State aid to low-cost airlines : worthwhile if durable ?

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Résumé

Modified in 2014, guidelines on State aid open up possibilities for operating aid. In this paper, we analyse these support mechanisms economically in order to show that they could be logical for airport infrastructure management, and therefore compatible with the criterion of private investors in a market economy. To this end, we have modelled the airport as a two-sided platform which manages the trade-offs that exist between its aeronautical and commercial activities. In addition, we have shown that a link exists between aid intensity and ex-ante regulation of aeronautical charges. If aeronautical charges are regulated by price caps, airline carriers, who enjoy higher negotiating power, could reap the largest portion of overall gains. *Keywords* : State Aid, Two-Sided Market, Externalities, Air Transport.
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1 Introduction

Both the authorities responsible for applying competition rules and the regulatory authorities for public accounts are frequently required to focus on the situation surrounding secondary airports and the agreements that can tie in low-cost carriers (LCCs). Some agreements are criticised as being excessively favourable to the companies in question. On this basis, there are two emerging issues. This first issue stems from the competitive effects of these agreements. Subsidies made available to LCCs can be considered as public aid. The latter should be notified in order to ensure compliance with internal market operational rules. Within the framework of the more economic approach implemented by the Commission, public aid can be authorised if it addresses a failure identified in the market. Therefore, aid in itself is not prohibited, however it must have been notified, and must not distort competition between airline carriers. Since the early 2000s, the European Commission has established a number of formal procedures which have resulted in the annulment of many agreements. These formal procedures are reflected by the reclassification of potential support mechanisms to public aid and an injunction requiring LCCs to repay funds received to the airport infrastructure manager [1].

The second problem is due to the budgetary impacts of these agreements. Secondary airports in Europe are characterised by their operational deficits, often linked to structural overcapacity. Financial support given to airline carriers in a bid to generate traffic can effectively reduce potential losses by covering variable costs and absorbing at least a portion of fixed costs. This support may be noted by the rationality that would be that of private investors in a market economy. An airport infrastructure manager can reasonably support an LCC on a sustainable basis using reductions to aeronautical charges [2]. However, this raises questions on the distribution of relative gains. The contract between the airline carrier and the airport infrastructure manager does not unite two actors with equal negotiating power. The LCC can obtain significantly reduced aeronautical charges which may raise concerns of distorted competition between carriers (Malavolti and Marty [2010]), and also of collectively sub-optimal tax competition phenomena (Malina [2012]). The difficulty primarily originates from the fact that secondary airports experience issues with overcapacity, and that opportunities for LCCs to trade-off between various destinations place them in a monopsonistic situation [3]. Agreements signed by airports and carriers can reflect this imbalance. For example, the Conseil Supérieur de l'Aviation Civile (Higher

1. This was the case in Nimes for Ryanair (SA.22961, €6.4m), in Pau for Ryanair (SA.22614, €2.4m) and Transavia (€400,000).

2. In certain cases, the European Commission positioned itself in favour of the private investor in a market economy. This was the case for Frankfurt Hahn and Ryanair (IP/08/956), and Saarbrücken Airport and Air Berlin (IP/12/156).

3. In the framework of the OECD report on the analysis of strategic interactions between airline carriers and airports [2009], Starkie explained that it is harder for an airport to use its market power if the latter is over-capacitated, and if direct competition in the airport between airline carriers is low. Moreover, a report by the Conseil Supérieur de l'Aviation (CSAC - High Council for Civil Aviation) released in 2017 on French airport mergers estimated that relationships between carriers and low-traffic airports are characterised by 'reverse monopolies' on the part of airline carriers.

Council for Civil Aviation) [2017] notes the existence of marketing contracts, not only concerning reductions in aeronautical charges, but also sharing of the airport's commercial revenue [4].

Our work seeks to propose modelling in a two-sided market, enabling economic analysis of the criterion of private investors in a market economy to be carried out. Airport income originates from two areas : on one hand it is the product of aeronautical charges, and on the other of commercial revenue (parking, subleasing of commercial spaces, etc.). This model was developed for intermediation platforms (Rochet and Tirole [2003], [2006], Armstrong [2006], Hagiu and Wright [2015], Verdier [2016]). A two-sided platform is characterised by the external network effects that it generates between competitors. The presence of consumers on one side of the platform creates value on the other, resulting in distortion of the tariff structure between the two sides becoming potentially favourable in order to maximize revenues. Externalities can be bi-directional or simply uni-directional. We apply this theoretical framework to airport infrastructures, in line with an increasing amount of literature. Initial analyses of airports in terms of two-sided markets were developed by Gillen [2011], Malavolti [2014], Ivaldi et al. [2015]. Gillen [2011] evidenced the possibility of generating additional commercial revenue able to offset reductions in air tariffs, enabling companies to increase the number of destinations serviced and therefore the number of passengers using the infrastructure. The weight of non-aeronautical revenue in the economic equilibrium of airports must not be overlooked. For example, in 2014, over 60% of airports de Paris' profits were of a commercial nature. This percentage steadily grew between 2009 (54%) and 2014 (61%) (ADP, [2014]). Initial empirical analysis carried out in the United States by Ivaldi et al. [2015] showed the existence of externalities between commercial and aeronautical activities, justifying the adoption of a two-sided approach by airports. It is for this reason that we prefer the two-sided approach as opposed to vertical integration when formalising the airport business model. Criticism against adopting this approach for airports is mainly based on the fact that externalities are only observed on each side of the model and do not intersect (see for example, Fröhlich [2011]). However, recent developments in analysis of the two-sided approach reinforce the model's validity is low. Moreover, a report by the Conseil Supérieur de l'Aviation (CSAC - High Council for Civil Aviation) released in 2017 on French airport mergers estimated that relationships between carriers and low-traffic airports are characterised by 'reverse monopolies' on the part of airline carriers. 4. According to the CSAC, these contracts can be assimilated to back margins imposed by large-scale distributors on small producers. In this respect, they inevitably raise questions on vertical restrictions which will not be directly addressed in this paper for the moment. See, for example, Rey [2003] for general economic analysis on vertical restrictions, and Wright [2007] for an analysis of their impact on consumer welfare. Note that commercial air transport sharing agreements may have beneficial effects as shown by Fu and Zhang [2010], as

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in the case of uni-directional externality (Hagiu and Wright [2015]). As such, the model remains valid even if the decision made by passengers to travel is not unequivocally affected by the commercial services offered by the airport.

