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Abstract

This paper studies the effects of concession revenue sharing contracts to analyze how airport-airline vertical structures compete for passengers in the same catchment area. The analysis studies the effects of such contracts depending on airport ownership structure. We show that private airports tend to share less concession revenues than public ones eventually leading to lower welfare levels. These results have relevant policy implications when concession revenue sharing contracts are specified in practice.
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1. Introduction

A number of changes have occurred in the last decades that have modified market structure and the competition in air transport markets. In particular, the deregulation of the airline market coupled with the privatization process of airports has intensified the competition between airports. This has pushed agents to search for new strategies to achieve a competitive advantage. In addition to revenues from aeronautical charges, concession revenues (coming from non-aeronautical activities) have turned decisive once airports cannot rely on public financing. In fact, ATRS (2018) found that non-aeronautical revenue in major airports reached over 70% of their total revenue. Moreover, ACI (2018) reveals that worldwide the average of concession revenues remained at 39.4% of total revenues. Nevertheless, it is airlines that generate those revenues, which airports earn as a positive externality. Airports and airlines have signed agreements whereby concession revenues are shared, given the complementarity between the demand for aviation services and the demand for concession services. Over time, concession revenue sharing contracts have become increasingly common. 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.

This paper studies the effects of concession revenue sharing contracts in a model of airport-airline pairs that compete in a certain catchment area. Due to the growth in the number of airports around the world, many situations arise where two or more airports compete for attracting the same passengers, that is, they share the same catchment area. Examples 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. Then, nowadays passengers face the decision among airport-airline pairs, instead of an airline within a single airport context; for example, a passenger traveling from London to Alicante could fly with either Ryanair from Stansted or with EasyJet from Gatwick. Thus, these contracts serve to align the interests of airports and airlines in order to attract passengers and improve the profit of the vertical chain. Furthermore, revenue sharing alters airline competition, e.g. by providing special treatment to particular carriers, which may raise market power issues.

We present the effects of revenue sharing contracts when airports pursue different objectives. The literature has typically considered private airports that maximize profits. Although the literature suggests that welfare maximization will deliver different results compared to profit maximization, we extend the literature on airport competition by comparing the equilibrium outcomes under two public airports, two private airports and one public-one private airport when revenue sharing contracts are employed. We find that when two airports compete with each other, they can use the sharing proportion to influence competition and increase the number of passengers at the expense of the other competing airport. On the other hand, the level of the sharing proportion is directly related to the aeronautical charge.

The aeronautical charge is linked to the type of regulation existing at each airport which, in general, is chosen by the regulatory institutions of the sector. In practice, we can find different regulatory frameworks and different forms of regulatory constraints such as rate of return, price cap or sliding-scale. The need to regulate airports is due to the increasing privatization of the sector. For example, according to Forsyth et al. (2020), at Belgian, German, Dutch, and Greek airports rate of return regulation applies. On the other hand, airports applying price-cap regulation "include many of the largest European airports, including London Heathrow, Paris Charles de Gaulle, Lisbon, Vienna and the major Italian airports." In contrast, public airports do not have a regulatory system per se, but they maintain low prices. An example in this sense are the Spanish airports, whose management is centralized by a public company, AENA, which since 2015 has been partially privatized. We show that if the aeronautical charge is high enough, the airport shares all the concession revenues with the airline. In that manner, airlines obtain the whole positive externality they generate.

Furthermore, the comparison of different airport ownership regimes unveils that when airports distribute all their concession revenues with the airlines, that is, the sharing proportion is equal to one we find that the level of traffic, airfares and profits will be the same. This fact shows that with a high enough aeronautical charge, the ownership effect is neutralized. On the other hand, in the case where airports do not share all their concession revenues, which is what happens in practice, it is confirmed that the privatization of airports causes a social welfare reduction. In addition, private airports tend to share less concession revenues than public ones.

In recent years, the vertical relationship between airports and airlines is a matter of increasing attention among scholars (see D'Alfonso and Nastasi (2014)). Basso and Zhang (2007) reviewed the evolution that the vertical relationship of airports and airlines has had in the literature. They differentiate between the traditional approach, in which airlines are taken as price takers, that is, the decisions on the level of traffic fall directly to the airport, and the vertical structure approach, with airports supplying an input to airlines (Basso and Zhang (2008)). In the vertical structure approach, airlines behave strategically, and given the vertical relationship, airports, which are located in the upstream market, can influence the decisions of airlines and the equilibrium in the downstream market. Barbot (2009), in a setting where two vertical structures compete with each other, determined that there are incentives to establish vertical agreements. However, as Barbot and D'Alfonso (2014) states, not every vertical agreement sustains. Later, Barbot (2011) analyzed the effects of three different types of agreements for the case of one airport ans several airlines, and D'Alfonso and Nastasi (2012) make the same analysis, although with two vertical structures competing. Barbot (2011) collects the agreements from Starkie (2009). The types of agreements that are the most common are: (1) the European case, in which companies negotiate rates with the airport, therefore, they end up paying a lower price than the rest of the airlines that do not sign any agreement ; (2) the Australian case, where airlines sign long-term terminal leases and its management; and (3) the case of US, in which airlines pay the airport the variable costs of its facilities plus a part of the fixed costs.

Then, there are incentives for signing vertical agreements between airports and airlines, which is supported by Barbot et al. (2013) who found evidence of vertical collusion in two scenarios, when there is a main national carrier in a small airport, or in the case of low cost carriers in secondary airports. However, there is a trade-off between competition and welfare. Signing vertical agreements solves the problem of double marginalization because of the integration between an upstream and a downstream firm, but in turn, they surface anti-competitive issues in the downstream market. Specifically, this occurs when an airport offers exclusive agreements where only a few airlines benefit, altering the competition between the airlines operating at the airport. Nevertheless, these papers do not consider concession revenue sharing contracts.

Zhang and Zhang (1997) were the first to introduce concession revenue sharing contracts in the literature following a traditional approach. Later, Zhang et al. (2010) and Fu and Zhang (2010) characterized the contract under the vertical structure approach. Fu and Zhang (2010) studied the competitive and welfare implications when an airport offers airlines the option of sharing its concession revenue. On the other hand, Zhang et al. (2010) analyzed the degree of revenue sharing depending on the downstream market structure; that is, if the airlines services are substitutes, complements or independent. Furthermore, they also study the case of two competing airports, in which case, upstream competition results in a higher degree of revenue sharing. These papers all asume profit-maximizing airports.

The next section sets out the basic model where two public airports compete and provides some comments about the contract. Section 3 introduces private airports and compares the different scenarios. Finally, we conclude with some remarks and policy recommendations.

