A NEW APPROACH TO THE ANALYSIS OF AIRPORT PRICING, CAPACITY AND OWNERSHIP

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ABSTRACT

Airport pricing has been studied using two approaches: the *airport market approach*, which uses a classical partial equilibrium model, and the *airline market approach* that models –in fairly simple ways– oligopolistic airline markets to then calculate the additional toll that airlines should be charged to attain maximization of social welfare. While the first approach has been shown to be an inadequate approximation, the second approach has only looked at congestion pricing, abstracting from other important issues such as airports' capacity and the effects of privatization. Here, an extended oligopoly model for the downstream market –the airline market– is used, in order to try to answer the questions that have been put forward in both approaches. It is shown that airports' capacity and pricing rules do not necessarily coincide with what has been obtained previously in the literature. In the case where there is coincidence, results are extended to more general settings. Novel insights are provided, particularly regarding the role of differentiation and market structure at the airline level, schedule delay cost and the importance of the scope for vertical control from the part of airports. Theoretical and numerical results show a quite unattractive picture for privatization, particularly if it is done in such a way that airports will be managed independently.

1. INTRODUCTION

Airport pricing has attracted the attention of economists for more than 35 years. Initially, attention was devoted to the efficiency of pricing practices by airport authorities and the need to take into account congestion, which even then was afflicting passengers and airlines. These alleged inefficiencies and the factual wave of privatizations and/or partnerships that started in the late eighties throughout the world (following the example of the UK) induced, in addition, a focus on the effects of privatization and the efficiency of different regulatory schemes.

There have been essentially two approaches to examine these issues: the *one-market approach*, which follows a classical partial equilibrium analysis and where *consumer surplus* is measured by integration of the airport's demand, and the newer *airline-market approach*, where the airline market is formally modeled as an oligopoly, model that is then used to analyze the airports market. Basso (2005), however, showed that a correct analysis of airport pricing simply cannot avoid formal modeling of the downstream airline market, otherwise airlines profits and passenger surplus will not be adequately included in the social welfare function, showing that the second approach is the one to employ. The problem is that the one-market approach has been used to study many more issues than the airline-market approach. The latter has looked at optimal runway pricing under congestion but not at other matters such as privatization or optimal capacity. This paper remedies this problem. This is done by using an airline oligopoly model proposed by Basso (2005), which has the advantage of generalizing the models that have been put forward previously in this literature. With the oligopoly model and its results at hand, airport pricing, capacity and ownership are studied analytically. The paper is as follows. In the next section the main features of the oligopoly model are presented; this is limited to the bare basics for space reasons. In section three the airports market is analyzed. Results and comparisons regarding price and capacity under different pricing and ownership schemes are provided, together with analyses about the influence of the airline market structure in the outcome of the airports markets, and the incentives of airports to try to change the downstream market structure. Section four concludes.

2. THE OLIGOPOLY MODEL IN THE AIRLINE MARKET

The model is presented in detail in Basso (2005). We consider two airports –indexed by h=1,2– and N airlines with identical cost functions that face differentiated demands for round trips. Demand for airline i depends on its full price and the full price of all other airlines. Full price is dependent on the air ticket, schedule delay cost and the delay at the airport. The game we are interested in is a two stage game: first, airports choose a price per take-off/landing, P, and a capacity, K, then airlines –in Cournot fashion– choose their quantities. We resort to backward induction to find sub-game perfect equilibria, looking at the airline sub-game first. The unique symmetric Cournot Nash equilibrium of this sub-game induce a demand for airports given by $Q(P_h, K_h; N)$ or, if one defines $P=P_1+P_2$, an inverse demand for airports given by $P(Q, K_h; N)$. With these, the sub-game equilibrium airlines' profits (industry wide) can be obtained as:

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

where S is the (constant) product between aircraft size and load factor; g is passengers' schedule delay cost provoked by the difference between actual and their desired departure time; $D^h(Q, K_h) = Q/(K_h(K_h - Q))$ represents flight delay because of congestion at airport h; α is passengers' value of time; β is airlines' extra cost per minute of delay; c is airlines' pure operating cost per flight (without delay); and A, B and E are positive demand parameters. Since the interval between departures depends on the frequency, g is a function of the number of flights of each airline, Q/N, and obviously $g'(\cdot)<0$. The degree of differentiation is given by B-E; when B=E airlines are homogenous for consumers and when E=0 demands are totally independent.

