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Platform pricing and consumer foresight: The case of airports*

Ricardo Flores-Fillol[†] Alberto Iozzi[‡] Tommaso Valletti[§]

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Abstract

Airports have become platforms that derive revenues from both aeronautical and commercial activities. The demand for these services is characterized by a one-way complementarity in that only air travelers can purchase retail goods at the airport terminals. We analyze a model of optimal airport behavior in which this one-way complementarity is subject to consumer foresight, i.e., consumers may not anticipate in full the ex post retail surplus when purchasing a flight ticket. An airport sets landing fees, and, in addition, also chooses the retail market structure by selecting the number of retail concessions to be awarded. We find that, with perfectly myopic consumers, the airport chooses to attract more passengers via low landing fees, and also sets the minimum possible number of retailers in order to increase the concessions' revenues, from which it obtains the largest share of profits. However, even a very small amount of anticipation of the consumer surplus from retail activities changes significantly the airport's choices: the optimal airport policy is dependent on the degree of differentiation in the retail market. When consumers instead have perfect foresight, the airport establishes a very competitive retail market, where consumers enjoy a large surplus. This attracts passengers and it is exploited by the airport by charging higher landing fees, which then constitute the largest share of its profits. Overall, the airport's profits are maximal when consumers have perfect foresight.

Keywords: two-sided markets, platform pricing, one-way demand complementarity, consumer foresight.

JEL classification: L1, L2, L93.

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1 Introduction

The airport business is increasingly becoming a platform activity. Airports derive revenues from two different but interlinked sides: the so-called aeronautical activities offered to airline companies (where the landing charges paid by airlines represent the lion's share), and non-aeronautical revenues that relate to all commercial activities taking place inside the airport terminals, such as shops, food and beverage, car parking, etc. According to the management consulting firm Arthur D. Little (2009), airports aim to achieve 50% of their revenues from non-aeronautical sources, with retail representing the main source. In the five-year period 2005-09, airport retail revenues grew by 14% per year driven mainly by airports' strategy to develop non-aeronautical revenues. The 50% revenue split is confirmed by more recent industry reports (see, e.g., ACI, 2012; ATRS, 2013).

Airports have increased the floor space dedicated to duty-free shops significantly, focusing largely on core retail categories (Perfume and Cosmetics, Alcohol and Tobacco). In 2008, the retail project at Beijing Airport Terminal 3 was completed with the design of star architect Norman Foster and a staggering floor space of 1,000,000 m². It was the largest airport passenger terminal building in the world, soon to be surpassed by Dubai International Airport's Terminal 3 which has 1,700,000 m² of floor space. It is clear, however, that in order to do their shopping, passengers need to be attracted to the airport first and this happens only when they fly. The decision whether to fly is influenced by the fare charged by airlines, but it is also closely linked to variables chosen by airports. Most directly, the landing fee (i.e., the charge imposed to airlines for the use of the airport infrastructure) is part of the airlines' cost and, therefore, it affects the level of demand for air services when passed through to passengers into final flight fares. Landing fees can also have a sizeable external effect on the airport retail activities by affecting the number of passengers making use of the airport facilities. As a result, an increase in the landing fee may have a positive effect on the aeronautical revenues but, at the same time, a countervailing negative effect on commercial revenues due to the reduction in the number of passengers. As airports often enjoy considerable market power with respect to airlines, these landing fees are sometimes subject to regulation. Airports have recently claimed for a recognition of the two-sided nature of their business to show the limited degree of market power they enjoy in setting landing fees, which would justify lifting any regulatory constraint on these charges (Charles River Associates, 2013).

In this paper we propose a model to study the optimal pricing strategy of an

airport that operates a platform that can generate revenues both from traditional aeronautical activities and from non-aviation (retail) activities. Should an airport use its market power to ask for relatively high landing fees, even though this may risk shrinking demand for commercial services? Should the airport allow for several concessions for similar services (e.g., various competing coffee shops), or should it instead limit within-airport competition, awarding only very few concessions per type of service, thus enhancing the revenues that can be extracted from firms bidding for the concessions? The answer must lie in unraveling the extent to which a better customer experience at the airport terminal can, in turn, enhance the demand for flight services.

Our model introduces three important and novel contributions to the existing literature on airport pricing. First, we make explicit the *one-way complementarity* between the demand for air travel and retail products. Air services are bought by consumers as a primary product, while retail services play the role of the secondary product, being demanded exclusively by those who consume the primary product. Second, we model the degree of *consumer foresight*, that is, the extent to which passengers anticipate, at the time of purchasing their flight, the retail consumer surplus they will obtain when at the airport terminal. Third, our paper is also the first to recognize the endogenous nature of the *market structure* in the airport retail activities; the airport itself determines the market structure of the retail market through different instruments, such as the number and the composition of the concessions awarded, the type of contract used or the layout of the airport premises.¹

We build a model that derives the demand functions for air travel and retail services, where the demand for air travel depends on the expected surplus that the consumer anticipates to obtain from the consumption of the retail good. Then we perform a two-stage equilibrium analysis. In the first stage, the airport sets the landing fee and chooses the number of retailers allowed to operate concessions in its terminals. In the second stage, retail firms and airlines simultaneously choose their prices and quantities, respectively. To analyze how consumer foresight affects the equilibrium outcome, we distinguish along the analysis among perfectly myopic

¹On the other hand, although the airport chooses the landing fee to be charged to airlines, it has a limited capacity (sometimes no capacity at all) to determine the airline market structure. In Europe, airports have no power to determine the airline market structure since the use of slots is based on rules such as ‘grandfather rights’ (i.e., an operator which currently uses a slot can retain the slot each period) or ‘use-it-or-lose-it’ rules (i.e., airlines must operate slots as allocated by the coordinator at least 80% of the time during a season to retain historical rights to the slots). In the US, airlines typically sign contracts with airport authorities to regulate the access to the infrastructure and they do not need to own slots.

consumers, almost myopic consumers, and forward looking consumers.

