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Abstract

Despite the airport privatization and deregulation trend in recent years, whether or not the privatized or commercialized airports should be left unregulated is still an open question. Related to this issue, one question that has received a very little attention to date is if and how pricing behavior of unregulated airports affect downstream airline competition, especially the competition between airlines offering differentiated services such as the case of full service airlines (FSA) vis-à-vis low cost carriers (LCC). If the upstream monopoly (airport) hinders downstream (airline) competition, the welfare effects of the upstream unregulated monopoly may be much larger than initially suspected. This aspect of airport pricing has not been formally incorporated in the debate on airport price regulation.

In this paper, we study a duopoly model to capture the differential competitive effects of changing airport user charges on FSAs and LCCs. By making reasonable assumptions on differential price elasticities, unit costs and competitive behavior as manifested by firm-specific conduct parameters, we perform numerical simulations to measure differential effects on an FSA and an LCC of increasing airside user charge by an unregulated upstream monopolist airport.

Our analytical and numerical results suggest existence of the asymmetric effects of an airport's monopoly pricing on LCC and FSA. That is, LCCs suffer more from an identical cost increase than FSAs and are, therefore, more vulnerable to monopolistic pricing practices of an unregulated airport. This implies that unregulated airport pricing would reduce the extent of competition in downstream airline markets, and thus, cause a further detrimental effect on welfare over and above the first-order dead weight loss of airport's monopolistic pricing. Considering that LCCs have brought considerable reduction of average fares and the associated welfare gains, it is important for the governments to take into account of these asymmetric effects of increasing airport user charges on FSAs and LCCs when they consider the form and extent of regulation or deregulation.

Although our model and simulation work deal specifically with the effect of airport pricing on downstream airline markets, our framework of analysis may be applicable to analysis of any policy affecting costs of FSAs and LCCs including security levies as well as potentially adaptable to other upstream-downstream industry cases.

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1. Introduction

The competitive effects of input price increases form an important research and policy topic for two reasons. First, lacking upstream competition may influence downstream competitiveness and reduce welfare. Secondly, markets with volatile input prices may be prone to effects on downstream competitiveness as well. Both features are clearly present in aviation, where airports with market power provide indispensable inputs to airlines.

This subject is primarily important for the regulation of privatized airports. Starting with the privatization of the three airports in the London area (Heathrow, Gatwick, and Stansted) and four other airports in the UK to BAA plc. in 1987, many airports around the world have already been or are in the process of being privatized. The majority stakes of Copenhagen Kastrup International Airport, Vienna International Airport and Rome's Leonardo Da Vinci Airport have been sold to private owners. Many other European airports are in the process of being privatized. Auckland International Airport and Wellington International Airport in New Zealand and a large number of major Australian airports have been privatized as well. South Africa, Argentina, Mexico and many Asian countries including Japan are also considering privatizing their airports.¹ Canada is currently reviewing the regulatory oversight issues on its local airport authorities which were set up as not-for-profit corporations to manage major airports.

Since the late 1990s economists have been arguing whether privatized airports need to be regulated in the first place. Studies on country-specific options and experiences on this issue include Forsyth (1997, 2002a, b), Beesley (1999), Starkie and Yarrow (2000), and Starkie (2001). In particular, Beesley (1999) argues that the price-cap regulation is inappropriate, particularly in the case of London's Heathrow. Starkie (2001) further concludes that *ex-ante* regulation for airports might be unnecessary because the airports are unlikely to abuse their monopoly power due to the existence of complementarity between the demand for aviation services and the demand for concession and other commercial services (concession).²

Indeed, some countries have moved towards a situation in which there is no formal price regulation but only monitoring of privatized airports (Forsyth, 2002b). For example, New Zealand does not impose formal price regulation of its privatized airports. Instead, since 1988, Auckland, Christchurch and Wellington airports have been subject to "light-handed" regulation which requires airport to disclose contractual terms, financial reports and performance measures. In Australia, primarily based on recommendation of the Productivity Commission (2001), on 1 July, 2002 the government ended the price-cap regulation from all privatized airports for a period of five years.³ Towards the end of the five-year test period an

¹ See Hooper (2002) for the list of Asian airports that are being considered for privatization.

² Besides *ex-ante* regulation (ROR, price-cap), there is also *ex-post* regulation (conduct regulation). It is important to point out that those economists who argue for deregulation usually have the former in mind and are not proposing that conduct regulation be abolished also.

³ At the same time, the Parliamentary Secretary to the Treasurer directed the Australian Competition and Consumer Commission (ACCC) to undertake formal monitoring of prices, costs and profits (Price Monitoring)

independent review will be conducted in order to decide whether or not some sort of price regulation on the airports need to be re-established.

There are some evidences to suggest that the airports attempted to raise prices after deregulation, and interested parties have had considerable concerns that airports may abuse their market power. Three regulatory reviews were conducted in New Zealand after the 1988 deregulation, the last of which started in May 1998 and took five years to finish. In Australia, Virgin Blue applied to the Australian Competition Tribunal to declare airside services at the Sydney Airport as commercial services to be treated according to the Trade Practices Act of Australia. The Declaration of the airside services at the Sydney Airport under the TPA would force the Sydney Airport's management to negotiate with the airlines before setting new fees or changing existing level of fees including aircraft landing charges. In case there is a major disagreement between the airport and the airlines, then the matter is referred to a binding arbitration by ACCC. Virgin Blue, a major LCC in Australia, believes that Sydney Airport under the current system has the ability and incentive to increase airside service charges substantially, and thus harm its ability to compete. Interestingly, Virgin Blue's major competitor, Qantas Airlines, supported the Declaration Application.

The subject of the research treated in this paper has been motivated by our involvement in the Virgin Blue vs. Sydney Airport case before the Australian Competition Tribunal. In this paper reports some analytical results we obtained during our investigation for the case. In particular, we analyze how an increase in airport charge would affect the downstream airline competition, especially when airlines offer differentiated products (services) in the market place. A duopoly model with differentiated products is used to obtain analytical results. Due to strict confidentiality restrictions on the rich data to which we had access to, we are not able to report empirical results from real market data. Instead, a numerical example and sensitivity tests are used to simulate the differential effects of an identical increase in airside services prices (mainly aircraft landing fees) on FSAs and LCCs.