2. Public airports and vertical structure competition

2.1. Basic model

Consider in this section two public airports, which compete for passengers, in a common catchment area that offer flights to the same destination areas. One and a different airline operates in each airport. There is airline competition because they provide substitute differentiated services in the eyes of passengers. The following utility function of a representative passenger describes the preferences:

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

For a, b and d being positive constants and y denoting an outside good used as the numeraire. The q_i's represent the number of passengers served by each airline in a given origin-destination route. Subscript i is used for one vertical structure formed by an airport-airline pair, whereas the other is identified by subscript j. Parameter a, denotes the maximum willingness to pay for traveling. 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:[1]

$$p_i = a - b\, q_i - d\, q_j \quad \forall \quad i, j = 1, 2 \quad i \neq j \tag{2}$$

[1]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 $\frac{\partial p_1}{\partial q_1}\frac{\partial p_2}{\partial q_2} - \frac{\partial p_1}{\partial q_2}\frac{\partial p_2}{\partial q_1} = b^2 - d^2 > 0$.

in the region of quantity space where airfares become positive, where p_i is the airfare paid for traveling 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 is regulated, 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. The simple representation of the net concession revenue, h, where it is strictly complementary to passenger volume has been used by Zhang et al. (2010), Fu and Zhang (2010), and Yang et al. (2015), among others. Concession profits are, precisely given by $h\ r_i q_i - f_i$, 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. Therefore, airline $i's$ profits appear as $\pi_i = (p_i - c - w + hr_i)q_i - f_i$.

Airports also have two sources of revenue. They obtain wq_i from aeronautical activities. Note that w cannot be changed from the airport unilaterally since it is regulated. The other source comes from non-aeronautical activities, and it is composed of the share of concession revenues they keep, $(1 - r_i)hq_i$ plus the fixed fee, f_i. Finally, τ is the marginal aeronautical costs, while fixed costs are normalized to zero. Cost symmetry between airports has been assumed for the sake of the exposition. It is nevertheless true that cost asymmetries would be realistic if one looked at airport competition between a hub and a satellite airport. Some comments are made below once the symmetry assumption is relaxed. Therefore, airport profits are:

$$\Upsilon_i = (w - \tau)q_i + (1 - r_i)hq_i + f_i \tag{3}$$

The revenue sharing contract considered has been employed by Zhang et al. (2010) and Fu and 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 it 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.

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), that follows a sequential structure in which the revenue sharing parameter is determined in a first step and the fixed payment is determined in a second step, 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.The next subsections characterize the subgame perfect Nash equilibrium of the game, which is solved in the standard backward way.

2.2. Downstream airline competition

Airline i chooses q_i to maximize the following profits expression:

$$\pi_i = (p_i - c - w + r_i h) q_i - f_i \tag{4}$$

Solving the two first-order conditions system and using the inverse demand functions in (2), the second-stage equilibrium values of q_i denoted by superscript star, as a function of r_i and r_j are obtained.[2] These are given by:

$$q_i^*(r_i, r_j) = \frac{(a-c-w)(2b-d) + (2b\, r_i - d\, r_j)h}{4\, b^2 - d^2} \quad \forall i,j = 1,2 \quad i \neq j; \tag{5}$$

where the total number of passengers in the industry is:

$$Q^* = q_i^* + q_j^* = \frac{2(a-c-w) + h(r_i + r_j)}{2b+d} \tag{6}$$

[2]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 $(\frac{\partial^2 \pi_i}{\partial q_i^2}\frac{\partial^2 \pi_j}{\partial q_j^2} - \frac{\partial^2 \pi_i}{\partial q_i \partial q_j}\frac{\partial^2 \pi_j}{\partial q_j \partial q_i} = 4\, b^2 - d^2 > 0)$. Also, there is strategic substitution among airlines $(\frac{\partial^2 \pi_i}{\partial q_i \partial q_j} = -d < 0)$.

And the equilibrium prices are,

$$p_i^*\left(r_i, r_j\right) = \frac{(2b-d)(ab+(b+d)(c+w)) - hr_i\left(2b^2-d^2\right) - bdhr_j}{4b^2-d^2} \quad \forall i,j=1,2 \quad i \neq j. \tag{7}$$

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

Equation (5) shows how airports compete to attract passengers through airlines using the sharing proportion. Absent concession revenues, the equilibrium number of passengers contains the usual terms, that is, the oligopoly profitability term corrected by the effect of substitutability between services. Now the consideration of concession revenues has a pro competitive 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 $\frac{2bh}{4\ b^2-\ d^2}$. This increase in demand comes partly from the loss of passengers from the rival airport, $\frac{dh}{4\ b^2-\ d^2}$, plus a part that is generated by increasing demand for price reductions. It also improves welfare because the overall effect is to increase the total number of passengers by $\frac{h}{2b+d}$.

As can be seen, the inclusion of concession revenue sharing affects airport competition. Airports can play with this tool to attract more traffic to the detriment of their competitors. Since the rival airports will respond in a like manner, an increase in total traffic is observed boosting consumer surplus. This argument is proven in Zhang et al. (2010). We show it for the linear demand case and emphasize the effects on airport competition, while Fu and Zhang (2010) considers one airport and several airlines with equal revenue sharing.

2.3. The revenue sharing equilibrium

The objective function of public airports is to maximize social welfare (SW), 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. 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, to 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 and Mantin (2014). For a more complete analysis see Czerny

(2013) and Flores-Fillol et al. (2018).

The contract values are obtained through a two-step procedure. First, social welfare is maximized to obtain r_i with $i = 1, 2$, and then each airport-airline pair bargains over the fixed payment, f_i with $i = 1, 2$.

After maximizing SW with respect to r_i, the equilibrium sharing proportion[3] denoted by a star, is given by:

$$r_i^* = r_j^* = \begin{cases} \frac{(a-c)b+w(b+d)+(h-\tau)(2b+d)}{h(b+d)} & \text{if } max\{0, w^+\} < w < w^* \equiv \frac{-(a-c+h)b+(2b+d)\tau}{(b+d)} \\ 1 & \text{if } w^* \leq w \leq \tau \end{cases} \tag{8}$$

As can be seen, the sharing proportion is affected by the degree of differentiation of the airlines services, b, d, the operating costs of the vertical pair, c and τ, the willingness to pay of passengers, a, and the aeronautical and commercial revenues of the airport, w and h. The aeronautical charge, w, is regulated and is key to establish if the sharing proportion is equal to or less than one, that is, if the airports share all the concession revenues with the airlines or just a proportion of them. On the aeronautical charge, there is also a condition to ensure a non-negative sharing proportion when $w > w^+ \equiv \frac{-(a-c)b-(h-\tau)(2b+d)}{b+d}$. Thus, $0 < r_i^* < 1$ as long as $w^+ < w < w^*$. It must be noted that the sharing proportion, r_i, can mathematically fall outside the [0,1] interval. If r_i were negative, then output would be lower than in the absence of contracts, which would raise antitrust concerns because of their effects in restricting competition. If r_i exceeded 1, then airports would give away part of their aeronautical revenues finding it hard to make profits because aeronautical charges are regulated. Thus, and as done by Fu and Zhang (2010) and Saraswati and Hanaoka (2014), we assume $0 < r_i < 1$ to focus on the strategic effects of the concession revenue sharing contracts.