Consumer surplus in the airline market equilibrium is given by

$$CS(P_h, K_h, N) = \frac{(B + (N-1)E)S^2 Q(P_h, K_h, N)^2}{2N} \tag{2}$$

The integral of $Q(P_h, K_h; N)$, which in the *one-market approach* was used to represent *consumer surplus*, was shown to actually be:

$$\int_P^\infty Q(P, K_h, N)\, dP = \Phi + CS - \frac{BS^2Q^2}{2N} - \frac{(N-1)}{N}(\alpha S + \beta)\int_P^\infty Q\frac{\partial Q}{\partial P}\left(\sum_h D_Q^h\right)dP \tag{3}$$

Both functions, $Q(P_h, K_h; N)$ and $P(Q, K_h; N)$, do not have closed form expressions. However, they can obviously be used to analyze the airports market as long as relevant derivatives and their signs are known. Straightforward comparative statics enabled this, leading to the following:

$$\frac{\partial Q}{\partial N} > 0,\ \frac{\partial Q}{\partial P_h} < 0,\ \frac{\partial Q}{\partial K_h} > 0,\ \frac{\partial^2 Q}{\partial P_h^2} < 0,\ \frac{\partial^2 Q}{\partial P_h \partial K_h} > 0, \frac{\partial P}{\partial Q} < 0, \frac{\partial P}{\partial N} > 0, \\ \frac{\partial^2 P}{\partial Q \partial N} > 0,\ \frac{\partial^2 P}{\partial Q^2} < 0,\ \frac{\partial P}{\partial K_h} > 0,\ \frac{\partial^2 P}{\partial Q \partial K_h} > 0,\ \frac{\partial^2 P}{\partial K_h^2} < 0,\ \frac{\partial^2 P}{\partial K_1 \partial K_2} = 0,\ \frac{\partial^2 P}{\partial K_h \partial N} < 0 \tag{4}$$

3. AIRPORTS MARKET

3.1 System of Private Airports

We are first interested in the decisions of a System of Private Airports (SPA). By this, I mean that pricing and capacity decisions at both airports are made by a single entity which maximizes profits; this is truly a monopoly situation. Decision variables are Q, P (which is the sum of P_1 and P_2), K_1 and K_2. Q and P however are related through the demand function. We will use Q and K_h as decision variables –that is, we will use the inverse demand function $P(Q, K_h; N)$– but obviously results do not vary if we choose them otherwise. It is assumed, as is usually done in the literature, that airports' costs are given by $C(Q) + rK$, where C represents operating costs and rK capital costs. The problem the SPA faces is given by

$$\max_{Q,K_1,K_2} \pi(Q,K_h;N) = P(Q,K_h;N)Q - 2C(Q) - (K_1 + K_2)r \tag{5}$$

First order conditions lead to the following pricing and capacity rules:

$$P = 2C' + P/\varepsilon_P \tag{6}$$

$$Q(\partial P/\partial K_h) = r \quad , \; h = 1,2 \tag{7}$$

where ε_P is the (positive) price elasticity of airports' demand. It can be proved that, at the optimum, $K_1 = K_2 = K$ but it cannot be proved that second order conditions hold globally.[1] Simulation shows that they do hold for a large range of parameter values, though. (6) is the familiar market failure in which monopolies set price above marginal cost. (7) shows that private airports increase capacity until the marginal revenue of doing so equals the marginal cost of providing the extra capacity. The monopoly system of airports only cares about the last *consumer*: increasing capacities by ΔK allow the airport to charge an extra ΔP, 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 is that the marginal revenue perceived by the airport is not necessarily a measure of the social benefit of an increase in capacity (Spence, 1975).

