Airport Capacity and Congestion Pricing with both Aeronautical and Commercial Operations

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Abstract

In this paper, we study airport decisions on pricing and capacity investment with both aeronautical and concession operations. In addition, the airport under consideration is serving air carriers who have market power. We find that a profit-maximizing airport would over-invest in capacity in the sense that the marginal (social) benefit of capacity is smaller than the marginal (social) cost. This tendency of overinvestment still holds when the private airport is under the regulatory constraint of cost recovery in its aeronautical operation (the dual-till regulation). We also find that the capacity investment by a public airport will be socially efficient in the sense that the marginal benefit of capacity is equal to the marginal cost of capacity. However, somewhat surprisingly, the capacity investment of the public airport will be inefficient if it is under regulatory constraints. Specifically, the airport will also over-invest in capacity, whether it is under a single-till regulation or a dual-till regulation. Finally, it is noteworthy that the inefficiency in airport investment is driven by the interaction between the airport and the carriers who have market power.

Keywords: Airport charges, Capacity investment financing, Commercial revenue, Regulation, Market power
1. Introduction

It is well known in the literature that congestion tolls by a congestible facility such as airport serve two purposes: first as a means for demand management and second as a source for investment financing. When carriers have market power, they will be able to internalize congestion costs – fully by a monopolist and partially by oligopolists – by setting a higher ticket price so that passengers will eventually bear the costs that they impose on each other (see Daniel, 1995; Brueckner, 2002, 2005; Brueckner and Van Dender, 2008; Pels and Verhoef, 2004; Zhang and Zhang, 2006; Basso and Zhang, 2007; Johnson and Savage, 2006; Morrison and Winston, 2007). Such practice by the carriers can well serve the purpose of demand management, as the higher ticket price will curtail demand and reduce congestion. Nevertheless, the internalization of congestion costs by the carriers would effectively deprive the airport of an important source of funds for its capacity investment, which may lead to financial problems for the airport.

This paper investigates the impact of carriers’ self-internalization of congestion on an airport’s pricing and capacity investment. An innovation of our paper, as compared to the existing literature, is that we shall investigate the role of commercial (concession) operations in the airport pricing, financing of capacity investment, and airport regulation. Commercial operations refer to non-aeronautical activities occurring within terminals and on airport land, including terminal concessions, and car parking and rental. For the last two decades, commercial revenues have grown faster than aeronautical revenues; as a result, they become the main income source of many airports. At medium to large U.S. airports, for instance, commercial business represents 75-80% of the total airport revenue (Doganis, 1992). Furthermore, commercial operations tend to be more profitable than aeronautical operations (Jones et al., 1993; Starkie, 2001), owing partly to the ‘locational rents’ enjoyed by a busy gateway airport and partly to prevailing regulations and charging mechanisms (e.g., Starkie, 2001). While aeronautical operations are subject to various forms of regulation – either explicitly or implicitly – commercial operations are usually unregulated. One consequence of this profit disparity is that the profits made from commercial activities may be used to cross-subsidize aeronautical operations, thereby eliminating the need for government aid (see, e.g., Zhang and Zhang, 1997, 2003).¹

¹ Note that the empirical observation that commercial operations tend to be more profitable than aeronautical services is not necessarily a justification for the modeling approach adopted in this paper. Rather, the paper explores its implications for airport pricing, financing and regulation. We also note that given our attention on airport congestion and commercial revenues, our analysis mainly apply for large and busy gateway airports served
This brings out the issue of whether and how aeronautical and concession operations should be regulated (see Beesley, 1999; Starkie, 2001; Oum, Zhang and Zhang, 2004, among many others). It is well-known that firms under the traditional rate-of-return (ROR) regulation is prone to overinvestment in fixed assets (Averch and Johnson, 1962), which results in overcapacity and a low productive efficiency. Oum, Zhang and Zhang (2004) pointed out that the presence of the concession profits would result in a twist in the firms’ investment behavior. Specifically, with aeronautical operations under the ROR regulation, a profitable concession operation would provide the right incentives for a profit-maximizing airport to make socially efficient investment in capacity. Oum, Zhang and Zhang also investigated price-cap regulations when concession profits are concerned, and found that a profit-maximizing airport would under-invest in capacity whether the airport is subject to a single-till regulation or a dual-till regulation.

It is worth noting that these results are obtained under the implicit assumption that the airports are serving atomistic airlines. In the absence of concession operations, Zhang and Zhang (2006) examined the capacity investment by the airports when airlines have market power and found that a profit-maximizing airport would over-invest in capacity. The present paper examines the impacts of concession revenue on airport pricing, financing and regulation when airlines have market power. How will the consideration of concessions affect the comparison of aeronautical (runway) pricing between the public and private airports and their capacity investment and financing decisions? What are the consequences of the alternative regulations associated with concession profits for the efficiency of airport investment?