Our main findings can be summarized as follows. In the presence of perfectly myopic consumers, the solution is simple: the airport chooses the minimum possible number of retailers and a landing charge strictly lower than the standard monopoly charge. This is because there is no reason to introduce any retail competition: the maximum retail profits will be extracted, and this has no impact on ex ante demand for flights, as consumers are myopic. As for landing fees, the airport can exploit the complementarity between aeronautical and retail activities by attracting more passengers with lower landing fees, as passengers will then purchase a certain amount of retail goods at the airport's terminal. In other words, under consumer myopia the airport platform makes most money from retail services, and less money (even zero, under some parameter configurations) from landing fees.

This result changes as soon as one departs from the assumption of consumer myopia. Looking at the extreme case of perfectly forward looking consumers, we find that the relative importance of the two revenue sources is exactly reversed. The airport chooses a very competitive retail sector and, because of the very intense retail competition, does not derive profits from the retail sector. However, forward-looking consumers do anticipate the benefits they will receive from purchases at the airport's terminal, and therefore their demand for the complementary main product, flights, is expanded and the airport can charge much higher landing fees to the airlines. With almost myopic consumers, the result depends on the degree of product differentiation in the retail sector. When there is little differentiation, strong competition among retailers makes the airport prefer the most concentrated retail structure, but it also raises the landing fee (as compared to the case with perfectly myopic consumers) since some retail consumer surplus is now anticipated by air travelers. When differentiation is large, the airport instead prefers not to derive profits from aeronautical services (thus setting landing fees to zero) and boost the expected consumer surplus by awarding a certain number of concessions to additional retailers.

As illustrated above, the balance of the airport's profits between aeronautical and retail activities changes dramatically with the consumers' foresight. In equilibrium, we find that the highest aggregate profits are always obtained when consumers have perfect foresight. However, profits are not monotonic in the degree of foresight, and we find conditions such that a small increase in their foresight decreases profits.

While airports and their characteristics represent the motivation for the model

of platform pricing that we analyze, it is easy to think of other settings to which the model could be applied, with suitable adaptations. In general terms, we study pricing when a supplier offers a primary and a secondary good, and where, in order to purchase the secondary good, the consumer must have initially purchased the primary good. We have in mind a situation where the primary good is more ‘salient’ in the initial purchasing decision, compared to the secondary good’s consumption that can be decided after the initial purchase. Saliency here corresponds to our degree of consumer foresight. In the case of airports, the primary good is the (derived) demand for passengers, while the secondary good is some retail activity at the terminal. Applications can be manifold: people may go to shopping malls for a primary activity (e.g., going to a movie theater) but may end up also purchasing a secondary good (a meal, or some other type of shopping); hotels charge for rooms, but may also additionally sell in-room services (telephone calls, laundry, meals) that are not necessarily anticipated when booking a room; banks usually offer interests (i.e., a negative price) on bank accounts, but set different charges for overdrafts or other banking services that the consumer may not take fully into account when choosing the bank; even mobile phones can be seen as platforms that sell a primary product (a bundle of minutes for calls and text messages), but also supply secondary services whose consumption (and costs) may not be perfectly anticipated by users (such as international roaming charges, or downloads of certain applications). In these examples, the degree of vertical integration and delegation varies (for hotels or banks, for instance, most secondary goods are directly supplied by the supplier of the primary product) but the question of market structure is still of general interest. For shopping malls, the setting for the secondary product is very close to ours: as with airports, the mall chooses the type of retailers, but cannot determine directly the price of their goods. Also, mobile providers have to decide whether to make their platform open (which possibly makes entry by app providers easy, leading to competitively-priced secondary products) or closed (in which case the mobile platform would try to share the rents that could eventually accrue to the app providers, for instance by proposing exclusivity fees). While each setting would have its distinguishing features, our model is useful generally to think about these other environments too.

The paper is organized as follows. In Section 2 we relate our paper to the existing literature. In Section 3 we present the model and derive the demand functions for air travel and for retail services. Then in Section 4 we perform the equilibrium analysis, distinguishing between the cases of perfectly myopic consumers, almost myopic consumers, and forward looking consumers. Finally,

Section 5 concludes. Proofs are provided in the Appendix.

2 Literature review

The two-sided platform nature of the airport business is often cited (Zhang and Zhang, 1997; Starkie, 2001; Wright, 2004; Gillen, 2011; Gillen and Mantin, 2012; Ivaldi *et al.*, 2012), although few formal treatments exist.² While our paper is the first to study an airport’s optimal pricing strategy to both sides, including the optimal concentration of the retail business, there is a large literature on airport pricing. Zhang and Zhang (2010) and Kratzsch and Sieg (2011) assume perfectly rational consumers that purchase both air and retail services. Czerny (2006) considers demands for aeronautical and concessions services to be perfectly linked. D’Alfonso *et al.* (2013) provide a more elaborated model on the relationship between retail and air travel demand, where the demand for retail services depends on the number of air travelers. A common element in all these papers is the presence of three groups of stake-holders (passengers, airlines, and airport), but no strategic behavior is considered for retail firms. Another important difference of our contribution with respect to the existing literature on airport pricing has to do with the aim of the paper. While the previous literature has traditionally adopted a normative approach to discuss the effect of different types of airport regulation in the presence of congestion, our purpose is to provide a broader positive analysis of the effect of consumer foresight on platform pricing. To keep the model as transparent as possible, we do not incorporate airport congestion.³

As compared to other platforms, airports have their own peculiarities derived from the one-way complementarity between the demand for air services (primary good) and retail services offered at the terminals (secondary good). In our model, at the moment of purchasing the flight ticket, consumers may not correctly anticipate the surplus they will obtain from the retail good once in the airport. This imperfect anticipation is the result of several phenomena. First, consumers may suffer from myopia (to a varying degree) because the nature of their utility function makes them (partly or fully) unable to take into account future purchases when buying the primary good. This is in line with a number of studies studying the issue of limited rationality in solving consumption problems (Strolz, 1995;

²The first papers to study two-sided markets are Caillaud and Jullien (2003), Parker and Van Alstyne (2005), Armstrong (2006), and Rochet and Tirole (2003 and 2006).