We are also interested in seeing how optimal Q, P and K –recall that capacities are equal– change with N. Differentiating both (6) and (7) with respect to N and solving we get

$$\frac{dQ^{SPA}}{dN} = \frac{\pi_{QN}\pi_{KK} - \pi_{QK}\pi_{KN}}{\pi_{QQ}\pi_{KK} - \pi_{QK}} \qquad \frac{dK^{SPA}}{dN} = \frac{\pi_{KN}\pi_{QQ} - \pi_{QK}\pi_{QN}}{\pi_{QQ}\pi_{KK} - \pi_{QK}} \tag{8}$$

where, for second order conditions to hold, π_{QQ}, π_{KK} and the denominator must be negative. We also have that $\pi_{QK} = P_{QK}Q + P_K > 0$, $\pi_{QN} = P_{QN}Q + P_N > 0$ and $\pi_{KN} = P_{KN}Q < 0$ –see (4). Therefore, the signs cannot be determined a priori and, as a consequence, we cannot know analytically how P^{SPA} change with N.[2] What we do know, however, is that as N increases, profits of the system of private airports increases. To see this, simply differentiate profits evaluated at optimal Q and K with respect to N and apply the envelope theorem: $d\pi/dN = \pi_Q Q_N^{SPA} + \sum \pi_{K_h} K_N^{SPA} + \pi_N = \pi_N = Q^{SPA} P_N > 0$.[3]

[1] It can be shown that the first two principal minors of the Hessian matrix have opposite signs, but for the third that cannot be done. A necessary condition for second order conditions to hold though, is $\pi_{QQ} = 2P_Q + QP_{QQ} - 2C'' < 0$. The first two terms are negative, while the third term would be positive, because it is usually assumed that airport have operational economies of scale. Therefore, overall, π_{QQ} will be negative if C is not *too* concave. This may occur here, because evidence suggests that the economies of scale arise from the presence of fixed costs while marginal costs are rather constant.

[2] In fact, if π_{QK}, π_{QN} and π_{KN} were positive, then π would be supermodular in (Q,K,N) and $dQ^{SPA}/dN > 0$, $dK^{SPA}/dN > 0$ would follow directly from results in lattice programming. See e.g. theorem 2.3 in Vives (1999).

[3] Numerical simulation showed that Q and K increased with N, while P decreased marginally.

3.2 System of Public Airports

We now consider a system of public airports that maximizes social welfare. We will denote this case by W. As it is clear now, the social welfare (*SW*) function is not simply the integral of airports' demand plus airports' profits –see (3). The correct *SW* function can be obtained in two ways. First, directly from the expressions for consumers' surplus (2), total airlines' profits in the sub-game equilibrium (1), and airports profits[4]

$$\max_{Q,K_1,K_2} SW(Q,K_h;N) = P(Q,K_h;N)Q - 2C(Q) - (K_1+K_2)r + \frac{(B+(N-1)E)S^2Q^2}{2N}$$
$$+QS\left[A - \frac{QS}{N}(B+(N-1)E) - g\left(\frac{Q}{N}\right) - \alpha\sum D^h\right] - Q\left[c + P + \beta\sum D^h\right] \quad (9)$$

A second way to obtain *SW* is to use the expression (3) for the integral of airports' demand in order to find Φ+*CS*, use $\int_P^\infty Q(P,K_h,N)\,dP = \int_0^Q P(Q,K_h,N)\,dQ - P(Q,K_h,N)\,Q$ and then add airports profits. We get

$$\max_{Q,K_1,K_2} SW(Q,K_h;N) = \int_0^Q P(Q,K_h,N)\,dQ - 2C(Q) - (K_1+K_2)r + \frac{BS^2Q^2}{2N}$$
$$+\frac{(N-1)}{N}(\alpha S+\beta)\int_P^\infty Q\frac{\partial Q}{\partial P}\left(\sum_h D_Q^h\right)dP \quad (10)$$