With respect to the case in which $r_i^* < 1$, the less differentiated the services are, d tends to b, the lower the share proportion is. This is because it is easier to attract passengers from

[3]First order conditions are specified in the appendix. Second derivatives entail: (i)the concavity condition; (ii) strategic substitution between sharing proportions; (iii) and the stability condition.

the other airport the more similar the services are. Therefore, the airport can achieve the same impact with a lower sharing proportion.

The sharing proportion can be one, $r_i^* = 1$, due to two reasons. Either if the aeronautical charge is large enough, $w \geq w^*$, or under a specific system of airport regulation. There are two accounting approaches that apply to the various regulation systems, which are the single and the dual-till system. In a price-cap setting, the single-till approach cross-subsidizes the aeronautical charge with concession revenues, that is, these revenues are used to cover the airport infrastructure cost. The airport goal with the aeronautical charge is to cover completely its infrastructure costs through own revenues, that is, $w^{ST} = min\{w : w = \tau - h\}$. As it can be seen, the aeronautical charge per passenger covers the net infrastructure cost once the concession revenues have been extracted. On the other hand, the dual-till approach splits the two sources of revenue, regulating just the aeronautical part, that is, $w^{DT} = min\{w : w = \tau\}$.[4] In order to calculate the aeronautical charge, what is used is the gross infrastructure cost. It is easily seen that the aeronautical charge is fewer in the single till approach. 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 the dual-till approach, $w = \tau$, airports share the whole concession revenues, $r_i^* = r_j^* = 1$. That is, if the airport charges the full aeronautical costs τ, then, it will share all concession revenue back with the airline.*

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 $(a - c - \tau + h)b > 0$, which is the case. By definition, $h, b > 0$, and to guarantee positive equilibrium quantities, 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 equilibrium sharing proportion less than one, a single-till approach or some cross-subsidization is required, that is with $w < \tau$. In this case, an increase in the aeronautical share increases the sharing proportion; specifically, $\frac{\partial r}{\partial w} = \frac{1}{h} > 0$.

Once the sharing proportion has been chosen, a Nash bargaining process is set in order to obtain the equilibrium fixed payment, f_i. The bargaining power of each agent will determine its

[4]See Czerny et al. (2016) for a deeper analysis on single and dual-till approach regulation.

amount. However, f_i does not have any influence on the number of passengers. The parameter $\varphi \in (0,1)$ represents the bargaining power of airports. If $\varphi = 1$ the whole bargaining power goes to the airport while for $\varphi = 0$ the airline holds the power. The Nash bargaining problem is given by:

$$\underset{f_i}{Max} \quad \left[SW - SW^0\right]^{\varphi} \left[\ \pi_i - \pi_i^0\right]^{1-\varphi} \tag{9}$$

where the additional gains of the concession revenue sharing contract are shared. The superscript *0* denotes the case without revenue sharing. By maximizing the Nash bargaining problem, the resulting equilibrium fixed payment is given by:

$$f_i^* = (r_i h - Y)q_i^* + X(p^0 - c - w) = \pi_i - \pi_i^0 \tag{10}$$

where $X = \frac{(2br_i - dr_j)h}{4b^2 - d^2}$ is the difference in quantities once the revenue sharing contract is assigned, $q_i^* - q_i^0$. And $Y = -\frac{((2b^2-d^2)r_i + bdr_j)h}{4b^2-d^2}$, is the difference on prices, $p_i^* - p_i^0$.

In any case, the fixed payment does not affect the consumer surplus, but serves as a mechanism that distributes the benefits of the vertical pair among the agents that comprise it. Equation (10) shows that in a vertical structure, when the airport is public, the equilibrium fixed payment is the same as the additional gains of the concession revenue sharing contract. Hence, airlines operating in public airports do not benefit from the contract. The airport shares with the airlines part of its commercial revenues to increase traffic and, therefore, its aeronautical and non-aeronautical revenues. On the other hand, the airport is able to extract a surplus of the airlines through the fixed payment, and this is independent of the bargaining power parameter φ.

Once the concession revenue sharing contract is obtained, the corresponding equilibrium variables are reported below.

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 two outcomes that can be observed depend on whether the sharing proportion is below one or is equal to one, which in turn depends on the value of the aeronautical charge.[5] As can be seen in part *a)*, the aeronautical charge w is eliminated from the results, which means complete vertical integration and achieving the first-best outcome. Alternatively, in the case when the sharing proportion is one, the airport cannot completely internalize the effect that a concession revenue sharing contract has on traffic. This lower traffic level leaves the airport-airline pair with positive surplus at the expense of consumers, finally resulting in lower total welfare.

These results show the importance of aeronautical regulation and how it affects the level of traffic. Faced with this situation with public airports, regulators should seek a sufficiently low aeronautical charge to guarantee that the sharing is not complete. In this way, the elimination of the distortion created by w implies that total welfare is maximized and the agents transfer their benefits to passengers. What is achieved is that the consumer surplus is maximized, a condition that is lost if the aeronautical charge causes the sharing proportion to be one. This also highlights the debate on what type of regulation is effective in which situations. Here it is observed that a dual-till would lead to a social welfare loss.

Also, as with the sharing proportion, the less differentiated the services are, d tends to b, the lower the equilibrium values reported in Result 1 are. When $r_i^* < 1$, public airports reduce their sharing when competition downstream is more intense. Because airports maximize social welfare, the competitive effect is smaller, which causes the sharing proportion to decline. This,

[5] The model can be solved by assuming that in stage 1, one of the airport-airline pairs decides the terms of the revenue sharing contract before the other pair. This possibility would comply with the situation at some important airports with dominant carriers. If both airports are public the outcomes reported in Result 1 are the same, whether decisions at stage 1 are taken simultaneously or sequentially. Computations available on request.

in turn, makes traffic to fall and, therefore, consumer surplus and social welfare diminish.