Our model also seeks to provide a response to the issues posed by sectoral regulation. This concerns investigating the impact that charge reductions have on the economic equilibrium of the airport. In Europe, aeronautical charges are regulated by price caps [5]. Secondary platforms very rarely manage to balance their accounts (ECA [2014]) ; this problem is due to the fact that the deficit is offset by public funds. It is therefore a matter of reconciling the infrastructure operator's optimal performance with minimisation of their deficit. Our model shows that ex-ante regulation of aeronautical charges is not neutral in terms of the distribution of trading gains for both contracting parties. While price cap regulations ensure that an airport in a monopolistic position does not extort an excessive portion of airline carrier returns, they are unable to limit the exercise of market power by companies in monopsonistic situations. If the market's two-sided nature makes it possible to offset lost profits on the aeronautical side via additional revenue on the commercial side, then complete exoneration of the charges, or even negative charges, could be considered [6]. For example, this could take the form of commercial revenue-sharing with the LCC. However, if this agreement results in a net gain for all contracting parties in relation to the initial status, distribution between the LCC and the airport manager cannot be presumed. Furthermore, charge reductions are offset by public resources. State aid is at stake whether it goes directly to the LCC or whether it supports operational equilibrium of airport infrastructure. As such, interdependence exists between the ex-ante regulation of aeronautical charges and the ex-post monitoring of State aid intensity assessed by the competition authority. Therefore, we aim to demonstrate the way in which ex-ante regulation modes (price caps or price floors) can impact aid intensity assessed ex-post, as well as the distribution of contract gains between the various actors, within the scope of this paper. Compliance of the support mechanism with the European framework for State aid is assessed ex-post if the Market Economy Investor Principle is at stake, and ex-ante by means of notification if State aid is at stake. In our model, we assume that the support mechanism consists of a reduction to aeronautical charges [7]. As such, everything occurs as if the LCC were actually negotiating a comprehensive subsidy with the airport. This is why we have simplified our analysis by considering that aid monitoring is focused on a 'flat rate' subsidy.

Our work also facilitates understanding of the link between ex-ante charge regulations and

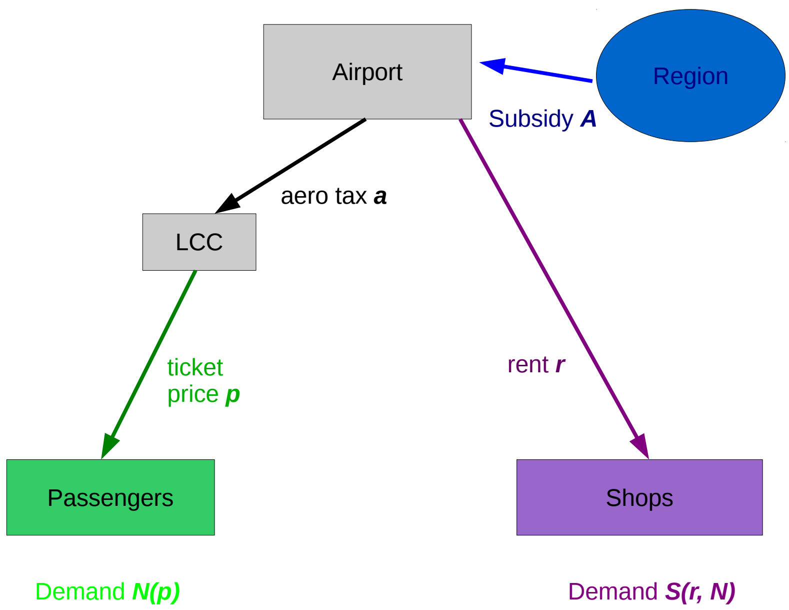
5. This regulation seeks to prevent the manager from potentially abusing its market power, resulting in principle from their naturally monopolistic position. However, secondary airports do not retain such market power, to the extent that they must leverage existing infrastructure, sustain destinations serviced in a context within which airline carriers can easily arbitrate between several airports and represent the airport's only client.

6. Furthermore, we have shown that the absence of charges on one side of a two-sided platform can be economically justified (see Malavolti and Marty [2013]).

7. Other support mechanisms exist, such as the co-financing of marketing campaigns, that we liken to this mode in our analysis, for convenience.

ex-post monitoring of State aid. It shows that one way to reduce aid intensity (and therefore LCCs ability to acquire surplus) could be to establish charge regulations in the form of price floors rather than price caps. In other words, the regulation of aeronautical charges in the form of price floors in airports devoid of market power reduces the portion of surplus created by the agreement and accumulated by LCCs. We have not carried out welfare analysis, but the underlying idea is that the higher the surplus accumulated by the LCC, the greater the support required for secondary airports to achieve operational equilibrium ; support via the injection of public funds, costly in collective terms. In the next section, we will present the model and its primary results. The last section discusses results obtained and sets out suggestions for future research.

2 Modelling of State aid for secondary airports



Our model considers airports as platforms that connect passengers with shops located in the terminal. This interaction takes place via companies that bring traffic into the airport. As such, aeronautical charges a , dependent on the number of passengers travelling with the airline, and a price r, representing rental costs for commercial space, are fixed. The demand for transport is expressed in the number of passengers, in line with the ticket price. Note that $N(p)$, is the demand for travel directed at airline carriers, where p is the ticket price paid per passenger. Demand decreases in line with the ticket price and is maximal for a zero-priced ticket. In this case, it is worth $\bar{N}$. The aeronautical charge is proportional to this demand by calculation principle. In addition, non-aeronautical activities are predominantly represented by the demand for rental space inside the terminal (for shops) or outside the terminal (for car rentals). With $S(r, N)$, denoting demand, where S represents the number of spaces, it is a decreasing function of the rental price r, and an increasing function of the number of passengers N, since they represent potential customers for these shops or rentals [8].