³The literature on congestion pricing focuses on the question of whether a hub operator will internalize the congestion externality; see Daniel (1995), Brueckner (2002), Mayer and Sinai (2003), and Rupp (2009).

and Busse *et al.*, 2013). Secondly, rational consumers purchasing more than one product may not be fully informed on the terms prevailing in all the markets (Lal and Matutes, 1994; Verboven, 1999; and Gans and King, 2000). Finally, before arriving at the airport terminal, consumers are assumed not to know for certain (but simply to have an expectation) their preferences for the retail good. This aims at capturing the fact that, at the time of buying the flight ticket, a passenger does know exactly whether she will want, say, to spend time in a restaurant for a meal or simply go to a bar for a coffee, as this depends on contingencies that cannot be foreseen when booking the flight. This feature of our model is also shared in other contexts. For instance, in behavioral economics, there are papers where uninformed consumers do not know their ideal taste *ex ante* and, thus, they are uncertain as to which product they will finally buy. Therefore, they experience *ex ante* uncertainty in the price and match-value dimension, and form reference-point distributions in these two dimensions (Heidhues and Köszegi, 2009; and Karle and Peitz, 2014).⁴

A large body of literature has studied markets where primary and secondary goods are traded (or, with alternative definitions, markets with aftermarkets, or markets for standard goods and add-ons). This same issue has been tackled by Oi's (1971) classic study of two-part pricing by a Disneyland monopolist, where he concludes that the firm can extract completely the consumer surplus with the fixed admission fee, while setting the price of rides at marginal cost. This result arises as consumers are assumed to have the same behavior with respect to rides, so that there is no reason to introduce metering as a screening device. Although we obtain a similar result as in Oi (1971) when consumers are sufficiently forward-looking, this result breaks down completely as consumers exhibit a certain degree of myopia, despite the fact that the *ex post* demand is homogenous across consumers. Our model departs from this literature in three ways. First, prices for the secondary good are not directly set by the monopolist, but are determined by the strategic interaction between independent retailers. The only way the airport has to affect retail prices is via the number of concessions.⁵ Second, the

⁴This *ex ante* uncertainty has also been applied in the literature on product returns (Shulman *et al.*, 2011). A similar hypothesis is made by Gal-Or (1997 and 1999) in the context of the health industry where a consumer is asked to choose between two insurance companies which have a direct relationship with two differentiated hospitals, and only after getting ill she observes her preference parameter between the two hospitals. Finally, in a model of airline scheduling, Brueckner (2004) assumes that passengers, when purchasing their flight tickets, do not know their preferred departure time and then they look at airfares and their expected average schedule delay (which is decreasing with the airline's flight frequency).

⁵In the context of the mobile application industry, Gans (2012) studies the effects the differ-

surplus consumers derive from the secondary goods does not depend only on their prices, like in Oi, but also on the number of varieties (in our model, the number of concessions) and therefore on transportation costs. Third, we study explicitly the role of consumer foresight, which is not part of Oi’s analysis.

Some recent literature has looked at the problem of primary and secondary products typically in oligopoly markets with different types of consumers.⁶ Two general findings in this literature should be recalled. The first one underlines that the distortion on prices is larger the lower is the degree of demand complementarity, the less able are the consumers to forecast future prices, and the more different are the consumers’ types in the market. The second one points out that the platform’s profitability is higher the less able are the consumers to anticipate the net benefits they obtain from the secondary good (typically for informational problems).

Finally, our problem shows similarities with the vast literature on shopping malls (see Carter, 2009, for a survey). Part of this literature is concerned with the instruments to internalize the externalities between the different outlets within a shopping mall, and between the shopping mall and the neighboring activities/properties. The most commonly investigated instruments are the composition of the commercial outlets (Hagiu, 2009), the nature of the contracts between the landlord and the commercial outlets (Miceli and Sirmand, 1995; Pashman and Gould, 1998), control rights over non-contractible decisions (Hagiu and Wright, forthcoming), the allocation of space within the shopping mall (Brueckner, 1993), and its geographical locations (Carter and Vandelland, 2006). The literature on platforms has also studied when technological hubs should be proprietary or open (Economides and Katsamakas, 2006; Boudreau, 2010; Huang *et al.*, 2013; and Casadesus-Masanell and Llanes, forthcoming), or when additional content should be given out for free (Hagiu and Spulber, 2013). Our paper is more limited in scope in that, for instance, we do not analyze the incentives to innovate in complementary products. However, we do share the view that retailing activities can be made more or less competitive so that consumers can enjoy a varying degree of surplus, which is an equivalent to making the platform more ‘open’ to complementary products. The difference is that, in our basic setting, the consumer purchases only one retail product *ex post*, and thus there is no obvious demand-expansion channel for the platform, leading to more retailing activities because

ent structures of contractual and pricing arrangements between a platform owner and a content provider.

⁶See Klemperer (1995), Ellison (2005), Gabaix and Laibson (2006), and Shulman and Geng (2013).

this eventually results in customers purchasing more products. In our model, retailing activities can affect ex ante consumer surplus only from expected retail prices.

3 The model

An airport operates as a monopolist in providing both aeronautical services and retail commercial services. Aeronautical services are sold to n_A airline companies competing *à la* Cournot to supply passengers; airlines pay a per passenger fee, denoted as ℓ (landing charge), to the airport for the use of the airport infrastructure. The airport also awards concessions to retailers that trade in the airport commercial area; the airport chooses the number of retail concessions, denoted as n_R , and awards them by means of an auction. The n_R retailers are symmetrically located along a Salop circle of unit length and compete by setting prices to customers.

Passengers derive their utility from the consumption of flights and retail goods. Passengers decisions are made in a two-step process: first, they purchase their flight tickets; second, they make their retail purchases once in the airport. Hence, only passengers who fly may also buy the retail goods, so that the retail market is a pure complement to the airline market (but not vice versa).

We consider a two-stage game model with the following sequence of actions. In the first stage, the airport sets a uniform landing charge for airlines and selects the number of retailers. In the second stage, airline companies compete by choosing simultaneously and non-cooperatively their quantities, and retailers simultaneously and non-cooperatively set their retail prices at the airport. Once these decisions are made, passengers make their flight and retail purchases, and payoffs are collected. We analyze a game of full information and use subgame perfection as the equilibrium concept.