One wonders whether the results are affected by the symmetric cost assumption in airports. When the equilibrium sharing proportion is below one, we find that the most efficient airport increases its sharing proportion relative to the symmetric cost case. Therefore, there is a transfer of passengers from the less efficient airport to the more efficient one yet total traffic is not affected. In the case that the equilibrium sharing proportion is equal to 1, the only change is in the profits of the less efficient airport, which decrease in the same amount as social welfare does.

Proposition 3. *At the revenue sharing equilibrium with two public airports facing competition, when airlines are symmetric and provide substitutable services, (i) traffic and welfare are greater and (ii) prices are lower than in the absence of revenue sharing, for all* $r_i \leq 1$.

Proposition 1 already advanced these results. Instead, it was necessary to do the checks due to the interactions that take place between airports and airlines. It is noted that the concession revenue sharing improves the situation of passengers, no matter what their level is. This fact urges authorities to consider this type of vertical agreements between airports and airlines. Despite the fact that anti-competitive issues could arise, there are improvements that benefit the passengers.

3. Private airports in the vertical structures

In 1987, the UK decided to privatize some airports, this measure was followed afterwards by many countries. Although various reasons existed for it, the main reason for privatization was the need of self-financing because of the budget constraints governments suffered. As a consequence, several kinds of ownership structure coexist. The basic model presented in section 2 has focused on public airports, while now we are going to consider also private airports, the usual case examined in the literature, to see the main differences between them. Subsection 3.1 considers two private airports whereas subsection 3.2 has one public and one private airport. The second stage where airlines compete in quantities remains the same, and the changes happen in the first stage where airlines interact with airports.

3.1. Private structures in the upstream market

Consider now two private airports competing that implying their respective objective functions change as they pursue profit maximization. In this case, each airport-airline pair maximizes its aggregate profit when choosing the sharing proportion r_i, $\underset{r_i}{Max} \quad \Upsilon_i + \pi_i$. Joint profit maximization is chosen following the trend in the specific literature as Barbot (2011) and D'Alfonso and Nastasi (2012) which analyze different vertical airport-airline agreements, and Fu and Zhang (2010) who analyze concession revenue sharing contracts, because it is assumed that it is in both firms' interest, when competing with the other vertical pair, to capture the largest proportion of passengers form the total pool, and this is achieved just by choosing the revenue-sharing parameter to maximize a profit sum of the vertical pair. Then, the equilibrium sharing proportion, denoted by superscript P for private, is given by:

$$r_i^P = r_j^P = \begin{cases} \frac{(a-c)d^2 + w\left(4b^2+2bd-d^2\right)+2b(2b+d)(h-\tau)}{h(4b^2+2bd-d^2)} & \text{if } max\{0, w^{P+}\} < w < \frac{-d^2(a-c+h)+2b(2b+d)\tau}{4b^2+2bd-d^2} \equiv w^P \\ 1 & w^P \leq w \leq \tau \end{cases} \tag{11}$$

As in the basic model, there is a condition ensuring that $r_i^P > 0$. In this case it is when $w > w^{P+} \equiv \frac{-(a-c)\ d^2-2b(2b+d)(h-\tau)}{4\ b^2+2bd-\ d^2}$. Then, $0 < r_i^P < 1$ as long as $w^{P+} < w < w^P$, and w is positive.

Notice that the bounds on w that determine when the sharing proportion falls below one do not coincide with the previous case. In fact, the one for private airports is greater than the one for public airports, $w^P > w^*$. *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.[6] This fact also happens with the values of w such that the sharing proportion is positive and less than one, $w^{P+} > w^+$. Regarding the regulation system, Proposition 2 continues to hold, so that the sharing is complete under the case in which a dual-till regulation system takes place.

To make the sharing proportion positive, the authorities have to impose a higher aeronautical charge. This means that in a situation with private airports, the aeronautical charge should be larger compared to the case with public airports to ensure concession revenue sharing.

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

Regarding downstream differentiation, as long as d tends to b, the sharing proportion when $r_i^P < 1$ increases. When d tends to b, airline services are more substitutes, so competition in the downstream market intensifies. This increase in competition causes the airport to increase the sharing proportion to compensate for the loss of passengers due to a more competitive situation. This result is the opposite of the previous case with two public airports. In this case, the increase in competition among airlines causes private airports to increase the sharing proportion.

After obtaining the sharing proportions, the Nash bargaining problem is solved to obtain the fixed payment in this case. The objective function changes to $\underset{f_i}{Max} \quad \left[\Upsilon_i - \Upsilon_i^0 \right]^{\varphi} \left[\pi_i - \pi_i^0 \right]^{1-\varphi}$. The change with respect to the basic model is that private airports maximize their profits. Furthermore, consumer surplus is not part of this negotiation. Then, the resulting fixed payment is given by:

$$f_i^P = \varphi((h - Y)q_i^* + X(p^0 - c - \tau)) - (1 + r_i^P)q_i^* + X(w - \tau) \tag{12}$$

It can be seen that in a private airports setting, the bargaining power of the agents involved is important to determine the fixed payment, an element that does not play any role when airports are public. It is observed how, as the bargaining power of the airport increases, the value of the fixed rate increases, $\frac{\partial \ f_i^P}{\partial \varphi} > 0$, as expected. Once the sharing proportions and the fixed payments are computed, the equilibrium variables are reported below.

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

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

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

Result *2 b)* unveils that ownership structure is irrelevant in the presence of revenue sharing contracts as long as the aeronautical charge is large enough. This situation happens as long as the airports share completely their concession revenue with airlines, $r = 1$. Then, airlines fully internalize the positive externality they generate. We also note that Proposition 3 holds in this scenario. Thus, concession revenue sharing contracts, even with private airports, improves traffic levels and social welfare, lowering the airfares, and this corresponds with Proposition 4 in Zhang et al. (2010), which we report for the linear case while emphasizing the role of aeronautical charges.

A notable difference with regard to the basic case is that the existence of private airports means that consumer surplus is not maximized when $r_i, r_j < 1$. In this case, the social welfare is shared among the different agents. The joint profits between airports and airlines are shared depending on the bargaining power of airports. This shows that although consumer surplus is lower in a private setting, the results improve when concession revenue sharing is allowed.[7]

The next sub-section analyzes the concession revenues sharing contract in the last possible scenario, when a private and a public airport compete. It also shows a comparison of the three scenarios analyzed.

3.2. Asymmetric competition

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 pair will consequently have a different equilibrium contract. Superscript A denotes the asymmetric case, subscript 1 is the private airport whereas subscript 2 identifies the public airport.

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

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

[7] In the case of sequential game in stage one, the leader in the game, as it anticipates the other airport-airline pair decision, increases the contract parameters (the sharing proportion and the fixed payment) in order to gain more passengers thus getting more profits than under a simultaneous game. In contrast, the follower pair suffers a decrease both in its passengers and profits. The overall results are that total traffic increases in the sequential case, which leads to better results in terms of consumer surplus and social welfare. Computations available on request.

while the sharing proportion for the public airport is given by,

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

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

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

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

where $w_1^A > w_2^A$.