We also assume that there are no cross effects of the price of rental and the number of customers. Airport costs are composed of variable costs, essentially dependent on the number of passengers in the terminal and denoted $CV(N)$, increasing function of N ; and fixed costs, denoted CF, corresponding to investments carried out (runway, terminal, car parks, commercial buildings, etc.) designed to install production capacity for both aeronautical and non-aeronautical services. As such, profit made by the airport structure can be expressed as follows :

$$\Pi_{\text{airport}} = aN(p) - CV(N(p)) + rS(r, N(p)) - CF$$

Where $aN(p)$ represents aeronautical revenues, $rS(r, N(p))$, commercial revenues, $CV(N(p)) + CF$, the airport's total costs. Financially sustainable airports are, above all, airports with high levels of activity (Paris Airports - ADP), Frankfurt Airport - Fraport, etc.). As such, by definition these airports are not concerned by State aid-funded investments. This paper is interested in airport platforms which are not profitable in view of low demand for services (passengers and shops) combined with high fixed costs. As such, State aid is justified once variable profit is positive, for example if we are in an area where variable costs are covered, but not fully fixed costs. Therefore, the technical assumption corresponding to this scenario is as follows : the airport's profit is assumed to be negative even in the best possible case, i.e. for all possible values and combinations of $N(p)$, S, r and a, total profit is negative without additional aid. A fixed amount, denoted A in our model, is therefore paid to the structure. This amount is indirectly limited by the French Competition Authority in compliance with its guidelines and decision-making practice. The LCC therefore calculates the maximum amount of aid that can be accepted based on the latter, with $\bar{A}$ denoting this amount.

In addition, aeronautical charges paid by the airline carrier are regulated on the basis of a theoretical natural monopoly situation. The regulator takes into account all airport revenue and costs before setting a price floor, denoted $\bar{a}$ [9].

8. We have chosen a positive externality exerted on shop revenues by passenger flows. A number of two-sided models take into consideration externalities that cross over both sides of the market (video games, shopping centres, newspapers, etc.). In the present case, it can be considered that shops also exert an externality on passengers. However, as it is difficult to determine the sign of this externality, we can consider that the presence of shops is desired by passengers. Consumers undoubtedly consider it preferable to wait in an airport with plenty of shops. However, some studies show that waiting times could be extended due to the presence of shops, who are prepared to pay higher rent if it means passengers spend longer in the airport. See for example Torres et al., 2005 and Malavolti, 2014. With studies failing to conclude on a sign, we prefer not to consider externalities exerted ex-ante on passengers by shops. On the other hand, results will be discussed according to the sign of this externality.

9. The scope of regulation varies according to the size of the airport : as per ICAO guidelines (document

In our analysis, the airport has one sole airline carrier as a client and is therefore considered as economically dependent. The airline carrier will make the airport a take-or-leave offer [10] in the form of a contract establishing (a, r, A), while also ensuring that it is in the airport's interest to accept the offer. For small secondary airports, activity is dependent on a contract provided by a single airline carrier. As such, we envisage that the airport will accept the offer as long as profit resulting from the agreement is non-negative [11]. It can be considered that some of the infrastructure's fixed costs are irrecoverable and must be paid regardless of whether the airline carrier offers the airport a contract or not. For example, this concerns taking account of fixed costs relating to existing facilities (runway, terminal, etc.). On the other hand, a portion of the fixed costs will only be pledged once the contract is accepted, such as fixed costs inherent to the management of commercial spaces or in the creation of external car parks/upgrading them to comply with standards. For simplicity, we have normalised irrecoverable fixed costs to 0.

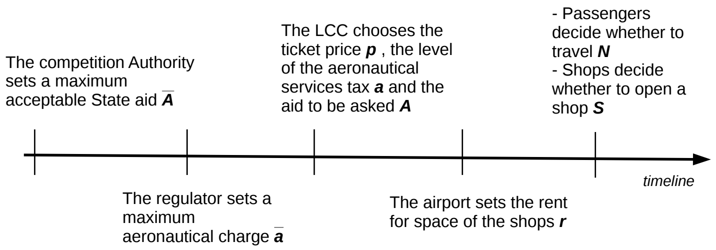
The purpose of this paper is to propose a model of the relationship between an LCC and an economically dependent airport, and to understand how ex-ante regulatory tools (maximum aeronautical charges) and ex-post regulatory tools (operating aid) interact and influence decisions made by economic actors. The application that we are proposing to study has the following form, shown in Figure **??**.

9082), small European airports generally adhere to single till regulation, while larger airports opt for dual till regulation. Single till corresponds to a situation in which the scope of regulation includes all airport revenue. The dual till principle corresponds to a situation in which only aeronautical revenue is included. Economic literature became interested in this issue, reaching various conclusions. A first series of papers (Starkie [2001] ; Starkie and Yarrow [2008]) carries out analysis on the impact of the type of regulation implemented on the airport's long-term objectives. By using a capital cost approach, the papers show that the airport's investment incentives are reduced if it is not able to retain sufficient resources. They therefore conclude that dual till regulation is preferable. However, more recent papers (Fröhlich [2011] ; Malina et al. [2012] ; Malavolti [2014]) reach opposite conclusions when the airport is considered as a platform. These studies recommend single till regulation in order to consider existing externalities between both sides of the market ; aeronautical and commercial. Lastly, Perrot [2014] suggests that for large airports, issues concerning congestion can justify dual till regulation. The consequence on the equilibrium price structure as a result of positive externalities exerted by passengers on shops is that shops subsidise on airport tax reductions, and therefore indirectly subsidise passengers. As such, at equilibrium, there are more passengers in the airport, which increases congestion problems. As such, if the social costs of congestion are sufficiently high, it may be preferable to regulate the airport using two separate tills.

10. By way of illustration, it should be noted that some airports conclude commercial profit-sharing contracts. This is the case for Ryanair in France, who make sharing car parking revenue a condition of service launches at certain airports. This is also the case in Tampa, Florida where the airport shares revenue from commercial concessions with companies operating in its infrastructure. Fu et al. [2011] present this example in their paper on the analysis of vertical relationships between airline carriers and airports.

