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Abstract

In the last decades the number of airports has grown substantially leading to situations where two or more airports share the same catchment area. On the other hand, the airlines market has been partially deregulated which has intensified competition. All of these have motivated the formation of controversial vertical agreements as they raise possible anti-competitive issues. This paper considers a type of vertical agreement, concession revenue sharing contract, to analyze how airport-airline vertical structures compete for passengers when they share a catchment area. The analysis distinguishes the effect of ownership structure of airports. Parallel alliances in the airlines market are also considered. Our results point out that airports have incentives to share the whole concession revenues, and that parallel alliances may improve Social Welfare. These results have policy implications because this kind of contract encourages Social Welfare, so they should to be leniently looked, just as the formation of alliances.

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1 Introduction

The fast growth in the air industry has led to the need for more airports. Consequently, rivalry between airports has intensified when they share the same catchment areas.[1] Nowadays, passengers face the decision among airport-airline pairs, instead of an airline within a single airport context; for example, a passenger travelling from London to Alicante could fly with either Ryanair from Stansted or with EasyJet from Gatwick. Hence, airports and airlines share a common purpose, that is, to attract more passengers. This has produced the birth of various types of agreements in practice.[2] However, even though most of those contracts solve the double marginalization problem, they surface anti-competitive issues in the downstream market (Barbot 2011, D'Alfonso & Nastasi 2012).

Our paper considers concession revenue sharing contracts (that allow airlines to participate in the non-aeronautical revenues got by airports) to study their impact on airport competition. Concession revenues turned decisive after governments around the world began to privatize airports. In fact, ATRS (2015) found non-aeronautical revenue in major airports reached over 70%, and the average worldwide remained around 50%. Nevertheless, it is airlines that generate those revenues, which airports acquire as a positive externality. Airports containing large potential over concession revenues have incentives to share them in order to attract more passengers (Gillen & Mantin 2014). Over time, concession revenue sharing contracts have become increasingly common.[3] Thus, airports may affect the downstream market making airlines more competitive, and encouraging passenger welfare.

The literature about the airport industry has moved from the traditional approach to the vertical-structure approach, Basso & Zhang (2008). The traditional approach took airlines as price takers; however, recent research has examined the vertical structure approach where strategic behavior in the airline market has been introduced, see Barbot (2009, 2011) and D'Alfonso & Nastasi (2012). The latter approach suggests that airports and airlines have incentives to cooperate when there is airport competition; but, even though those agreements solve the double marginalization problem, they raise anti-competitive issues.

Concession revenue sharing contracts, on the other hand, allow airlines to take part in the positive externality they generate. Zhang & Zhang (1997) were the first in introducing this kind of contracts in the literature following a traditional approach. Later on, Zhang et al. (2010) and Fu & Zhang (2010) characterized the contract for the vertical structure approach; we shall follow their characterization in this paper. In contrast, the present analysis focuses on how airports

[1]Evidence of airports sharing catchment areas are London, Paris, Rome and Milan in Europe, or San Francisco, Chicago, New York, Washington, Dallas, Detroit, Houston, and Los Angeles in the US. Alternatively, other ways of airport competition are in international markets such as Fiumicino in Rome and Malpensa in Milan, Barcelona and Madrid in Spain, Brussels and Amsterdam, Brussels and Paris in Europe.

[2]D'Alfonso & Nastasi (2012) list agreements observed in practice and provide interesting examples.

[3]For example, Tampa International Airport has been sharing revenue with airlines since 2000. In 2006, it shared 20% of its net revenue with its signatory airlines. The Greater Orlando Aviation Authority (2010) is also implementing similar revenue sharing arrangements covering the 2009 to 2013 fiscal years. The revenue remaining after satisfying all requirements is divided between the parties, with 30% allocated to signatory airlines and 70% allocated to the airport authority in the 2009 and 2010 fiscal years, and respective shares of 25% and 75% applying in 2011-2013. The signatory airline share is distributed among the airlines based on each airline's share of enplaned passengers. In 2002, the Frankfurt Airport signed a five-year agreement with Lufthansa and other airlines.

use the revenue sharing contract to compete rather than looking into the direct effects of such contracts thus moving further the analysis by Zhang et al. (2010) in that a Nash bargaining process over the contract is applied and different airport management/ownership scenarios are considered.

The second part of our analysis considers parallel alliances in the downstream market. Following the Airline Deregulation Act in 1978 US, the airlines' market got very hectic. Regulation worldwide did not allow for free entry by airlines, which limited their expansion. Furthermore, in the most profitable years, the margins in the industry hardly even reached 2,5-3%; very smooth in comparison with other markets, see Doganis (2006). In spite of low returns, other strategic incentives led airlines to get allied.[4] The three major global alliance groups made up 73,6% of the world market in 2008: Star Alliance (29,8%), One World (23,2%), and Sky Team (20,6%), see Zhang & Czerny (2012). Therefore, the second part looks into the effects of parallel alliances over the sharing contract, and how it affects airport rivalry. Following Zhang & Zhang (2006) an equity alliance[5] is examined because "it tends to yield greater firm values, measured in stock returns, than other types of strategic alliances," which implies airlines incorporate a fraction of its partners' profit in its decision.

Park (1997) differentiated between complementary and parallel alliances, and he studied their effects. Subsequently, Park et al. (2001) and Zhang & Zhang (2006) found that complementary alliances benefit the industry whereas parallel alliances raise welfare concerns. Thus attention within the literature has focused on complementary alliances where network effects have been considered.[6] The paper contributes to the parallel alliance literature studying its effects on a vertical structure approach. Contrary to preceding results, concession revenue sharing makes parallel alliances welfare improving in some cases. This result underlines new insights for policy makers.

The next section sets out the benchmark model where two public airports compete and provides some comments about the contract. Section 3 introduces private airports and compares the different scenarios. Parallel alliances in downstream market and their effects are presented in Section 4. Finally we conclude with some remarks and policy recommendations. Proofs are in the Appendix.

2 The Benchmark Model

Two airports in a common catchment area that offer flights to the same destination areas compete for passengers. One and a different airline operates in each airport. There is airline competition because they provide substitute differentiated services in the eyes of passengers.

[4]For instance, Zhang & Zhang (2006) reported: "strategic alliances allow firms to expand their networks, take advantage of product complementarities, realize economies of scale and scope, and improve product quality and customer service."

[5]Some examples are: Air France/KLM alliance, the Cathay Pacific/Air China alliance, and Qantas/Air New Zealand alliance.

[6]Some examples are Brueckner (2001), Adler & Smilowitz (2007),Flores-Fillol & Moner-Colonques (2007), and Flores-Fillol (2009).

The following utility function of a representative passenger describes the preferences:

$$U(q_1, q_2) = a(q_1 + q_2) - \frac{b}{2}q_1^2 - \frac{b}{2}q_2^2 - dq_1q_2 + y \tag{1}$$

For a, b and d being positive constants and y denoting an outside good used as the numéraire. The q_i's represent the number of passengers served by each airline in a given origin-destination route. Parameter a, denotes the maximum willingness to pay for travelling. Parameter d, which is assumed to be smaller than b, measures the degree of substitutability between airline services, so that a higher d implies less differentiated services, while $d = 0$ corresponds to the case of independent services. After utility maximization subject to the budget constraint (defined as $M = y + p_1q_1 + p_2q_2$ with M denoting the representative consumer's income), the following inverse demand system for services is obtained:[7]

$$p_i = a - bq_i - dq_j \quad \forall \quad i, j = 1, 2 \tag{2}$$

in the region of quantity space where airfares become positive, where p_i is the airfare paid for travelling with airline i.