Although we focus our analysis on air transport industry, our approach to analysis is likely to have a wider application to other industries and markets. Other network-oriented industries such as other transport modes and electric power firms face a limited upstream competition due to the natural monopoly nature of most networks. Transport and energy sectors are also characterized by volatile input prices. The Third Party Access pricing has been an important research topic in some network sectors, notably in telecommunication and energy networks

Third party access (TPA) to the network is an important condition for effective competition in network sectors.⁴ TPA refers to both the possibility of access and the conditions under which the access can take place. One important condition is the price under which access is granted, the access fee. Much of the literature relates to situations where the upstream (network) supplier is vertically integrated with one of the downstream competitors, which is not very relevant in the relation between airports and airlines since, as far as known to us, not a major airport owns an airline.

The remainder of this paper is organized as follows. Section 2 discusses theoretical derivation of the impact of an identical increase in input cost (airport's airside service fees) on competition in the downstream airline markets. A numerical simulation and results are

related to the supply of aeronautical services and related services at seven major airports: Adelaide, Brisbane, Canberra, Darwin, Melbourne, Perth and Sydney airports.

⁴ See, for instance Laffont *et al.* (1998), Lewis and Sappington (1999) and Granderson (2000)

presented in section 3. The final section concludes and discusses the results.

2. Effects of Airport Charge Increase on Competition in Downstream Airline Market

As airports provide essential inputs to airlines, it follows immediately that when the airport charge is increased above socially optimal level (competitive level), air travel volume will be reduced below socially optimal level, leading to a social welfare loss. This issue has been extensively studied in the literature of double marginalization and natural monopoly regulation. However, so far the impact of airport charges on downstream airline competition has received little attention. Even less attention has been given to the impacts of changing airport charges on the competition between Full Service Airlines (FSAs) and Low Cost Carriers (LCCs).

This problem is worth a scrutiny as LCCs' activities appear to be more sensitive to airport charges. Many LCCs around the world actually started their business by using secondary airports taking advantage of their lower airport charges and less congestion. For example, Ryanair could not have achieved such a successful service on the Dublin-London route if they had to use Heathrow airport. Also, it is well known that Southwest starts typically their operations at secondary airports in U.S. It is well known that European LCCs, especially Ryanair, drive a hard bargain with airports and local business interests in order to extract best charges and service conditions. Some LCCs are apparently successful in gaining even a subsidy from the airport for an initial period of their service initiation. The agreement between Brussel's Charleroi Airport and Ryanair was under investigation by European Commission as the commercial assistance to Ryanair by the airport was accused as constituting an illegal state subsidy (Piling, 2003). Ryanair paid, in average, \$1 or less per passenger to eight provincial UK airports during the 1998 – 2000 period while the average aeronautical revenue at major airports in Europe were above \$8 per passenger (Barrett 2004). LCCs' high sensitivity to airport charges is also evidenced by the fact that some LCCs chose to abandon a market if they do not get a deep discount on airport charges continuously, as the airports seek to recover their investments made during their "promotion" periods. For example, Dublin, London's Luton airport and Manchester have experienced a reduction in LCC services after revising initial low airport changes. (see Francis, Fidato and Humphreys (2003) and Barrett (2000)). All these suggest that LCCs are more sensitive to the terms of airport access terms than FSAs. Meanwhile, LCCs have been credited as a major contributor to airline competition and average fare reduction, as documented, for example, in Windle and Dresner (1996) and Dresner, Liu and Windle (1999). Understanding the possible differential impacts of airport charge on LCCs and FSAs is, therefore, of great importance for airport regulators and airline competition policy makers.

Although double marginalization and competition between FSAs under the assumption of homogeneous products have already been studied by others, as their results provide a good benchmark against which to compare our duopoly results on differentiated products we present briefly a duopoly model with homogeneous product in section 2.1 below before presenting the differentiated products duopoly model.

2.1 The benchmark case: Homogeneous Product Duopoly

Most previous studies on LCC competition have focused on their pricing effects on the aviation market without explicitly treating product differentiation between FSA and LCC, an important feature of the competition. This may overlook the differential impacts of a change in external condition such as changes in input prices, taxes, security charges, etc. In this section, we will first model duopoly competition when firms offer homogenous products. Analytical results obtained will then be used as a benchmark with which to compare the results of the differential product duopoly model presented later.

Suppose two firms offer homogenous product to the market with constant marginal costs c_1 and c_2 , where $c_1 > c_2 > 0$. They face the same linear market demand:

$$(1) \quad P = a - b(q_1 + q_2),$$

where q_1 and q_2 represent two firms' outputs respectively. Each firm maximizes profit by setting its own output, taking into account of the other firm's reaction. Each firm's profit function can be written as:

$$(2) \quad \pi_i = q_i[a - b(q_i + q_j)] - q_i c_i$$

The first order conditions (FOC) for profit maximization are as follows:

$$(3) \quad \frac{\partial \pi_i}{\partial q_i} = a - b(q_i + q_j) - bq_i(1 + v_i) - c_i = 0$$

Where $v_i = \frac{dq_j}{dq_i}$ denotes the conduct parameter (conjectural variation) of firm i , following

Oum, Zhang and Zhang (1993). The conduct parameter is a measure of how firms compete. When firms are symmetric, a conduct parameter of 1 corresponds to perfect collusion, a zero conduct parameter corresponds to Cournot competition while a conduct parameter of -1 denotes Bertrand competition. Combining the first order conditions of both firms, we obtain the following system of equations (4):

$$(4) \quad \begin{cases} bq_1(2 + v_1) + bq_2 = a - c_1 \\ bq_1 + bq_2(2 + v_2) = a - c_2 \end{cases}$$

solving for equilibrium output for each firm yields:

$$(5) \quad \begin{cases} q_1 = \frac{(a + av_2 + c_2) - (2 + v_2)c_1}{b(3 + v_1v_2 + 2v_1 + 2v_2)} \\ q_2 = \frac{(a + av_1 + c_1) - (2 + v_1)c_2}{b(3 + v_1v_2 + 2v_1 + 2v_2)} \end{cases}$$

It immediately follows that when two firms engage in equally aggressive competition such that $v_1 = v_2 = v$, an efficient firm has larger output $q_1 < q_2$ and higher profit $\pi_1 < \pi_2$, provided that $v > -1$. In the special case where $v = -1$, all output is provided by the firm with the lowest costs and profits are zero for all other firms.