Our analysis shows that a private airport will tend to over-invest in capacity, whether unregulated or regulated. Furthermore, a regulated public airport would also tend to over-invest in capacity, whether it is under a single-till or dual-till regulation concerning the aeronautical and concession revenues, which is in contrast to the underinvestment tendency discussed in Oum, Zhang and Zhang (2004) when carriers are atomistic. It is noteworthy that the overinvestment problem would be present as long as carriers have market power. These results have practical implications for airport congestion pricing, financing and regulation and for such issues as airline mergers/alliances, since changes in the airline market structure could have direct consequences for airport financing and efficiency.

The paper is organized as follows. Section 2 sets up the model on airport-carrier interaction. Section 3 analyzes pricing and investment decisions for two types of airports: a private, profit-maximizing airport and a public, welfare-maximizing airport. Section 4 examines the effects of regulation on airport pricing and investment. Section 5 contains the concluding remarks.

by full service carriers, although the principles derived might apply to other types of airport as well.
2. Model of Airline-Airport Interaction

Consider an airport with an aggregate demand \( Q(\rho) \), where \( \rho \) represents the ‘full price’ faced by passengers:

\[
\rho = P + D(Q, K) .
\] (1)

In words, the full price is the sum of ticket price, \( P \), and cost of congestion delay, \( D \), with the latter depending on total traffic \( Q \) and capacity \( K \) at the airport. For simplicity, \( Q \) is measured by the number of flights. This measurement is equivalent to the number of passengers if each flight has an equal number of passengers, which holds when all flights use identical aircraft and have the same load factor. This latter condition is assumed to hold, which is also common in the recent literature on airport congestion pricing.

For the delay cost function, we make the standard assumption that \( D(Q,K) \) is differentiable in \( Q \) and \( K \) and

\[
\frac{\partial D}{\partial Q} > 0, \quad \frac{\partial D}{\partial K} < 0, \quad \frac{\partial^2 D}{\partial Q^2} > 0, \quad \frac{\partial^2 D}{\partial Q \partial K} < 0 .
\] (2)

This assumption is quite general, requiring only that increasing traffic volume will increase congestion while adding capacity will reduce congestion, and that the effects are more pronounced when there is more congestion.

The airport is served by \( N \) air carriers, and the model of airline and airport behavior is based on a two-stage game. In the first stage the airport decides on the airport charge \( \mu \) and capacity \( K \), where \( K \) is continuously adjustable. In the second stage, each carrier chooses its output in terms of the number of flights, \( q_i \), to maximize profit (for \( i = 1,2, \ldots, N \)). The carriers’ outputs are homogeneous, so the aggregate output \( Q \) is given by \( \sum_i q_i \). The ‘full’ price is then determined by the inverse demand function \( \rho(Q) \), and the equilibrium ticket price \( P \) is established according to (1).

We examine the subgame perfect equilibrium of this two-stage game. In the second stage we assume Cournot behavior in modeling airline competition.\(^2\) We

\(^2\) Cournot behavior has been assumed in the literature; see, e.g., Brueckner (2002, 2005) and Pels and Verhoef (2004). Brander and Zhang (1990, 1993), among others, find some
further assume that the carriers are symmetric and that each carrier has a constant per-flight cost $c$ and a zero fixed cost. This cost specification simplifies analysis but is not crucial to our results. By equation (1), the ticket price is the difference between the full price and the cost of delay, so the profit function for carrier $i$ can be written as:

$$\pi_i = q_i \times (\rho - D) - cq_i - \mu q_i,$$  \hspace{1cm} (3)

where $\rho = \rho(\sum q_i)$. The Cournot equilibrium is characterized by the first-order conditions,

$$\frac{\partial \pi_i}{\partial q_i} = \rho - D + q_i (\rho' \frac{\partial D}{\partial Q}) - c - \mu = 0, \; \forall i$$  \hspace{1cm} (4)

and second-order conditions,

$$\frac{\partial^2 \pi_i}{\partial q_i^2} = 2(\rho' \frac{\partial D}{\partial Q}) + q_i (\rho'' - \frac{\partial^2 D}{\partial Q^2}) < 0.$$  \hspace{1cm} (5)

By conditions (2) and $\rho' < 0$ (downward-sloping demand), the second-order conditions will hold if $\rho'' \leq \frac{\partial^2 D}{\partial Q^2}$, which is true when $\rho''$ is non-positive (or small if it is positive).