Air travel demand. Each passenger is characterized by a parameter, z , which illustrates her travel benefit, i.e., the utility she derives from consuming the (homogeneous) flight service. The utility of a potential passenger is given by

$$U(p_A, \mathbf{p}_R; z, \delta) = z + \delta CS(\mathbf{p}_R) - p_A, \quad (1)$$

where p_A is the airfare and $\mathbf{p}_R = (p_1, p_2, \dots, p_{n_R})$ is the vector of prices set by the n_R vendors of the retail good; z is the benefit passenger z receives when traveling,

uniformly distributed over the support $(-\infty, 1]$, with unit density.⁷ Note that $CS(\mathbf{p}_R)$ is the *expected* retail consumer surplus that the consumer anticipates to derive from the consumption of the retail good (to be discussed later). The parameter $\delta \in [0, 1]$ tells if and how much the consumer takes into account the utility she derives from the consumption of the retail good when making her flight purchase decision: if $\delta = 0$, the consumer is perfectly myopic and the flight is bought based only on the utility the consumer derives strictly from it; while, if $\delta = 1$, the consumer has perfect foresight and fully anticipates the retail consumer surplus at the airport already when purchasing the flight. Values of δ between 0 and 1 denotes intermediate cases of foresight.

Each consumer purchases at most one flight ticket, as long as the net utility is non-negative, i.e., $U(\cdot) \geq 0$. Let \tilde{z} be the flight utility parameter of the consumer that is just indifferent between flying and not flying. In other words, $U(p_A, \mathbf{p}_R; \tilde{z}, \delta) = 0$ so that

$$\tilde{z}(p_A, \mathbf{p}_R) \equiv p_A - \delta CS(\mathbf{p}_R). \quad (2)$$

Since z is uniformly distributed below 1, then the aggregate demand for flights (i.e., the number of passengers traveling from the airport) is

$$Q_A(p_A, \mathbf{p}_R) = 1 - \tilde{z}(p_A, \mathbf{p}_R) = 1 - p_A + \delta CS(\mathbf{p}_R), \quad (3)$$

whenever this is positive.

Retail market demand. The n_R retailers sell an homogeneous good and are symmetrically distributed on a Salop circle of length 1, with $n_R \geq 2$.⁸ Since access to the retail market is only available to passengers, the mass of potential passengers/consumers is equal to $Q_A(p_A, \mathbf{p}_R)$. All these consumers have a unit demand for the retail good. Each consumer has a taste parameter for the (differentiated) retail good, denoted by x , which is uniformly distributed over the support $[0, 1]$ and is taken to be their position along the unit circle.⁹

⁷The distribution is unbounded from below simply in order to have an elastic demand for airlines. This avoids having to introduce case distinctions when the passengers' market could be fully covered.

⁸In the Salop model, it is standard to analyze the case with at least two firms. We could easily allow for a retailer monopolist, but the solution for the monopoly price would be analytically different from the one in case of 2 or more firms. Having $n_R \geq 2$ avoids this case distinction, which is not central for our analysis.

⁹We consider a retail market in which all retailers offer goods which are substitute to one other. In reality, one may find many non-substitutable products at any airport terminals, like

For a consumer located at x along the circle, retail utility when buying from the nearby retail firm located in x_i is given by $u = v - p_i - t |x - x_i|$. We assume that v is always sufficiently high so that the market is fully served. As it will become clear at a later stage, this is always true when

$$v > \frac{5}{8}t, \quad (4)$$

which is assumed hereafter.

Individual firm's demand is derived in the standard way. Assume one of the n_R retailers is located at 0, and call it firm i . The symmetry of its rivals' locations implies that one of the nearby firms, say firm j , is located at $1/n_R$. The marginal consumer between firm i and j , denoted by x_{ij} , is found by equating the utility derived from buying from either firm, resulting in

$$\tilde{x}_{ij} = \frac{1}{2n_R} + \frac{p_j - p_i}{2t}. \quad (5)$$

Assuming symmetry in the prices set by all the rival firms to firm i , the market share for firm i is given by

$$x_i(p_i, p_j) = 2\tilde{x}_{ij} = \frac{1}{n_R} + \frac{p_j - p_i}{t}, \quad (6)$$

and the demand for firm i becomes $X_i(p_i, p_j; \mathbf{p}_R) = x_i(p_i, p_j) Q_A(p_A, \mathbf{p}_R)$.

To save on notation, retailers' costs are normalized to zero. Thus retailer i 's profits are given by

$$\pi_i = p_i X_i(p_i, p_j; \mathbf{p}_R) = p_i \left(\frac{1}{n_R} + \frac{p_j - p_i}{t} \right) [1 - p_A + \delta CS(\mathbf{p}_R)]. \quad (7)$$

The above expression makes it clear that a retailer's profits depend on the number of traveling passengers, which, in turn, depends on their expectation on the consumer surplus they enjoy in the retail market.

When deciding whether or not to buy the flight ticket, consumers are not yet

food and clothing. A simple way to include this feature in our model would be to imagine several Salop circles, each one for retailers selling goods which are substitute to one other but not to goods offered by other retailers located on a different circle. In this case, we could easily endogenize the number of non-competing varieties (i.e., the number of circles). This extension would magnify the effect of the retail activities in our model. A more challenging extension is one with consumers being budget constrained; this would possibly add an issue of cross-substitutability among varieties (channeled through income effects) that is outside the scope of our analysis.

aware of their location on the unit circle. In other words, a passenger does not know in advance whether she will want, say, to spend time in a restaurant for a meal or simply go to a bar for a coffee, as this depends on contingencies that cannot be foreseen when booking the flight. Only on the day of the flight the precise taste parameter (the location x in our model) will be revealed. Still, a passenger may anticipate she will want either a coffee or a meal on the day she flies. Therefore, passengers are able only to form an expectation of the surplus they will be able to enjoy in this market. Passengers' priors consider that each location along the Salop circle is equally likely.¹⁰ Hence, the value of the expected surplus when one retailer charges p_i and all other retailers charge symmetrically p_j (let \mathbf{p}_j denote the vector of these prices) can be expressed as follows

$$\begin{aligned} CS(p_i, \mathbf{p}_j) = & 2 \int_0^{x_{ij}} (v - p_i - tx) dx \\ & + 2 \int_{x_{ij}}^{\frac{1}{n_R}} \left[v - p_j - t \left(\frac{1}{n_R} - x \right) \right] dx \\ & + \frac{n_R - 2}{n_R} \left(v - p_j - \frac{t}{4n_R} \right). \end{aligned} \quad (8)$$

The first term is the expected value of the utilities of the consumer who expects to be located on the right-side (clockwise) of firm i and purchase from it; this is multiplied by 2 to include the same expectation on the left-side of firm i . The second term is the expected value of the utilities of the consumer who expects to purchase from the first retailer j on the right of firm i (hence at a distance $\frac{1}{n_R} - x$ away from j); this is again multiplied by 2 for the same argument. The last term represents the expected utilities from purchasing with the remaining $n_R - 2$ symmetric firms.