Note that there is no value of *N* for which this reduces to the so-called *social welfare function* in the one market approach. The two *SW* functions will lead to different results initially but, of course, they can be transformed into one another. Here, we use the expression for the *SW* function that leads more directly to an expression that is easy to interpret. For the quantity (pricing) decision I use (10), for capacity I use (9). First order conditions lead to

$$P = 2C' + \frac{(N-1)}{N}(\alpha S+\beta)Q\sum_h D_Q^h - \frac{BS^2Q}{N} \quad (11)$$

$$-Q(\alpha S+\beta)(\partial D/\partial K_h) = r \qquad , \; h=1,2 \quad (12)$$

Again, at the optimum, K_1=K_2=*K*, second order conditions do not hold globally but simulation shows they hold for all relevant cases, and results do not change if we use *P* and K_h instead. 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' manages to induce the outcome of social welfare maximization in the airline market. As can be seen, the final charge will be above or below marginal cost depending on whether the congestion effect or the

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[4] This has not been the usual case in the airport pricing literature as discussed in Basso (2005). In many cases, airports profits are not considered. A notable exception is Barbot (2004).

market power effect dominates. For the airline monopoly case, congestion is perfectly internalized and airports charges will be below marginal cost (and probably below zero). The third term in fact amounts to subsidizing firms with market power in order to increase social welfare. The implicit assumption is, evidently, that there is no other mechanism in place to control this market power. The congestion term was first found by Brueckner (2002). Pels and Verhoef (2004) later pointed out that the market power term was also needed (although Brueckner acknowledged this by stating that in the presence of market power the pure congestion charge may not be optimal). There are some differences between Pels and Verhoef's result and my 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 (12), while 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 I have N firms in a differentiated Cournot setting (iii) they assumed a linear in traffic delay function while mine is not (iv) they assumed a fixed capacity while here capacity is not fixed. Therefore, it can be seen that their main insight expands to a more general case. Two more comments are important regarding the pricing equation: first, I have clearly abstracted from airports' budget adequacy issues; I come back to this later on. Second, the result in equation (12) shows that the fourth term in the expression we obtained for the integral of airports demand, (3), deals with uninternalized congestion. Just as part of consumer surplus is lost because of market power, there are profits and consumer surplus lost because of uninternalized congestion, and that is what that term is capturing.

As for capacity, public airports will add capacity until the costs of doing so equate the benefits in saved delays to passengers ($-Q\alpha S\sum D_K^h$) and airlines ($-Q\beta\sum D_K^h$). It is clear that this capacity decision is different from the decision (a system of) private airports make, because they care about extra revenues and not extra social benefits. This result differs from what was obtained in the *one market approach*: there it was 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 (e.g. Oum et al. 2004). The divergence is undoubtedly caused by the fact that there, the *social welfare function* was actually not social welfare.

The signs of dQ^W/dN and dK^W/dN cannot be determined a priori either.[5] What we can know is how the social welfare changes with N in equilibrium. For this, differentiate SW, evaluated at optimal Q and K, with respect to N and apply the envelope theorem:

$$\frac{dSW}{dN} = \frac{(B-E)S^2Q^2}{2N^2} + Sg'\left(\frac{Q}{N}\right)\frac{Q^2}{N^2} \quad (13)$$

The first term in the right hand side is non-negative while the second is negative. It can be seen that when homogeneity is strong, (13) is negative and therefore it is better for social welfare to have one firm. This may appear surprising but the explanation is simple: with 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 airlines are differentiated ($B>E$), (13) may become positive for some parameter

[5] Simulations show that Q, K and P increase with N.

values. In that case, the expansion of demand bring about by a new firm will overweight the increased schedule delay cost due to reduced frequencies. The notable thing is that, under enough homogeneity, a monopoly airline is optimal but there is no need to regulate it: the public airports system would subsidize it to induce the optimal quantity (this is true in this national and non-network setting and 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 his model featured homogeneity and no schedule delay cost.