11. 11. The profit that the airport can make outside of the transaction can also correspond to the possibility to conclude a contract with another airline carrier. On this condition, the airport will choose the most attractive contract among those proposed. However, these contracts can be uncertain or even non-existent. In any case, State aid implicated in these contracts relates to start-up aid for new routes launched. We are focusing on aid for potentially sustainable activity.

Figure 1 – Timeline



The airline carrier's strategy is expressed as follows :

$$
\begin{aligned}
\underset{\{p,r,a,A\}}{Max}\ \Pi_{\text{LCC}} = \quad & pN(p) - aN(p) - C(N(p)) & & \\
s.t. \quad & \Pi_{\text{airport}} = aN(p) - CV(N(p)) - CF + A + rS(r, N(p)) \quad \geq 0 & & (C_1) \\
& a \leq \bar{a} & & (C_2), \\
& 0 \leq A \leq \bar{A} & & (C_3), \\
& p \in \mathbb{R}^+, r \in \mathbb{R}^+, a \in \mathbb{R} & & ,
\end{aligned}
$$

$pN(p)$ represents the airline carrier's revenue from the sale of N plane tickets priced at p, with $aN(p)$ representing access costs to aeronautical services paid by the airline carrier to the airport to handle N passengers. $C(N(p))$ corresponds to all variable costs supported by the airline carrier when N passengers travel1 [12]. This is an increasing and convex function in N.Constraints C_2 et C_3 represent regulatory constraints to be satisfied. The amount of aeronautical charges retained a cannot exceed the price cap imposed by the regulator $\bar{a}$. However, nothing prevents the aeronautical charges from being equivalent to a subsidy i.e $a^* < 0$ at equilibrium if profit optimisation leads to this. Operating aid A requested is necessarily positive and cannot exceed the maximum level authorised by competition authorities. Constraint C_1 represents the airport's participation constraint.

Proposition 1 *At equilibrium, the LCC extracts all profit made by the airport with the help of the operating aid requested, which is maximal.*

$$\Pi_{airport} = 0$$

12. For simplicity, we have normalised the airline's fixed costs to zero.

$$A^* = \bar{A}$$

Preuve.
Let the quadruplet solution to the maximisation programme (p^*, r^*, a^*, A^*) be such that $C_1(p^*, r^*, a^*, A^*) > 0$. So $\tilde{a} < a^*$ is such that $C_1(p^*, r^*, \tilde{a}, A^*) > 0$ and such that $\tilde{a}$ satisfy the other constraints C_2 et C_3. The airline carrier's profit is therefore higher since only a is modified. $\Pi_{\mathrm{LCC}}(p^*, r^*, \tilde{a}, A^*) > \Pi_{\mathrm{LCC}}(p^*, r^*, a^*, A^*)$. This solution is therefore preferable. As such, it is impossible to find a solution if constraint C1 does not reach optimum saturation.

We further assume that $A^* < \bar{A}$, then $C_1(p^*, r^*, a^*, \bar{A}) > C_1(p^*, r^*, a^*, A^*) \geq 0$. It is therefore possible to find $\tilde{a} < a^*$ such that $C_1(p^*, r^*, \tilde{a}, \bar{A}) = C_1(p^*, r^*, a^*, A^*) \geq 0$ which results in higher profits for the airline carrier. $\Pi_{\mathrm{LCC}}(p^*, r^*, \tilde{a}, \bar{A}) > \Pi_{\mathrm{LCC}}(p^*, r^*, a^*, A^*)$. To conclude, constraint $C_3$is binding at equilibrium.

■

The result is robust since it does not depend on the form of the airline carrier or airport's profit functions, however the natural conditions required for convexity of the problem tell us that the LCC has sufficient decision variables to extract all profit from the airport as a result of the operating aid available to it. Above all, and in a more attractive way, this result highlights interaction between ex-ante regulatory tools such as maximum aeronautical charges, and ex-post regulatory tools such as the maximum amount of operating aid that can be requested. More precisely, it appears that the aeronautical charges and State aid requested are substitute instruments used by the airline carrier to satisfy the airport's participation constraint. The higher the amount of operating aid, the easier the participation constraint is to meet, while the airline carrier's profits do not change. Responsive to the amount of aeronautical charges requested since it represents a direct cost, the airline carrier can use its market power to reduce charges, in turn increasing its profit without modifying constraints. State aid will therefore be set at the maximum amount. The airport's participation constraint will be also be saturated, since without modifying other maximisation arguments, it can be adjusted by the amount of aeronautical charges. It will be set at the lowest possible amount in order to satisfy the airport's participation constraint. As such, it is perfectly conceivable that the programme's optimum aeronautical charge is a subsidy that the airport pays to the airline carrier in order to attract passengers ; future customers of shops in the airport. Here, the two-sided structure is perfectly logical : this solution is only conceivable if the variable portion of the airport's profit is sufficiently significant in relation to $-CF + \bar{A}$. This variable portion is composed of aeronautical and commercial revenue. If commercial revenue is sufficient, the airline carrier may therefore reduce aeronautical charges to the same extent in order to increase its profit.

In the interests of clarity, we have modified the programme in order to optimise it in relation to the number of passengers N. This is possible since by definition, the function $N(p)$ is strictly decreasing in p par définition. Furthermore, following Proposition 1, the airport's participation constraint enables optimal aeronautical charges to be set. As such, simply reinserting it into the regulation constraint for aeronautical charges C_2 to transform the programme as follows :

$$
\begin{array}{llr}
\underset{\{N,r\}}{Max}\Pi_{\text{LCC}} = & p(N)N + rS(r,N) + \bar{A} - CV(N) - CF - C(N) & \\
s.t. & CV(N) + CF - \bar{A} - rS(r,N) - \bar{a}N \leq 0 & (C_2) \\
 & N \in \mathbb{R}^+, r \in \mathbb{R}^+ & ,
\end{array}
$$