Using (5), the expected retail consumer surplus in (8) becomes

$$CS(p_i, \mathbf{p}_j) = v - p_j - \frac{t}{4n_R} + \frac{p_j - p_i}{n_R} + \frac{(p_j - p_i)^2}{2t}. \quad (9)$$

This is the value that passengers *may* anticipate, according to their degree of foresight, δ , when booking a ticket.

¹⁰An alternative approach would be to assume that consumers, at the time of buying their flight ticket, know their location, but do not know the firms' locations along the Salop circle. The two approaches lead to identical expressions for the expected consumer surplus.

4 Equilibrium analysis

In this Section, we first analyze the second-stage equilibrium in which retailers and airlines choose their prices and quantities, respectively (Subsection 4.1). Then we consider the first-stage equilibrium in which the airport chooses landing charges and the number of retail concessions (Subsection 4.2). Finally, we examine the implications of the equilibrium analysis in terms of airport's profits (Subsection 4.3).

4.1 Second-stage equilibrium

We solve for the second-stage equilibrium, when retail firms and airlines simultaneously choose their prices and quantities, respectively.

Retail market. We first analyze the problem faced by the retail firms. Each retail firm chooses its price to maximize its profits given in (7), where $CS(\cdot)$ is as in (9). Formally, retail firm i 's problem can be expressed as follows

$$\begin{aligned} \max_{p_i} \pi_i(p_i, \mathbf{p}_j) = & p_i \left(\frac{1}{n_R} + \frac{p_j - p_i}{t} \right) \\ & \times \left[1 - p_A + \delta \left(v - p_j - \frac{t}{4n_R} + \frac{p_j - p_i}{n_R} + \frac{(p_j - p_i)^2}{2t} \right) \right]. \end{aligned} \quad (10)$$

Then the following Proposition can be formulated.

Proposition 1. *The optimal retail price is given by*

$$p_R(p_A) = \frac{t\delta(4 + 3n_R) + 4\gamma n_R^2 - \sqrt{16t\delta n_R^2(t\delta - \gamma n_R) + [t\delta(4 + 3n_R) + 4\gamma n_R^2]^2}}{8\delta n_R^2}, \quad (11)$$

where $\gamma \equiv 1 - p_A + v\delta$. When $\delta > 0$, this optimal retail price is always below the Salop equilibrium price, i.e.,

$$p_R(p_A)|_{\delta>0} < p_R(p_A)|_{\delta=0} = \frac{t}{n_R}. \quad (12)$$

This Proposition characterizes the optimal retail price as a function of the price prevailing in the airline market, p_A . Notice that, in case of perfectly myopic consumers (i.e., $\delta = 0$), (11) reduces to $p_R = t/n_R$, the standard Salop symmetric equilibrium price. In this limiting case, there is no interaction between the airline and the retail markets: retail competition does not affect the airport's derived

demand, since passengers do not anticipate any surplus from commercial services. By contrast, when retailers face forward looking consumers (i.e., $\delta > 0$), they always have an incentive to set a price *lower* than in the case of myopic consumers. Indeed, with forward looking consumers, a lower retail price increases the number of travelers, which in turn positively affects the retailer's profits.

Airline market. In the airline market, airlines compete by choosing simultaneously and non-cooperatively their quantities, denoted as q_k for the generic k -th airline. In line with the literature, aeronautical services are sold to airline companies at a uniform fee per passenger, denoted as ℓ (landing charge).¹¹ All other costs are assumed to be linear, identical across airlines and, without further loss of generality, normalized to zero. Airline k 's profits are

$$\pi_k = [p_A(q_k, Q_{-k}) - \ell] q_k, \quad (13)$$

where Q_{-k} denotes the sum of quantities offered by the other $n_A - 1$ firms. Using (13) and inverting (3), we can write the maximization problem for airline k as follows

$$\max_{q_k} \pi_k = [1 + \delta CS(p_R) - q_k - Q_{-k} - \ell] q_k. \quad (14)$$

where we suppress, from now onwards, the vector notation in $CS(\cdot)$ due to the symmetry of retail prices.

Differentiating with respect to q_k and exploiting symmetry at equilibrium ($Q_{-k} = (n_A - 1)q_k$), we obtain the equilibrium quantity for an airline

$$q_A(p_R) = \frac{1 - \ell + \delta CS(p_R)}{n_A + 1}. \quad (15)$$

Notice that this is a *standard* Cournot expression for a linear demand with n_A competitors and marginal cost equal to ℓ (that is, $\frac{1-\ell}{n_A+1}$), plus a term $\delta CS(p_R)$ that acts as a demand shifter and depends on the extent to which consumer surplus from retail activities exists and is internalized by passengers when booking tickets.¹²

Finally, we have that $p_A = 1 - n_A q_A + \delta CS(p_R)$, where $CS(p_R) = v - p_R - \frac{t}{4n_R}$ (which comes from (9) after applying symmetry). Note that since $p_R \leq t/n_R$ and $n_R \geq 2$, assumption (4) ensures that $CS(p_R) > 0$. Using (15), we finally obtain

¹¹This is employed, for instance, by Zhang and Zhang (2006), Czerny (2006 and 2013), Zhang and Zhang (2010), Kratzsch and Sieg (2011), D'Alfonso *et al.* (2013), and Haskel *et al.* (2013).

¹²The first-order condition yields $\partial \pi_k / \partial q_k = 1 + \delta CS(p_R) - 2q_k - Q_{-k} - \ell$. It is straightforward to verify that the second-order condition holds.

the equilibrium airfare

$$p_A(p_R) = \frac{n_A \ell + 1}{n_A + 1} + \delta \frac{v - p_R - \frac{t}{4n_R}}{n_A + 1}. \quad (16)$$

As before, the first term is the standard equilibrium price in a Cournot model. The second term is instead the consumer's surplus in the retail market. The higher is the expected surplus and the higher is the consumers' foresight, the greater is the outward shift of the demand curve and therefore the equilibrium price.