We turn now to comparisons between the SPA and 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. Does this mean that it is possible 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 nice way to make comparisons feasible is to assume first a fixed capacity. This lead to proposition one (this and the following propositions are presented without proof for space reasons, but proofs are available upon request from the author).

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

To compare capacity decisions, various cases can be distinguished. First, there is the case of actual capacities. As explained, quantity and capacity are defined simultaneously in a system of equations. We could therefore compare actual capacities and quantities. A more interesting question is, however, 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 (2^{nd} best case)? Is the distortion in capacity a mere byproduct of monopoly pricing? To analyze these two cases, we will 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 analyses, the reader will find strong similarities with Spence (1975) examination of provision of quality by a monopolist. Indeed, under this modeling, *K* can be seen as a measure of quality. Spence's insights, although pervasive, do not apply here directly. Due to the congestion externality and the vertical characteristic of the airport-airline markets, proofs have to be worked out differently.

Proposition 2: For a given *Q*, the system of private airports will oversupply capacity with respect to public ones.

As for actual capacities and quantities, from proposition 2 it is clear that if 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 will be higher than the W ones. If the output restriction is severe, $Q^{SPA}(K) << Q^{W}(K)$, then the conclusion is reversed. Note that the case $Q^{SPA} > Q^{W}$, $K_i^{SPA} > K_i^{W}$ (these are the actual values) is not precluded analytically. However, numerical simulations showed that, in fact, actual traffic and capacities of SPA are well below W ones: private airports will have capacities and traffic that are less than a third of what a system of public airports will have. Delays, though, will be smaller. This is important; congestion has been the main driver of research in this area and proponents of privatization have argued that private airports would charge efficient congestion and peak load prices, responding to market incentives for expansion (Borenstein, 1992). If one measures the result of privatization only by the effects it has on congestion, privatization may appear as a better idea than it actually is.

To analyze the 2nd best social welfare capacity, we consider the following second best *SW* function: $\tilde{S}W(K) \equiv SW(Q^{SPA}(K))$ –which is social welfare subject to SPA (monopoly) pricing–, and maximize it with respect to *K* (recall $K_1=K_2=K$). How does the second best social welfare capacity, $\tilde{K}^W$, compare to K^{SPA}? Unfortunately, we cannot say much analytically here; if $Q^{SPA}(K) \approx Q^W(K)$, then $K^{SPA} > \tilde{K}^W$. If $Q^{SPA}(K) << Q^W(K)$ then $\tilde{K}^W$ may be above K^{SPA}. This second case seems more natural: 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 airlines and passengers. Numerical simulations showed that, in fact, this is the relevant case and, also, that $K^{SW} > \tilde{K}^W$.

3.3 Maximization of Joint Profits: Airlines and Airports

The reason why it is interesting to look at this case is not only because a formal coalition between the system of private airports and airlines may be achieved[6] but because through a very simple pricing scheme –two part tariff–, 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 before but with this fee added to the cost function. Obviously, this fee does not affect the quantity decisions of the airlines 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.[7] This is well-know in the vertical control literature and is somewhat surprising that almost no author has analyzed or mentioned it (the only exception I am aware of is Borenstein, 1992, who comment on this). The difference is that, here, the upstream company, the airport, has a quality (capacity) that matters.

