Should regional airports be allowed to pay long-term operating aid to low-cost carriers?

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The guidelines on state aid, modified in 2014, provide simpler start-up aid rules for new routes and open the way to transitory operating aid schemes. These support measures, such as discounts on landing or terminal charges, can make sense from an economic point of view and can comply with the private market investor principle. For this purpose, we model the airport as a two-sided platform, performing a trade-off between its aeronautical and commercial activities. Furthermore, we highlight the relationship between the intensity of aid and the form of ex ante regulation of airport charges. If these charges are regulated using a price-cap mechanism, the airline may use its negotiating power to extract the majority of the surplus generated by the contract. Conversely, regulation based on a price-floor mechanism may make it possible to limit the airline's ability to extract gains and thus reduce the level of the subsidy needed to balance the airport's budget.

FAUT-IL AUTORISER DES AIDES D'EXPLOITATION PÉRENNES VERSÉES PAR LES AÉROPORTS RÉGIONAUX AUX COMPAGNIES À BAS COÛTS ?

Les lignes directrices sur les aides publiques, modifiées en 2014, ouvrent désormais la possibilité d'aides à l'exploitation. Nous analysons économiquement ces mesures de soutien pour montrer qu'elles peuvent s'avérer rationnelles pour le gestionnaire d'une infrastructure aéroportuaire, et donc être compatibles avec le critère de l'investisseur privé en économie de marché. À cette fin, nous proposons une modélisation de l'aéroport comme une plate-forme biface, exploitant les externalités présentes entre activités aéronautiques et activités commerciales. Nous montrons en outre qu'un lien existe entre l'intensité de l'aide et le mode de régulation ex ante des redevances aéroportuaires. Si ces dernières sont régulées par prix plafonds, la compagnie aérienne dont le pouvoir de négociation est plus élevé pourra s'approprier la plus large part des gains de l'échange.

Keywords: state aid, two-sided market, air transport, aeronautical charges

Mots clés : aides d'État, marché biface, transport aérien, redevances aéroportuaires

JEL codes: D43, K23, L13, L43, L93.

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INTRODUCTION

Both competition authorities and public accounts authorities have often turned a critical eye on secondary airports and on the agreements made with low-cost carriers (hereafter LCCs). Some contracts have been called into question for being too favorable to the airlines involved. They create two kinds of problems.

First, there are the problematic effects that these contracts have on competition. The financial support LCCs may receive may be considered state aid. This aid needs to be provided transparently, to ensure compliance with the operating rules of the Single Market. As part of the more economic approach undertaken by the European Commission (2005; 2014), state aid may be allowed if it is meant to address an identified market failure. Aid is not prohibited in and of itself, but it must be reported in advance and not cause any distortion of competition between airlines. The European Commission has launched several formal procedures since the start of the 2000s leading to the cancellation of various agreements. These procedures resulted in a reclassification of potential support measures as state aid and in injunctions against LCCs, requiring them to repay any funds disbursed by the airport infrastructure manager.[1]

The second set of problems are related to the budgetary effects of these agreements. Secondary European airports often run operating deficits due to structural overcapacity. Airport managers expect public support for airlines to generate an increase in traffic that will make it possible to cover both its associated variable costs and some of the airport's fixed costs. Such support can be rationalized under the private market investor principle. Infrastructure managers can rationally increase service by reducing aeronautical charges, perhaps on a long-term basis.[2] At the same time, an additional concern related to the distribution of gains among stakeholders must be considered.

Agreements between airlines and airport infrastructure managers do not bring together two parties with equal negotiating power. LCCs may obtain significant reductions in airport charges, creating the threat of distortions of competition between airlines (Malavolti and Marty 2010), as well as collectively suboptimal tax competition (Malina, Albers, and Kroll 2012). The problem arises largely because secondary airports are built with excess capacity and because LCCs' opportunities for arbitrage between different destinations puts them in a monopsony position.[3] Agreements signed between

1. This was the case, for example, in Nîmes for Ryanair (6.4 million euros) and in Pau for Ryanair (2.4 million euros) and Transavia (400,000 euros).

2. The European Commission has, in some cases, come down in favor of the private market investor principle. Such was the case for Frankfurt-Hahn Airport and Ryanair (IP/08/956), and for Saarbrücken Airport and Air Berlin (IP/12/156).

3. David Starkie, in a 2009 OECD report on the analysis of strategic interactions between airlines and airports, states that airports have a harder time exercising their market power when they have excess capacity, and when direct competition at an airport between different airlines is low. Also, in its report on the French airport network, the Conseil supérieur de l'aviation civile (French

airports and airlines can reflect this imbalance. For example, the Conseil supérieur de l'aviation civile (French Civil Aviation Authority) (2017) has recorded marketing contracts that include both reduced aeronautical charges and provisions to share the airport's commercial revenues.[4]

The contribution of this article is to propose a two-sided market model for the economic equilibrium of airport infrastructures, allowing us to undertake an economic analysis of the private market investor criterion.

Airports basically earn revenue from two sources: aeronautical charges and commercial revenues (from parking lots, leases on commercial space, etc.). This model was developed for intermediation platforms (Rochet and Tirole 2003; 2006; Armstrong 2006; Hagiu and Wright 2015; Verdier 2016). Two-sided platforms are characterized by the external network effects that they generate between participants. The presence of consumers on one side of the platform creates value on the other side, so that the optimal solution may be to distort the pricing structure between the two sides in order to maximize revenues. Externalities may exert an influence in both directions, or only from one side to the other. We apply this theoretical framework to airport infrastructures, in line with a growing part of the literature.