Properties of second-stage equilibrium. Using (11) and (16), it is now possible to solve for the second-stage equilibrium airfare and retail price. As the resulting expressions for these second-stage equilibrium retail and airline prices are rather cumbersome and not needed for the analysis that follows, we do not present the explicit expressions here. Some useful comparative statics results are shown instead in the following Proposition.

Proposition 2. *In the second-stage, the equilibrium retail price varies as follows with respect to the landing charge and the number of retailers:*

$$\left. \frac{\partial p_R}{\partial n_R} \right|_{\delta=0} < 0; \quad \left. \frac{\partial p_R}{\partial n_R} \right|_{\delta>0} \leq 0; \quad \left. \frac{\partial p_R}{\partial \ell} \right|_{\delta=0} = 0; \quad \left. \frac{\partial p_R}{\partial \ell} \right|_{\delta>0} < 0.$$

In the standard Salop model, where the price is equal to t/n_R , it is obvious that the retail price p_R decreases in the number of competing retailers with myopic passengers. As we show in the proof, this feature typically carries over also to the case of forward looking consumers, despite a countervailing force due to the market expansion effect when consumers anticipate retail surplus. It is only under particular circumstances that this intuitive result may be reversed (a necessary but not sufficient condition is that δ is very large, n_A is very small and also v is very small). As for the landing fee, it is interesting that the retail price decreases in the landing fee for every $\delta > 0$. An increase in ℓ causes directly an increase in the airfare, so that passengers reduce their demand both for flights and for commercial services; as a consequence, retailers try to counteract this effect by decreasing their retail prices.

4.2 First-stage equilibrium

In the first stage, the airport sets the landing fee and chooses the number of retailers allowed to operate concessions in its terminals. We assume that the

concessions are awarded competitively by means, e.g., of a first-price sealed-bid auction to many potential firms, all identical, bidding non-cooperatively for the concessions. This implies that the airport is able to fully extract any profits deriving from the retail side. We can then write the airport's profits as follows

$$\Pi(\ell, n_R) = n_A q_A(p_R)(\ell + p_R), \quad (17)$$

where we assume no airport costs (which are irrelevant in our analysis on the optimal choice of ℓ and n_R). At an interior solution, the following first-order conditions must hold

$$\frac{\partial \Pi}{\partial \ell} = q_A \left(1 + \frac{\partial p_R}{\partial \ell} \right) + \left(\frac{\partial q_A}{\partial \ell} + \frac{\partial q_A}{\partial p_R} \frac{\partial p_R}{\partial \ell} \right) (\ell + p_R) = 0, \quad (18)$$

$$\frac{\partial \Pi}{\partial n_R} = q_A \frac{\partial p_R}{\partial n_R} + \left(\frac{\partial q_A}{\partial n_R} + \frac{\partial q_A}{\partial p_R} \frac{\partial p_R}{\partial n_R} \right) (\ell + p_R) = 0, \quad (19)$$

where $q_A = \frac{1+\delta(v-p_R-\frac{t}{4n_R})-\ell}{1+n_A}$, $\frac{\partial q_A}{\partial \ell} = -\frac{1}{1+n_A}$, $\frac{\partial q_A}{\partial p_R} = -\frac{\delta}{1+n_A}$, and $\frac{\partial q_A}{\partial n_R} = \frac{\delta t}{4(1+n_A)n_R^2}$, while $\frac{\partial p_R}{\partial \ell}$ and $\frac{\partial p_R}{\partial n_R}$ are as characterized in Proposition 2. The solution to this maximization problem is complex in general, as the Hessian matrix of the profit function is not negative definite everywhere, and we must additionally check that $\ell \geq 0$ and $n_R \geq 2$. Still, we can go a considerable way by looking at analytical solutions in some important limiting cases, before resorting to numerical solutions.

Perfectly myopic consumers ($\delta = 0$). We start by looking at the limiting case of perfectly myopic consumers, i.e., $\delta = 0$. In this case, there is no interaction between airport and commercial services, and the cross effects $\partial q_A / \partial p_R$, $\partial q_A / \partial n_R$, and $\partial p_R / \partial \ell$ all simplify to zero. When evaluated at the second-stage equilibrium, the first-order conditions (18) and (19) reduce to

$$\frac{\partial \Pi}{\partial \ell} = 1 - 2\ell - \frac{t}{n_R} = 0, \quad (20)$$

$$\frac{\partial \Pi}{\partial n_R} = -\frac{n_A t (1 - \ell)}{(n_A + 1) n_R^2} = 0. \quad (21)$$

From inspection of (3), it is immediate to see that ℓ cannot exceed 1 when $\delta = 0$, given that $p_A \geq \ell$. Hence, (21) is negative everywhere and the airport will always choose to award a number of concessions resulting in the maximum admissible concentration, which is $n_R = 2$ under our model assumptions. An interior solution for ℓ is instead possible, depending on the value of t . This is formalized in the following Proposition.

Proposition 3. *Let $\ell^*|_{\delta=0}$ and $n_R^*|_{\delta=0}$ be the equilibrium landing fee and number of retailers respectively, when consumers are perfectly myopic. Then*

$$i) \ell^*|_{\delta=0} = \begin{cases} \frac{1-\frac{t}{2}}{2} & \text{if } t < 2, \\ 0 & \text{if } t \geq 2, \end{cases}$$

$$ii) n_R^*|_{\delta=0} = 2.$$

Therefore, the airport chooses the minimum possible number of retailers and a landing charge strictly lower than $1/2$. This result is easy to interpret. First, with perfectly myopic passengers, retail profits are obviously maximized with fewer retailers, and this does not backfire as passengers do not foresee the resulting higher retail price when booking their flights. Second, and precisely because passengers are very lucrative to the airport once they are attracted there, the airport has an incentive to set a landing charge which is lower than the standard monopoly charge that an airport that cannot internalize the profits accruing from retail activities would otherwise charge. This is because the airport can exploit the complementarity between aeronautical and retail activities by attracting more passengers that will purchase a certain amount of retail goods at the airport's terminals. If t is sufficiently high (that is, the only two retailers are highly differentiated and compete very little against each other), the landing fee can even be set at zero: the airport prefers in this case to make no profits from airlines, but extract as much as possible from the retail side.