Airline i's profit function, π_i, is composed of two terms, the standard operating profits and profits derived from concessions. Operating profits are $(p_i - c - w)q_i$, where w denotes aeronautical charges per passenger paid by airlines to airports and c is the marginal cost per passenger. On the other hand, passengers spend money on non-aeronautical services at the airport, which generates additional revenue, denoted by hq_i, where h is the per passenger net surplus generated. Concession profits are, precisely given by $hr_iq_i - f_i$, where r_i is the proportion (share) of concession revenues that go to airline i and f_i is the fixed payment made by the airline to the airport in exchange.[8]

Airports also have two sources of revenue. From aeronautical activities they obtain wq_i, noting that w cannot be changed unilaterally since it is regulated; whereas, non-aeronautical activities yield the airports a share of concession revenues, $(1-r_i)hq_i$ plus the fixed fee.[9] Finally, τ is the marginal aeronautical costs, while fixed costs are normalized to zero. Therefore, airport i's profits denoted by Υ_i, are equal to $(w - \tau)q_i + (1 - r_i)hq_i + f_i$, for $i = 1, 2$.

Agents make decisions in two stages. In the first stage, each airport-airline pair decides simultaneously and independently over the concession revenue sharing contract (r_i, f_i), which is the outcome of a Nash bargaining process. In the second stage, airlines compete for the number of passengers served, given the sharing proportions. To solve the model the subgame perfect Nash equilibrium is obtained.

[7] The inverse demand system satisfies the usual properties: (i) downward-sloping demand $\frac{\partial p_i}{\partial q_i} = -b < 0$; (ii) own effects dominate cross effects $\frac{\partial p_1}{\partial q_1}\frac{\partial p_2}{\partial q_2} - \frac{\partial p_1}{\partial q_2}\frac{\partial p_2}{\partial q_1} = b^2 - d^2 > 0$.

[8] The revenue sharing contract considered has been employed by Zhang et al (2010) and Fu & Zhang (2010), and contains two variables, (r, f). The sharing proportion, r, displays the effort of airports to pursue more passengers. In exchange, airports ask airlines for a fixed payment which can be seen, for example, as a compromise to make any investment or to be attached to that airport for several years. We assume the two variable contract because is consistent with situations in which airports and airlines can commit to medium-/long-term cooperation. Furthermore, Zhang et al (2010) stated that this contract "gets more traffic volume and Social Welfare" than the contract with just one variable.

[9] This simple representation where net concession revenue is strictly complementary to passenger volume has been used by Zhang et al (2010), Fu & Zhang (2010), and Yang et al (2015), among others.

2.1 Second stage: airline competition

Airline i chooses q_i, for $i = 1, 2$, to maximize the following equation:[10]

$$\pi_i = (p_i - c - w + r_i h) q_i - f_i \tag{3}$$

Solving the two first-order conditions system and using the inverse demand functions, the equilibrium values of q_i and p_i in the second stage denoted by superscript star, as a function of r_i and r_j are obtained.[11] These are given by:

$$q_i^*(r_i, r_j) = \frac{(a - c - w)(2b - d) + (2br_i - dr_j)h}{4b^2 - d^2} \quad \forall i, j = 1, 2 \quad i \neq j; \tag{4}$$

And,

$$p_i^*(r_i, r_j) = \frac{(2b - d)(ab + (b + d)(c + w)) - hr_i\left(2b^2 - d^2\right) - bdhr_j}{4b^2 - d^2} \quad \forall i, j = 1, 2 \quad i \neq j. \tag{5}$$

Proposition 1 *Airports bring in more passengers and induce lower airfares if they raise the sharing proportion, i. e.* $\frac{\partial q_i^*}{\partial r_i} > 0, \frac{\partial p_i^*}{\partial r_i} < 0$.

Equations (4) and (5) show how airports compete attracting passengers through airlines using the sharing proportion. Absent concession revenues, the equilibrium number of passengers contains the usual terms, the oligopoly profitability term corrected by the effect of substitutability between services. Now the consideration of concession revenues has a procompetitive effect as they shift outwards the respective reaction functions. An increment in the own sharing proportion allows the airport to obtain an increase in passengers of size $\frac{2bh}{4b^2-d^2}$. This also improves welfare because the overall effect is to increase the total number of passengers by $\frac{h}{2b+d}$.

2.2 First stage: the revenue sharing contract

The benchmark case assumes two public airports. Public airports objective function is to maximize SW, [12] where $SW = \sum_{i=1}^{2} (\Upsilon_i + \pi_i) + CS$. Also, $CS = U(q_1, q_2) - \sum_{i=1}^{2} p_i q_i$. Consumer Surplus only considers aeronautical activities, so any effects derived from shopping at the airport are not taken into account in consumer welfare.[13]

The contract equilibrium values are obtained through a two-step procedure. First, Social Welfare is maximized to obtain r_i with $i = 1, 2$, and then airports and airlines bargain over the fixed payment, f_i with $i = 1, 2$.[14]

[10] Empirical evidence from Brander & Zhang (1990, 1993) states that the model which best fits with airline market competition is Cournot; moreover, it is widely used in the literature.

[11] Both the second-order conditions for a maximum ($\frac{\partial^2 \pi_i}{\partial q_i^2} = -2b < 0$) and the stability conditions are satisfied ($\frac{\partial^2 \pi_i}{\partial q_i^2}\frac{\partial^2 \pi_j}{\partial q_j^2} - \frac{\partial^2 \pi_i}{\partial q_i \partial q_j}\frac{\partial^2 \pi_j}{\partial q_j \partial q_i} = 4b^2 - d^2 > 0$). Also, there is strategic substitution between services ($\frac{\partial^2 \pi_i}{\partial q_i \partial q_j} = -d < 0$).

[12] It is considered public airports maximize social welfare following Zhang & Czerny (2012), Czerny (2013), and Gillen & Mantin (2014) among others.

[13] Although there are activities which may derive positive welfare effects, most of them substitute the place of consumption. For instance, the welfare effects of buying clothes or eating at the airport are the same, or very similar, as doing these activities in a mall. This approach of normalizing consumer surplus of concession revenues to zero is applied by Zhang et al (2010) and Gillen & Mantin (2014). For a more complete analysis see Czerny (2013) and Flores-Fillol et al (2015).

[14] This Nash Bargaining process is aimed to include the countervailing power between airports and airlines.