Letting $\varepsilon \equiv -\frac{dQ}{d\rho}(\rho/Q) = -\rho'/\rho'Q$ denote the (positive) demand elasticity.

empirical evidence that rivalry between airlines is consistent with Cournot behavior. In terms of modeling, Cournot assumption also provides a convenient way to capture alternative market structures such as monopoly (by setting $N=1$) and perfect competition (with $N$ becoming sufficiently large). Along with Cournot oligopoly, both the monopoly and especially perfect-competition cases will be examined in the text. Nonetheless, Cournot rivalry does not apply universally, e.g., when there is a competitive fringe. Daniel and Harback (2008) consider a case where a Stackelberg leader faces a competitive fringe and find that carriers in that case do not internalize congestion. (We can further show that their result could be extended to the case in which the leader group consists of several Cournot carriers.) See Brueckner and Van Dender (2008) for further discussion on the implications of market structures for congestion pricing. In general, the impact of alternative market structures on airport financing and regulation is less clear however, and remains as an area for further research.

5 Here, it is assumed that only passengers suffer from airport congestion delays. The analysis can be extended immediately to the case where both passengers and airlines will incur costs due to airport congestion.
with respect to full price and noting that \( \rho - D = P \), equation (4) can be rewritten as:

\[
P = \mu + c + s_i \left( Q \frac{\partial D}{\partial Q} + \frac{\rho}{\epsilon} \right)
\]  

(6)

where \( s_i = q_i / Q \) is carrier \( i \)'s market share. It is clear from (6) that the (per-flight) ticket price is equal to the carrier’s operating costs – which include the airport charge – plus some extra charges. These extra charges are contained in the parenthesis on the right-hand side (RHS) of (6) with two components: The first component, \( Q(\partial D / \partial Q) \), is the marginal delay cost to all flights due to one flight. The second component, \( \rho / \epsilon \), is a pure markup term, which reflects the carrier’s market power and is related inversely to the demand elasticity. Brueckner (2002, 2005) pointed out that carriers having market power would internalize some of the congestion delay cost according to their market share, which is confirmed by equation (6). In particular, for a monopoly carrier, \( s_i = 1 \) and the congestion delay will be fully reflected in the ticket price, whilst for atomistic (perfectly competitive) carriers, \( s_i = 0 \) and the congestion delay will not enter the ticket price. Similarly, equation (6) shows that the markup is incorporated in the ticket price by the factor of the carriers’ market share. Notice that since the carriers are symmetric, (6) implies that \( s_i = 1 / N \).

When airlines make output decisions in the second stage, they take airport charge \( \mu \) and airport capacity \( K \) as given. Zhang and Zhang (2006) derived the following comparative-static results concerning the carriers’ aggregate output with respect to \( \mu \) and \( K \):

\[
\frac{\partial Q}{\partial \mu} = \frac{N}{(N + 1)(\rho' - \frac{\partial D}{\partial Q}) + Q(\rho'' - \frac{\partial^2 D}{\partial Q^2})},
\]  

(7)

and

\[
\frac{\partial Q}{\partial K} = \frac{N \frac{\partial D}{\partial K} + Q \frac{\partial^2 D}{\partial Q \partial K}}{(N + 1)(\rho' - \frac{\partial D}{\partial Q}) + Q(\rho'' - \frac{\partial^2 D}{\partial Q^2})}.
\]  

(8)
Notice that expressions (7) and (8) share the same denominator, which is negative when carriers’ outputs are 'strategic substitutes' (Bulow et al., 1985). The latter is a standard condition for Cournot competitors, and is also assumed in the present analysis. Thus we have:

$$\frac{\partial Q}{\partial \mu} < 0, \quad \frac{\partial Q}{\partial K} > 0,$$

that is, the aggregate (equilibrium) output decreases in airport charge, but increases in airport capacity. These comparative-static results are sensible, and will be used in subsequent analysis.

3. Airport Pricing and Investment

The above analysis shows that the airport decisions – airport charge $\mu$ and airport capacity $K$ – can influence subsequent output competition, which in turn affects the airport’s financial position. Taking the second-stage equilibrium outputs into account, the airport chooses $\mu$ and $K$ to achieve its own objective. These decisions may in reality be set by a profit-maximizing airport operator or a welfare-maximizing public authority. In this paper we will consider two alternative airport objectives: namely, a public airport that maximizes social welfare and a private airport that maximizes profit. These two airports may be subject to different forms of regulatory constraints.