Almost myopic consumers ($\delta \rightarrow 0$). We now look at the case of almost myopic consumers. In other words, we investigate the effect on ℓ^* and n_R^* of an infinitesimal increase from 0 of the parameter δ . Our results are summarized in the following Proposition.

Proposition 4. *Let $\ell^*|_{\delta \rightarrow 0}$ and $n_R^*|_{\delta \rightarrow 0}$ be the equilibrium landing fee and number of retailers when δ is positive but infinitesimally small. Let also $t_1 \equiv \frac{8(1+\delta v)}{4+5\delta}$ and $t_2 \equiv \frac{4n_A(1+\delta v)}{\delta(3+8n_A)}$. Then*

$$i) \ell^*|_{\delta \rightarrow 0} \cong \begin{cases} \frac{1-\frac{t}{n_R}}{2} + \frac{\delta}{8} \left(4v - \frac{5t}{n_R} \right) & \text{if } t \leq t_1, \\ 0 & \text{if } t > t_1, \end{cases}$$

$$ii) n_R^*|_{\delta \rightarrow 0} \cong \begin{cases} 2 & \text{if } t < t_2, \\ \frac{5\delta t n_A + \sqrt{\delta t n_A [25\delta t n_A + 48(n_A + 1)(1+\delta v)]}}{4n_A(1+\delta v)} & \text{if } t \geq t_2. \end{cases}$$

The first point to note is that the optimal choices detailed in the Proposition are approximated values since they are obtained using the first-order Taylor's expansions around $\delta = 0$ of (18) and (19). Clearly, the accuracy of these approximations increases the smaller is the value of δ . In the limiting case of $\delta = 0$, the

optimal choices we find are indeed identical to $\ell^*|_{\delta=0}$ and $n_R^*|_{\delta=0}$; this can be seen immediately by substituting $\delta = 0$ into $\ell^*|_{\delta \rightarrow 0}$ and $n_R^*|_{\delta \rightarrow 0}$ and noting that, when $\delta = 0$, the threshold t_1 equals 2 while t_2 goes to infinity.

Proposition 4 illustrates that even a very small degree of foresight can have a significant impact on the airport's optimization choices. When t is sufficiently small, there is little differentiation and possibly too strong competition among retailers, hence the airport still chooses the most concentrated retail market structure. However, as the retail consumer surplus is now partly anticipated by passengers, there is an upward demand shift for flights that induces the airport to increase its landing fee above the *myopic* landing fee (i.e., $\ell^*|_{\delta=0}$). Hence, $\ell^*|_{\delta \rightarrow 0}$ is strictly greater than $\ell^*|_{\delta=0}$ and this fee can also increase above the standard monopoly level, which is $1/2$ in this model with linear demand and unit intercept.

When instead t is high enough, the airport sets the landing fee to zero, as in Proposition 3, and derives no profits from aeronautical services. But now, in order to attract more passengers to retail services, it prefers to boost their expected consumer surplus by awarding concessions to additional retailers, so that $n_R^* > 2$ when t is high enough. While this has a depressing effect on ex post retail profits, the ex ante demand expansion effect of having additional passengers prevails.

Forward looking consumers ($\delta \gg 0$). We finally consider the case of consumers with foresight about the retail market when making flight purchases. We can still find full analytical solutions when the consumer preference parameter δ is *large* enough. When instead the parameter δ is not so large, the highly non linear nature of the problem at hand prevents us from fully characterizing the optimal airport's choices analytically. We then resort to numerical methods to illustrate that the solutions' features highlighted for very low and very large values of δ actually carry over also for intermediate values of δ . We start by stating the following Proposition.

Proposition 5. *Let $\ell^*|_{\delta \geq \frac{4}{5}}$ and $n_R^*|_{\delta \geq \frac{4}{5}}$ be the equilibrium landing fee and number of retailers respectively, when consumers are forward looking with $\delta \geq 4/5$. Then*

- i) $\ell^*|_{\delta \geq \frac{4}{5}} = \frac{1}{2} (1 + \delta v)$,
- ii) $n_R^*|_{\delta \geq \frac{4}{5}} \rightarrow \infty$.

The nature of the airport's optimal solution now changes completely. When δ is above the critical value of $4/5$, the airport has the incentive to make the retail market as fragmented as possible, in order to increase the surplus consumers can obtain when purchasing the retail good at the airport. Consumer surplus goes up

not only because retail prices decrease down to marginal costs, but also because consumers find more product varieties, thus reducing transportation costs. As δ is high, this expected retail consumer surplus has a large effect on the demand for flights. This goes up considerably, and the airport can increase its profits by raising the landing fee above the monopoly value that it would charge if it could not appropriate the retail profits. Notice that the airport derives zero profits from awarding concessions (as no rents are obtained there), yet it is able to charge a landing fee above $1/2$ because of the demand expansion effect.

To illustrate the optimal airport choices also for values of δ between 0 and $4/5$, for given combinations of the exogenous parameters n_A and v , we find by numerical methods the optimal values of ℓ and n_R as a function of δ and t . These results are illustrated in Figure 1, together with those obtained analytically and already presented in the Propositions of this Section.¹³ Panel A of Figure 1 plots the optimal number of retailers as a function of δ , for different values of t . We observe that n_R^* is always equal to 2 (i.e., its minimum value) when δ is sufficiently low, it then becomes an increasing function of δ for intermediate values of δ , and it goes to infinity for $\delta \geq 4/5$, irrespective of t . For values of δ below $4/5$, the optimal number of retailers is always (weakly) monotonically increasing in t : this implies that the airport is prepared to allow for less concentrated retailers as long as they do not compete too intensely against each other.

The optimal landing fee is illustrated in panel B of Figure 1, again as a function of δ , and for different values of t . When $\delta > 4/5$, the optimal landing fee, fully characterized in Proposition 5, is shown in the Figure to be identical for all values of t and increasing in δ . Below this threshold level of δ , the optimal landing fee depends on the parameter t . In particular, when t is sufficiently low, ℓ^* is always strictly positive and also strictly increasing with δ . This is because, for low values of t , retail competition is very strong even if the airport awards the minimum possible number of concessions: the airport cannot extract high rents from the retail side, and relies mostly on aeronautical services to make money, via sufficiently high landing fees. Instead, for higher values of t , the relative importance of the two sources of revenues is reversed: we can even observe $\ell^* = 0$ when δ is intermediate (and then it becomes increasing in δ). Retail competition is now not very intense, and high rents can be extracted from the retail sector. The airport can therefore afford making little (even 0) money from the aeronautical

¹³The numerical analysis is primarily meant to illustrate the smoothness and monotonicity of our results for the range of δ for which we cannot solve the problem analytically and is therefore not affected by the choice of the exact values of the exogenous parameters of the model. The numerical values of the optimal airport's choices are available from the authors upon request.