2.2.1 Sharing proportion

After maximizing SW with respect to r_i, the optimal sharing proportion[15] denoted by a star is:

$$r_i^* = r_j^* = \begin{cases} \frac{(a-c)b+w(b+d)+(h-\tau)(2b+d)}{h(b+d)} & \text{if } w < \frac{-(a-c+h)b+(2b+d)\tau}{(b+d)} \equiv w^* \\ 1 & \text{otherwise} \end{cases} \quad (6)$$

As indicated above, aeronautical charges, w, are regulated. There are two accounting approaches that apply to the various regulation systems, which are the single and the dual-till system. The single-till approach cross-subsidizes the aeronautical charge with concession revenues, whereas the dual-till approach splits the two sources of revenue, regulating just the aeronautical part. Thus, for the latter approach the regulated charge is computed matching the aeronautical cost, i.e. $w = \tau$. The dual-till approach has become relevant once airports exploit their commercial facilities.

Proposition 2 *In the case of dual-till approach, $w = \tau$, airports share the whole concession revenues,*[16] $r_i^* = r_j^* = 1$.

Note that $r_i^* = r_j^* = \frac{(a-c)b+w(b+d)+(h-\tau)(2b+d)}{h(b+d)}$ is larger than one when $w = \tau$, if and only if $(a - c - \tau)b > 0$, which is the case. By definition, $h, b > 0$, and to guarantee that market exists, it is required that $a \geq c+\tau$, that is, the maximum willingness to pay for a flight must be at least equal to airlines' marginal cost. In order to find an optimal sharing proportion less than one, it is required a single-till approach or some cross-subsidization, that is with $w < \tau$. In this case an improvement in technical efficiency reduces the sharing proportion (specifically, $\frac{\partial r}{\partial w} = \frac{1}{h} > 0$).

2.2.2 Bargaining over the fixed payment

On the other hand, a Nash bargaining process is set in order to obtain the equilibrium fixed payment f_i. The bargaining power of each agent will determine the amount. However, f_i does not have any influence in the number of passengers. The bargaining power is denoted by φ with $\varphi \in (0, 1)$. If $\varphi = 1$ the whole power goes to the airport while for $\varphi = 0$ the airline holds the power and the airport makes zero profits. The Nash bargaining problem is given by:

$$\underset{f_i}{Max} \quad [SW]^{\varphi}[\pi_i]^{1-\varphi} \quad (7)$$

which yields,

$$f_i^* = (p_i^* - c - w + r_i^* h)q_i^* \quad (8)$$

Public airports' equilibrium fixed payment makes airlines profit equal to zero; i.e. the airlines' participation constraint is binding. Hence, airlines operating in public airports always get zero economic profits; therefore, any improvements in airline's performance is extracted by the airport.

[15] Second derivatives entail: (i)The concavity condition; (ii) Strategic substitution between sharing proportion; (iii) and the stability condition.

[16] This result is also found in Zhang et al (2010) and Fu & Zhang (2010) where $\tau = 0$ and $w > 0$.

After substitution for r_i^*, the fixed payment that matches the airlines' participation constraint is:

$$f_i^* = f_j^* = \begin{cases} \frac{b(a-c+h-\tau)^2}{(b+d)^2} & \text{if } r_i^* = r_j^* < 1 \\ \frac{b(a-c+h-w)^2}{(2b+d)^2} & \text{if } r_i^* = r_j^* = 1 \end{cases} \quad (9)$$

Once the concession revenue sharing contract is obtained, the corresponding equilibrium variables follow.

Result 1 *In a public airports setting with concession revenue sharing it happens that:*
a) when $r_i^* = r_j^* < 1$

1. $q_i^* = \frac{a-c+h-\tau}{b+d}$;
2. $p_i^* = c + \tau - h$; *the first best is achieved making airfares equal to net marginal cost.*
3. $\Upsilon_i^* + \pi_i^* = 0$
4. $SW^* = CS^* = \frac{(a-c+h-\tau)^2}{b+d}$.

b) when $r_i^* = r_j^* = 1$

1. $q_i^* = \frac{a-c+h-w}{2b+d}$;
2. $p_i^* = \frac{ab+(b+d)(c+w-h)}{2b+d}$;
3. $\Upsilon_i^* + \pi_i^* = \frac{((a-c+h)b+w(b+d)-\tau(2b+d))(a-c+h-w)}{(2b+d)^2}$
4. $CS^* = \frac{(b+d)(a-c+h-w)^2}{(2b+d)^2}$;
5. $SW^* = \frac{(a-c+h-w)((3b+d)(a+h-c)+(b+d)w-2(2b+d)\tau)}{(2b+d)^2}$.

The contract extracts all rents from airports and airlines decrease airfares up to the first-best when the sharing proportion is such that some concession revenues are kept by the airport. Industry profits are equal to zero and consequently social welfare coincides with the gains derived by passengers. This would be the ideal case as it replicates the social optimum. In case the sharing proportion is equal to one, total passengers are reduced, airfares are higher, industry profits are positive and social welfare is lower.

3 Public vs Private airports

In 1987 the UK decided to privatize some airports, this measure was followed afterwards by many countries. The main reason to privatize some airports was the need of self-financing because of the budget constraints governments suffer. As a consequence, several kinds of ownership coexist. The Benchmark model has focused on public airports, while now we are going to consider also private airports to see the main differences between them. The second stage where airlines compete remains the same, and the changes happen in the first stage where airlines interact with airports.

3.1 Two private airports

Consider now two private airports competing that implying their respective objective functions change as they pursue profit maximization.

3.1.1 Sharing proportions

In this case, each airport-airline pair maximizes its aggregate profit, $\underset{r_i}{Max} \quad \Upsilon_i + \pi_i$. They look for the sharing proportion that best suits them. Then, the sharing equilibrium denoted by a P from private is:

$$r_i^P = r_j^P = \begin{cases} \frac{(a-c)d^2+w\left(4b^2+2bd-d^2\right)+2b(2b+d)(h-\tau)}{h(4b^2+2bd-d^2)} & \text{if } w < \frac{-d^2(a-c+h)+2b(2b+d)\tau}{4b^2+2bd-d^2} \equiv w^P \\ 1 & \text{otherwise} \end{cases} \tag{10}$$

where Proposition 2 continues to hold. Also notice that the bounds on w that determine when the sharing proportion falls below one do not coincide. In fact, the one for private airports is greater than the one for public airports. This means that, the regulation on w may have a different effect on the sharing proportion depending on the ownership structure of airports. In any case, full sharing will arise in more cases when airports are public.[17]

3.1.2 Bargaining over the fixed payment

The bargaining process in this game solves the next problem: $\underset{f_i}{Max} \quad [\Upsilon_i]^{\varphi}[\pi_i]^{1-\varphi}$, and the resulting fixed payment is given by:

$$f_i^P = (\varphi(p_i^* - c + h - \tau) - (w - \tau + (1 - r_i^P)h))q_i^* \tag{11}$$

substituting for the corresponding (r_i^P, r_j^P), which yields,

$$f_i^P = f_j^P = \begin{cases} \frac{2b\left(2b^2\varphi+d^2(1-\varphi)\right)(a-c+h-\tau)^2}{(4b^2+2bd-d^2)^2} & \text{if } r_i^P = r_j^P < 1 \\ \frac{(a-c+h-w)(b\varphi(a-c+h+w-2\tau)-(2b+d(1-\varphi))(w-\tau))}{(2b+d)^2} & \text{if } r_i^P = r_j^P = 1 \end{cases} \tag{12}$$

Once the equilibrium terms of the contract are obtained, we can find the effects of privatization. Under the private setting, both types of agents, airports and airlines make positive profits, unless one type has full bargaining power which implies it gets everything. Then, Social Welfare doe not coincide anymore with Consumer Surplus as happens in the benchmark for the case where $r_i^* < 1$. Both Social Welfare and Consumer Surplus are lower because airfares go up, which make the total number of passengers in the industry to fall. Thus, we can conclude that full airport privatization is not socially desirable because airports and airlines rise their profits at the expense of passengers and the former gains are more than compensated by the latter losses. Finally, it is worth to mention that the fixed part of the sharing contract is lower for the private airport case, when the sharing proportions are both either smaller than one, or both equal to one.