The airline carrier's objective function is not only composed of profit made from selling airline tickets to passengers $(p(N)N - C(N))$,but also from the airport's profit taken from the aeronautical charges, since they are classed as a cost for the airline carrier $(rS(r,N) - CV(N) - CF)$. The airline carrier incorporates the fact that it will request maximum State aid available in order to facilitate acceptance of the offer it will make to the airport. Let the Lagrange multiplier be $\mu \in \mathbb{R}^+$ associated with the airline carrier's programme maximisation constraint (C_1)The programme becomes a maximisation programme in Lagrangian form $\mathcal{L}(r,N)$ in which first-order conditions are expressed as follows :

$$
\begin{array}{lllr}
\frac{\partial \mathcal{L}}{\partial N} = & p(N^*) + N^* \frac{\partial p}{\partial N} - \frac{\partial C}{\partial N} + (1+\mu^*)(r^* \frac{\partial S}{\partial N}) - (1+\mu^*)\frac{\partial CV}{\partial N} \quad -\mu^* \bar{a} & = 0 & (CN1) \\
\frac{\partial \mathcal{L}}{\partial r} = & (1+\mu^*)(r^* \frac{\partial S}{\partial r} + S(r^*, N^*)) & = 0 & (CN2) \\
 & \mu^*(CV(N^*) + CF - \bar{A} - r^* S(r^*, N^*) - \bar{a}N^*) & = 0 & (CN3),
\end{array}
$$

The condition $(CN2)$ sets the rental price for commercial spaces at the monopoly price level. For all $\mu \geq 0$, $(CN2)$ is true iff $r^* \frac{\partial S}{\partial r} + S(r^*, N^*) = 0$. The airline carrier behaves as a monopoly, as the airport would have done, vis-à-vis the shops. As such, we are presented with the standard outcome of the airline carrier's application of a margin rate in relation to marginal costs (zero in our model), a margin rate which is all the more significant since sensitivity of demand for commercial space in relation to the rental price is low, i.e. $\frac{\partial S}{\partial r}$ In addition, the higher N^* is, the higher r^* will be too ; since demand for commercial space increases in line with the number of passengers in the airport, a result of our two-sided model taking into account the externality that aeronautical activity exerts on commercial activity [13].

The first condition $(CN1)$ is composed of a first element $p(N^*) + N^* \frac{\partial p}{\partial N}$corresponding to the airline carrier's profit maximisation condition if it were not in a dominant position. This condition would determine the monopoly price for tickets sold to passengers. Several additional effects are taken into account, including the airport's marginal costs $\frac{\partial CV}{\partial N}$ which will tend to reduce the optimal number of passengers, considering the airport's commercial profit which increases in line with the number of passengers, $(r^* \frac{\partial S}{\partial N})$,and lastly, consideration of the constraint of aeronautical charge regulation, which goes in the direction of reducing the passenger number at equilibrium

13. 13. Note that the solution r would have been the same if chosen freely by the airport, taking into consideration both sides of the market, since it would have applied its monopoly power and therefore determined the same rental price level for commercial space. See Malavolti [2014] for analysis of two-sided market impacts on equilibrium price structure.

if the constraint is not saturated (or more precisely, if the multiplier is non-zero at equilibrium, i.e. $\mu^* > 0$).

These three conditions give a local maximum if the concavity of L is guaranteed (see Annex A), which is the case for reasonable assumptions of demand and cost functions. In order to illustrate these results, we will specify the model and clarify the solutions in order to comment on their evolution in relation to relevant model parameters. Let inverse demand for tickets on behalf of consumers be : $p(N) = \alpha\bar{N} - \alpha N$. The price is zero when demand is maximal, i.e. equal to $\bar{N}$.Demand is decreasing in line with price. Let demand for commercial space, decreasing in line with the price of rental space and increasing in line with the number of passengers in the following form be$S(r, N) = \beta N - \rho r + \bar{S}$.Airline carrier and airport costs are assumed to increase linearly in line with the number of passengers $CV(N) = \gamma N$ and $C(N) = \theta N$. We assume that $\alpha > 0$, $\beta > 0$, $\rho > 0$, $\gamma > 0$, $\theta > 0$, $\bar{N} > 0$, $\bar{S} > 0$. First-order conditions give :

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial N} &= -2N^*\alpha + \bar{N}\alpha + r^*\beta - \gamma - \theta + \mu^*(\bar{a} + r^*\beta - \gamma) &&= 0 && (CN_1)\\
\frac{\partial \mathcal{L}}{\partial r} &= (1+\mu^*)(\bar{S} + N^*\beta - 2r^*\rho) &&= 0 && (CN_2)\\
&\mu^*(\gamma N^* + CF - \bar{A} - r^*(\beta N^* - \rho r^* + \bar{S}) - \bar{a}N^*) &&= 0 && (CN_3),
\end{aligned}$$

The programme is concave under reasonable conditions shown in Annex A, and it therefore allows a global maximum. Characterisation of this global maximum creates discussion, particularly regarding the constraint on maximum aeronautical charges. Aeronautical charges are a parameter set by the regulator and imposed on the airline carrier. ā is capped in line with regulation rules which take into consideration the airport's incremental costs and market conditions. We are particularly interested in the case where the authorised price cap is high enough so as not to become a constraint for the airline carrier. This leaves the airline carrier with the opportunity to select a charge that is potentially lower than the price cap, or even potentially negative (i.e. an airport subsidy in its favour), in line with the model's parameters (notably characteristics of transportation service demand).

Proposition 2 *If consumers are sufficiently sensitive to the ticket price $\alpha \geq \underline{\alpha} = \frac{-\bar{S}\beta + 2(\gamma+\theta)\rho}{2\bar{N}\rho}$, then the airline carrier is able to obtain a strictly lower access charge from the airport infrastructure manager than that of the cap imposed by the regulator ($\mu^* = 0$).*

Furthermore, the higher the maximum State aid $\bar{A}$ is, the lower the optimal aeronautical charges a^* will be. If profit generated by commercial activity is sufficiently high, the optimal charge even becomes a subsidy in favour of the LCC.

Preuve.