3.1 Welfare-maximizing airport

Consider first a public airport whose mandate is to maximize social welfare ($SW$). Since there are three groups of stakeholders in the model – passengers, airlines and airport – $SW$ is the sum of passenger (consumer) surplus, airline profits, and the airport’s profit. As a result, the objective of such an airport can be formulated as follows:

$$\max_{\mu, K} SW$$

where, using (3),

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4 The various components of the welfare function have equal weights in the cases examined below. It may be useful to look into the distribution of welfare weights and its consequences. We discuss the issue further in the concluding remarks.
\[ SW = \left[ \int_{0}^{\theta} \rho(\xi) d\xi - \rho Q \right] + \left[ \sum_i (Pq_i - cq_i - \mu q_i) \right] + [\mu Q - c_0 Q - r K] + V \]

\[ = \int_{0}^{\theta} \rho(\xi) d\xi - D Q - cQ - c_0 Q - r K + V \]  

(10)

and V denotes per-flight concession surplus

\[ V = CS + R. \]  

(11)

In these equations, \( c_0 \) is the airport’s unit operating cost of aeronautical operation and \( r \) is the airport’s cost of capital. Further, CS is the per-flight consumer surplus from concession consumption and R is the per-flight airport profit in concession operations.

This model of concession surplus is a simple but perhaps extreme representation where revenues are strictly complementary to flight volumes. This strict complementarity could be relaxed with more general specifications of the non-aeronautical revenues (or surplus) such as \( V = V(Q, x) \) where \( x \) represents other exogenous or endogenous factors that determine the equilibrium in the market for concession goods or services, including competition from off-site providers of goods and services, price level at the airport, commercial space available at the airport, etc.\(^5\)

With this general specification, the strict complementarity is no longer needed in the sense that 1) \( Q = 0 \) does not necessarily imply \( V = 0 \); and 2) \( V \) needs not to be monotonously increasing in \( Q \). As far as the airport charges and airport capacity decisions are concerned, however, the more general specification of \( V \) would not make material differences in our analysis below so long as \( \partial V / \partial Q > 0 \) holds in the relevant range.\(^6\) Therefore, for simplicity, we will use the strict model of constant \( V \) in our analysis.

The first-order conditions for the optimization problem are derived below:

\[ \frac{\partial SW}{\partial \mu} = (\rho - D - Q \frac{\partial D}{\partial Q} - c_0 - c) \frac{\partial Q}{\partial \mu} + \frac{\partial Q}{\partial \mu} V = 0, \]

(12)

\[ \frac{\partial SW}{\partial K} = (\rho - D - Q \frac{\partial D}{\partial Q} - c_0 - c) \frac{\partial Q}{\partial K} - Q \frac{\partial D}{\partial K} - r + \frac{\partial Q}{\partial K} V = 0 \]

(13)

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\(^5\) For a specification that models the interdependence of aviation demand and concession price, see Czerny (2006).

\(^6\) In the limiting case of no complementarity between concession operations and aeronautical operations at the airport, the concession revenues could be viewed as a constant exogenous to airport’s aeronautical operations. In that case, the effects of the non-aeronautical services would be reflected in the distortions that they bring into the budget constraint if the airport is under a single-till regulation, which in turn would affect the results concerning the forms of airport regulation.
Condition (12) leads to

\[ \rho - D - Q \frac{\partial D}{\partial Q} - c_0 - c + V = 0, \tag{14} \]

which gives

\[ P = c_0 + c + Q \frac{\partial D}{\partial Q} - V. \tag{15} \]

This simply states that the socially optimal ticket price should be the social marginal cost, which is the sum of airport operating cost, carrier operating cost, and congestion delay cost, less surplus in concession consumption.

Substituting (15) into (13) gives the optimality condition for capacity investment:

\[ -Q \frac{\partial D}{\partial K} = r \tag{16} \]

This condition states that the marginal effect of reduction in congestion cost by capacity expansion – which is the shadow value of capacity – is equal to the marginal cost of capacity. Therefore, in this case, the capacity decision by the airport is socially efficient.

In our model, the ticket price is established to clear the market after the carriers’ output decisions are made. However, exogenous to the carriers, the airport charge, \( \mu \), is set in the first stage so as to induce the optimal outcome in the later stage. Specifically, equation (6) in Section 2 reveals the link between an airport charge and ticket price. Substituting (6) into (15) and simplifying, we get

\[ \mu = c_0 + (1 - s_i) Q \frac{\partial D}{\partial Q} - s_i \frac{\rho}{\varepsilon} - V, \tag{17} \]

where \( s_i = 1/N \).

Equation (17) has the clear interpretation that the optimal airport charge is equal to the airport’s operating cost per flight plus a charge for uninternalized congestion, less a subsidy to correct airline exploitation of market power, minus the gain from concessions. If the market-power correction exceeds the correction for uninternalized congestion, the airport charge \( \mu \) will be less than the airport’s operating cost \( c_0 \), implying a subsidy from the airport to airlines (Pels and Verhoef, 2004).
Furthermore, (17) reveals that there is an additional rebate which is amount to $V$ in the airport charge. Intuitively, this is a recognition of the multi-output complementarity between the passenger flights and the concession consumption brought about by the flights.