On the other hand, we must also ensure that the sharing proportion is positive. Thus,

$$\begin{cases} r_1^A > 0 \quad if \quad w > \frac{-2b\ d^2(a-c)(b-d)-(h-\tau)(8\ b^4-6\ b^2\ d^2-2b\ d^3+\ d^4)}{8\ b^4-8\ b^2\ d^2+\ d^4} \equiv\ w_1^{A+} \\ r_2^A > 0 \quad if \quad w > \frac{-(a-c)(8\ b^4-8\ b^3\ d+2b\ d^3-\ d^4)-(h-\tau)(16\ b^4-8\ b^3\ d-8\ b^2\ d^2+2b\ d^3)}{8\ b^4-8\ b^2\ d^2+\ d^4} \equiv\ w_2^{A+} \end{cases}$$

In this case, $w_1^{A+} > w_2^{A+}$, therefore, to ensure that the sharing proportion is always positive we must have that $w > w_1^{A+}$. Otherwise, there may be a case in which the private airport would have a negative sharing proportion. But this raises another question, whether the value of w_1^{A+} is greater than the values of w that make the sharing proportion equal to one, (w_1^A, w_2^A). It can be checked that $w_1^A > w_1^{A+}$, that is, the sharing proportion of the private airport is less than one. However, this is not necessarily true for the public airport, since w_2^A can be bigger or smaller than w_1^A+, so there is a range of w values for which $0 < r_2^A < 1$, and that happens when the net concession revenue per passenger is high enough, that is, $h > \frac{(a-c-\tau)\ (2b-d)^2(2\ b^2-\ d^2)}{2b(b-d)(4\ b^2+bd-\ d^2)} \equiv\ h^A$. Otherwise, the sharing proportion of the public airport would always be one.

This situation leaves three possible scenarios depending on the value of the aeronautical charge, w. If $w < w_2^A$ the pairs of contracts correspond to those reported above. If $w_2^A < w < w_1^A$, the public airport shares all its concession revenues, $r_2^A = 1$, while the private airport does not, $r_1^A < 1$. Finally, if $w > w_1^A$ both sharing proportions are the same and equal to one, $r_1^A = r_2^A = 1$.

Once all the conditions under which the sharing proportions are positive and less than unity are identified, the case can be analyzed in which the private airport distributes all its concession revenue and the public does not, that is, $r_1^A = 1$ and $r_2^A < 1$. There are two conditions under which this case is met depending on the value of the net concession revenue per passenger, h, and the aeronautical charge, w. These conditions are:

$$if \begin{cases} h > \ h^A \quad and \quad w_2^A < w < \ w_1^A \\ h < \ h^A \quad and \quad w_1^+ < w < \ w_1^A \end{cases}$$

Under these conditions, the resulting contracts are as follows:

$$\begin{cases} r_1^A = \frac{(a-c)(2b-d)d^2+w(8b^3-4bd^2+d^3)+h(8b^3-2bd^2-d^3)-\tau(8b^3-2bd^2)}{4bh(2b^2-d^2)} \\ r_2^A = 1 \end{cases}$$

Once the contracts have been calculated in all possible situations, the values of traffic, airfares and the benefit of the agents in each case are obtained.

Result 3. *In an asymmetric airports setting with concession revenue sharing it happens that: a) for* $r_1^A < 1$ *and* $r_2^A < 1$*, which happens as long as* $h > \ h^A$ *and* $w_1^+ < w < w_2^A$*,*

1. $q_1^A = \frac{4\ b^2(b-d)(a-c+h-\tau)}{(8\ b^4-8\ b^2\ d^2+\ d^4)}$
2. $q_2^A = \frac{(8\ b^3-6\ b^2 d-2b\ d^2+\ d^3)(a-c+h-\tau)}{(8\ b^4-8\ b^2\ d^2+\ d^4)}$
3. $p_1^A = \frac{2ab(b-d)(2b^2-d^2)+(4b^4+4b^3d-6b^2d^2-2bd^3+d^4)(c-h+\tau)}{(8\ b^4-8\ b^2\ d^2+\ d^4)}$
4. $p_2^A = \frac{a(2\ b^3d-2\ b^2\ d^2-b\ d^3+\ d^4)+(8b^4-2b^3d-6b^2d^2-bd^3)(c-h+\tau)}{(8\ b^4-8\ b^2\ d^2+\ d^4)}$
5. $\Upsilon_1^A + \ \pi_1^A = \frac{2\ b^3\ (b-d)^2(2\ b^2-\ d^2)\ (a-c+h-\tau)^2}{(8\ b^4-8\ b^2\ d^2+\ d^4)^2}$
6. $\Upsilon_2^A + \ \pi_2^A = \frac{d\ (b-d)(2\ b^2-\ d^2)\ (8\ b^3-6\ b^2\ d-2b\ d^2+\ d^3)(a-c+h-\tau)^2}{(8\ b^4-8\ b^2\ d^2+\ d^4)^2}$
7. $CS^A = \frac{b\ (80\ b^6-64\ b^5\ d-92\ b^4\ d^2+72\ b^3\ d^3+16\ b^2\ d^4-12b\ d^5+\ d^6)(a-c+h-\tau)^2}{2(8\ b^4-8\ b^2\ d^2+\ d^4)^2}.$
8. $SW^A = \frac{(112\ b^7-96\ b^6\ d-132\ b^5\ d^2+104\ b^4\ d^3+40\ b^3\ d^4-24\ b^2\ d^5-5b\ d^6+2\ d^7)(a-c+h-\tau)^2}{2(8\ b^4-8\ b^2\ d^2+\ d^4)^2}$

b) when $r_1^A = \ r_2^A = 1$ *Result 1 part b) holds.*

c) for $r_1^A < 1$ *and* $r_2^A = 1$*:*

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

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

3. $p_1^A = \frac{a(2b-d)+(c-h)(2b+d)+wd+2b\tau}{4b}$

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

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

6. $\Upsilon_2^A + \pi_2^A = \frac{((a-c+h)(4b^2-2bd-d^2)-w(4b^2-d^2)+2bd\tau)((a-c+h)(4b^2-2bd-d^2)+w(4b^2-3d^2)-2\tau(4b^2-bd-2d^2))}{16b(2b^2-d^2)^2}$