Result 2 *In a private airports setting with concession revenue sharing, it happens that:*
a) when $r_i^P = r_j^P < 1$

1. $q_i^P = \frac{2b(a-c+h-\tau)}{(4b^2+2bd-d^2)}$;
2. $p_i^P = \frac{a(2b^2-d^2)+(c-h+\tau)2b(b+d)}{(4b^2+2bd-d^2)}$
3. $\Upsilon_i^P + \pi_i^P = \frac{2b(2b^2-d^2)(a-c+h-\tau)^2}{(4b^2+2bd-d^2)^2}$

[17] All thresholds on w for the different cases are provided and ranked in the Appendix.

4. $CS^P = \frac{4b^2(b+d)(a-c+h-\tau)^2}{(4b^2+2bd-d^2)^2}$.

5. $SW^P = \frac{4b(3b^2+bd-d^2)(a-c+h-\tau)^2}{(4b^2+2bd-d^2)^2}$

b) when $r_i^P = r_j^P = 1$ Result 1 part b) holds.

Next section analyzes the sharing contract in the last possible scenario, when a private and a public airport compete. It also shows the ranking where the values of the three cases are compared.

3.2 Private and public airport

As already mentioned, only the first stage is different where now two airports with a different ownership structure (and hence different objective functions) compete. Each airport-airline vertical structure has a different equilibrium contract because there is no longer symmetry. Superscript A denotes the asymmetric case, and subscript 1 is the private airport whereas subscript 2 the public airport.

By proceeding as above, the equilibrium contracts for the case of sharing proportions smaller than than one are obtained . In particular, the private airport contract reads:

$$(r_1^A, f_1^A) = (\frac{2bd^2(a-c)(b-d)+w(8b^4-8b^2d^2+d^4)+(8b^4-6b^2d^2-2bd^3+d^4)(h-\tau)}{h(8b^4-8b^2d^2+d^4)}, \frac{8b^3(b-d)^2(2b^2\varphi+d^2(1-\varphi))(a-c+h-\tau)^2}{(8b^4-8b^2d^2+d^4)^2})$$

while the public airport one is,

$$(r_2^A, f_2^A) = (\frac{(a-c)(8b^4-8b^3d+2bd^3-d^4)+w(8b^4-8b^2d^2+d^4)+(h-\tau)(16b^4-8b^3d-8b^2d^2+2bd^3)}{h(8b^4-8b^2d^2+d^4)}, \frac{b(8b^3-6b^2d-2bd^2+d^3)^2(a-c+h-\tau)^2}{(8b^4-8b^2d^2+d^4)^2})$$

The conditions over the aeronautical charge that makes the sharing contract smaller than one for the private and the public airport are, respectively:

$$w < \frac{\tau(8b^4-6b^2d^2-2bd^3+d^4)-2bd^2(b-d)(a-c+h)}{8b^4-8b^2d^2+d^4} \equiv w_1^A,$$

$$w < \frac{\tau(16b^4-8b^3d-8b^2d^2+2bd^3)-(8b^4-8b^3d+2bd^3-d^4)(a-c+h)}{8b^4-8b^2d^2+d^4} \equiv w_2^A$$

where $w_1^A > w_2^A$.

In case $w > w_1^A$, the sharing proportion in the private airport is one, then the contract reads:

$$(r_1^A, f_1^A) = (1, \frac{(a-c+h-w)(b\varphi(a-c+h)+\tau(1-\varphi)(2b+d)-w(b(2-\varphi)+d(1-\varphi)))}{(2b+d)^2})$$

On the other hand, if $w > w_2^A$, the sharing proportion in the public airport is one, thus:

$$(r_2^A, f_2^A) = (1, \frac{b(a-c+h-w)^2}{(2b+d)^2})$$

Result 3 *In an asymmetric airports setting with concession revenue sharing it happens that:*
a) when $r_i^A < 1$ and $r_j^A < 1$

1. $q_1^A = \frac{4b^2(b-d)(a-c+h-\tau)}{(8b^4-8b^2d^2+d^4)}$

2. $q_2^A = \frac{(8b^3-6b^2d-2bd^2+d^3)(a-c+h-\tau)}{(8b^4-8b^2d^2+d^4)}$

3. $p_1^A = \frac{2ab(b-d)(2b^2-d^2)+(4b^4+4b^3d-6b^2d^2-2bd^3+d^4)(c-h+\tau)}{(8b^4-8b^2d^2+d^4)}$

4. $p_2^A = \frac{a(2b^3d-2b^2d^2-bd^3+d^4)+(8b^4-2b^3d-6b^2d^2-bd^3)(c-h+\tau)}{(8b^4-8b^2d^2+d^4)}$

5. $\Upsilon_1^A + \pi_1^A = \frac{2b^3(b-d)^2(2b^2-d^2)(a-c+h-\tau)^2}{(8b^4-8b^2d^2+d^4)^2}$

6. $\Upsilon_2^A + \pi_2^A = \frac{d(b-d)(2b^2-d^2)(8b^3-6b^2d-2bd^2+d^3)(a-c+h-\tau)^2}{(8b^4-8b^2d^2+d^4)^2}$

7. $CS^A = \frac{b(80b^6-64b^5d-92b^4d^2+72b^3d^3+16b^2d^4-12bd^5+d^6)(a-c+h-\tau)^2}{2(8b^4-8b^2d^2+d^4)^2}$.

8. $SW^A = \frac{(112b^7-96b^6d-132b^5d^2+104b^4d^3+40b^3d^4-24b^2d^5-5bd^6+2d^7)(a-c+h-\tau)^2}{2(8b^4-8b^2d^2+d^4)^2}$

b) when $r_i^A = r_j^A = 1$ Result 1 part b) holds.

In the following Proposition we present several interesting comparisons among the three ownership scenarios considered above.

Proposition 3 *1. The comparison of the three ownership airport structures yields the following orderings when every $r < 1$ and $w < w_2^A$:*

(a) $r_2^A > r_i^* > r_i^P > r_1^A$ and $f_2^A > f_i^* > f_i^P > f_1^A$

(b) $q_2^A > q_i^* > q_i^P >_1^A$ and $p_i^P > p_1^A > p_2^A > p_i^*$

(c) $SW^* > SW^A > SW^P$ and $CS^* > CS^A > CS^P$ and $Q^* > Q^A > Q^P$

2. When $r = 1$ for each scenario:

(a) Result 1 part b) holds by any scenario. Then, it does not matter the ownership/governance scenario because the result is going to be the same. The only difference is about the fixed part in the revenue sharing contract. $f_i^* = f_2^A < f_i^P = f_1^A$

The sharing proportion and the fixed payment ranking in the same way because if an airport shares more concession revenues, it also asks for a higher effort or compensation form airlines. The reason why the public airport in the asymmetric setting shares the higher amount is because it wants to balance the negative effect that make the private airport to maintain the same level of passengers in the industry. Since r_i choices behave as strategic substitutes for airports; the private airport share is ranked the smallest.
The number of passengers is directly related to the sharing proportion; however, airfares are ranked following the level of privatization in the industry. That shows that private settings lead to higher airfares than public settings.
Social Welfare, Consumer Surplus, and total passengers rank in the same way. The effects of privatization damage passengers at the expenses of the other agents; however, the gains of these are not enough to cover the losses of passengers.