Notice that (17) can be rewritten as:

$$
\mu = [c_0 + c + Q \frac{\partial D}{\partial Q} - [c + s, Q \frac{\partial D}{\partial Q} + s, \frac{\partial P}{\partial \epsilon} - V].
$$

The terms in the first bracket on the RHS represent the social marginal cost (SMC) incurred by the airport, the carriers, and other passengers, when a passenger makes a trip, whereas the terms in the second bracket reflect the airlines’ net revenue (ticket price net of airport charge). Therefore, we can by (15) and (17) write

$$
\mu = SMC - (P - \mu - V)
$$

Equation (18) indicates that the optimal airport charge essentially makes up for the difference between the social marginal cost (what the passengers should pay) and the carriers’ net revenue after payment of airport charge (what the carriers charge) plus a rebate from concessions.

This leads to the following proposition:

**Proposition 1.** For a welfare-maximizing public airport, the optimal airport charge is set at the level such that the ticket price paid by passengers is equal to the social marginal costs less the surplus on concession consumption per flight.

In essence, the objective of the airport charge, as formulated in Proposition 1, is to make passengers eventually pay a ticket price equating the social marginal cost. Furthermore, as passengers traveling through the airport create a demand for concession consumption, airport charge is further reduced to reflect this multi-output complementarity. While this achieves the optimality of the ticket price, the airport itself may suffer from financial deficit. In practice, airport charges are paid by the carriers in terms of landing/take-off fees (apart from the airport fees/taxes directly collected by airports from passengers). Although it is expected that the benefits of a lower airport charge would be passed over to passengers, it is hard to argue that a below-cost airport charge levied to a carrier is not a subsidy to the carrier. Consequently, the idea of a public airport giving a subsidy to a monopoly carrier (or oligopoly carriers) while itself asking for financial help might be politically implacable. This suggests that a public airport would face a financial dilemma if welfare maximization is to be pursued.
3.2 Profit-maximizing airport

Several options may be available to prevent an airport from becoming a public burden. The airport may be privatized or commercialized, or may be subject to regulations of self-financing. In this article we shall consider these two alternatives: i.e., a privatized airport, and an airport under regulatory constraints. Consider first a private airport pursuing profit maximization:

$$\text{max}_{\mu, K} \mu Q - c_0 Q - r K + QR .$$

The first-order conditions for optimality are:

$$\begin{align*}
(\mu - c_0 + R) \frac{\partial Q}{\partial \mu} + Q &= 0 , \quad (19) \\
(\mu - c_0 + R) \frac{\partial Q}{\partial K} &= r . \quad (20)
\end{align*}$$

Substituting the comparative static result (7) into (19) and simplifying, we obtain

$$\mu = c_0 + (1 + \frac{1}{N})(Q \frac{\partial D}{\partial Q} + \frac{\rho}{\varepsilon}) + \frac{Q^2}{N} (\frac{\partial^2 D}{\partial Q^2} - \rho^\prime) - R . \quad (21)$$

When carriers are atomistic, i.e., $N \to \infty$, (21) shows that

$$\mu \to c_0 + Q \frac{\partial D}{\partial Q} + \frac{\rho}{\varepsilon} - R .$$

In this case, the private airport operator will charge a full congestion toll, $Q (\partial D / \partial Q)$, plus a price markup, $\rho / \varepsilon$, owing to its monopoly power. However, the airport charge will be reduced by the amount of concession profits (per flight), $R$. Apparently, the airport is using concession profits to cross-subsidize aeronautical operations.

As for the capacity investment, we can solve (20) to yield the following equation:

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7 While atomistic carriers won’t be able to charge any markups, the airport can induce a monopoly carrier’s markup downstream by directly imposing the component in its charge.
By (7) and (8), the above equation is equivalent to:

$$-\frac{Q}{\partial Q / \partial \mu} \frac{\partial Q}{\partial K} = r$$  \hspace{1cm} (22)$$

Using the basic assumption (2), we conclude that

$$-\frac{Q \partial D}{\partial K} - \frac{Q^2}{N} \frac{\partial^3 D}{\partial Q \partial K} = r$$ \hspace{1cm} (23)$$

Comparing (24) with (16) reveals that the profit-maximizing airport will over-invest in capacity in the sense that the marginal benefit of capacity investment is smaller than the marginal cost of capacity. We summarize our findings in the following proposition.