If the two firms' marginal costs are increased by the same amount, dc , firm 1's output will change by:

$$(6) \quad dq_1 = \left(\frac{dq_1}{dc_1} + \frac{dq_1}{dc_2} \right) dc = \frac{-(1+v_2)}{b(3+v_1v_2+2v_1+2v_2)} dc$$

And by symmetry for firm 2:

$$(7) \quad dq_2 = \left(\frac{dq_2}{dc_1} + \frac{dq_2}{dc_2} \right) dc = \frac{-(1+v_1)}{b(3+v_1v_2+2v_1+2v_2)} dc$$

Clearly, the denominator of (6) and (7) is positive for all $v > -1$, implying that both firms experience an equal amount of output reduction when they are equally aggressive. As the low-cost firm has a higher output level, it faces a proportionally smaller output reduction, despite the fact that it faces a proportionally higher unit cost increase than its higher cost competitor.

If, on the other hand, conduct parameters differ between the two firms, the picture can change. Suppose, as is most likely the case, that the low cost producer competes more aggressively (i.e. $0 \geq v_1 > v_2 \geq -1$), then it follows from equations (6) and (7) that the reduction in output will be larger for the low cost producer ($0 \geq dq_1 > dq_2$).

In summary, when two firms offer homogenous products and engage in equally aggressive competition:

- The firm with lower cost achieves larger output and higher profit;
- When there is an identical increase in marginal costs, firms experience the same amount of output reduction, so that the lower cost firm is harmed proportionally less in terms of output and profit reduction; and
- But, if we introduce differences in the conduct parameters, assuming that the lower cost firm is more aggressive in competition, we find that it will experience a larger amount of output reduction.

2.2 Differentiated Duopoly Competition Model

Clearly the homogeneous product assumption used above is not realistic for modeling the competition between FSA and LCC. Both FSA and LCC offer multiple products in the market. FSAs typically offer a combination of first class and business class services, full fare economy, shallow discount services, and a fair amount of deep discount services. Although LCCs are well known for selling cheap deep discount tickets, they also offer increasingly flexible services comparable to full economy and shallow discount tickets sold by FSA. As such, FSAs and LCCs may be regarded as offering homogenous products in the lower end of the market segments, but overall FSAs offer a superior product compared to LCC with higher costs. Previous studies such as Richards (1996) and Windle and Dresner

(1999) confirm that LCCs in general target more price sensitive travelers with inferior services.

To analyze the competition between FSA and LCC by taking into account of their product differentiation formally, we utilize a differentiated duopoly model proposed by Dixit (1979) and treated further in Singh and Vives (1984). Throughout this section, we assume firm 1 to be the FSA and firm 2 the LCC, both facing following demand system:

$$(8) \begin{cases} p_1 = a_1 - b_1q_1 - kq_2 \\ p_2 = a_2 - kq_1 - b_2q_2 \end{cases}$$

which corresponds to a representative consumer maximizing a quadratic and strictly concave utility function $U(q_1, q_2) = a_1q_1 + a_2q_2 - \frac{1}{2}(b_1q_1^2 + 2kq_1q_2 + b_2q_2^2)$. Concavity implies that $b_1b_2 - k^2 > 0$. And the demand function can be rewritten as:

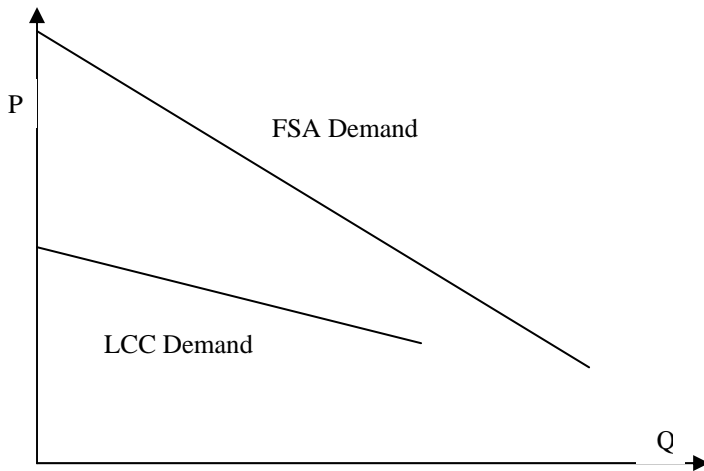
$$(9) \begin{cases} q_1 = \frac{1}{b_1b_2 - k^2} [(a_1b_2 - a_2k) - b_2p_1 + kp_2] \\ q_2 = \frac{1}{b_1b_2 - k^2} [(a_2b_1 - a_1k) + kp_1 - b_1p_2] \end{cases}$$

The restriction of positive quantities implies the following constraints:

$$(10) (a_1b_2 - a_2k) > 0 \text{ and } (a_2b_1 - a_1k) > 0$$

The stylized demand function can be depicted as in figure 1, based on our empirical observation in the aviation market:

Figure 1. Stylized Demand System



Since LCCs focus on price-sensitive customers, they face more price-elastic demand. Utilizing the fact that, in general, a firm's price impacts more on their own market output

than on the supply quantity of the substitutes (competitor's output), we can further impose the following constraints to our model:

$$(11) \quad \begin{cases} a_1 > a_2 > c_1 > c_2 \\ b_1 > b_2 > k > 0 \end{cases}$$

Where c_1 and c_2 are firms' constant marginal costs. We restrict to the case where two firms produce substitutes, implying that $k > 0$. If we further restrict to the case where two firms can effectively compete with each other, then we can impose $a_2 > c_1$ used in (11).