The first analyses of airports as two-sided markets were developed by Gillen (2011), Malavolti (2016), and Ivaldi, Sokullu, and Toru (2015). Gillen (2011) showed the possibility of generating additional commercial revenues that could compensate for reduced aeronautical charges, allowing airlines to increase their services and therefore the number of passengers using the infrastructure. The impact of nonaeronautical revenues on airports' economic equilibrium must not be overlooked. For example, in 2014, more than 60% of Paris Aéroport's profits were commercial. This proportion rose steadily between 2009 (54%) and 2014 (61%) (Paris Aéroport 2014). The first empirical analyses conducted in the United States by Ivaldi, Sokullu, and Toru (2015) show the existence of externalities between commercial activities and aeronautical activities, justifying a two-sided approach to airports.

This is why we opt for a two-sided approach rather than a vertical chain in the formalization of our airport business model. The main critique of this approach to airports is that the externalities are only observed from one side to the other, and not in both directions (see, for example, Fröhlich 2011). However, recent developments in two-sided analysis have extended the model's validity to cover cases of unidirectional externalities (Hagiu and Wright 2015). The model, therefore, remains valid even if passengers' travel

Civil Aviation Authority) (2017) concluded that relationships between airlines and low-activity airports are characterized by "inverse monopolies" that favor airlines.

4. According to the French Civil Aviation Authority, these contracts can be likened to the back margins that large retailers impose on small producers. In doing so, they raise questions about vertical restraints that will not be addressed directly in this article. See, for example, Rey (2003) for a general economic analysis of vertical restraints, and Wright (2007) for an analysis of their impact on consumer welfare. We should note that airport commercial revenue sharing agreements can be beneficial, as shown by Fu and Zhang (2010), because they internalize demand effects. They do, nevertheless, harm competition between airlines.

decisions are not unequivocally affected by the range of commercial services within the airport infrastructure.

Our model also aims to provide an answer to certain regulatory problems in the sector. We examine the impact of charge reductions on the economic equilibrium of airport infrastructures. In Europe, airport charges are subject to price-cap regulation.[5] Secondary platforms are only rarely able to balance their accounts (European Court of Advisors 2014). The problem is that these deficits are often offset by public funds. The issue is therefore to reconcile the optimal behavior of the infrastructure operator with the minimization of its deficit. Our model shows that an ex ante regulation of aeronautical charges is not neutral in terms of the distribution of gains between the two parties to the agreement. While price-cap regulation guarantees that an airport in a monopoly situation will not extort excessive fees from airlines, it does not limit the exercise of market power by an airline in a monopsony situation.

Because the two-sided nature of the market makes it possible to offset a loss of earnings on the aeronautical side with additional revenues on the commercial side, it might be possible to completely eliminate the charge, or even to institute a negative charge.[6] This might take the form of the sharing of commercial revenues with the LCC. However, while such agreements might result in a net gain for all parties relative to the initial situation, we cannot assume that this will be shared equally between the LCC and the infrastructure manager.

Further, charge reductions are often counterbalanced by public resources. This means that state aid is provided, whether directly to the LCC or to help maintain the operating equilibrium of the airport infrastructure. There is therefore an interdependent relationship between the ex ante regulation of aeronautical charges and the ex post evaluation of the intensity of state aid by competition authorities. In this article, we aim to show how different forms of ex ante regulation (price caps and price floors) can impact the ex post evaluation of the intensity of state aid, as well as the distribution of gains from the contract between the different parties.

The support measure's compliance with EU state aid regulations is evaluated ex post for private market investors, and ex ante through notification in the case of state aid. In our model, we treat support measures as reduction rates on charges. This allows us to treat each situation as if the LCC were negotiating a comprehensive subsidy agreement with the airport. That is why we can simplify our analysis by considering aid control to be focused on a "lump-sum" subsidy.

5. This regulation is meant to prevent the manager from abusing its market power, which arises from its natural monopoly situation. However, secondary airports do not have the same market power, because they need to make their existing infrastructures profitable and secure service in a context in which airlines can easily arbitrage between several airports where they will be the only client.

6. We have also shown that offering something for free on one side of a two-sided platform can make economic sense (see Malavolti and Marty 2013).

We develop a better understanding of the connection between the ex ante regulation of charges and the ex post evaluation of state aid. We will show that one way to limit the intensity of state aid (and therefore LCCs' ability to derive a surplus) might be to institute price-floor regulation of charges, rather than price-cap regulation. In other words, price-floor regulation of aeronautical charges at airports with little to no market power may limit the share of the surplus generated by the agreement that the LCC can obtain. We do not conduct a welfare analysis, but the underlying idea is that the greater the share of the surplus obtained by the LCC, the greater the support needed to maintain the secondary airport's operating balance. This support will take the form of costly injections of public funds.

In the next section, we will present our model and its main results. The final section will discuss the results and propose avenues for future research.

A MODEL OF STATE AID FOR SECONDARY AIRPORTS

Our model defines the airport as a platform that connects passengers with shops in the terminal. This interaction takes place thanks to the airlines that bring traffic to the airport. An aeronautical charge a is then set depending on the number of passengers traveling with the airline, and a price r is set for the commercial space rented. Transport demand, expressed as the number of passengers, is a function of the ticket price. $\mathrm{N}(p)$ represents travel demand addressed to airlines, where p is the ticket price paid by each passenger. This demand decreases as the ticket price increases and is maximal for a ticket price of zero. In this case, it is equal to $\bar{\mathrm{N}}$. The airport charge is calculated proportionally, based on this demand. Nonaeronautical activities are mostly represented by rental demand for spaces within the terminal (for shops) or outside the terminal (for car rental companies). This demand, given as $\mathrm{S}(r, \mathrm{N})$, where S represents the number of locations, decreases as the rental price r rises, and increases along with the number of passengers N, since passengers represent potential customers for shops or other renters.[7] We assume that there are no cross effects between the rental price and the number of customers.