**Proposition 2.** (i) For atomistic carriers \((s_i = 0)\), a profit-maximizing airport will set the airport charge as the sum of the marginal cost of aeronautical operation and a full congestion toll, plus a monopoly markup, and minus the concession profit per flight. (ii) Conditional on the aggregate output \(Q\), the capacity investment by the airport is socially inefficient in the sense that the marginal benefit is smaller than the marginal cost of capacity.

The intuition for the problem of inefficient investment can be explained as follows. Given the passengers’ full price \(\rho = P + D(Q, K)\) and carriers’ pricing rule (6), we have

$$\rho = \mu + D + c + \frac{1}{N} \left( Q \frac{\partial D}{\partial Q} + \frac{\rho}{\rho} \right)$$ \hspace{1cm} (25)$$

In essence, equation (25) represents the composition of the passengers’ full price (total costs), which consists of the airport charge, cost of congestion delay that is endured during the trip, costs of airline operation and the extra charges captured by the carriers who have market power.

First consider the case of a competitive market, where \(s_i = 0\) or \(1/N = 0\) and
\[ \rho = \mu + D + c. \] (26)

By the nature of demand, \( \rho \) only depends on \( Q \). Therefore, keeping total demand \( Q \) unchanged, a higher airport charge can be offset by a reduction in congestion delay. In other words, there exists an effect of substitution between capacity expansion and airport charge as shown below:

\[ \delta \mu = \frac{\partial D}{\partial K} \delta K \] (27)

where variations \( \delta \mu \) and \( \delta K \) are subject to \( Q \) being constant. In this regard, equation (22) can be interpreted as the optimal marginal rate of substitution between airport charge and capacity, keeping \( Q \) unchanged. Combining (27) with (22) yields

\[ -Q \frac{\partial D}{\partial K} = r \]

which is in agreement with (16).

When the carriers have market power, however, this relationship has a twist. Equation (25) reveals that a reduction in congestion cost now would have two effects that can contribute to an increase in airport revenue without changing the full price and total demand. The first is the direct effect of a lower congestion delay that is endured by the passengers, captured by the first term on the LHS of (23). The second effect is a lower ticket price paid to airlines by the passengers, because the internalized portion of congestion delays also declines as the airport expands capacity. The latter effect is captured by the second term on the LHS of (23) as shown below:

\[ \frac{\partial}{\partial K} \left( \frac{1}{N} Q \frac{\partial D}{\partial Q} \right) \delta K = \frac{Q}{N} \frac{\partial^2 D}{\partial K \partial Q} \delta K \]

In a sense, this second effect gives the airport a more favorable marginal rate of substitution between expanding capacity and raising airport charge. Consequently, the airport will be more inclined to invest in capacity when carriers have market power.

4. Budget-Constrained Airports

Now we consider an airport that is under the regulatory constraint requiring the airport to achieve exact cost recovery. There are two versions of this constraint: the
so-called ‘single till’ regulation and ‘dual till’ regulation. For the single-till regulation, airport should make overall cost recovery when both the aeronautical and concession operations are considered together. In this case, the airport is not allowed to make any profits (except for covering the cost of capital). For the dual-till regulation, only the aeronautical operation is subject to cost recovery.

4.1 Regulated public airport

We first examine a public airport under the single-till regulation while pursuing welfare maximization. The problem of such an airport is formulated as follows:

$$\max_{r,K} SW$$

$$\text{s.t. } \mu Q - c_0 Q + RQ - rK = 0$$

where SW is shown in (10).

The first-order conditions for the above problem are derived below:

$$\frac{\partial SW}{\partial \mu} = (\rho - D - Q \frac{\partial D}{\partial Q} - c_0 - c + V) \frac{\partial Q}{\partial \mu} + \lambda (\mu - c_0 + R) \frac{\partial Q}{\partial \mu} + \lambda Q = 0, \quad (28)$$

$$\frac{\partial SW}{\partial K} = (\rho - D - Q \frac{\partial D}{\partial Q} - c_0 - c + V) \frac{\partial Q}{\partial K} - Q \frac{\partial D}{\partial K} - r + \lambda (\mu - c_0 + R) \frac{\partial Q}{\partial K} - \lambda r = 0$$

(29)

where $\lambda$ is the Lagrangean multiplier. Simplifying (28), (29) and using (7) and (8) leads to

$$-Q \frac{\partial D}{\partial K} - \frac{\lambda}{1 + \lambda} \frac{Q^2}{N} \frac{\partial^2 D}{\partial Q \partial K} = r. \quad (30)$$