See annex B. ■

Passenger demand ultimately determines the airline carrier's optimal strategy : if demand is highly sensitive to the ticket price, then selecting a low price will have a significant effect on the number of passengers travelling. In order to balance its profit, the airline carrier lowers its aeronautical charges in order to maintain its profit, since this reduces its costs [14]. The airline carrier may attract higher levels of traffic in the airport as a result of the low ticket price, and therefore increase profit made from commercial activity. Furthermore, the greater the externality exerted on commercial activity by passengers is (measured by the parameter β in our model), the higher the commercial profit will be. At equilibrium, the higher the impact of the externality, the higher the number of passengers transported at equilibrium. As such, the amount of aeronautical charges retained can lead to subsidising of the LCC once the airport's commercial profits are high enough. This externality relates to the definition provided on the two-sided nature of airport activity.

It should also be noted that it is possible to establish equivalence between the intensity of the reduction obtained by the LCC and the support mechanism $\bar{A}$. The airline carrier can request an even greater reduction considering the potential gains linked with the agreement for the airport and European competitive jurisprudence in terms of the framework for State aid. It can negotiate significant reductions in charges from a strong position, enabling it to monopolise a large portion of the gains, and which will result in higher amounts of aid. The regulation of charges using price caps does not limit the extent to which charges can be reduced, and so neither does it enable the amount of aid to be capped. As a result, both ex-ante and ex-post regulatory instruments are linked. For example, the implementation of a floor price, i.e. a minimum value for aeronautical charges, would enable the amount of support allocated to the infrastructure to be reduced without changing equilibrium results. This would both limit the LCC's capacity to appropriate overall gains and reduce the amount of public funds required to finance the aid. In other words, it may be preferable to cap the amount of aid that can be paid to an airport manager devoid of market power by regulating aeronautical charges via a floor price.

It is impossible to carry out welfare analysis directly within the framework of our model since objectives specific to each of the regulators have not been established. On the other hand, this analysis can be simulated by comparing profits generated by the contract with investment made by the airport manager when State aid is requested. If operation leverages resources, then we can consider that investment of the support mechanism for the activity will have been profitable.

It is a matter of comparing profits made by the airline carrier and the airport to the value of the State aid requested at equilibrium. According to Proposition 1, the airport makes no profit and maximum aid has been requested, i.e. worth $\bar{A}$. We must therefore ensure that

$$r^*S(r^*, N^*) + p(N^*)N^* - C(N^*) - CV(N^*) - CF + \bar{A} \geq \bar{A}$$

According to our specification, this means that the investment is profitable to the extent that fixed costs are not too high. This is an altogether natural condition : if fixed costs are very high despite significant support, the infrastructure will never be able to cover fixed costs as a result of its activity. The upper threshold for acceptable fixed cost values constrains all acceptable

14. 14. The airline carrier cannot recover the airport's total profit via the contract it proposes. Its best option is therefore to reduce the airport's portion of profit corresponding to the cost of aeronautical services.

parameters. We must take $\alpha > \alpha_4 = \frac{5\beta^2}{4\rho}$, in other words, sensitivity to the demand for transport in line with the ticket price, even higher than $\underline{\alpha}$.

Proposition 3 *he support mechanism can be considered as a profitable investment as per the private investor, as long as fixed costs are not excessive. The airline carrier's profit is effectively higher than the amount of State aid, making the investment profitable when :*

$$CF \leq \bar{CF} = \frac{-\bar{S}^2\alpha(-5\beta^2 + 4\alpha\rho) + (-\bar{N}\alpha + \gamma + \theta)(\beta^2 + 12\alpha\rho)(\bar{S}\beta - (-\bar{N}\alpha + \gamma + \theta)\rho)}{(\beta^2 - 4\alpha\rho)^2}$$

which is true for $\alpha \geq Max[\underline{\alpha}, \frac{5\beta^2}{4\rho}]$.

Preuve.

See Annex C. ■

3 Conclusion

Our model illustrates the rationale for an airport infrastructure manager behaving as a private investor in a market economy to grant operating aid to LCCs, support which, more importantly, is sustainable. For this reason, it reinforces flexibility brought about by guidelines published in 2014 and would, in principle, justify reductions to aeronautical charges which would no longer be classed as transitory. Consideration of externalities between airports' aeronautical and non-aeronautical business segments enables aid transferred to LCCs to generate and sustain destinations serviced (i.e. to increase passenger flows) to be 'financed' by additional revenue generated by commercial activities (car parks, shops, etc.). As a result, a private investor in a market economy may be willing to accept that not all their costs will be covered on this side, by considering gains incurred on the other side. Drastic reductions in charges (virtually eliminated) or even commercial revenue sharing clauses (in other words, negative aeronautical charges) can therefore constitute economic defence on the basis of efficiency, even if they are perennial and non-transitory.

Such agreements between secondary airport managers and airline carriers potentially enable secondary airports to operate at equilibrium, or at the very least, to limit their operating deficit. The exchange therefore results in a gain, which can be broken down into two parts. The first part concerns territorial impacts (linked to improved access or better connectivity, for example.). The second may lie in the saving of public resources required to offset the airport's operational deficit. Yet, thanks to being in a potentially monopsonistic position (observed in a number of regional European airports), the LCC can confiscate a large portion of this surplus. This translates to fewer public funds saved for the community. A solution would be to cap aid intensity, which is what the Commission does ex-post via its decision-making practice. Another solution, as highlighted in our work, would be to consider the equivalence between the intensity of airport tax reductions and the intensity of the State aid required. Current regulation using price caps is sensical for airports equipped with market power vis-à-vis airline carriers. It ensures that the latter do not abuse their position by extorting an excessive portion of operator surpluses for which airports are essential facilities. This position does not apply to regional airports : they are in competition with each other for LCCs. Demand aimed at the latter, particularly concerning the leisure client segment, is very sensitive to price and less sensitive to the destinations it services. Airport managers must guarantee the existence of serviced destinations in their infrastructure at all costs, where costly public, non-reusable investments have been made ex-ante. Faced with economic dependence aggravated by sunk costs, the LLC can implement a contractual hold-up strategy 1linked to the demand for fixed aeronautical charges significantly below the price cap, or at no charge at all if not a negative one (linked to commercial revenue sharing, co-financing of marketing campaigns, etc.) Price cap regulations do not enable restriction of the amount of aid required to offset the fact that the LCC appropriates any gains linked to the agreement to be limited. They should, in principle, restrict the amount of aid transferred in the form of a charge reduction. Yet, State aid is not always at stake if we consider cases where the terms of the agreement satisfy the Market Economy Investor Principle . As such, we need to find a way to limit the LCC's capacity to take advantage of the airport's dependence. Our model notes that the gain it may appropriate increases in line with the extent of the externality exerted on commercial activity by passengers. We have not carried out welfare analysis within the context of this paper ; however, it could be considered that the collective cost of appropriation will increase in line with the marginal costs of the public funds used. As such, we propose to cap the LCC's capacity to monopolise this gain by substituting ex-ante regulation of aeronautical charges via price caps with price floors for airports devoid of market power. This would enable ex-ante limitation of aid intensity.