We will denote this case as TPT, for two-part tariff. As in the W case, there are two ways to write the joint profits function: first, directly deleting consumers' surplus in (9); or, we can use the integral of airports' demand (3) and the expression for CS in (2) to get:

[6] This issue has received little attention in the past but that is changing; see e.g. Gillen and Morrison (2003), who assume, in most of their models, formal coalitions between airports and monopoly airlines.

[7] Suppose airports not only charge a per flight price but also charge a fixed-fee to each airline. Airports will have to choose, Q, K_1, K_2 and T, the fixed fee. The fixed fee does not affect quantity decisions of the airlines as it vanishes when deriving the first order conditions in the airlines profit maximization problem. The problem of the airports is then $\text{Max}_{Q,K,T}\ P(Q,K_h,N)\cdot Q - 2C(Q) - (K_1+K_2)\cdot r + T\cdot N$ subject to $\phi^i(P,K_h,N) - T \geq 0$ (ϕ^i is airline i's profit). Because here $\phi^i = \phi^1\ \forall\ i$ and the airports benefit from high fixed fees, it would choose $T=\phi^1$. The problem of the airport would then be exactly as in maximization of joint profits, maximizing with respect to Q, K_1 and K_2.

$$\max_{Q,K_1,K_2} \pi + \Phi = \int_0^Q P(Q,K_h,N)\,dQ - 2C(Q) - (K_1 + K_2)r - \frac{(N-1)ES^2Q^2}{2N} + \frac{(N-1)}{N}(\alpha S + \beta)\int_P^\infty Q\frac{\partial Q}{\partial P}\left(\sum_h D_Q^h\right)dP \tag{14}$$

Note that when N=1, that is when the airline market is monopolized, the last two terms in (42) vanish and we get exactly what would have been called *social welfare* in the *one market approach* (although it clearly leaves consumers outside completely). Thus, we have another strong reason to study the max joint profits case: it would help us to see what happens when managers of public airports maximize the wrong social welfare function.

As before, we use the expression that leads more directly to readily interpretable results: (14) for pricing and the other one for capacity. First order conditions lead to[8]

$$P = 2C' + \frac{(N-1)}{N}(\alpha S + \beta)Q\sum_h D_Q^h + \frac{(N-1)ES^2Q}{N} \tag{15}$$

$$-Q(\alpha S + \beta)(\partial D / \partial K_h) = r \quad , h = 1{,}2 \tag{16}$$

The variable part of the price charged by the system of private airports, (15) 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 uninternalized congestion cost of each carrier, a horizontal externality. Third, it adds a term to fight the *business stealing effect,* a horizontal externality, which is typical of oligopoly. The first two components are in line with maximization of social welfare while the third moves in the opposite direction. In fact, the system of private airports, by charging two part tariffs, manage to obtain the outcome of cooperation or coordination between competitors in the airline market. This result has not been obtained in the airport pricing literature before; even if there is some degree of competition downstream, the private airports manage to destroy it, in order to maximize profits downstream. 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. This does not imply that this is worse for social welfare than the system charging linear prices (as in SPA) because here, two other harmful externalities are dealt with; numerical simulations confirm this. As for capacity, the rule is the same as in the social welfare case because the system of private airports is trying to maximize profits downstream.

Again, the signs of dQ^{TPT}/dN and dK^{TPT}/dN cannot be determined a priori[9] but we can know how, in equilibrium, joint profits change with N. The usual procedure leads to

$$\frac{d(\pi + \Phi)}{dN} = \frac{(B-E)S^2Q^2}{N^2} + Sg'\left(\frac{Q}{N}\right)\frac{Q^2}{N^2} \tag{17}$$

[8] Again, at the optimum $K_1 = K_2 = K$, second order conditions do not hold globally but do locally in numerical simulations, and results do not change if P and K_h are taken as the decision variables.

[9] Simulations show that Q, K and P increase with N.