7. We have chosen to include a positive externality exerted on shop revenues by the flow of passengers. Some two-sided models consider the cross externalities between the two sides of a market (video games, shopping centers, newspapers, etc.). In the case at hand, we can consider that shops also exert an externality on passengers. However, the sign of this externality is difficult to determine: we can assume that the presence of shops is desired by passengers. Consumers undoubtedly prefer waiting in an airport where they are surrounded by shops to one that is empty. Some studies, however, have shown that waiting times can be increased due to the presence of shops, which are prepared to pay more in rent in order to keep passengers in the airport for longer. See, for example, Torres et al. (2005) and Malavolti (2016). Because previous studies have not come to a conclusion about the sign for this factor, we have chosen not to consider the ex ante externality exerted by shops on passengers. On the other hand, the results will be discussed based on the sign of this externality.

The airport's costs include variable costs, which largely depend on the number of passengers in the airport, given as VC(N), an increasing function of N; and fixed costs, given as FC and corresponding to past investments (runway, terminal, parking lots, commercial spaces, etc.) to build production capacity for aeronautical and nonaeronautical services. Thus, the airport's profit may be written as:

$$\Pi_{\text{airport}} = a\mathrm{N}(p) - \mathrm{VC}(\mathrm{N}(p)) + r\mathrm{S}(r, \mathrm{N}(p)) - \mathrm{FC},$$

where $a\mathrm{N}(p)$ represents aeronautical revenues, $r\mathrm{S}(r, \mathrm{N}(p))$ represents commercial revenues, and $\mathrm{VC}(\mathrm{N}(p)) + \mathrm{FC}$ represents the airport's total costs. In general, financially viable airports are those that have high levels of activity: ADP (Paris Aéroport) and Fraport (Fraport AG Frankfurt Airport Services Worldwide) are by definition not the kind of airports concerned with state aid in the form of investment. The airport platforms that interest us here are those that, due to low demand for their services (passengers and shops) combined with high fixed costs, are not profitable. State aid is justified when variable profit is positive—that is, when variable costs are covered, but not all fixed costs. The technical hypothesis for this situation is as follows: the airport's profit is assumed to be negative even in the best possible scenario, that is, for all values and combinations of $\mathrm{N}(p)$, of S, of r, and of a, total profit is negative without additional aid. A fixed amount, noted as A in our model, is then allocated to the airport. This amount is indirectly limited by the European Commission through its guidelines and past decisions. The LCC will then use these guidelines and decisions to determine the maximal amount of aid that could be accepted, noted as $\bar{\mathrm{A}}$.

In addition, the aeronautical charge paid by the airline is determined based on a theoretical natural monopoly situation. The regulator sets a price cap, given as $\bar{a}$,[8] based on all of the airport's revenues and costs.

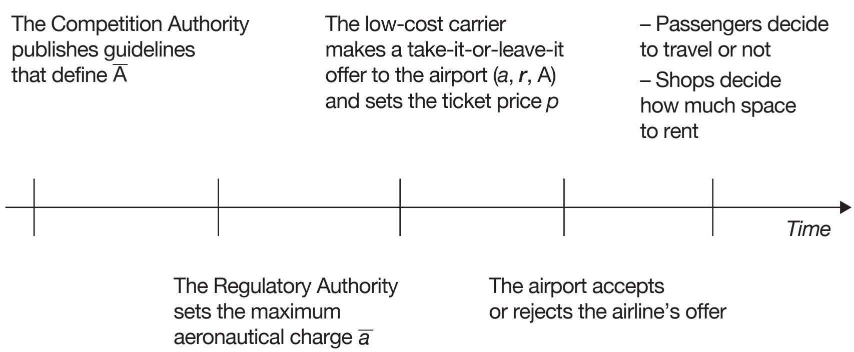
In our model, the airport has a single airline as its client, upon which it is economically dependent. The airline will make the airport a take-it-or-leave-it

8. The scope of regulation varies depending on airport size: as recommended by the International Civil Aviation Organization (2012), small European airports generally use single-till regulation, whereas larger structures opt for dual-till regulation. In single-till regulation, the scope of regulation includes all of the airport's revenues. In dual-till regulation, only aeronautical revenues are included. Various economics articles have examined this problem, with differing conclusions. An initial series of texts (Starkie 2001; Starkie and Yarrow 2008) analyzed the impact of this type of regulation on long-term airport objectives. They used a capital cost approach to show that the airport's investment incentives are reduced if the airport is not able to retain enough resources. They therefore concluded that dual-till regulation is preferable. However, some more recent articles (Fröhlich 2011; Malina, Albers, and Kroll 2012; Malavolti 2016) draw opposite conclusions, considering the airport as a platform. These works recommend single-till regulation to account for the externalities that exist between both sides of the market (aeronautical and commercial). Finally, Perrot (2014) suggests that, at large airports, congestion issues may justify dual-till regulation. Ultimately, the impact on the equilibrium price structure of the positive externalities exerted by passengers on shops is that shops subsidize discounts on airport taxes, indirectly subsidizing passengers, too. At equilibrium, therefore, there are more passengers at the airport, increasing congestion. If the social costs of congestion are high enough, dual-till regulation may be preferable.

offer[9] in the form of a contract that sets (a, r, A), while also ensuring that it is in the airport's interest to accept the offer. For small secondary airports, their business depends entirely on just one contract with a single airline. We will therefore assume that the airport will accept the offer as long as the profit it expects to see from the agreement is non-negative.[10] This allows us to account for the fact that some of the airport's fixed costs are unrecoverable and must be paid, whether or not the airline makes an offer to the airport. These include, for example, the fixed costs of existing facilities (runway, terminal). On the other hand, other fixed costs only arise when the offer is accepted, for example the fixed costs of setting up commercial spaces, or the construction or upgrading of an external parking lot. For the sake of simplicity, we normalize unrecoverable fixed costs to zero.

The goal of our article is to propose a model for the relationship between an LCC and an economically dependent airport, and to better understand how ex ante (maximum aeronautical charge) and ex post (operating aid) regulatory tools interact and influence the decisions of various economic actors. The interplay we intend to study is represented in Figure 1.