A A Concavity of the airline carrier's programme

Conditions sufficient enough to obtain a maximum, if one exists, are dependent on the concavity of $\mathcal{L}$. The Lagrangian can be decomposed into various functions of which concavity ensures an optimal solution is obtained. $\mathcal{L}$ is expressed as follows :

$$\mathcal{L} = p(N)N - C(N) - aN + (1+\mu)(rS(r,N) - CV(N) + aN) + \mu(\bar{a} - a)N + (1+\mu)(\bar{A} - CF)$$

The first expression corresponds to profit made by the airline carrier $p(N)N - C(N) - aN$. This profit is concave in $N > 0$ iff $\frac{\partial^2 \Pi_{LCC}}{\partial N^2} \leq 0$, which gives the sufficient condition (CS_{LCC})

$$\begin{array}{lll} \frac{1}{N}(-2\frac{\partial p}{\partial N} + \frac{\partial^2 C}{\partial N^2}) & \geq & \frac{\partial^2 p}{\partial N^2} \quad (CS_{LCC}) \\ \text{pour} & N > 0 & \end{array}$$

We will ensure sure that $N \neq 0$ at equilibrium. This condition is typically satisfied if passenger demand $p(N)$ is linear in N. Otherwise, the condition requires that if the effects of the price on the second-order number of passengers are increasing, i.e. $\frac{\partial^2 p}{\partial N^2} > 0$,then the latter remain limited in relation to first-order demand effects, in addition to convexity effects of airline carrier costs which is aworking hypothesis of the model. The second expression corresponds to profit made by the airport, multiplied by the multiplier $\mu \geq 0$: $(1+\mu)(rS(r,N) - CV(N) + aN)$.

As is the case for the airline carrier, the concavity of this programme is desirable in the interests of analysis. It is guaranteed provided that

$$\begin{array}{llll} \frac{\partial^2 CV}{\partial N^2} & \geq & r\frac{\partial^2 S}{\partial N^2} & (CS^1_{\text{airport}}) \\ \frac{-2}{r}(\frac{\partial S}{\partial r}) & \geq & \frac{\partial^2 S}{\partial r^2} & (CS^2_{\text{airport}}) \\ (r\frac{\partial^2 S}{\partial N^2} - \frac{\partial^2 CV}{\partial N^2})(r\frac{\partial^2 S}{\partial r^2} + 2\frac{\partial S}{\partial r}) - (\frac{\partial S}{\partial N})^2 & & & (CS^3_{\text{airport}}) \\ \text{pour} & r > 0 & & \end{array}$$

We will ensure sure that, at equilibrium $r \neq 0$ (CS^1_{airport}) is guaranteed as the airport's variable costs are convex, and the impact of the externality on the demand for rental space is decreasing in line with the number of passengers in the airport. Returns from the positive externality are assumed as decreasing for the sake of practicality. (CS^1_{airport}) is typically checked concerning demand for space $S(r,N)$ linear in r. Enfin, (CS^3_{airport}) Lastly, the condition (CS3) requires checking. It is valid provided that the effect of the externality on the demand for rental space is not too high in relation to the effects on costs and the direct effect on the price $S(r,N)$. Finally, the expression $\mu(\bar{a} - a)N + (1+\mu)(\bar{A} - CF)$ is linear in N, and therefore does not change the concavity of the general programme.

To conclude, if conditions (CS_{LCC}), (CS^2_{airport}) and (CS^3_{airport}) are satisfied,a local maximum can be obtained. If conditions are strictly met, a global maximum can be obtained. The conditions for our specifications are as follows :

$$\begin{array}{llll} \frac{\partial^2 \mathcal{L}}{\partial N^2} & = & -2\alpha & (CS_1) \\ \frac{\partial^2 \mathcal{L}}{\partial r^2} & = & -2\rho(1+\mu) & (CS_2) \\ \frac{\partial^2 \mathcal{L}}{\partial N^2}\frac{\partial^2 \mathcal{L}}{\partial r^2} & -[\frac{\partial^2 \mathcal{L}}{\partial r \partial N}]^2 & = -\beta^2(1+\mu) - 4\alpha\rho & (CS_3) \\ \text{for} & \mu \geq 0 & & \end{array}$$

$(CS_1) < 0$ and $(CS_2) < 0$ for all $\alpha > 0$ and $\rho > 0$ and $\mu \geq 0$. $CS_3 > 0$ iff $\alpha \geq \alpha_0 = \frac{(1+\mu)\beta^2}{4\rho}$.