7. $CS^A = \frac{1}{32b(2b^2-d^2)^2}((a^2+c^2+h^2-2ac+2h(a-c))(32b^4-32b^2d^2+4bd^3+5d^4)+w^2(16b^4-20b^2d^2+5d^4)+\tau^2(16b^4-12b^2d^2)-(a-c+h)(w(32b^4-40b^2d^2+4bd^3+10d^4)+\tau(32b^4-24b^2d^2+4bd^3))+\tau w4bd^3)$

8. $SW^A = \frac{1}{32b(2b^2-d^2)^2}((a^2+c^2+h^2-2ac+2h(a-c))(96b^4-64b^3d-48b^2d^2+28bd^3+3d^4)-w^2(16b^4-20b^2d^2+5d^4)+\tau^2(48b^4-32b^3d-20b^2d^2+16bd^3)-(a-c+h)(w(32b^4-32b^3d-8b^2d^2+12bd^3-2d^4)+\tau(160b^4-96b^3d-88b^2d^2+44bd^3+8d^4))+\tau w((64b^4-32b^3d-48b^2d^2+12bd^3+8d^4)))$

In all cases, it happens that *the public airport chooses a greater sharing proportion than the private airport.* The public airport, which looks after common interests, has the function of counteracting to favor the common good. Thus, the sharing proportion is superior to offset the loss of existing passengers due to the presence of the private airport.

In the following Proposition we present several interesting comparisons among the three ownership scenarios considered above. For simplicity, and in order to extract some conclusions, we just compare the symmetric situations where airports sharing proportions are less than one, $r_i, r_j < 1$, or equal to one, $r_i = r_j = 1$.

Proposition 4. 1. *The comparison of the three ownership airport structures yields the following orderings when every $r < 1$ and $w < w_2^A$:*

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

(b) $q_2^A > q_i^* > q_i^P > q_1^A$ *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* $Q^* > Q^A > Q^P$

(d) $\Upsilon_i^P + \pi_i^P > \Upsilon_i^A + \pi_i^A > \Upsilon_i^* + \pi_i^* = 0$

2. *When $r = 1$ for each scenario for $w > w_1^A$:*

(a) *Result 1 part b) holds by any scenario. Then, the ownership scenario does not matter. The only difference is about the fixed part in the revenue sharing contract:*

   i. $f_i^* = f_2^A > f_i^P = f_1^A$ *as long as* $w_1^A < w < w^f$.

   ii. $f_i^* = f_2^A < f_i^P = f_1^A$ *as long as* $w > w^f$.

The sharing proportions are ranked in a way where public airports share more than private. The reason why the public airport in the asymmetric setting shares the highest amount is because it wants to balance the negative effect that makes 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 sharing proportion 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 expense of the other agents; however, their gains are not enough to cover the passenger losses.

Therefore, it can be concluded that the privatization of airports entails a welfare loss, above all for passengers. In the case where public and private airports coexist, the behavior of the public airport compensates for the negative effect on welfare caused by the presence of the private airport. That is why its sharing proportion is the greatest.

In the case that all the scenarios are compared when the sharing proportion is one, the above presented results are equal. This fact has policy implications because with a sufficiently large aeronautical charge the factor of airport ownership is eliminated. On the other hand, there is a welfare loss when $r = 1$, so it would be advisable to establish a sufficiently low aeronautical charge to favor a better vertical integration and so this would be transferred to the passengers.

4. Extension - Vertical heterogeneity and cost asymmetry

Throughout the paper we have considered symmetry between airports and airlines to facilitate the tractability of the model, as well as to reach clearer conclusions about the competitive effect of concession revenue sharing contracts. In this section, we relax that assumption of symmetry and analyze the case of vertical asymmetry, where different types of passengers are considered, and cost asymmetry, where each vertical structure offers different qualities, with differences in costs.[8]

An asymmetric scenario is usual in cases where two airports compete for the same catchment area as we have assumed in the model. In general, there is a main airport where operates airlines called full-service carriers (FSC), and secondary airports that are located nearby to take advantage of the synergies, and attract other types of passengers. In this case, airlines operating there are low-cost carriers (LCC), with a point-to-point system. Due to the obvious differences, we introduce the existing asymmetries between both types of airports. Furthermore, this extension is analyzed under the assumption that both airports are private.

4.1. Vertical heterogeneity - Different types of passengers

Airports compete with each other through the airlines that operate in them. In this case, there are two airlines with different strategies, and they attract different types of passengers. Following Alderighi et al. (2012), we assume that passengers are vertically heterogeneous. That is, there are passengers who have a greater willingness to pay, known as business passengers, compared to others who give greater importance to airfares, leisure passengers. In the model shown, LCC airlines focus strictly on leisure passengers, while FSCs offer service to both types of passengers. Therefore, we have adapted these specifications to the model used in this paper.

In this case, there are two different demands, business and leisure passengers. The utility and, therefore, the inverse demand of leisure passengers are equal to equations 1 and 2. Instead, a new utility and inverse demand for business passengers is introduced, such that,

$$U(q_B) = (a + \lambda)q_B - \frac{b}{2}q_B^2 + y \tag{13}$$

then, the inverse demand is, $p_B = a - bq_B$. Business passengers have a higher willingness to pay, which is reflected by parameter λ. Furthermore, business passengers also incurs in higher costs for FSC airlines, $c + \epsilon$. If we consider that airport 1 is main with an FSC airline, and airport 2 is the secondary airport with an operating LCC, airlines profits are:

[8]Extension computations are provided under request.

$$\pi_1 = \theta(p_B - (c+\epsilon) - w + r_1 h)q_B + (1-\theta)(p_{L1} - c - w + r_1 h)q_{L1} - f_1 \tag{14}$$

$$\pi_2 = (p_{L2} - c - w + r_2 h)q_{L2} - f_2 \tag{15}$$

where, parameter θ denotes the percentage of FSC airline business passengers. If $\theta = 0$ the case is the previous analysis, and if $\theta = 1$ both airports are fully differentiated, then having two monopolies. Thus, the FSC airline has a monopoly on business passengers and competes for leisure passengers with the LCC of airport 2. The rest of the model and the stages remain intact.

What we find is that parameters related with business passengers (ϵ, λ), just affects business passengers results. A higher maximum willingness to pay of business passengers increases business airfares and traffic, increasing joint profits of the main airport and the FSC airline. On the other hand, higher costs of business passengers also increases airfares, but reduces business traffic, also reducing joint profits.