Figure 1 – *Decision tree*



The airline's program is written as follows:

$$\underset{\{p,r,a,\mathrm{A}\}}{\mathrm{Max}}\ \mathrm{P}_{\mathrm{LCC}} = p\mathrm{N}(p) - a\mathrm{N}(p) - \mathrm{C}(\mathrm{N}(p)),$$

$$\text{s.t. } \Pi_{\text{aéroport}} = a\mathrm{N}(p) - \mathrm{CV}(\mathrm{N}(p)) - \mathrm{CF} + \mathrm{A} + r\mathrm{S}(r, \mathrm{N}(p) \geq 0(\mathrm{C}_1)),$$

$$a \leq \overline{a}(\mathrm{C}_2),$$

$$0 \leq \mathrm{A} \leq \overline{\mathrm{A}}(\mathrm{C}_3),$$

$$p \in \mathbb{R}^+, r \in \mathbb{R}^+, a \in \mathbb{R},$$

9. For example, we might note that some airports sign commercial profit-sharing agreements. This is the case for Tampa, Florida, where the airport shares revenues from its commercial concessions with the airlines that use its infrastructure. Fu, Homsombat, and Oum (2011) use this example in their article analyzing the vertical relationships between airlines and airports.

10. The profit that the airport can make outside of this transaction may also influence the likelihood that it will sign an agreement with another airline. Given various options, the airport will choose the contract that is most advantageous to it. However, these contracts might be uncertain, or even nonexistent. In any case, the state aid involved in these contracts is mostly start-up aid for opening up new routes. We are focused on operating aid that may become long-term.

where $p\mathrm{N}(p)$ represents the airline's revenues from the sale of N tickets at price p, $a\mathrm{N}(p)$ represents the costs of access to aeronautical services paid by the airline to the airport to take on N passengers, $\mathrm{C}(\mathrm{N}(p))$ corresponds to the total variable costs borne by the airline when it transports N passengers.[11] This is an increasing and convex function of N. The constraints C_2 and C_3 represent regulatory constraints that must be met. The selected level for the aeronautical charge a therefore cannot exceed the price cap set by the regulator $\overline{a}$. On the other hand, nothing prevents the aeronautical charge from acting as the equivalent of a subsidy, i.e., $a^* < 0$ at equilibrium if profit maximization allows it. The requested operating aid A must be positive and cannot exceed the maximal level allowed by the competition authorities. The constraint C1 represents the constraint of airport participation.

PROPOSITION 1: *At equilibrium, the LCC captures all of the profit generated by the airport, notably due to the requested operating aid, which is maximal.*

$$\Pi_{\text{airport}} = 0,$$
$$\mathrm{A}^* = \overline{\mathrm{A}}$$

Proof. Let the quadruplet solution to the maximization program $(p^*, r^*, a^*, \mathrm{A}^*)$ be such that $\mathrm{C}_1(p^*, r^*, a^*, \mathrm{A}^*) > 0$. There must be $\tilde{a} < a^*$ such that $\mathrm{C}_1(p^*, r^*, \tilde{a}, \mathrm{A}^*) > 0$ and such that $\tilde{a}$ satisfies the other constraints, C_2 and C_3. The airline's profit is then higher, since only a is modified: $\Pi_{\mathrm{LCC}}(p^*, r^*, \tilde{a}, \mathrm{A}^*) > \Pi_{\mathrm{LCC}}(p^*, r^*, a^*, \mathrm{A}^*)$. This solution is therefore preferable, and no solution can be found where constraint C_1 is not saturated at the optimum.

Let us also suppose that $\mathrm{A}^* < \overline{\mathrm{A}}$, so $\mathrm{C}_1(p^*, r^*, a^*, \overline{\mathrm{A}}) > \mathrm{C}_1(p^*, r^*, a^*, \mathrm{A}^*) \geq 0$. It is therefore possible to find $\tilde{a} < a^*$ such that $\mathrm{C}_1(p^*, r^*, \tilde{a}, \overline{\mathrm{A}}) = \mathrm{C}_1(p^*, r^*, a^*, \mathrm{A}^*) \geq 0$, which gives more profit to the airline: $\Pi_{\mathrm{LCC}}(p^*, r^*, \tilde{a}, \overline{\mathrm{A}}) > \Pi_{\mathrm{LCC}}(p^*, r^*, a^*, \mathrm{A}^*)$.
In conclusion, constraint C_3 is saturated at the optimum. ■

This result is robust, since it does not depend on the form of the profit functions for the airline and the airport, but rather on natural conditions necessary for the convexity of the problem. It shows us that the LCC has enough decision variables to be able to extract all of the profit from the airport, notably thanks to the operating aid that the airport can access. Ultimately, and more interestingly, this result highlights the interaction between ex ante regulatory tools (maximal aeronautical charge) and ex post tools (maximal requested operating aid). More specifically, it appears that aeronautical charges and requested state aid are substitute tools that the airline uses to satisfy the constraint of airport participation. In fact, the higher the operating aid, the easier it is to satisfy the constraint of participation, even though the airline's profit remains unchanged. This means that the airline, which is sensitive to

11. We have normalized the airline's fixed costs to zero for the sake of simplicity.

the level of the aeronautical charge since it represents a direct cost, can use its market power to decrease the charge and thus increase its profit, without modifying any of the constraints. State aid must then be set at its maximum. The constraint of airport participation must also be saturated, because it can be adjusted through the level of aeronautical charge without changing any of the other maximization arguments. This charge will be set as low as possible to satisfy the constraint of airport participation. It may therefore be that the optimal charge for this program is a subsidy that the airport pays to the airline to attract passengers—that is, future customers for the airport's shops. This is where the two-sided structure shows its advantage: this solution is only possible if the variable portion of the airport's profit is large enough in relation to – FC + $\bar{A}$. This variable portion is made up of aeronautical and commercial revenues. If commercial revenues are high enough, the airline can reduce aeronautical charges in order to increase its profit.