Assuming that both firms maximize profits by setting output quantities, then the FOC for firm 1 may be written as:

$$\frac{\partial \pi_1}{\partial q_1} = -(b_1 + k \frac{\partial q_2}{\partial q_1})q_1 + a_1 - b_1 q_1 - k q_2 - c_1 = 0$$

where we can denote firm 1's conduct parameter as $v_1 = \frac{\partial q_2}{\partial q_1}$. Firm 1 and 2's FOCs define their respective reaction functions, which constitute the following system of equations:

$$(12) \quad \begin{cases} a_1 - (2b_1 + kv_1)q_1 - kq_2 - c_1 = 0 \\ a_2 - kq_1 - (2b_2 + kv_2)q_2 - c_2 = 0 \end{cases}$$

When the two firms do not collude in the market⁵, we have $-1 \leq v_i \leq 0$, which implies:

$$(13) \quad \begin{cases} m = (2b_1 + kv_1) > b_1 > k > 0 \\ n = (2b_2 + kv_2) > b_2 > k > 0 \end{cases}$$

Note that our earlier restriction that $b_1 > b_2$ implies that $m > n$ for all $v_1 \geq v_2$. Solving the FOC equation systems leads to firms' equilibrium outputs given each firm's conduct parameter:

$$(14) \quad \begin{cases} q_1 = \frac{n(a_1 - c_1) - k(a_2 - c_2)}{mn - k^2} \\ q_2 = \frac{m(a_2 - c_2) - k(a_1 - c_1)}{mn - k^2} \end{cases}$$

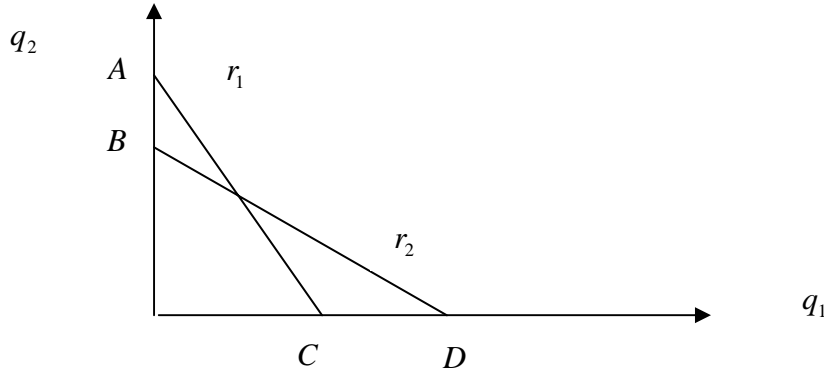
Since $(mn - k^2) \geq [b_1 + (b_1 - k)][b_2 + (b_2 - k)] - k^2 > 0$, positive output implies that

$$(15) \quad \begin{cases} n(a_1 - c_1) - k(a_2 - c_2) > 0 \\ m(a_2 - c_2) - k(a_1 - c_1) > 0 \end{cases}$$

⁵ This refers to the cases when firms engage in competition more aggressively than Cournot.

Restrictions in equation (15) ensure that two firms' reaction functions intersect each other so that a unique Nash Equilibrium exists. This is depicted in the following stylized figure 2.

Figure 2. Two Firms' Reaction Functions Intersect



Where r_1 and r_2 are firm 1 and 2's reaction functions respectively, and $A = \frac{a_1 - c_1}{k}$, $B = \frac{a_2 - c_2}{n}$, $C = \frac{a_1 - c_1}{m}$, $D = \frac{a_2 - c_2}{k}$ are the points where these reaction functions intersect with each firm's output axis.

For clarity of interpretation, solution (14) can be rewritten as follows:

$$(16) \left\{ \begin{array}{l} q_1 = \frac{na_1 - ka_2}{mn - k^2} - \frac{n}{mn - k^2}c_1 + \frac{k}{mn - k^2}c_2 \\ q_2 = \frac{ma_2 - ka_1}{mn - k^2} + \frac{k}{mn - k^2}c_1 - \frac{m}{mn - k^2}c_2 \end{array} \right.$$

That is, each firm's output depends on the degree of product differentiation (as measured by k)⁶, firms' costs and conduct parameter.

As in the previous section, let us look at the effect of an identical increase in marginal costs (i.e. $dc_1 = dc_2 = dc$) on both firms' outputs. By applying such an identical marginal cost increase to the system of equations in (16), we obtain:

⁶ More precisely, the degree of product differentiation depends on the relative values of k , b_1 and b_2 in equation

(8). In fact, $\frac{k^2}{b_1 b_2}$ may be regarded as a more appropriate measure of product differentiation.

$$(17) \quad \begin{cases} dq_1 = \left(\frac{\partial q_1}{\partial c_1} + \frac{\partial q_1}{\partial c_2} \right) dc = -\frac{n-k}{mn-k^2} dc \\ dq_2 = \left(\frac{\partial q_2}{\partial c_1} + \frac{\partial q_2}{\partial c_2} \right) dc = -\frac{m-k}{mn-k^2} dc \end{cases}$$

It can be seen that when two firms engage in equally aggressive competition ($v_1 = v_2 = v$), $k < (n = 2b_2 + kv) < (m = 2b_1 + kv)$, which implies that $|dq_1| < |dq_2|$. This result means that when duopoly firms adopt a similar strategy in setting quantity (same conduct parameter), then the firm facing less price-elastic demand will end up reducing its output less than its competitor (the firm facing higher price-elastic demand). In our case, when an FSA and an LCC engage in equally aggressive competition, the equilibrium passenger volume of LCC will be reduced more than that of FSA when an identical increase in marginal cost occurs to both firms. It is important to note that this finding is strengthened if we assume that the LCC competes more aggressively than the FSA, implying $0 \geq v_1 > v_2 \geq -1$.

Then, what can we be said about the relative reduction in outputs of the two firms from equations (17)? To answer this question, we express equation (17) in relative terms as below:

$$(18) \quad \begin{cases} \frac{dq_1}{q_1} = -\frac{n-k}{n(a_1-c_1)-k(a_2-c_2)} dc \\ \frac{dq_2}{q_2} = -\frac{m-k}{m(a_2-c_2)-k(a_1-c_1)} dc \end{cases}$$

It can easily be shown that $(a_2 - c_2) < (a_1 - c_1)$ is a sufficient condition to ensure that the LCC's output is more affected proportionally than the FSA's output.