Regarding the allocation of the FSC passengers, θ, affects the strategic behavior of airports. Both, FSC and LCC compete only for leisure passengers, therefore, as the proportion of business passengers grows, the FSC's sharing proportion decreases, since it has less capacity to attract leisure passengers. On the contrary, the secondary airport increases the sharing proportion, and it becomes more competitive, taking advantage of the shortage of leisure passengers at the main airport. Furthermore, as long as the number of business passengers increases, airfares of business and leisure passengers do. Then, there is an overall loss of traffic; however, LCC traffic increases. Thus, more business passengers produces a transfer of leisure passengers from the FSC to the LCC airline. Joint profits of both vertical structures increase due to the fact that the higher the percentage of business passengers, a greater monopoly position is achieved by the two vertical structures. In the most extreme case, the FSC airline would only carry business passengers, and there would be no competition in the leisure passengers market. This has a direct impact on the consumer surplus, which is reduced by reducing the well-being of the passengers.

En definitiva, podemos decir que la existencia de business passengers altera la competencia en el leisure market. Ante un escenario de competencia por catchment area, las FSC airlines pueden decidir la distribucin de tipos de pasajeros para encontrar la situacin ms beneficiosa para ellos, siempre y cuando se atienda a la demanda existente. Tanto aerolneas como aeropuertos buscan constantemente la diferenciacin y la apertura de nuevos mercaods para tener una posicin ventajosa y aumentar su rentabilidad. Normalmente lo hacen a travs de la apertura de nuevos mercados, pero en aquellos mercados en los que compitan la distribucin de los pasajeros es un elemento diferenciador.

In summary, we can say that the existence of business passengers alters competition in the leisure market. Faced with a scenario of competition for catchment area, FSC airlines can decide the allocation of types of passengers to find the most beneficial situation for them, as long as the existing demand is met. Both airlines and airports are constantly looking for differentiation and the opening of new markets to have an advantageous position that increases their profitability. Normally they do it through the opening of new markets; however, in those competing markets the allocation of passengers is a differentiating element.

4.2. Leisure cost asymmetry between FSC and LCC

Traditional airlines, FSC, offer different products, in this case for business and leisure passengers. They do this at a higher cost than LCCs, which offer a reduced range of services, but at a lower cost. To complete the previous extension with vertical heterogeneity, we now consider that the costs of the LCC are fewer than the costs of the leisure passengers of the FSC, $c - \mu$, modifying Equation 15. In this way, we can see the effects of the cost asymmetry. Then, FSC costs for leisure passengers are c, and $c + \epsilon$ for business passengers.

Cost asymmetry reinforces the effect of vertical heterogeneity on the strategic behavior of airports. The higher efficiency of the LCC allows the secondary airport to increase its sharing proportion. As airports strategic relationship is substitute, the main airport reduces its sharing proportion. The effect on passengers is direct, since the number of leisure passengers in general increases, due to the fact that the growth at the secondary airport is greater than the loss at the main airport. At the same time, there is a loss of business passengers, as it becomes more attractive to travel in leisure, since the airfares go down in both airlines. That is, the total number of passengers increases due to the cost asymmetry in the leisure market. Similarly, the consumer surplus, which is directly related to the number of passengers, increases for leisure passengers and decreases for business passengers.

Regarding to joint profits of both vertical structures, the secondary airport with the LCC airline increases their profits once imposing cost asymmetry, whereas the main airport and FSC airline decreases it. After summarizing every change made, social welfare improves with the cost efficiency of LCCs under this specifications and assumptions.

Thus, the existence of LCCs in secondary airports competing, in part, with FSC located in mains airports in the same catchment area, increases the size of the available market and lowers airfares for leisure passengers. At the same time, it intensifies the specialization and differentiation between the different types of airlines, which is spread to airports competition. Airports, through concession revenue sharing contracts, or other contracts that allow total or partial vertical integration, influence the strategies carried out by airlines in the downstream market.

5. Concluding remarks

This paper has investigated the competition between two vertical structures formed by an airport-airline pair through concession revenue sharing contracts, where two airports share a catchment area. The concession revenue sharing contracts allow for the exploitation of the complementarities between aeronautical and commercial revenues. This paper focuses on analyzing how airports are able to influence the downstream market to compete with other airports located within the same catchment area; airports may pursue different objectives. In reality, competition comes from airlines that share the same destination, but airports can influence their decisions through vertical contracts such as concession revenue sharing. It is found that, effectively, airports can attract passengers from competing airports using the sharing proportion as a mechanism. When both airports are public, and the sharing proportion is less than one, the first-best is achieved, because the complementarities within the vertical structure are internalized. On the other hand, a privatization process would harm the levels of social welfare and consumer surplus, in addition to increasing airfares.

As a general conclusion, airports can influence the downstream market through contracts such as concession revenue sharing. Airports compete through the airlines that operate there and that are the ones who attract passengers. A positive externality is created in which airports exploit their commercial part to extract a greater income from passengers. Through concession revenue sharing contracts, the airlines can internalize this externality and so increase their traffic levels. Both airports and airlines have incentives to sign some type of vertical contract, the contract analyzed allows both to benefit from the current development and operation of the non-aeronautical area of the airports. It is also evident that the privatization of airports produces worse results than those of a public nature; however, in this matter there are other parameters to be taken into account such as financing needs.

Another aspect worth a comment is the consideration of several airlines operating at airports. This modifies the results, especially given the existence of concession revenue sharing contracts. Note that there is an element of competition within an airport in addition to the competition between vertical structures. Zhang et al. (2010) analyzed airport competition with n-airlines operating in each airport finding that competition within an airport causes the sharing proportion to decline, because that rivalry in the downstream market already produces an effect that increases traffic. On the other hand, the increase in competition in the downstream market of the rival airport increases the sharing proportion. It is because the increase in competition causes a transfer of passengers and that is why the airport decides to increase the sharing proportion, to counteract that negative effect it causes.

Nowadays and due to the market power that is related to airports, there are several ways to regulate aeronautical charges. This paper does not enter to value regulation, but it does show how institutions can set aeronautical charges to increase welfare. In general terms, it can be said that if concession revenue sharing contracts are in place, it is better to choose a sufficiently low aeronautical charge to guarantee that airports can effectively influence the downstream market by increasing traffic. In a setting made up of private airports, when considering parallel airline alliances, if a sufficiently low aeronautical charge is set, this type of alliance becomes welfare-improving and increases the level of traffic. As can be seen, the choice of the aeronautical charge by the authorities has consequences, not only in the level of traffic or welfare, but also in the structure of markets. A new horizon opens up where vertical structures can be allowed through certain types of agreements, such as concession revenue sharing contracts, and the formation of parallel alliances between airlines.

This paper also has other implications for future research. There are cases in which there are multi-airport areas where more than two airports compete. Thus, it would be interesting to study multi-airport competition analyzing cooperation upstream, and/or network effects of airlines. Because there are only two airlines, the effects of the network have not been analyzed. Different treatments to the net concession revenue, h, instead of a direct relationship with demand, adding an incentive scheme to airlines, is also a possibility to be considered. Finally, compare this setting with other vertical agreements in order to look for possible differences and conclusions.