4 Parallel alliances in downstream market

The second part of this paper considers the formation of parallel alliances in the downstream market. Airlines get allied in order to survive and to gain access to other markets; consequently, many alliances with several motivating forces are spread worldwide. Park (1997) distinguished between complementary and parallel alliances. The fact that more airport rivalry appears, implies that the chance to find parallel alliances increases. The purpose of this section is to analyze how parallel alliances affect the sharing proportions, airport competition and social welfare.

$$\underset{q_i}{Max} \quad \Pi_i = \pi_i + \alpha \pi_j \tag{13}$$

Equation 13 shows the actual airlines' maximization problem. When airlines cooperate its objective function changes, and they maximize its own profit plus a weight on their partner's profit. $\alpha \in [0, 1]$ denotes the degree of cooperation; $\alpha = 0$ represents the Cournot case whereas $\alpha = 1$ symbolizes a single airline. The degree of cooperation, α, is taken equal for all airlines involved following Zhang & Zhang (2006). They stated that "an equity alliance tends to yield greater firm values, measured in stock returns, than other types of strategic alliances."

Due to the damaging effects of parallel alliances in the economy, they have not been widely studied. This kind of alliances reduces competition, as a result of the concentration in the downstream market. Thus, the degree of cooperation will determine if the scenario seems more like a Cournot, or a monopoly case. Yet, as long as the degree of airlines cooperation increases, the number of passengers in the industry is reduced[18] because airlines can charge higher airfares; hence Consumer Surplus decreases. Otherwise, airlines have incentives to cooperate because they obtain larger profit, at the expense of airport profits and consumer surplus. As a result, welfare decreases downward, explaining why parallel alliances are harmful. However, airports are also a main character in the industry. With vertical relations, airports have a say because they can influence the downstream market.

Proposition 4 *As a response to airline cooperation, airports increase the concession revenue sharing proportion, i.e.* $\frac{\partial r_i}{\partial \alpha} > 0$*; except for the case of the public airport in the asymmetric ownership structure when sharing proportions are strategic substitutes.*

As explained above, airports can bring in more passengers as long as they share more concession revenues. Hence, in order to mitigate the loss of passengers due to the collusion in the downstream market, airports increase their sharing proportions.

The variables sharing proportions behave as strategic substitutes, which means that when one airport increases the sharing proportion, the other airport's decreases and so happens to its profit. However, the fact that parallel alliances are incorporated introduces a new scenario.

Proposition 5 *Airports' strategic relation changes from substitutability to complementarity for a large enough degree of cooperation among airlines, that is for* $\alpha \in (\hat{\alpha}, 1]$*, where* $\hat{\alpha} =$

[18] Park et al (2001) found empirical evidence saying that a parallel alliance decreases total traffic by an average of 11-15%.

$(\frac{2b^2-d^2-2b\sqrt{b^2-d^2}}{d^2})$.

For a better understanding, suppose airlines merge and form a monopoly. The single airline will prefer the airport with the highest sharing proportion to increase its profit; i.e. the airline can to transfer passengers between airports for the sake of its benefit. Aware of that, airports, to avoid passenger transferability, behave as strategic complements in sharing proportions ; i.e., if one airport increases its sharing, the rival increases it too.

Proposition 3 part a) still holds in the presence of parallel alliances. However, the effect of parallel alliances over the Social Welfare is different. Next Proposition specifies the conditions for Social Welfare to increase with the degree of cooperation. Hence,

Proposition 6 *If there is at least one private airport and the sharing proportions are smaller than one, parallel alliances are welfare improving for any degree of cooperation, i.e.* $\frac{\partial SW}{\partial \alpha} > 0$. *Furthermore, when the sharing proportions are equal to one, Social Welfare increases with the degree of cooperation as long as* $\tau > \frac{(a-c+h)(b+\alpha d)+(b+d)w}{2b+(1+\alpha)d}$. *For the particular case of dual-till, it happens that welfare decreases,* $\frac{\partial SW}{\partial \alpha} < 0$.

Social Welfare components are affected differently depending on the setting. In the case of two private airports, only consumers gain, which is a good reason to allow parallel alliances in this scenario. Airports lose profits because of the effort made to counteract the downstream concentration. Whereas, airlines are also worst off because airports extract a larger fixed fee. Nevertheless, airlines, even getting worse, they may have other incentives to be engaged.

Finally, the case with airports from different ownership/governance is not quite clear, because public airports try to countervail the opportunistic behavior of private airports. However, with very similar airlines' services, and an enough degree of downstream cooperation, the same results as in the two private airports case are obtained.

5 Conclusion

This paper contributes to the concession revenue sharing literature by analyzing how airport-airline vertical structures compete. The fast growing in the industry has led airports to compete for the catchment area. This has modified the passengers' set of choices, where they have to decide between vertical airport-airline structures. Airports, due to this kind of arrangement, can to influence in the downstream equilibrium in a direct relationship. The effects of airport privatization are also analyzed. Though many reasons could lead governments to privatizations of airports, the economic analysis says that it is detrimental to consumers and welfare. Some reasons that have have been appointed are the efficiency in the performance; even though there is no empirical evidence that public airports are less efficient. However, competition enhances efficiency. Another reason is to obtain private financing, which can be mitigated with the exploitation of commercial activities, or through vertical contracts with airlines.

The paper also considers other aspects of great relevance nowadays. The consideration of two types of ownership/governance is lined up with the actual case where several privatization processes have resulted airports with much distinct ownership. Public airports share more concession revenues, as expected. Analogously, a parallel alliance in the downstream market is considered. Previous literature has considered this kind of alliance to be harmful. However, there is no analysis in the vertical structure approach. With the setting presented, parallel alliances can be welfare improving. Airports, to alleviate the loss of passengers due to downstream cooperation increase the sharing proportion which brings in more passengers.

Finally, this work is a contribution to the literature on airport competition in different senses; though the scope is wider and some extra considerations could be made. For future research, it will be interesting to study multi-airport competition analyzing cooperation upstream, and/or network effects of airlines. It also can consider a different treatment to the net concession revenue, instead of a direct relationship with demand, adding an incentive scheme to airlines. Since airport privatization movement, several regulation systems coexist; hence, knowing which one fits better in this setting will be fascinating.

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Appendix

Throughout the paper there are some restrictions on the value of relevant parameter which are used in the proofs that follow.