The analysis is similar to the social welfare case; with homogeneity or little substitutability, (17) is negative and therefore airports prefer to have only one airline downstream. But here market power is not controlled as in the W case. What is remarkable is that for the SPA case, the larger the N the better, irrespective of the degree of substitutability. This was Borenstein (1992) 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" (p.68). His comment is supported by these results; however, in this model, airports letting a single firm to dominate –through some mechanism not included in the model– is not necessarily a bad thing. Social welfare may actually go up. This is so because, for $N>1$, we still have that the congestion externality is internalized and that competition is absent, i.e. as in a monopoly case. But, as explained before, a monopoly will offer higher frequencies, even higher than the frequency offered by each airline in the coordinated case, reducing schedule delay cost. Note also that when airports are relatively indifferent between $N=1$ or higher –when (17) is slightly positive–, they may still prefer to let a single airline dominate as the pricing rule becomes simpler: (i) airports do not need to estimate the second and third terms of the pricing rule (which is something indeed difficult) (ii) they would need to worry about assessing the right fixed fee for only one firm. All in all, recognizing the scope for vertical control in airport pricing is really important as policies regarding airports, such as privatization, have indeed significant and rather unexplored consequences in the airline market.

I turn now to comparisons of prices and capacities. Clearly, P^{TPT} is larger than P^{W} and is always above marginal cost. In general we have

Proposition 3: For a given K the TPT airports will: (i) Induce fewer flights than the W ones (ii) Induce more flights that the SPA ones

Proposition 4: For a given Q the TPT airports will: (i) Have the same capacity as W airports (ii) Have less capacity than a SPA airport.

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

As before, whether actual TPT capacities are below or above SPA capacities will depend on whether the output restriction of SPA airports is severe or not with respect to TPT, but numerical simulations show that TPT airports are bigger, both in terms if traffic and capacities, than SPA ones (TPT airports are about half W ones). Note that proposition 5 shows that if pricing and capacities are decided using the wrong social welfare function, as in the *one market approach*, the result will be airports that are too small in terms of both, capacity and traffic. What about 2nd best capacity? It has been argued before that a capacity rule such as the one TPT airports follow would be efficient because it is identical to the W airports' one. However, the question we try to answer here is, do TPT airports induce distortions in capacity that go beyond what is induced only by pricing? To analyze this we maximize social welfare subject to the restriction of TPT pricing. We conclude

Proposition 6: The TPT airports undersupply capacity with respect to second best social welfare capacities (in spite of having the same capacity rule).

Hence, TPT airports induce two different distortions. They price too high and, additionally they undersupply capacity. In contrast, the analytical comparison between *SW* first and second best capacities is inconclusive, although simulations show that the former is larger than the latter.

Before leaving this section, there is a lesson that can be extracted regarding the W case and that is that budget adequacy, which was not guaranteed previously, may be achieved through a fixed fee. Lump-sum transfers will not affect marginal decisions of airlines and therefore public 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 Loeab-Magat mechanism. A less efficient alternative is Ramsey prices: the Lagrange multiplier, which captures the severity of the budget constraint, will balance the charge between efficient price (11) and profit maximizing prices, (6) enabling cost recovery.

3.4 Independent Private Airports

So far, there has been no apparent need to have two airports in the model. The reason to have them is that airports are usually priced (or privatized) individually, and this induces a different set of problems. First, is the tactical decision of airports prices or quantities? Previously, this made no difference but here it does. Given that the direct demands each airport faces is given by $Q^1(P_1,P_2,K_1,K_2) = Q^2(P_1,P_2,K_1,K_2) = Q(P_1+P_2,K_1,K_2)$, we will take prices as tactical variables. This means that airports will behave as Bertrand oligopolists with complement products. Second, is the choice of prices and capacities simultaneous or in two stages, K_h first and then P_h? The first case is usually called open-loop, the second one closed-loop. Results do differ. We look first at linear prices –we will denote this case IPA–, in the open-loop case. Here airports choose P_h and K_h simultaneously in a non-cooperative game. Each airport's program is

$$\max_{P_h,K_h} \pi^h = Q^h(P_1,P_2,K_1,K_2)P_h - C(Q_h) - K_h r \quad , \quad h = 1,2 \tag{18}$$