For the sake of clarity, we have modified the program to optimize it in relation to the number of passengers N. This is possible because, by definition, the function N(p) is strictly decreasing in p. Following Proposition 1, the constraint of airport participation also makes it possible to set the optimal level of aeronautical charge. All that needs to be done is to reinsert it into the aeronautical charge regulation constraint C_2 to get the following transformed program:

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

The airline's objective function includes not only the profit from the sale of airline tickets to passengers (p(N)N – C(N)), but also the airport's profit, minus the aeronautical charge, since it is a cost for the airline, (rS(r, N) – VC(N) – FC). The airline understands that it must request the maximum available state aid to increase the likelihood of its offer being accepted by the airport.

Let $\mu \in \mathbb{R}^+$ be the Lagrange multiplier associated with the constraint (C_1) of the airline's maximization program. The program becomes a maximization program in the form of a Lagrangian $\mathcal{L}$ (r, N) whose first-order conditions are as follows:

$$\frac{\partial \mathcal{L}}{\partial N} = p(N^*) + N^* \frac{\partial p}{\partial N} - \frac{\partial C}{\partial N} + (1+\mu^*)\left(r^* \frac{\partial S}{\partial N}\right) - (1+\mu^*)\frac{\partial CV}{\partial N} - \mu^* \bar{a} = 0, \quad \text{(CN1)}$$

$$\frac{\partial \mathcal{L}}{\partial r} = (1+\mu^*)\left(r^* \frac{\partial S}{\partial r} + S(r^*, N^*)\right) = 0, \quad \text{(CN2)}$$

$$\mu^*\left(CV(N^*) + CF - \bar{A} - r^* S(r^*, N^*) - \bar{a}\,N^*\right) = 0. \quad \text{(CN3)}$$

Condition NC2 sets the rental price for commercial spaces at the level of the monopoly price. In fact, for any $\mu \geq 0$, NC2 is true if and only if $r^* \frac{\partial S}{\partial r} + S(r^*, N^*) = 0$. The airline behaves like a monopoly, just as the airport would have done in relation to its shops. We thus observe the classic result of the airline applying a margin rate to its marginal costs (which are zero in our model). This margin rate rises as the sensitivity of demand for commercial space to the rental price decreases, i.e., as $\frac{\partial S}{\partial r}$ decreases. Also, the higher N^* is, the higher r^* will be, since demand for commercial space increases with the number of passengers in the airport. This is because our two-sided model takes into account the externality exerted by aeronautical activity on commercial activity.[12]

The first condition, NC1 is made up of an initial element $p(N^*) + N^* \frac{\partial p}{\partial N}$ that corresponds to the profit maximization condition for the airline if it is not in a dominant position. This condition sets the monopoly price for tickets sold to passengers. Several additional effects are taken into account: the airport's marginal costs $\frac{\partial CV}{\partial N}$, which will tend to reduce the optimal number of passengers; the airport's commercial profit, which will rise with the number of passengers, ($r^* \frac{\partial S}{\partial N}$); and the aeronautical charge regulation constraint, which will reduce the number of passengers to equilibrium if the constraint is not saturated (more precisely, if the multiplier is not zero at equilibrium, i.e., $\mu^* > 0$).

These three conditions give a local maximum if $\mathcal{L}$ is proven to be concave (see Appendix I). This is the case for reasonable hypothetical demand and cost functions.

To illustrate these results, we will specify the model and explain the solutions, commenting on how they change in relation to the model's relevant parameters. Let us assume an inverse demand for tickets from consumers: $p(N) = \alpha\bar{N} - \alpha N$. The price is zero when demand is maximal, i.e., equal to $\bar{N}$. Demand decreases as the price increases. Let us assume that demand for commercial space decreases as the rental price increases, and that it increases along with the number of passengers, in the form $S(r, N) = \beta N - \rho r + \bar{S}$. . The airline's and the airport's costs are assumed to grow linearly with the number of passengers: $VC(N) = \gamma N$ and $C(N) = \theta N$. We assume that $\alpha > 0$, $\beta > 0$, $\rho > 0$, $\gamma > 0$, $\theta > 0$, $\bar{N} > 0$, $\bar{S} > 0$. The first-order conditions give:

12. It should be noted that the solution for r^* would have been the same if the airport had chosen it freely, considering both sides of the market, since it would have used its monopoly power to set the same price for rental space. See Malavolti (2016) for an analysis of the impact of the two-sided nature of the market on the price structure at equilibrium.

$$\frac{\partial \mathcal{L}}{\partial \mathrm{N}} = -2\mathrm{N}^{*}\alpha + \bar{\mathrm{N}}\alpha + r^{*}\beta - \gamma - \theta + \mu^{*}\left(\bar{a} + r^{*}\beta - \gamma\right) = 0, \qquad \text{(CN1)}$$

$$\frac{\partial \mathcal{L}}{\partial r} = \left(1+\mu^{*}\right)\left(\bar{\mathrm{S}} + \mathrm{N}^{*}\beta - 2r^{*}\rho\right) = 0, \qquad \text{(CN2)}$$

$$\mu^{*}\left(\gamma\mathrm{N}^{*} + \mathrm{CF} - \bar{\mathrm{A}} - r^{*}\left(\beta\mathrm{N}^{*} - \rho r^{*} + \bar{\mathrm{S}}\right) - \bar{a}\,\mathrm{N}^{*}\right) = 0. \qquad \text{(CN3)}$$

The program is concave under the reasonable conditions given in Appendix I, and it therefore allows a global maximum. The characteristics of this maximum are subject to discussion, especially in terms of the constraint on the maximal aeronautical charge. This aeronautical charge is a parameter set by the regulator that the airline must comply with. $\bar{a}$ is a price cap set based on regulatory rules that account for airports' incremental costs and for market conditions. The most interesting case for us is one in which this authorized price cap is high enough to not become a constraint for the airline. Such a situation would allow the airline to select a charge level that may be lower than the price cap, or even negative (i.e., acting as a subsidy from the airport to the airline), depending on the parameters of the model (especially the characteristics of the demand for transport services).