1. $b > d > 0$
2. $a, c, \tau, h, w > 0$
3. $a > c + \tau$
4. $\alpha \in [0, 1]$
5. $\varphi \in [0, 1]$

Second order conditions in the first stage of the game

1. Concavity
   (a) Public airports
   $\frac{\partial^2 \mathrm{SW}}{\partial \mathrm{r}_i^2} = -\frac{b\left(4b^2-3d^2\right)h^2}{\left(4b^2-d^2\right)^2} < 0$
   (b) Private airports
   $\frac{\partial^2 \Upsilon_i + \pi_i}{\partial \mathrm{r}_i^2} = -\frac{4b\left(2b^2-d^2\right)h^2}{\left(4b^2-d^2\right)^2} < 0$
2. Strategic substitution
   $\frac{\partial^2 SW}{\partial r_i \partial r_j} = \frac{\partial^2 \Upsilon_i + \pi_i}{\partial r_i \partial r_j} = -\frac{d^3 h^2}{\left(4b^2-d^2\right)^2} < 0$
3. Stability condition
   (a) Public airports
   $\frac{\partial^2 \mathrm{SW}}{\partial \mathrm{r}_1^2}\frac{\partial^2 \mathrm{SW}}{\partial \mathrm{r}_2^2} - \frac{\partial^2 \mathrm{SW}}{\partial \mathrm{r}_1 \partial \mathrm{r}_2}\frac{\partial^2 \mathrm{SW}}{\partial \mathrm{r}_2 \partial \mathrm{r}_1} = \frac{(b-d)(b+d)h^4}{\left(4b^2-d^2\right)^2} > 0$
   (b) Private airports
   $\frac{\partial^2 \Upsilon_1 + \pi_1}{\partial r_1^2}\frac{\partial^2 \Upsilon_2 + \pi_2}{\partial r_2^2} - \frac{\partial^2 \Upsilon_1 + \pi_1}{\partial r_1 \partial r_2}\frac{\partial^2 \Upsilon_2 + \pi_2}{\partial r_2 \partial r_1} = \frac{\left(16b^4-12b^2d^2+d^4\right)h^4}{\left(4b^2-d^2\right)^3} > 0$

Thresholds over the sharing proportion

We set conditions over the aeronautical charge to know when the different sharing proportions are smaller than one. These conditions depend on the ownership structure of airports we have considered arising four thresholds. These thresholds show in which cases the aeronautical charge is smaller than one. The different thresholds are:

1. $w^* \equiv \frac{-(a-c+h)b+(2b+d)\tau}{(b+d)}$, for the two public airports case.
2. $w^P \equiv \frac{-d^2(a-c+h)+2b(2b+d)\tau}{4b^2+2bd-d^2}$, for the two private airports case.
3. $w_1^A \equiv \frac{-2bd^2(b-d)(a-c+h)+\tau\left(8b^4-6b^2d^2-2bd^3+d^4\right)}{8b^4-8b^2d^2+d^4}$, for the private airport in the asymmetric case.
4. $w_2^A \equiv \frac{-\left(8b^4-8b^3d+2bd^3-d^4\right)(a-c+h)+\tau\left(16b^4-8b^3d-8b^2d^2+2bd^3\right)}{8b^4-8b^2d^2+d^4}$, for the public airport in the asymmetric case.

The thresholds are ranked in this way: $w_1^A > w^P > w^* > w_2^A$. Thus, the public airport in the asymmetric case is going to reach the whole concession revenue $r = 1$ before than anyone.

Proof. Proof about the aeronautical revenues ranking

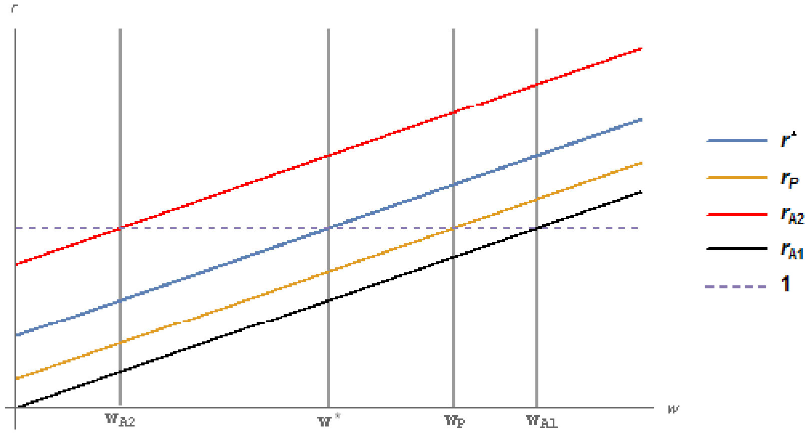
1. To prove that $w_1^A > w^P$, notice that $w_1^A - w^P = \frac{d^3(2b-d)\left(2b^2-d^2\right)(a-c+h-\tau)}{(4b^2+2bd-d^2)(8b^4-8b^2d^2+d^4)}$ which is positive.
2. By the same reasoning, $w^P > w^*$ if $w^P - w^* = \frac{(2b+d)\left(2b^2-d^2\right)(a-c+h-\tau)}{(b+d)(4b^2+2bd-d^2)}$ is positive, which is true.
3. Similarly, $w^* > w_2^A$, when $w^* - w_2^A = \frac{d^3\left(2b^2-d^2\right)(a-c+h-\tau)}{(b+d)(8b^4-8b^2d^2+d^4)}$ is positive, which is true.

■

In the next graph we have the sharing proportions plotted. In the abscissa axis is the aeronautical charge. The dotted line represents when the sharing proportion reaches one, so we can see graphically in which case there are more chances to find airports sharing the whole concession revenues.

Then, if the regulator imposes an aeronautical charge bigger than w_1^A, the result is going to be the same as if it imposes a dual-till regulation system, because in every scenario the sharing proportion will be one, it is, airports will share the whole concession revenues with airlines.

Graphically:



Furthermore, the graph shows how public airports more likely share the whole concession revenues rather than private airports.

Proofs

Proof of Proposition 1

By inspection:

1. $\frac{\partial q_i^*}{\partial r_i} = \frac{2bh}{4b^2-d^2} > 0$
2. $\frac{\partial p_i^*}{\partial r_i} = -\frac{(2b^2-d^2)h}{4b^2-d^2} < 0$

Proof of Proposition 2

If $w = \tau$ then $r_i^* = r_j^* = \frac{(a-c-\tau)b+h(2b+d)}{(b+d)h}$. Thus, the sharing proportions are greater than one if $(a-c-\tau+h)b > 0$, which is true.

Proof of Proposition 3

1. We first prove the rankings when $r < 1$.

1.a. Regarding the terms of the contract rankings, $r_2^A > r_i^* > r_i^P > r_1^A$ and $f_2^A > f_i^* > f_i^P > f_1^A$

1.a.i) To prove that $r_2^A > r_i^*$, notice that $r_2^A - r_i^* = \frac{d^3\left(2b^2-d^2\right)(a-c+h-\tau)}{h(b+d)(8b^4-8b^2d^2+d^4)}$, which is positive.

1.a.ii) Similarly, $r_i^* > r_i^P$ if $r_i^* - r_i^P = \frac{(2b+d)\left(2b^2-d^2\right)(a-c+h-\tau)}{h(b+d)(4b^2+2bd-d^2)}$ is positive, which is true.