As c_i denotes the constant marginal costs of carrying one additional passenger, whereas a_i is the highest evaluation (for the first unit of consumption) for the service, we should have $a_i \gg c_i$, which in general leads to $(a_1 - a_2) > (c_1 - c_2)$ when two firms' services are fairly differentiated. However, if firm 1 and firm 2 offer almost homogenous product (implying $a_1 \approx a_2$), then one can see that the firm with higher marginal cost will lose proportionally more output. This is the same result as observed in the benchmark case treated in section 2.1

Let us now turn our attention to the effects of the identical cost increase on air fares. With each firm's outputs at the equilibrium, the price of each product can be obtained by substituting the equilibrium outputs in equation (14) into the respective demand functions:

$$(19) \quad \begin{cases} p_1 = \frac{(a_1 n - a_2 k)(m - b_1)}{mn - k^2} + \frac{b_1 n - k^2}{mn - k^2} c_1 + \frac{k(m - b_1)}{mn - k^2} c_2 \\ p_2 = \frac{(a_2 m - a_1 k)(n - b_2)}{mn - k^2} + \frac{k(n - b_2)}{mn - k^2} c_1 + \frac{mb_2 - k^2}{mn - k^2} c_2 \end{cases}$$

Each firm's equilibrium price increase caused by the cost increase dc can be written as:

$$(20) \left\{ \begin{array}{l} dp_1 = \left(\frac{\partial p_1}{\partial c_1} + \frac{\partial p_1}{\partial c_1} \right) dc = \frac{b_1 n - k^2 + mk - kb_1}{mn - k^2} = \left(1 - \frac{(m - b_1)(n - k)}{mn - k^2} \right) dc < dc \\ dp_2 = \left(\frac{\partial p_2}{\partial c_1} + \frac{\partial p_2}{\partial c_1} \right) dc = \frac{kn - k^2 + mb_2 - kb_2}{mn - k^2} = \left(1 - \frac{(m - k)(n - b_2)}{mn - k^2} \right) dc < dc \end{array} \right.$$

This means when an identical marginal cost increase occurs, neither firm can fully pass the cost increase to passengers. It is intuitively clear from equation (20) that $dp_1 > dp_2$ only needs

$$(m - b_1)(n - k) < (m - k)(n - b_2) \text{ or } [(b_2 - k)(v_1 - v_2) + (b_2 - b_1)(1 + v_2)] < 0$$

Which will hold when $v_1 \leq v_2$, provided that at least one of the two conduct parameters exceeds the value of -1. This suggests that FSAs have greater ability to pass on the cost increase to passengers.

As we have shown thus far, an identical marginal cost increase is likely to harm an LCC more than it will harm an FSA, both in terms of output and prices. Similarly, it can be shown that in general, the FSA's profit will be proportionally less harmed by an identical marginal cost increase. To show this, the two firms' profit functions can be written as:

$$(21) \left\{ \begin{array}{l} \pi_1 = (p_1 - c_1)q_1 = \frac{m - b_1}{(mn - k^2)^2} [n(a_1 - c_1) - k(a_2 - c_2)]^2 \\ \pi_2 = (p_2 - c_2)q_2 = \frac{n - b_2}{(mn - k^2)^2} [m(a_2 - c_2) - k(a_1 - c_1)]^2 \end{array} \right.$$

Therefore, an identical marginal cost increase dc will change firms' profit by:

$$(22) \left\{ \begin{array}{l} d\pi_1 = \left(\frac{\partial \pi_1}{\partial c_1} + \frac{\partial \pi_1}{\partial c_2} \right) dc = -2 \frac{m - b_1}{(mn - k^2)^2} [n(a_1 - c_1) - k(a_2 - c_2)](n - k) dc \\ d\pi_2 = \left(\frac{\partial \pi_2}{\partial c_1} + \frac{\partial \pi_2}{\partial c_2} \right) dc = -2 \frac{n - b_2}{(mn - k^2)^2} [m(a_2 - c_2) - k(a_1 - c_1)](m - k) dc \end{array} \right.$$

Like before, $(a_2 - c_2) < (a_1 - c_1)$ is a sufficient condition to ensure that the full service airline is proportionally less affected. However, as we have shown that firms' positive outputs implies the following:

$$\left\{ \begin{array}{l} n(a_1 - c_1) - k(a_2 - c_2) > 0 \\ m(a_2 - c_2) - k(a_1 - c_1) > 0 \end{array} \right.$$

From these, it immediately follows that $d\pi_1 < 0$ and $d\pi_2 < 0$ whenever $dc > 0$. That is, although FSA will be proportionally less harmed by such an identical cost increase, its

profitability will always be reduced. As such, unless the FSA is sure that such identical cost increase will drive the LCC out of the market, it is not in the FSA's interest to adopt the strategy of "Raising Rival's Cost", at least not in the form of encouraging an airport to raise the user charges it imposed on airlines (in such a way to increase marginal costs of both airlines by an identical amount). This may explain why Qantas joined Virgin Blue's declaration application. Although a price increase by Sydney airport would harm Virgin Blue more than it does Qantas (thus creating some competitive advantage for Qantas), it is impossible for Virgin Blue to totally abandon services to/from Sydney airport.

Although these results are derived from the assumption that firms have constant marginal costs, our general conclusions most likely continue to hold even if fixed costs are also considered. When airlines have fixed costs, their profits will be smaller given the same amount of output and price. Each firm's reaction function will have the same shape as before, but optimal outputs below a certain point now correspond to loss minimization instead of profit maximization. As LCCs typically operate on a route by route case while FSAs often consider the overall network effects, it is likely that LCCs will be the first to exit the market because its equilibrium outputs and profits more sensitive to an identical increase in airport charge. Of course, empirically this depends on each airline's existing profitability, cost and competition strategy.

In summary, so far we have obtained the following key analytical results when airlines compete by offering homogenous products, as in the case when an FSA competes with another FSA, or an LCC competes with another LCC, or an FSA competes with an LCC in the same market segment:

- When firms engage in equally aggressive competition, the firm with lower cost will achieve larger output and higher profits;
- When firms engage in equally aggressive competition, an identical increase in marginal cost will punish the high cost airline more as both its output and profit are reduced proportionally more; and
- A firm adopting a more aggressive competition strategy (manifested by a lower value of conduct parameter) will end up reducing its equilibrium output by a larger amount when an external shock (e.g., airport user charges) raises both firms' marginal cost by an identical amount.

When airlines engage in differentiated product duopoly, such as in the overall competition (as opposed to competition in a particular market segment) between an FSA and an LCC, we find that:

- An identical increase in marginal cost will harm an LCC more than an FSA as the former suffers proportionally more reduction of its output and profit than the latter;
- Neither the FSA nor the LCC can fully pass on such an external cost increase to consumers. Both firms will suffer a profit loss;
- If the LCC competes at least as aggressively as the FSA, an identical marginal cost increase would lead the LCC to reduce its output quantity by a larger amount than the FSA, and the LCC's price increase would be lower than that of the FSA.

That is, an identical cost increase will proportionally harm the LCC more as the airline is less able to pass on such a cost increase to its price sensitive consumers. Although such an identical marginal cost increase, such as per-passenger airport service charge, or government

imposed per-passenger security charge is likely to only constitute a small proportion of the total unit costs, its impacts may be non-trivial. As most airlines are currently operating at barely breakeven level, such cost increase will further reduce these airlines' profitability, possibly forcing them to reduce service levels or cease operations on some routes altogether.