As $\lambda > 0$, the above condition gives

$$-Q \frac{\partial D}{\partial K} < r. \quad (31)$$

This states that the marginal effect of reduction in congestion cost by capacity expansion is smaller than the marginal cost of capacity, an indication of overinvestment. Therefore, in this case, the capacity decision by the airport is socially inefficient.
An alternative is the dual-till regulation where only the aeronautical operation is subject to cost recovery. In this case, the airport’s objective can be formulated as follows:

$$\max_{\mu, K} SW$$

s.t. \( \mu Q - c_0 Q - rK = 0. $$

For this airport, the first-order conditions are derived as follows:

$$\frac{\partial SW}{\partial \mu} = (\rho - D - Q \frac{\partial D}{\partial Q} - c_0 - c + V) \frac{\partial Q}{\partial \mu} + \lambda (\mu - c_0) \frac{\partial Q}{\partial \mu} + \lambda Q = 0, \hspace{1cm} (32)$$

$$\frac{\partial SW}{\partial K} = (\rho - D - Q \frac{\partial D}{\partial Q} - c_0 - c + V) \frac{\partial Q}{\partial K} - Q \frac{\partial D}{\partial K} - r + \lambda (\mu - c_0) \frac{\partial Q}{\partial K} - \lambda r = 0 \hspace{1cm} (33)$$

Simplifying and applying (7) and (8) gives:

$$-Q \frac{\partial D}{\partial K} - \frac{\lambda}{1 + \lambda} \frac{Q^2}{N} \frac{\partial^2 D}{\partial Q \partial K} = r. \hspace{1cm} (34)$$

The above condition has the same format as (30). Accordingly, we have

$$-Q \frac{\partial D}{\partial K} < r. \hspace{1cm} (35)$$

This implies that the welfare-maximizing public airport under a dual-till regulation would still make overinvestment in capacity in the sense that the marginal effect of reduction in congestion cost by capacity expansion is smaller than the marginal cost of capacity.

4.2 Regulated private airport

In practice, the cost-recovery constraints are also applied to private airports whose objective is profit-maximization. As with the public airport, there are also two versions of the constraints: the single-till regulation and the dual-till regulation. The single-till regulation is undesirable however, as Oum, Zhang and Zhang (2004) showed that private airports under the single-till regulation are prone to inefficient investment and operations. Since the budget constraint is cost-based, a private airport under such a regulation would get exactly zero profit. Thus, the airport would not benefit from cost reduction and so the incentive to improve productive
efficiency, and/or reduce costs, may be removed from the airport side. An alternative to the exact cost recovery is the price-cap regulation where airport charges are subject to periodic reviews that take into account the expected productivity improvement. While the price-cap regulation provides the airport with the incentive to improve efficiency as the airport could keep the profits achieved by productivity gains in excess to what is expected, there are also undesirable consequences of the single-till price-cap regulation. Beesley (1999) and Starkie (2001) pointed out that, as traffic at the airport grows over time, increased concession profits would force the price cap to be set at a lower level in each review and towards zero for very busy airports. At congested airports, this ever lowering airport charge is clearly a wrong signal to the users of the airports.

We now consider the second version of the budget constraint, the dual-till regulation where only the aeronautical operation is subject to cost recovery. In this case, the airport can make profits in concession operations and so the objective of the airport can be formulated as follows:

\[ \max_{\mu, K} Q \]

\[ \text{s.t. } \mu Q - c_0 Q - rK = 0 \]

For this airport, the first-order conditions for optimality are derived below:

\[ R \frac{\partial Q}{\partial \mu} + \lambda [Q + (\mu - c_0) \frac{\partial Q}{\partial \mu}] = 0, \quad (36) \]

\[ R \frac{\partial Q}{\partial K} + \lambda [(\mu - c_0) \frac{\partial Q}{\partial K} - r] = 0, \quad (37) \]

\[ \mu Q - c_0 Q - rK = 0. \quad (38) \]

The budget constraint (38) dictates that the regulated airport charge is the average operating cost plus the capacity cost per flight:

\[ \mu = c_0 + \frac{rK}{Q} \]

Then solving (36) and (37) and applying (7) and (8) gives

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8 As Tretheway (2001) put it: “It was something like having an unlimited expense account: if you could produce a receipt, you would be reimbursed.”
\[-Q \frac{\partial D}{\partial K} - \frac{Q^2}{N} \frac{\partial^2 D}{\partial Q \partial K} = r\]  

(39)

Thus,

\[-Q \frac{\partial D}{\partial K} < r,

indicating that the airport will over-invest in capacity.

Comparing (39) with (23), we see that the rule for capacity expansion of an unconstrained profit-maximizing airport is identical to that of a private airport under the dual-till regulation. In both cases the airport will, conditional on the aggregate output Q, make inefficient investment in capacity. Again note that this inefficiency in investment is also a result of the airport-airline interaction. As the carrier market structure moves towards more competition, \( N \to \infty \) (or equivalently, \( s_i = 0 \)), we will have

\[-Q \frac{\partial D}{\partial K} \to r.