1.a.iii) In the same way, $r_i^P > r_1^A$ when $r_i^P - r_1^A = \frac{d^3(2b-d)\left(2b^2-d^2\right)(a-c+h-\tau)}{h(4b^2+2bd-d^2)(8b^4-8b^2d^2+d^4)}$ is positive, which is also the case.

Therefore, the full ranking $r_2^A > r_i^* > r_i^P > r_1^A$ is obtained.

1.a.iv) To prove that $f_2^A > f_i^*$, notice that $f_2^A - f_i^* = b\left(\frac{\left(8b^3-6b^2d-2bd^2+d^3\right)^2}{\left(8b^4-8b^2d^2+d^4\right)^2} - \frac{1}{(b+d)^2}\right)(a - c + h - \tau)^2$ must be positive.

This requires $\frac{\left(8b^3-6b^2d-2bd^2+d^3\right)^2}{\left(8b^4-8b^2d^2+d^4\right)^2} - \frac{1}{(b+d)^2} > 0$. Or equivalently $\frac{\left(8b^3-6b^2d-2bd^2+d^3\right)^2(b+d)^2-\left(8b^4-8b^2d^2+d^4\right)^2}{\left(8b^4-8b^2d^2+d^4\right)^2(b+d)^2} > 0$. The denominator is positive, whereas the numerator is positive as long as $2b^2 - d^2 > 0$, which is true.

1.a.v) $f_i^* > f_i^P$ when $f_i^* - f_i^P = b\left(\frac{1}{(b+d)^2} - \frac{2\left(2b^2\varphi+d^2(1-\varphi)\right)}{\left(4b^2+2bd-d^2\right)^2}\right)(a - c + h - \tau)^2$ is positive.

That requires the following term to be positive $\left(\frac{1}{(b+d)^2} - \frac{2\left(2b^2\varphi+d^2(1-\varphi)\right)}{\left(4b^2+2bd-d^2\right)^2}\right)$, or equivalently $\frac{(2b^2-d^2)(8b^2+8bd+d^2-2(b+d)^2\varphi)}{(b+d)^2\left(4b^2+2bd-d^2\right)^2} > 0$, which always holds.

1.a.vi) Finally, $f_i^P > f_1^A$, if
$f_i^P - f_1^A = 2b\left(\frac{1}{\left(4b^2+2bd-d^2\right)^2} - \frac{4b^2(b-d)^2}{\left(8b^4-8b^2d^2+d^4\right)^2}\right)\left(2b^2\varphi + d^2(1-\varphi)\right)(a-c+h-\tau)^2$ is positive.

It requires that $\left(\frac{1}{\left(4b^2+2bd-d^2\right)^2} - \frac{4b^2(b-d)^2}{\left(8b^4-8b^2d^2+d^4\right)^2}\right) = \frac{d(2b-d)\left(2b^2-d^2\right)\left(16b^4-4b^3d-14b^2d^2+2bd^3+d^4\right)}{\left(4b^2+2bd-d^2\right)^2\left(8b^4-8b^2d^2+d^4\right)^2}$, be positive which is always true since $\left(16b^4 - 4b^3d - 14b^2d^2 + 2bd^3 + d^4\right)$ is decreasing in d and it is positive for $d = b$.

Therefore, the full ranking $f_2^A > f_i^* > f_i^P > f_1^A$ is obtained.

1.b. Regarding price and quantity orderings, $p_i^P > p_1^A > p_2^A > p_i^*$ and $q_2^A > q_i^* > q_i^P > q_1^A$.

1.b.i) In order to prove that $p_i^P > p_1^A$, $p_i^P - p_1^A = \frac{d(2b-d)\left(2b^2-d^2\right)^2(a-c+h-\tau)}{(4b^2+2bd-d^2)(8b^4-8b^2d^2+d^4)}$ must be positive which is true.

1.b.ii) In the same way, $p_1^A > p_2^A$ as long as $p_1^A - p_2^A = \frac{\left(4b^4-6b^3d+3bd^3-d^4\right)(a-c+h-\tau)}{8b^4-8b^2d^2+d^4}$ is positive, which is also true.

1.b.iii) Similarly, $p_2^A > p_i^*$ if $p_2^A - p_i^* = \frac{d(b-d)\left(2b^2-d^2\right)(a-c+h-\tau)}{8b^4-8b^2d^2+d^4}$ is positive, which it holds.

Therefore, the full ranking $p_i^P > p_1^A > p_2^A > p_i^*$ is obtained.

1.b.iv) $q_2^A > q_i^*$ if $q_2^A - q_i^* = \frac{\left(2b^3d-bd^3\right)(a-c+h-\tau)}{(b+d)(8b^4-8b^2d^2+d^4)}$ is positive and it is.

1.b.v) For $q_i^* > q_i^P$, $q_i^* - q_i^P = \frac{\left(2b^2-d^2\right)(a-c+h-\tau)}{(b+d)(4b^2+2bd-d^2)}$ has to be positive, which is true.

1.b.vi) Finally, $q_i^P > q_1^A$, if $q_i^P - q_1^A = 2b\left(\frac{1}{4b^2+2bd-d^2} - \frac{2b(b-d)}{8b^4-8b^2d^2+d^4}\right)(a-c+h-\tau)$ is positive. Or equivalently if $\left(\frac{1}{4b^2+2bd-d^2} - \frac{2b(b-d)}{8b^4-8b^2d^2+d^4}\right) = \frac{d(2b-d)\left(2b^2-d^2\right)}{(4b^2+2bd-d^2)(8b^4-8b^2d^2+d^4)} > 0$, which is true.

Therefore, the full ranking $q_2^A > q_i^* > q_i^P > q_1^A$ is obtained.

c. Regarding the SW, CS and total number of passengers rankings $SW^* > SW^A > SW^P$, $CS^* > CS^A > CS^P$, and $Q^* > Q^A > Q^P$.

1.c.i) To prove that $SW^* > SW^A$, it is straightforward to see that $SW^* - SW^A = \frac{b(b-d)\left(4b^2-3d^2\right)\left(2b^2-d^2\right)^2(a-c+h-\tau)^2}{2(b+d)(8b^4-8b^2d^2+d^4)^2}$ is positive.

1.c.ii) To prove $SW^A > SW^P$, $SW^A - SW^P = \frac{(2b-d)\left(2b^2-d^2\right)^2\left(32b^6-16b^5d-40b^4d^2+12b^3d^3+14b^2d^4+bd^5-2d^6\right)(a-c+h-\tau)^2}{2(4b^2+2bd-d^2)^2(8b^4-8b^2d^2+d^4)^2}$ must be positive, which is true. Note that $\left(32b^6 - 16b^5d - 40b^4d^2 + 12b^3d^3 + 14b^2d^4 + bd^5 - 2d^6\right) > 0$ can be written as a polynomial of degree six of the ratio $\frac{d}{b} \equiv z \in [0,1]$. It has two real roots which are $z_1 = -1.108$ and $z_2 = 2.812$ and it happens that for $z \in [z_1, z_2]$ the polynomial is positive.

Therefore, the full ranking $SW^* > SW^A > SW^P$ is obtained.