We have shown that in theory, although an FSA's outputs and profits will be less impacted negatively by an external factor leading to an identical increase per-passenger marginal cost to both FSAs and LCCs (and thus, creating a competitive advantage over an LCC) an FSA will not adopt the "Raising Rival's Cost" strategy by encouraging airports raise airside user charges except when it is sure of the LCC's exit out of the market.

3. A Numerical Example

This section illustrates the mechanisms described in the previous sections, using a numerical example. The parameter values used here mimic a realistic aviation market, but we do not pretend to provide any form of empirical proof, nor do they represent any particular city pair market. All parameters used here are in accordance with the constraints and assumptions described in section 2, and reflect our best estimate based on our understanding of the air transport markets, in particular in the markets where an FSA and an LCC compete.

Assumptions:

We start with the likely values for some of the parameters so that the differentiated duopoly model described in section 2.2 can be calibrated. This base case provides some numerical results which enables one to appreciate the differential impacts of an identical marginal cost increase on an LCC and an FSA. Sensitivity tests are used so that we are sure these results hold for any reasonable ranges of the parameter values. The assumptions we made for the base case are:

- Conduct Parameters: We limit our analysis to non-collusive games, thus limiting ourselves to non-positive values for v_1 and v_2 . The base values we choose are $v_1 = v_2 = -0.5$.
- b_1 , b_2 and k : constraint (10) requires $b_1 > b_2 > k$. Parameter k measures how different the services provided by the two firms are. Let $k = t \cdot b_1$ ($0 < t < 1$), then if $t = 0$ the two firms' services are not substitutes at all, while $t = 1$ indicates that the FSA and LCC produce perfectly homogenous services. In the base case we assume $t = 0.7$.

We also assume $b_2 = \frac{b_1 + k}{2}$ so that constraint (10) is always satisfied.

- Market price elasticity for air travel: -1.4.
- Each firm's equilibrium price: Clearly these values serve as a numeraire only. For simplicity, we assume FSA's price at $p_1 = 100$ while the LCC's price is assumed to be 25% lower, i.e., $p_2 = 75$.
- Each firm's equilibrium output: Only the firms' relative shares matter. We assume that at equilibrium the FSA has a 60% market share carrying 60,000 passengers each month.

Model Results:

With the above assumptions, other parameters of the model can be derived as follows:

- Market output $Q = q_1 + q_2 = 100,000$.

- Market price $P = \frac{P_1q_1 + P_2q_2}{Q} = 90$
- b_1 : When both firms experience an identical price change $dp_1 = dp_2 = dp$, or an equivalent market price change of $dP = dp$, from the demand equation in (9) the total change in market output can be obtained as $dQ = dq_1 + dq_2 = \frac{2k - b_1 - b_2}{b_1b_2 - k^2} dp$. As market elasticity $e = \frac{dQ}{dP} \frac{P}{Q}$ is known, one can derive $b_1 = -\frac{3P}{e(2t+1)Q} = 0.0008$.
- Table 1 report the base case values of other parameters that we derived:

Table 1: Derived Parameter Values for Base Case

Parameters	b_2	c_1	c_2	a_1	a_2	e_{11}	e_{22}
Value	0.00068	68.7	58.9	170.7	136.1	-4.9	-6.48
Parameters	k	m	n	π_1	π_2	e_{12}	e_{21}
Value	0.00056	0.00133	0.00108	1,880,357	642,857	3.02	6.05

Note e_{ii} are firm's own price elasticity, while e_{ij} measures firm i 's cross elasticity with respect to firm j 's price. They have the right sign and are within a reasonable range⁷. With all of the parameter values, it is straightforward to calculate the impact of an identical increase in marginal cost. The results are summarized in table 2.

Table 2. Changes in Market Equilibrium Caused by Different % Increase in Airport Charge

%Charge Increase	50%	100%	150%	200%	250%	300%	350%	400%	450%	500%
% Δq_1	-0.4%	-0.8%	-1.2%	-1.6%	-1.9%	-2.3%	-2.7%	-3.1%	-3.5%	-3.9%
% Δq_2	-0.9%	-1.7%	-2.6%	-3.4%	-4.3%	-5.1%	-6.0%	-6.8%	-7.7%	-8.5%
% Δp_1	0.4%	0.8%	1.1%	1.5%	1.9%	2.3%	2.6%	3.0%	3.4%	3.8%
% Δp_2	0.5%	1.0%	1.5%	1.9%	2.4%	2.9%	3.4%	3.9%	4.4%	4.8%
% $\Delta \pi_1$	-0.8%	-1.5%	-2.3%	-3.1%	-3.8%	-4.6%	-5.4%	-6.1%	-6.9%	-7.6%
% $\Delta \pi_2$	-1.7%	-3.4%	-5.0%	-6.7%	-8.3%	-9.9%	11.6%	13.1%	14.7%	16.3%
% ΔP	0.4%	0.9%	1.3%	1.8%	2.2%	2.7%	3.1%	3.6%	4.0%	4.5%
% ΔQ	-0.6%	-1.1%	-1.7%	-2.3%	-2.9%	-3.4%	-4.0%	-4.6%	-5.2%	-5.7%

As expected, the reduction in LCC's profit is larger than that of the FSA, implying proportionally larger impacts on the LCC. Although the market price elasticity in the base case is only assumed to be -1.4, the corresponding LCC's firm-specific price elasticity is much larger in absolute value ($e_{22} = -6.48$). Together with its low cost, it is not surprising that even a moderate increase in airport charge will reduce its profitability significantly. One

⁷ Few studies have empirically estimated firm specific elasticity for airlines. Oum, Zhang and Zhang (1993) reported that UA and AA's firm specific elasticities are significantly above market elasticity. In many leisure routes the two firms' firm specific elasticity were as high as around -10.

should note that the LCC's price for the base case was assumed to be \$75. The reduction in airline's profitability will be more moderate for longer distance (more costly) routes. In the base case, the FSA loses fewer passengers and pass on greater proportion of the price increase to passengers. These are, of course, entirely consistent with our analytical results.