PROPOSITION 2: *If consumers are sufficiently sensitive to ticket price* $\alpha \geq \underline{\alpha} = \frac{-\bar{\mathrm{S}}\beta + 2\left(\gamma+\theta\right)\rho}{2\bar{\mathrm{N}}\rho}$*, the airline may obtain an access charge from the infrastructure manager that is strictly below the cap set by the regulator (*$\mu^* = 0$*).*
Also, the higher the maximal state aid level $\bar{\mathrm{A}}$*, the lower the optimal aeronautical charge a* will be. The optimal charge might even be a subsidy in favor of the LCC if the profit generated from commercial activity is high enough.*

Proof. See Appendix II. ■

Passenger demand is what ultimately determines the airline's optimal strategy: if this demand is highly sensitive to the ticket price, selecting a low ticket price will have a large effect on the number of passengers traveling. In order to balance its profit, the airline adjusts the aeronautical charge to a low level in order to maintain its profit, since this reduces its costs.[13] With its low ticket price, the airline is able to attract more traffic to the airport, helping to increase profit from commercial activity. Furthermore, the greater the externality exerted by passengers on commercial activity (measured by the parameter β in our model), the greater the commercial profit. At equilibrium, the greater the impact of this externality, the greater the number of passengers transported at equilibrium. Thus, aeronautical charge levels can

13. The airline cannot capture all of the airport's profits with the agreement that it offers. Its best option is therefore to reduce the share of the airport's profit that corresponds to aeronautical services costs.

be lowered to act as a subsidy for the LCC when the airport's commercial profit is large enough. This externality is related to our definition of the two-sided nature of airport activity.

It should be noted that there is also an equivalence between the intensity of the reduction obtained by the LCC and the support measure $\bar{A}$. The airline can demand a greater discount when it accounts for the airport's potential gains from the agreement and European competition case law on state aid control. It can use its strong negotiating position to obtain significant charge reductions, allowing it to capture a large proportion of the gains and leading to higher levels of aid. Price-cap regulation of charges does not make it possible to limit the level of the reduction in charges, so it cannot "cap" the amount of aid. This means that both the ex ante and ex post regulatory tools are related. For example, setting a price floor—that is, a minimum value for the aeronautical charge—would reduce the amount of support given to the infrastructure without changing the equilibrium results. It would both limit the LCC's ability to obtain the majority of the gains generated by the agreement and reduce the amount of public funds needed for aid. In other words, it may be preferable to cap, using price-floor regulation of the level of aeronautical charges, the amount of aid that can be allocated by an airport manager without market power.

In our model, a direct welfare analysis is not possible because we have not specified the objectives of each of the regulators. We can, however, approximate such an analysis by comparing the profits generated by the contract with the investment made by the airport manager when state aid is requested. If the operation frees up resources, we can assume that the investment of operating aid was profitable.

We will thus need to compare the profits of the airline and the airport with the amount of state aid requested at equilibrium. Under Proposition 1, the airport does not make any profit and the aid requested is maximal, i.e., equal to $\bar{A}$. We must therefore verify that:

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

In our specification, this means that the investment is profitable as long as fixed costs are not too high. This condition seems to be a natural one: if fixed costs are very high, even with significant support the airport will never be able to cover them with its activity. The upper bound for acceptable fixed cost values limits all of the acceptable parameters. We therefore need to find $\alpha > \alpha_4 = \dfrac{5\beta^2}{4\rho}$, that is, cases where the sensitivity of transport demand to the ticket price is greater than $\underline{\alpha}$.

PROPOSITION 3: *The support measure may be considered a profitable investment, as a private market investor might define it, when fixed costs are not too high. The airline's profit is greater than the state aid, making the investment profitable, when:*

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

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

Proof. See Appendix III. ■

CONCLUSION

Our model shows the rationality, for an airport infrastructure manager acting like a private market investor, of offering operating aid to LCCs—on a long-term basis. This conclusion aligns with the adjustments made in the 2014 European Commission guidelines, and it justifies a priori discounts on aeronautical charges for more than just a temporary period. When the externalities between the aeronautical and nonaeronautical sides of airports' activity are taken into account, we see that aid given to LCCs to generate and consolidate services (i.e., to increase passenger flows) can be "financed" by the additional revenues generated by the commercial side (parking lots, shops, etc.). In this situation, a private market investor might accept that it will not cover all of its costs on the aeronautical side, knowing that they will be covered by gains from the commercial side. Dramatic reductions of charges (making them almost zero) and commercial revenue sharing clauses (in other words, negative airport charges) may be economically justifiable on the basis of efficiency, even if they are adopted on a long-term basis, rather than as temporary measures.

Such agreements between secondary airport managers and airlines may allow the former to operate at equilibrium, or at least limit their operating deficit. A gain is therefore derived from the agreement. This gain may have two dimensions: first, advantages for the local area (opening up of isolated regions, increased connectivity, etc.); second, a saving of the public resources needed to offset the airport's operating deficit. In a monopsony situation, however (which can be observed in many European regional airports), the LCC may capture a large share of this surplus. This means less saving of public funds for the government. One solution might be to cap the intensity of aid. This is the ex post strategy adopted by the European Commission through its decisional practice.