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Appendix

Throughout the paper there are some restrictions on the value of the relevant parameters, 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

Before obtaining the second order conditions, here is the first order conditions, $\frac{\partial SW}{\partial r_i}$:

$$r_i(r_j) = \frac{(a-c+h-\tau)b(2b-d)^2+(h+w-\tau)(4b^3-3bd^2+d^3)-hr_jd^3}{hb(4b^2-3d^2)}$$

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

Thresholds on the sharing proportion

We set conditions on 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, giving rise to four thresholds. The different thresholds are:

1. $w^* \equiv \frac{-(a-c+h)b+(2b+d)\tau}{(b+d)}$, for the public airports case.

2. $w^P \equiv \frac{-d^2(a-c+h)+2b(2b+d)\tau}{4b^2+2bd-d^2}$, for the 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 any other.

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.

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.

Proofs

Proof of Proposition 1

By inspection:

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

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. First check the output level, although you can check the result in proposition 1.

The output level when there is no sharing is ${q_i}^{r_i=0} = \frac{a-c-w}{2b+d}$.

First we check the case when the sharing is less than one, so that it is verified that ${q_i}^{r_i<1} > {q_i}^{r_i=0}$, so that $\frac{a-c+h-\tau}{b+d} > \frac{a-c-w}{2b+d}$. Reorganizing terms and leaving the equality in terms of w the condition is obtained for the sharing to be positive, that is, $w > w^+ \equiv \frac{-(a-c)b-(h-\tau)(2b+d)}{b+d}$. Therefore, under this condition it is observed that the level of traffic when there is concession revenue sharing is greater than when there is not.

It is straightforward to see that ${q_i}^{r_i=1} > {q_i}^{r_i=0}$ and hence, $\frac{a-c-w+h}{2b+d} > \frac{a-c-w}{2b+d}$.

Following the same methodology, prices are analyzed: ${p_i}^{r_i=0} = \frac{ab+(b+d)(c+w)}{2b+d}$. First we see that ${p_i}^{r_i<1} < {p_i}^{r_i=0}$, so that $c+\tau-h < \frac{ab+(b+d)(c+w)}{2b+d}$. By rearranging the terms and clearing for w, $w > w^+ \equiv \frac{-(a-c)b-(h-\tau)(2b+d)}{b+d}$, which shows that, effectively, prices are reduced with concession revenue sharing.

The case when $r_i = 1$ is more trivial. We have that ${p_i}^{r_i=1} < {p_i}^{r_i=0}$ since $\frac{ab+(b+d)(c+w-h)}{2b+d} < \frac{ab+(b+d)(c+w)}{2b+d}$.

With respect to social welfare, $SW^{\ r_i=0} = \frac{(a-c-w)((a-c)(3b+d)+w(b+d)+2(h-\tau)(2b+d))}{(2b+d)^2}$. To check if $SW^{\ r_i<1} > SW^{\ r_i=0}$, what we do is to compute and check that $SW^{\ r_i<1} - SW^{\ r_i=0} > 0$, so that $SW^{\ r_i<1} - SW^{\ r_i=0} = \frac{((a-c)b+w(b+d)+(h-\tau)(2b+d)\ )^2}{(b+d)(2b+d)^2} > 0$, which is true because all terms are positive.

Finally, $SW^{\ r_i=1} - SW^{\ r_i=0} = \frac{h((a-c)2b+2w(b+d)+h(3b+d)-2\tau(2b+d))}{(2b+d)^2} > 0$, and for the term to be positive, the second term of the numerator must be. Therefore, it is noted that $SW^{\ r_i=1} > SW^{\ r_i=0}$ provided that $w > \frac{-(a-c)2b-h(3b+d)+2\tau(2b+d)}{2(b+d)}$. This is true as long as the condition that makes $r_i > 1$ is greater than this value, $w^* > \frac{-(a-c)2b-h(3b+d)+2\tau(2b+d)}{2(b+d)}$.

Proof of Proposition 4

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

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

1.a.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, so that $r_2^A > r_i^*$.

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 $f_2^A - f_i^* = \frac{(a-c+h-\tau)d(2b^2-d^2)}{(b+d)^2(2b+d)(8b^4-8b^2d^2+d^4)^2}((a-c+h-\tau)(16b^7+12b^6d+14b^5d^2+10b^4d^3-25b^3d^4-18b^2d^5+2bd^6+2d^7)+(w+h-\tau)2b(8b^6+16b^5d-16b^3d^3-7b^2d^4+2bd^5+d^6))$ must be positive, which is true by inspection.

1.a.v) Finally, $f_1^A > f_i^P$, that happens when $w < w^X$, where w^X is the condition that solves the inequality $f_1^A > f_i^P$.

This condition is true as long as $w^X > w_2^A$, or $w^X - w_2^A > 0$. Reordering we have that $(a-c-\tau)((2b+d)d^2(16b^4-4b^3d-14b^2d^2+2bd^3+d^4)+(2b-d)(2b^2-d^2)^2(8b^2+6bd-d^2)\varphi)+h(2b+d)(64b^6+32b^5d-64b^4d^2-36b^3d^3+10b^2d^4+6bd^5-d^6)-d(80b^6+48b^5d-10b^4d^2-56b^3d^3+28b^2d^4+10bd^5-3d^6)\varphi > 0$, which is true by inspection knowing that $b > d > 0$.

Therefore, we have that the fixed payments are higher in the asymmetric case, such as $f_2^A > f_i^*$ and $f_1^A > f_i^P$.

1.b. Regarding price and quantity orderings, we have that $p_i^P > p_1^A > p_2^A > p_i^*$ 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 holds true.

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 SW, CS and the 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

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

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

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

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

2. Finally, for the case where in all scenarios concession revenues are fully taken 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,

1. $f_{i}^{*}=f_{2}^{A}>f_{i}^{P}=f_{1}^{A}$ as long as $w_{1}^{A}<w<w^{f}$.
2. $f_{i}^{*}=f_{2}^{A}<f_{i}^{P}=f_{1}^{A}$ as long as $w>w^{f}$.

In order to prove it, notice that $f_{i}^{*}-f_{i}^{P}=\frac{h((2b+d)(2(a-c)(2-\varphi)-w(5-\varphi)+\tau(1+\varphi))+h(b(7-3\varphi)+2d(2-\varphi)))}{(2b+d)^{2}}$. This is positive as long as $w<w^{f}=\frac{(2b+d)(2(a-c)(2-\varphi)+\tau(1+\varphi))+h(b(7-3\varphi)+2d(2-\varphi))}{(5-\varphi)}$.