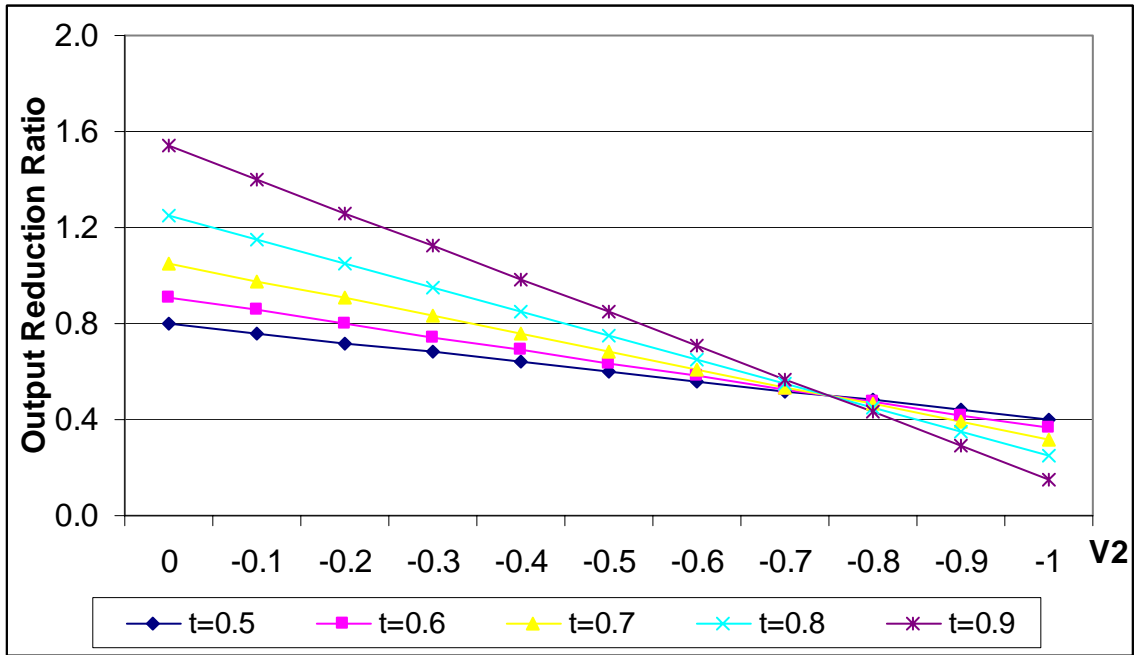
There are two major assumptions in our simulation: value of firms' conduct parameter, and parameter t (k) which measures the extent of product differentiation between LCC and FSA. Few studies estimated differential conduct parameters empirically using airline data on LCCs and FSAs. Haugh and Hazledine (1999) and Hazledine, Green and Haugh (2001) are exceptions that we are aware of. Although their studies found that the LCC does behave more aggressively in the trans-Tasman market (as evidenced by LCC's lower conduct parameter), they obtained this result based on calibration of their models instead of estimating the model parameters empirically from the real data. Although their finding supports our view that LCCs use more aggressive strategies (equivalent to a lower value of conduct parameter) than FSAs, it is necessary for us to conduct a sensitivity test on a plausible range of conduct parameter values in order to study sensitivity of our results.

First, we fix firm 1's conduct parameter to -0.5 ($v_1 = -0.5$) and change the value of firm 2's conduct parameter v_2 from 0 to -1, with an interval of 0.1. We calculate all market parameters for each pair of the conduct parameters and used to simulate for one unit (100%) increase in marginal cost for both carriers. Such tests are performed for the t value of 0.5 to 0.9 at an interval of 0.1 so that k takes values in the range of $[0.5b_1, 0.9b_1]$, respectively.⁸

We plot curves for the two firms' passenger reduction ratio $y = \frac{dq_1}{dq_2}$ in figure 3. These curves showing the FSA-LSA output reduction ratio are all downward sloping, implying that the more aggressive the LCC behaves, the higher will be its loss from an identical marginal cost increase relative to the FSA. Figure 3 shows also that the curve for a higher value of t is steeper than the ones for lower t values. This indicates that competition becomes more important as products are closer substitutes. Let us consider the extreme case (not in the figure) where the goods are no longer substitutes (i.e. $t=0$). In this case, the output reduction ratio curve in the figure would become a horizontal line, implying the absence of any effect of v_2 . This makes sense, since $t=0$ implies that both firms are monopolists in their own market segment.

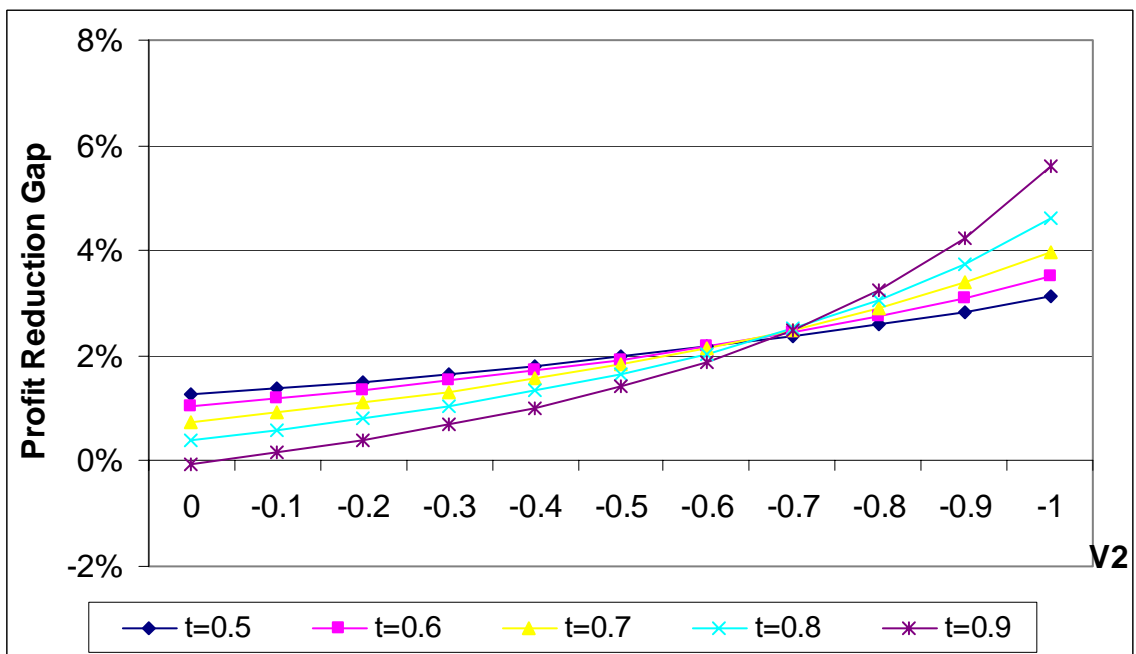
⁸ We did not simulate the case when firms offer perfect homogenous services ($t=1$) as the assumptions on equilibrium outputs and prices for the base case were unreasonable in this case.