Another solution, that which we would like to highlight in this article, would be to consider the relationship between the intensity of the discount on airport taxes and the intensity of the state aid needed. The current price-cap regulation makes sense for airports that have at least some market power vis-à-vis airlines. It helps prevent them from abusing their position to extort an excessive proportion of the surplus from operators, for whom these airports are essential facilities. The situation is quite different for regional airports. These airports compete with each other to attract LCCs. The demand for LCCs' services, especially from leisure travel clientele, is highly sensitive to price, but less sensitive to which locations are actually served. For their part, airport managers need to guarantee that their infrastructures will be served, where costly public investments have already been made which cannot be redeployed. Given this situation of economic dependence aggravated by unrecoverable costs, the LCC may employ a contract hold-up strategy, demanding that airport charges be set well below the cap price, or that they be eliminated or even made negative (through the sharing of commercial revenues, the co-financing of promotional campaigns, etc.).

Price-cap regulation does not make it possible to limit how much aid is needed to make up for the fact that the LCC captures all of the gain generated by the agreement. In principle, the amount of aid granted in the form of charge reductions should be limited. Of course, it is not always state aid that is at stake, since, in some instances, the terms of the agreement satisfy the criteria of the private market investor principle. We must therefore find a way to limit the LCC's ability to take advantage of the airport's dependence. In our model, we noted that the gain captured by the LCC is greater when the externality exerted by passengers on commercial activity is greater. We did not conduct a welfare analysis as part of this article, but we can still assume that the collective cost of this profit capturing rises along with the marginal cost of the public funds mobilized. Therefore, for airports that lack market power, our proposal is to limit the LCC's ability to capture this gain by replacing ex ante price-cap regulation of airport charges with price-floor regulation. This will make it possible to limit ex ante the intensity of aid.

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APPENDICES

I – Concavity of the airline's program

The conditions for reaching a maximum, if it exists, depend on the concavity of $\mathcal{L}$. This Lagrangian can be broken down into different functions, whose concavity makes it possible to obtain an optimal solution. $\mathcal{L}$ can be rewritten as follows:

$$\mathcal{L} = p(\mathrm{N})\mathrm{N} - \mathrm{C}(\mathrm{N}) - a\mathrm{N} + (1+\mu)\left(r\mathrm{S}(r,\mathrm{N}) - \mathrm{CV}(\mathrm{N}) + a\mathrm{N}\right)$$
$$+\mu(\bar{a} - a)\mathrm{N} + (1+\mu)\left(\bar{\mathrm{A}} - \mathrm{CF}\right).$$

The first expression corresponds to the airline's profit: $p(\mathrm{N})\mathrm{N} - \mathrm{C}(\mathrm{N}) - a\mathrm{N}$. This profit is concave when $\mathrm{N} > 0$, if and only if $\frac{\partial^2 \Pi_{\mathrm{LCC}}}{\partial \mathrm{N}^2} \leq 0$, which gives us the sufficient condition SCLCC:

$$\frac{1}{\mathrm{N}}\left(-2\frac{\partial p}{\partial \mathrm{N}} + \frac{\partial^2 \mathrm{C}}{\partial \mathrm{N}^2}\right) \geq \frac{\partial^2 p}{\partial \mathrm{N}^2} \qquad (\mathrm{CS}_{\mathrm{LCC}})$$

We will make sure that $\mathrm{N} \neq 0$ at equilibrium. This condition is typically satisfied if passenger demand $p(\mathrm{N})$ is a linear function of N. If not, the condition requires that, if the effects of price on the second-order number of passengers are increasing, i.e., $\frac{\partial^2 p}{\partial \mathrm{N}^2} > 0$, these effects are limited compared to the first-order demand effects, plus the convexity effects of the airline's costs (working hypothesis of the model).

The second expression corresponds to the airport's profit, multiplied by the multiplier $\mu \geq 0$: $(1 + \mu)(r\mathrm{S}(r, \mathrm{N}) - \mathrm{VC}(\mathrm{N}) + a\mathrm{N})$.

Similarly, for the airline, the concavity of this program is desirable in the context of this analysis. It is assured when:

$$\frac{\partial^2 \mathrm{CV}}{\partial \mathrm{N}^2} \geq r\frac{\partial^2 \mathrm{S}}{\partial \mathrm{N}^2}, \qquad (\mathrm{CS1}_{\text{aéroport}})$$

$$\frac{-2}{r}\left(\frac{\partial \mathrm{S}}{\partial r}\right) \geq \frac{\partial^2 \mathrm{S}}{\partial r^2}, \qquad (\mathrm{CS2}_{\text{aéroport}})$$

$$\left(r\frac{\partial^2 \mathrm{S}}{\partial \mathrm{N}^2} - \frac{\partial^2 \mathrm{CV}}{\partial \mathrm{N}^2}\right)\left(r\frac{\partial^2 \mathrm{S}}{\partial r^2} + 2\frac{\partial \mathrm{S}}{\partial r}\right) - \left(\frac{\partial \mathrm{S}}{\partial \mathrm{N}}\right)^2, \qquad (\mathrm{CS3}_{\text{aéroport}})$$

for any rental price $r > 0$.

We will make sure that $r \neq 0$ at equilibrium. SC1airport is ensured because the airport's variable costs are convex and the impact of the externality on the demand for rental space decreases with the number of passengers present in the airport. The outcomes of the positive externality are assumed to decrease, in the interest of realism. SC1airport is typically verified for a demand for space $\mathrm{S}(r, \mathrm{N})$, which is a linear function of r. Finally, SC3airport is a condition that remains to be verified. It is valid when the effect of the externality on the demand for rental space is not too high compared to the effects on costs and the direct effect of price r on demand $\mathrm{S}(r, \mathrm{N})$. Finally, the last expression $\mu(\bar{a} - a)\mathrm{N} + (1 + \mu)(\bar{\mathrm{A}} - \mathrm{FC})$ is a linear function of N, so it does not change the concavity of the overall program.

