\partial \pi^h}{\partial P_k} \frac{\partial \hat{P}_k}{\partial K_h} = \frac{\partial \pi^k}{\partial P_h} \frac{\partial \hat{P}_h}{\partial K_h} \frac{\partial \hat{P}_k}{\partial P_k}$$

(A.3)

where the symmetry of the problem was used. It is easy to check that the first derivative on the right hand side is negative; the second is positive: $\frac{\partial \hat{P}_h}{\partial K_h} = - (\frac{\partial^2 \pi^h}{\partial P_k \partial K_h} + (\frac{\partial^2 \pi^h}{\partial P_h^2})^{-1}$. Investment makes an airport tough then, in that $\frac{d\pi^k}{dP_h} \frac{\partial \hat{P}_h}{\partial K_h} < 0$. The third derivative is negative because prices are strategic substitutes (A.1 is negative). Hence (A.3) is positive, which shows that closed-loop capacities are larger than open-loop capacities: airports over invest in capacity following top-dog strategies. This directly leads to higher prices ($\frac{\partial \hat{P}_h}{\partial K_h} < 0$) but the effect on traffic cannot be signed.