Figure 3. Output reduction ratio (dc=1)



The corresponding differential changes in two firms' profits, $|\% \Delta \pi_2| - |\% \Delta \pi_1|$ are plotted as in figure 4. Note that since $\Delta \pi_i$ is negative for both firms, a positive differential number indicates that the LCC suffers more profit reduction proportionally.

Figure 4. Output reduction ratio (dc=1)



The profit reduction ratio curves are upward sloping, suggesting that the LCC will suffer more from the identical marginal cost increase as the more aggressively it behaves. Note that the curve for a high value of t is steeper than the ones for lower t values. This reflects again that competition becomes more important as products become closer substitutes. It can be

seen from the graph that when two firms offer fairly close services ($t = 0.9$) while the FSA competes much more aggressively than the LCC ($v_1 = -0.5$, $v_2 = 0$), it is possible that the FSA loses profits proportionally more than the LCC. This is consistent with our analytical results in section 2.1, which indicates when firms compete with homogenous products, a more aggressive competitor would be harmed more.

In sum, our numerical simulation and sensitivity tests on key parameters of our differentiated product duopoly model demonstrate the reliability of our results within reasonable parameter range. It also gives rough estimated values of the differential effects of an identical marginal cost increase (e.g., due to increase in airport's airside service charges including landing fees) on an FSA and an LCC, and thus on the competition in downstream airline markets an airport serves.

4. Discussion and Conclusion

With the worldwide trend of airport privatization and commercialization, the extent and form of airport regulation are becoming an important issue for policy makers and regulators. The level of an airport's user charge affects not only air travel demand and social welfare, but also competition in the downstream airline markets to/from that airport. This latter aspect of the effect of airport user charges have been overlooked and thus, have not been incorporated in the analysis of airport pricing and regulation. This paper attempt to fill this void in the past literature by showing that the level of competition in the downstream airline markets will be reduced when an airport increases its airside service charges (e.g., aircraft landing fees) by same amount to all airlines because such increase would reduce equilibrium outputs and profits of LCCs proportionally more than those of FSAs.

In section 2, using duopoly models, we have derived the following analytical results:

- When two airlines compete with homogenous products, an identical increase in airport charge would punish a higher cost airline by reducing its equilibrium output and profit proportionally more than those of its competitor.
- However, when two airlines compete with differentiated products such as the case where an FSA and an LCC compete with each other, the LCC will lose its output and profits proportionally more than its FSA competitor. As a result, such increase in airport user charge would harm competition in the downstream airline markets to and from that airport.
- We have analyzed influences of the extent of product differentiation (substitutability), the extent of difference in unit cost levels and the difference in the two firms' conduct parameters on the equilibrium outcomes. For example, when the LCC competes at least as aggressively as the FSA, the latter will be able to pass more of its marginal cost increase (caused by the increased airport user charges) to consumers in the form of air fare increase. Although an increase in airport's airside fee can thus increase competitive advantage of FSA vis-à-vis LCC, it is still not in the FSA's interest to encourage airports to increase airside user charge in order to take advantage of its increasing competitive advantage.

Our numerical simulation and sensitivity tests on key parameters confirmed all of our analytical findings. The simulation experiments further indicated the following empirical results:

- The ratio of FSA's output reduction relative to LCC's decreases as LCC's conduct parameter (v_2) moves from zero towards -1. This implies that the more aggressively LCC behaves, the higher will be the reduction of its output relative to FSA caused by an identical marginal cost increase;
- Competition becomes more important as the two firms (FSA and LCC) compete with closer substitutes;
- The differential amount of profit reduction between LCC and FSA increases as the LCC's conduct parameter (v_2) moves from 0 towards -1.0. This implies that the LCC's profit reduction relative to FSA's profit reduction will increase as LCC behaves progressively more aggressive.

Although in this paper we can not compare our simulation results explicitly with those of our work on the Virgin Blue vs. Sydney Airport case before the Australian Competition Tribunal because of the confidential nature of the data and results, we are satisfied that our simulation results in this paper are very consistent with the aggregate results we obtained using the real airline and airport data. In the Australian work, we obtained the results on the duopoly routes to and from Sydney. On the route markets where average air fares are in the range of [\$100, \$200], we found that a \$3 increase in the airport's airside service charge will likely reduce Virgin Blue's traffic volume by 2%-5%, which is 2 to 3 times of the FSA's simulated traffic reduction. Our simulation results in this paper and our Australian work indicate clearly that an increase in an airport's user charge will harm LCCs significantly more than FSAs, and thereby, impact negatively on the competition in the downstream air transport markets. Therefore, future analysis on airport pricing and price regulation should consider this additional welfare loss a monopolistic airport pricing may cause. This is especially important when there is no alternative airport in the vicinity to which airlines can move their operational bases.

Some economists argue that since the incentives for generating non-aviation revenues including concession and car parking revenues would constrain airport management from charging monopolistic airside services charges, there is no need to impose any price regulation on privatized airports. However, recently Oum, Zhang and Zhang (2004) have shown analytically that the airside service charges of an unregulated profit-maximizing airport are higher than those of a public airport under a breakeven budget constraint, even after the incentive provided by concession profits is taken into account. In addition, because of the extremely low price elasticity of air travel demand with respect to airports' user charges (Gillen, Oum and Tretheway (1998) report -0.01 to -0.1), any profit-maximizing airport management will have incentives raise airside user charges at least several hundred percentage points beyond the current levels even after considering effect of the demand complementarity between aircraft landing and concession activities. Therefore, the governments should consider carefully whether or not they need to impose some sort of price regulation on privatized airports.

While we have argued the need for some sort of price regulation on privatized airports, we have not treated any types and extent of regulation. Instead, we pointed out that policy makers and regulators need to take into account of the effect of airport pricing on competition in the downstream airline market when decisions on price regulation or deregulation of privatized airports are considered. Obviously, further research, especially empirical research, on the subject is needed since we were not able to publish the results based on real market data.

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