Taking first-order conditions, and imposing symmetry, we obtain the following

$$P = 2C' + 2(P/\varepsilon_P) \tag{19}$$

$$Q(\partial P/\partial K_h) = r \quad , \quad h = 1,2 \tag{20}$$

(19) is to be compared with the SPA case in (6); clearly $P^{IPA} > P^{SPA}$. This was expectable: it is the result of the horizontal double marginalization problem that arises in oligopoly when outputs are complements. In these cases, competition is bad for social welfare. The capacity rule is the same but obviously actual capacities will be different than in the SPA case as prices and capacities are decided simultaneously. Therefore, individual private airports will induce fewer flights and will have smaller capacities than a system of private airports. From propositions 1 to 4, we have that, for a given *K*, $Q^W > Q^{TPT} > Q^{SPA} > Q^{IPA}$. For given *Q*, we will have that, $K^{TPT} = K^W < K^{SPA} = K^{IPA}$. For actual capacities and prices, $Q^W > Q^{TPT}$, $Q^{SPA} > Q^{IPA}$, $K^{TPT} < K^W$ and $K^{IPA} < K^{SPA}$. Also, it can be showed that closed-loop capacities are larger than open-loop capacities; airports follow a *top-dog* strategy in Fudenberg and Tirole's (1984) terms.

If both airports individually use two part tariffs instead we get, in the open loop:

$$P = 2C' + 2\frac{(N-1)}{N}(\alpha S + \beta)Q\sum_h D_Q^h + 2\frac{(N-1)ES^2Q}{N} \tag{21}$$

$$-Q(\alpha S + \beta)(\partial D / \partial K_h) = r \qquad , \ h = 1,2 \tag{22}$$

Hence, individual airports using two part tariffs charge, in total, more than a system of private airports using two-part tariffs (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. Simulations showed that this problem is severe. Capacity rules on the other hand are as in TPT, therefore comparisons between this case and the system using two part tariffs is analogous to the comparison between TPT and W.[10]

4. FINAL COMMENTS

Airport pricing and ownership have been widely analyzed in the economics literature. Two main approaches have been used. *The one market approach* that uses a classical partial equilibrium model, and *the airline market approach*, which instead models rather simple oligopolistic airline markets and calculates the additional toll that airlines should be charged to attain maximization of social welfare. However, it has been shown that the *one market approach* is not a reasonable approximation so that an *airline market approach* is needed. Therefore, in this paper we used an airline oligopoly model –which encompasses previous models– to study the airport market, and attempted to answer both, the questions that have been already analyzed within this approach – congestion pricing– but also questions that were only examined with the *one market approach*. We showed this to be feasible and gained many insights, particularly regarding the role of differentiation and market structure at the airline level, schedule delay cost and the importance of the scope for vertical control from the part of airports. Regarding this last issue, we found important differences between private airports charging linear prices and private airports charging two parts-tariffs. In general, theoretical and numerical results showed, for this model, a quite unattractive picture for privatization, particularly if airports are privatized independently. Certainly, we presented here the worse case scenario for privatization so further work is needed.

The fact that the airline market cannot be ignored is certainly bad news as it greatly complicates both, regulation of private airports and the managing of public airports. The problem is that, to take optimal decisions, the amounts of information required are massive, even in simple settings like here. Regulation is certainly an issue too complicated on its own to be dealt with in this paper; hopefully, the results contained here will help bring new insights about it in the future.

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[10] The closed-loop case is not as obvious as with linear prices because airports now care about ϕ^1. It may happen that an increase in K_h raises ϕ^1, increasing the other airport's profit through the fee. These types of difficulties arise in agency problems when there are several principals and several agents, and is well-known in contract theory.

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