B Proof of Proposition 2 :

First order conditions give :

$$
\begin{array}{llll}
\frac{\partial \mathcal{L}}{\partial N} = 0 & \Leftrightarrow & N^* = \frac{\bar{S}\beta(1+\mu^*)+2\rho(\bar{N}\alpha+\gamma+\theta-\bar{a}\mu^*+\gamma\mu^*)}{4\rho\alpha-\beta^2(1+\mu^*)} & (CN_1) \\
\frac{\partial \mathcal{L}}{\partial r} = 0 & \Leftrightarrow & r^* = \frac{2\bar{S}\alpha+\beta(\bar{N}\alpha-\gamma(1+\mu^*)-\theta+\bar{a}\mu^*)}{4\rho\alpha-\beta^2(1+\mu^*)} & (CN_2) \\
\mu^*(\gamma N^* + CF - \bar{A} - r^*(\beta N^* - \rho r^* + \bar{S}) - \bar{a}N^*) & & = 0 & (CN_3) \\
\text{for} & \mu^* \geq 0 & &
\end{array}
$$

A certain number of constraints need to be checked in order to correctly calibrate the model. More specifically, we must also ensure that $N^* \geq 0$, $N^* \leq \bar{N}$, $r^* \geq 0$. Both cases should be considered, depending on whether the constraint is saturated or not. Let's assume tha $\mu^* = 0$

— $N^* \geq 0$ iff $\alpha \geq \alpha_1 = \frac{-\bar{S}\beta+2\rho(\gamma+\theta)}{2\bar{N}\rho}$; with $\alpha_1 > 0$ if $-\bar{S}\beta + 2\rho(\gamma+\theta) > 0$.

— $N^* \leq \bar{N}$ iff $\alpha \geq \alpha_2 = \frac{-\bar{S}\beta+2\rho(\gamma+\theta)+\bar{N}\beta^2}{6\bar{N}\rho}$, $\alpha_2 > 0$ if $\alpha_1 > 0$.

— $r^* \geq 0$ iff $\alpha \geq \alpha_3 = \frac{\beta(\gamma+\theta)}{\bar{N}\beta+2\bar{S}}$, with $\alpha_3 > 0$without additional conditions.

All constraints require a minimum α and as such, they are all compatible with each other. We now need to determine the relevant lower boundary for α. We will compare α_2 and α_0. The sign of their difference $\alpha_2 - \alpha_0$ is dependent on the sign $(-2\bar{S}\beta + \bar{N}\beta^2 + 4(\gamma+\theta)\rho)$ which can be decomposed into two elements, $-\bar{S}\beta+\bar{N}\beta^2+2(\gamma+\theta)\rho) > 0$ since $\alpha_2 > 0$ and $-\bar{S}\beta+2(\gamma+\theta)\rho) > 0$ if $\alpha_1 > 0$. As such, the sign of the difference is positive, i.e. $\alpha_2 > \alpha_0$. Equally, the sign of the difference between α_3 et α_0 is dependent on the same condition and is therefore true for all admissible α parameters. Comparison of thresholds α_3 et α_1 de même que des seuils α_2 et α_1 donne le même résultat : $\alpha_1 > \alpha_3$ and $\alpha_1 > \alpha_2$ on the condition that $\alpha_1 > 0$ and $\alpha_2 > 0$. Therefore, imposing an additional condition to categorise α_2 et α_3. We define $\underline{\alpha} = \alpha_1$.

The constraint on aeronautical charges is not saturated if the price cap set by the regulator is sufficiently high. This question cannot be fully answered without further setting of parameters. However, a non-zero set of parameters exists, for which $a^* < \bar{a}$. These parameters satisfy the sufficient constraint at optimum :

$$\frac{-\bar{A} + CF + CV(N^*) - r^*S(r^*, N^*)}{N^*} < \bar{a}$$

If the parameters satisfy this constraint, then it is not necessary to consider the case $\mu^* > 0$.

The solution for aeronautical charges is therefore a decreasing function of $\bar{A}$, as shown in the sign of the first derivative a^* in relation to $\bar{A}$. After calculation, the sign of the derivative is dependent on the sign of the following expression $\bar{S}\beta + 2\rho(\bar{N}\alpha - \gamma - \theta)$. This sign is negative for all $\alpha \geq \underline{\alpha}$.

The derivative of N^* with respect to the externality parameter β is posotove provided that $\alpha > \alpha_4 = \frac{\bar{S}(2\bar{S}\beta+\bar{N}\beta^2-4(\gamma+\theta)\rho}{4\bar{N}\rho(\bar{S}+\bar{N}\beta)}$. This does not add further constraints since the sign of the difference of α_4 et $\underline{\alpha}$ is dependent on $(-2\bar{S}\beta + \bar{N}\beta^2 + 4(\gamma+\theta)\rho)$ dof which the negativity has been shown above. For all $\alpha > \underline{\alpha}$, $\frac{\partial N^*}{\partial \beta} > 0$.

C Proof of Proposition 3 :

In order to check operational profitability for the public investor, we need to check that the airline carrier's profit, to which we add the airport's profit, is at best higher than $\bar{A}$,denoting aid transferred. We must therefore check that

$$r^*S(r^*, N^*) + p(N^*)N^* - C(N^*) - CV(N^*) - CF \geq 0$$

After calculations within the scope of our specification, the condition is dependent on the sign of the following expression :

$$-CF(\beta^2 - 4\alpha\rho) - \bar{S}^2\alpha(-5\beta^2 + 4\alpha\rho) + (-\bar{N}\alpha + \gamma + \theta)(\beta^2 + 12\alpha\rho)(\bar{S}\beta - (-\bar{N}\alpha + \gamma + \theta)\rho) \geq 0$$

First of all, we must ensure that the expression is not negative for all possible parameters. The first part represents fixed costs and is negative. The second part is dependent on parameter values, and lastly, the third expression is a positive value for $\alpha \in [\underline{\alpha}, \bar{\alpha}]$. As such, we are sure to find a subset of parameters that strictly satisfies this inequality. A condition could be imposed on the maximum value of fixed costs, for example.

$$CF \leq \bar{CF} = \frac{-\bar{S}^2\alpha(-5\beta^2 + 4\alpha\rho) + (-\bar{N}\alpha + \gamma + \theta)(\beta^2 + 12\alpha\rho)(\bar{S}\beta - (-\bar{N}\alpha + \gamma + \theta)\rho)}{(\beta^2 - 4\alpha\rho)^2}$$

This threshold $\bar{CF}$ is positive iff

$$-\bar{S}^2\alpha(-5\beta^2 + 4\alpha\rho) + (-\bar{N}\alpha + \gamma + \theta)(\beta^2 + 12\alpha\rho)(\bar{S}\beta - (-\bar{N}\alpha + \gamma + \theta)\rho) > 0.$$

this condition holds under the following sufficient condition $\alpha > \alpha_4 = \frac{5\beta^2}{4\rho}$.

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