In conclusion, if the conditions SCLCC, SC2airport, and SC3airport are satisfied, it is possible to obtain a local maximum. If they are strictly satisfied, the maximum will be global. In the case of our specification, the conditions are as follows:

$$\frac{\partial^2 \mathcal{L}}{\partial N^2} = -2\alpha, \qquad \text{(CS1)}$$

$$\frac{\partial^2 \mathcal{L}}{\partial r^2} = -2\rho(1-\mu), \qquad \text{(CS2)}$$

$$\frac{\partial^2 \mathcal{L}}{\partial N^2}\frac{\partial^2 \mathcal{L}}{\partial r^2} - \left[\frac{\partial^2 \mathcal{L}}{\partial r \partial N}\right]^2 = -\beta^2(1+\mu) - 4\alpha\rho, \qquad \text{(CS3)}$$

for all values of $\mu \geq 0$.

SC1 < 0 and SC2 < 0 for all values of $\alpha > 0$, $r > 0$, and $\mu \geq 0$

SC3 > 0 if and only if [Take formula from pdf]

II - Proof of Proposition 2

The first-order conditions give:

$$\frac{\partial \mathcal{L}}{\partial N} \Leftrightarrow N^* = \frac{\bar{S}\beta(1+\mu^*) + 2\rho(\bar{N}\alpha + \gamma + \theta - \bar{a}\mu^* + \gamma\mu^*)}{4\rho\alpha - \beta^2(1+\mu^*)}, \qquad \text{(CN1)}$$

$$\frac{\partial \mathcal{L}}{\partial r} \Leftrightarrow r^* = \frac{2\bar{S}\alpha + \beta(\bar{N}\alpha - \gamma(1+\mu^*) - \theta + \bar{a}\mu^*)}{4\rho\alpha - \beta^2(1+\mu^*)}, \qquad \text{(CN2)}$$

$$\mu^*\left(\gamma N^* + CF - \bar{A} - r^*(\beta N^* - \rho r^* + \bar{S}) - \bar{a}N^*\right) = 0, \qquad \text{(CN3)}$$

for all values of $\mu^* \geq 0$.

Some of the constraints need to be verified to calibrate the model correctly. More specifically, we need to make sure that $N^* \geq 0$, $N^* \leq \bar{N}$, $r^* \geq 0$. There are two possible outcomes, based on whether the constraint is saturated or not. Let us suppose that $\mu^* = 0$:

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

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

$r^* \geq 0$ if and only if $\alpha \geq \alpha_3 = \frac{\beta(\gamma+\theta)}{\bar{N}\beta + 2\bar{S}}$, with $\alpha_3 > 0$ without any supplementary conditions.

The constraints all require a minimum value for α, so they are all compatible with each other. Next, we need to find the lower bound for relevant values of α. Let us compare α_2 and α_0. The sign of their difference $\alpha_2 - \alpha_0$ depends on the sign of $\left(-2\bar{S}\beta + \bar{N}\beta^2 + 4(\gamma+\theta)\rho\right)$, and this difference can be broken down into two sub-elements, $\left(-\bar{S}\beta + \bar{N}\beta^2 + 2(\gamma+\theta)\rho\right) > 0$ because $\alpha_2 > 0$, and $\left(-\bar{S}\beta + 2(\gamma+\theta)\rho\right) > 0$ if $\alpha 1 > 0$. So, the sign of the difference is positive, i.e., $\alpha_2 > \alpha 0$. In the same way, the sign of the difference between α_3 and α_0 depends on the same condition, and is therefore true for all admissible α parameters. Comparing the thresholds α_3 and α_1, as well as the thresholds α_2 and α_1, gives the same result: $\alpha_1 > \alpha_3$ and $\alpha 1 > \alpha_2$, under the condition that

$\alpha_1 > 0$ and $\alpha_2 > 0$. There is therefore no need for another condition to classify α_2 and α_3. We define $\alpha = \alpha 1$.

The aeronautical charge constraint is not saturated if the cap level set by the regulator is high enough. We cannot fully answer this question without first setting the parameters. However, there is a non-zero set of parameters for which $a^* < \overline{a}$. These parameters satisfy the sufficient constraint at the optimum:

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

If the parameters satisfy this constraint, we will not need to handle cases where $\mu^* > 0$.

The solution for the aeronautical charge is therefore a decreasing function of $\overline{A}$, as shown by the sign of the first derivative of a^* with respect to $\overline{A}$. After calculation, the sign of the derivative depends on the sign of the following expression. $\overline{S}\beta + 2\rho\left(\overline{N}\alpha - \gamma - \theta\right)$. This sign is negative for all $\alpha \geq \underline{\alpha}$.

The derivative of N* with respect to the externality parameter β is positive when $\alpha > \alpha_4 = \dfrac{\overline{S}\left(2\overline{S}\beta + \overline{N}\beta^2 - 4(\gamma+\theta)\rho\right)}{4\overline{N}\rho\left(\overline{S} + \overline{N}\beta\right)}$. This is not an additional constraint because the sign of the difference between α_4 and $\underline{\alpha}$ depends on the sign of $\left(-2\overline{S}\beta + \overline{N}\beta^2 + 4(\gamma+\theta)\rho\right)$, which we have already shown to be negative. For all values of $\alpha > \underline{\alpha}$, $\dfrac{\partial N^*}{\partial \beta} > 0$.

III - Proof of Proposition 3

In order to verify the profitability of the operation for the public investor, we must ensure that the airline's profit plus the airport's profit is greater than $\overline{A}$, the amount of aid provided, at the optimum. We must therefore verify that:

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

After calculations as part of our specification, the condition depends on the sign of the following expression:

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

First, we must ensure that the expression is non-negative for all possible parameters. The first part represents fixed costs and is negative. The second part depends on the parameter values. The third term is positive for $\alpha \in \left[\underline{\alpha}, \overline{\alpha}\right]$. We can therefore be certain of finding a subset of parameters that strictly satisfy this inequality. A condition might, for example, be set for the maximal value that fixed costs might take:

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

This threshold $\overline{CF}$ is positive if and only if:

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

This condition is true at the following sufficient condition: $\alpha > \alpha_4 = \frac{5\beta^2}{4\rho}$.

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