That is, the inefficiency in capacity investment would tend to disappear when airlines become atomistic.

Oum, Zhang and Zhang (2004) showed that under a dual-till regulation, a private airport would tend to invest efficiently (if the regulation is in the form of the rate of return) or under-invest in capacity (if the regulation is in the price-cap form) if the carrier market is perfectly competitive (the carriers are all atomistic, i.e., \( s_i = 0 \)). Now we see that if the carrier market is not competitive, the airport would tend to over-invest in capacity and that as the carrier market structure moves more towards monopoly, the inefficiency in capacity investment would become more severe. We summarize our findings below.

Proposition 3. Conditional on the aggregate output Q, a private airport would over-invest in capacity whether it is unconstrained or under a dual-till regulation. A public airport would also over-invest in capacity whether it is under a single-till or dual-till regulation. For both types of airport, the overinvestment problem will be present as long as the carriers are non-atomistic. The more the carrier market moves towards monopoly, the more severe is the inefficiency in capacity investment.

The intuition for the overinvestment problem with the constrained public airport
is similar to the private airport, explained earlier after Proposition 2. In sum, an expansion in capacity that reduces congestion can not only raise the passengers’ willingness to pay but also cut the carriers’ ticket price owing to the decline of the marginal congestion cost that is internalized by the carriers. Both effects can contribute to a higher airport charge without changing the total demand. Consequently, when carriers have market power, reducing congestion is a more effective way to improve the airport’s financial position, whether it is for a private airport to extract profits or it is for a public airport being forced to recover costs.

5. Concluding Remarks

In this paper, we have studied airport decisions on pricing and capacity investment with both aeronautical and concession operations. In addition, the airport under consideration is serving air carriers who may have market power and behave like Cournot oligopolists or even monopolist. Under such settings, the carriers will attempt to internalize congestion delay costs their passengers impose one another. While this serves well for demand management by the carriers, it leaves the airport with less financial resource for capacity investment. If the airport were to pursue welfare maximization, the result would be financial deficit. Naturally, concession profits, if the airport is profitable, can be used to cross-subsidize the aeronautical operations.

We found that generally the aeronautical charge becomes lower when an airport has concession operations. For both private and public airports with concession operations, a cross-subsidy would happen in the sense that the airport would make profits on concession operations and at the same time would reduce airport charge in aeronautical operations, even though pricing rules on aeronautical operations may involve a monopoly markup over operating costs.

For airport capacity, we found that the profit-maximizing airport would over-invest in aeronautical capacity in the sense that the marginal benefit of capacity is smaller than the marginal cost. This overinvestment in capacity would persist even if the airport is under a dual-till regulation. We further found, somewhat surprisingly, that a public airport would also over-invest in capacity if the airport is subject to regulation, whether the form is a single-till or dual-till regulation. It is noteworthy that the inefficiency in capacity investment by both the private airport and public airport appears to be driven by the interaction between the airport and the carriers who have market power. Overall, our findings pointed out that reducing congestion is a more effective way to improve airport financing, whether it is for the private airports to increase profits or for the public airports being forced to recover costs.

The paper has also raised several issues and avenues for future research. First,
the various components of the welfare function have, as is fairly common in the literature, been assigned equal weights in the cases examined. It may be useful to look into the distribution of welfare weights and its consequences for airport privatization and regulation. For instance, competition authorities in both the European Union and the U.S. may give a higher weight to consumer surplus than to profits. Even within the consumer-surplus component, since we are concerned mainly with large and busy gateway airports served by network carriers, a significant portion of the passengers likely are foreigners. These passengers may receive a smaller weight in the national welfare function than domestic passengers. Analysis of unequal weights would thus be relevant for policy. Second, the airport charge has, as is common in the literature, been taken as exogenous to carriers. As Brueckner and Verhoef (2009) recently pointed out, this parametric view of airport charges may be less plausible when carriers have market power. In this case the carriers may not take congestion levels as exogenous, and so it is better to examine how they respond to a charging rule than to a number. Incorporating this idea with the analysis presented here would be an important further research topic.

Third, while the price rules were derived explicitly in the paper, for investment only the rules and the direction of deviations from optimal levels are determined. It would be important, and relevant for policy making (in terms of choosing between forms of governance and regulation), to further provide indications of how large deviations are in various cases. An estimation of magnitudes of the deviations would require a numerical exercise involving specific assumptions about passenger demands, carrier operating costs, congestion delay costs and the airport’s cost of capacity. We see such exercises as a natural extension of the analysis presented here, although beyond the scope of the present article.

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