1.c.iii) To prove $CS^* > CS^A$, notice that $CS^* - CS^A = \frac{1}{2}\left(\frac{2}{b+d} - \frac{b\left(80b^6-64b^5d-92b^4d^2+72b^3d^3+16b^2d^4-12bd^5+d^6\right)}{(8b^4-8b^2d^2+d^4)^2}\right)(a-c+h-\tau)^2$ is positive as long as the first term in parentheses is. This term can be written as $\frac{(b-d)\left(2b^2-d^2\right)\left(24b^5+16b^4d-22b^3d^2-16b^2d^3+bd^4+2d^5\right)}{(b+d)(8b^4-8b^2d^2+d^4)^2}$, which is positive.

1.c.iv) $CS^A > CS^P$ if $CS^A - CS^P = \frac{1}{2}b\left(\frac{80b^6-64b^5d-92b^4d^2+72b^3d^3+16b^2d^4-12bd^5+d^6}{(8b^4-8b^2d^2+d^4)^2} - \frac{8b(b+d)}{(4b^2+2bd-d^2)^2}\right)(a-c+h-\tau)^2$ is positive. The first term in parentheses can be written as $\frac{(2b-d)(2b+d)\left(2b^2-d^2\right)\left(96b^6-32b^5d-152b^4d^2+56b^3d^3+58b^2d^4-24bd^5+d^6\right)}{(4b^2+2bd-d^2)^2(8b^4-8b^2d^2+d^4)^2}$, which is positive since the term $\left(96b^6 - 32b^5d - 152b^4d^2 + 56b^3d^3 + 58b^2d^4 - 24bd^5 + d^6\right)$ is decreasing in d and positive for $d = b$.

Therefore, the full ranking $CS^* > CS^A > CS^P$ is obtained.

1.c.v) To prove that $Q^* > Q^A$, notice that $Q^* - Q^A = \frac{(b-d)(2b+d)\left(2b^2-d^2\right)(a-c+h-\tau)}{(b+d)(8b^4-8b^2d^2+d^4)}$ must be positive, which is true.

1.c.vi) $Q^A > Q^P$, if $Q^A - Q^P = \frac{(2b-d)\left(2b^2-d^2\right)\left(4b^2-2bd-d^2\right)(a-c+h-\tau)}{(4b^2+2bd-d^2)(8b^4-8b^2d^2+d^4)} > 0$, which is.

Therefore, the full ranking $Q^* > Q^A > Q^P$ is obtained.

2. Finally, for the case where in all scenarios concession revenues are fully obtained by airlines.

To obtain $r = 1$ in every scenario, it is required that $w > w_1^A$, and the different fixed payments rank as follows, $f_i^* = f_2^A > f_i^P = f_1^A$.

To prove that $f_i^* = f_2^A > f_i^P = f_1^A$, notice that $f_i^* - f_i^P = \frac{(1-\varphi)(a-c+h-w)(b(a-c+h)-\tau(2b+d)+w(b+d))}{(2b+d)^2}$. This is positive as long as $w > w^f = -\frac{(a-c+h)b+\tau(2b+d)}{b+d}$, which is true because $w_1^A > w^f$.

Proof of Proposition 4

Consider we are in the case of two public airports:

$$\frac{\partial r_i^*}{\partial \alpha} = \frac{\partial \frac{(a-c)(b+\alpha d)+(h-\tau)(2b+(\alpha+1)d)+w(b+d)}{h(b+d)}}{\partial \alpha} = \frac{d(a-c+h-\tau)}{h(b+d)} > 0$$

The partial derivative is always positive.

Proof of Proposition 5

To analyze the strategic relationship between airports, we have to know the sign of

$$\frac{\partial^2 SW}{\partial r_i^* \partial r_j^*} = \frac{dh^2\left(4\alpha b^2-(\alpha+1)^2d^2\right)}{((\alpha+1)^2d^2-4b^2)^2}$$

This sign is determined by the sign of $4\alpha b^2 - (\alpha+1)^2 d^2$. Solving this term to obtain the roots we get, $\alpha^- = (2b^2 - d^2 - 2b\sqrt{b^2-d^2})/d^2$, and $\alpha^+ = (2b^2 - d^2 + 2b\sqrt{b^2-d^2})/d^2$, where the term is positive for $\alpha^- < \alpha < \alpha^+$ with $\alpha^+ > 1$ and $0 < \alpha^- < 1$.

Then, airports are strategic substitutes if $\alpha^- < \alpha < 1$, and they are strategic complements as long as $0 < \alpha < \alpha^-$.

Proof of Proposition 6

1. In the case of two private airports with $r_i, r_j < 1$:

$$\frac{\partial SW^P}{\partial \alpha} = \frac{4bd^2\left(2b^2-(\alpha+1)d^2\right)(a-c+h-\tau)^2}{(4b^2+2bd-(\alpha+1)d^2)^3} > 0$$

2. In the asymmetric case with $r_i, r_j < 1$:

$$\frac{\partial SW^A}{\partial \alpha} = \frac{2bd^2(b-d)^2\left(2b^2-(\alpha+1)d^2\right)\left(8(1-\alpha)b^4+4\left(2\alpha^2+\alpha-1\right)b^2d^2-(\alpha+1)^3d^4\right)(a-c+h-\tau)^2}{(8b^4-4(\alpha+2)b^2d^2+(\alpha+1)^2d^4)^3} > 0$$

The denominator is positive since it is decreasing in α and positive when evaluated at $\alpha = 0$. Therefore it remains to prove that the next term in the numerator $\left(8(1-\alpha)b^4 + 4\left(2\alpha^2+\alpha-1\right)b^2d^2 - (\alpha+1)^3d^4\right) > 0$. Divide the expression by b^4, in this way a convex quadratic polynomial in ($x = (\frac{d}{b})^2$, with $x \in [0,1]$) is defined. The polynomial $\left(8(1-\alpha) + 4\left(2\alpha^2+\alpha-1\right)x - (\alpha+1)^3x^2\right)$ is positive for x in the interval formed by the roots. Note that the mentioned roots are $x^- = \frac{2\left(2\alpha^2+\alpha-1-\sqrt{\alpha(2\alpha^3-3\alpha+2)+3}+\right)}{(\alpha+1)^3}$ and

$x^{+} = \frac{2\left(2\alpha^2+\alpha-1+\sqrt{\alpha(2\alpha^3-3\alpha+2)+3}+\right)}{(\alpha+1)^3}$, with $x^{-} < 0 < 1 < x^{+}$, then proving that the term is positive for all $x \in [0,1]$

then the result is proven.

3. In the private and asymmetric case when $r_i, r_j = 1$:
   $\frac{\partial SW}{\partial \alpha} = -\frac{2d(a-c+h-w)((a-c+h)(b+\alpha d)-\tau(2b+(\alpha+1)d)+w(b+d))}{(2b+\alpha d+d)^3}$.
   In order to have $\frac{\partial SW}{\partial \alpha} > 0$, it is required $\tau > \frac{(a-c+h)(b+\alpha d)+(b+d)w}{2b+(1+\alpha)d}$.

4. With dual-till regulation and when $r_i, r_j = 1$:
   $\frac{\partial SW}{\partial \alpha} = -\frac{2d(b+\alpha d)(a-c+h-\tau)^2}{(2b+\alpha d+d)^3} < 0$.