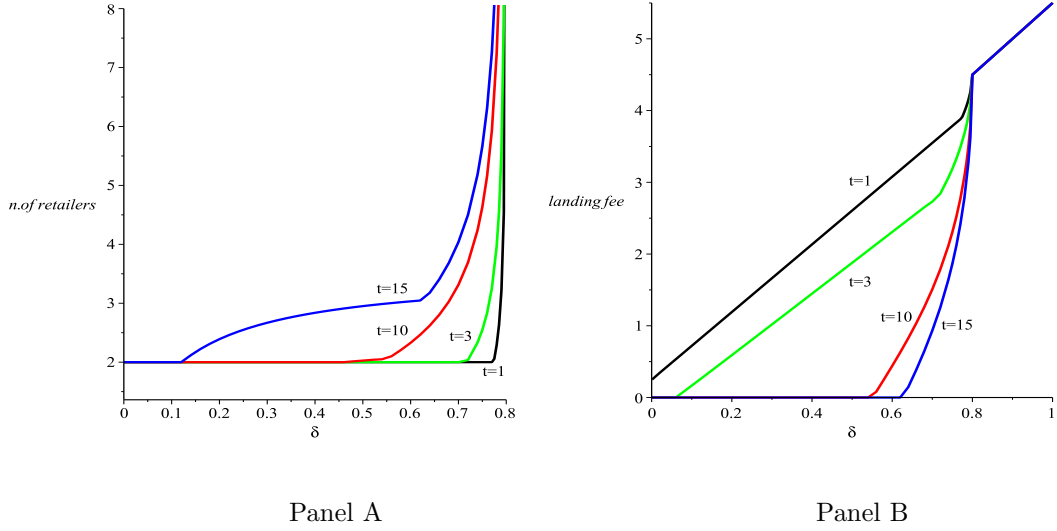


Figure 1: Optimal number of retailers (panel A) and landing fee (panel B) for $t = 1, t = 3, t = 10$ and $t = 15$ (when $v = 10$ and $n_A = 5$).

sector and concentrate on the optimal retail structure, which can include more than 2 retailers when this boosts the ex ante demand for traveling. For the entire range of δ , the optimal landing fee is (weakly) monotonically decreasing in t . We note again that the landing fee can in many instances be set above $1/2$ (the standard monopoly level), in particular when δ is large or when t is small.

Our results can be reinterpreted along the lines of the literature on two-part tariffs and, in particular, with Oi's (1971) classic study of a Disneyland monopolist.¹⁴ We obtain a result similar to Oi's, in that 'secondary' goods are priced at marginal cost, when passengers are sufficiently forward-looking: only then indeed the number of retailers goes to infinity, so that retail prices approaches retail marginal cost (0 in our model), and there are no transportation costs, so that ex post consumer surplus is maximized.¹⁵ However, this result breaks down completely as consumers exhibit a certain degree of myopia.

4.3 Airport's profits

The airport's choices described in the previous Sections are those which generate the highest airport's profits for a given parameter constellation. It is of interest to

¹⁴Czerny and Lindsey (2014) analyze a similar problem of a multiproduct monopolist selling core and side goods to consumers buying the different types of goods simultaneously.

¹⁵In our model, consumer surplus cannot be fully extracted by the ex ante fixed fee of a two-part tariff, as in Oi, since the airport does not sell directly the 'primary' good, but sets instead a linear landing fee for the derived demand from passengers.

discuss how these profits vary in relation to the consumer degree of foresight. In doing so, we not only look at the relationship between δ and the airport's aggregate profits, but also distinguish between the effect of δ on the relative profits from retail and aeronautical activities.

The degree of consumer foresight is assumed to be exogenous in our model. We note here, however, that it could be affected by the airport, for instance with appropriate informative campaigns.¹⁶ Hence a better understanding of the relationship between the airport profits and the degree of consumer foresight could not only inform the most appropriate airport's choices on landing fees and retail market structure, but also determine the incentive for the airport in engaging in advertising campaigns on the retail activities available on the airport site. However, since we do not model the cost side of advertising campaigns, we do not seek to characterize the optimal level of informative advertising.¹⁷ We are able to provide some interesting results on the role of δ on the firm's gross profits, which are presented in the following Proposition.

Proposition 6. *Let π^* , π_R^* , and π_A^* be the airport's equilibrium profits from all, retail, and aeronautical activities, respectively, with $\pi^* = \pi_R^* + \pi_A^*$. Let also $v_1 \equiv \frac{t(9tn_A+10n_A+4t)}{8n_A(t+2)}$ and $v_2 \equiv \frac{t(7n_A+2)}{8n_A}$. Then*

- i) Aggregate profits: π^* is highest when $\delta = 1$. Also, $\frac{\partial \pi^*}{\partial \delta}|_{\delta=0} > 0$ if and only if $v > v_1$ when $t < 2$ and $v > v_2$ when $t \geq 2$;*
- ii) Retail profits: $\pi_R^* > 0$ if and only if $\delta < 4/5$. Also, $\frac{\partial \pi_R^*}{\partial \delta}|_{\delta=0} > 0$ if and only if $v > v_2$;*
- ii) Aeronautical profits: $\pi_A^*|_{\delta=0} > 0$ if and only if $t < 2$. Also, $\frac{\partial \pi_A^*}{\partial \delta}|_{\delta=0} \geq 0$ for any v .*

The Proposition shows the effect of the degree of foresight of consumers on the profits the airport obtains from the different components of its business. These effects are characterized analytically for δ equal or around 0, and for δ equal or above 4/5. For intermediate values of δ , as in the previous Section, we resort to numerical simulations. Both types of results are jointly illustrated in Figure 2.

The highest aggregate profits are always obtained when δ is equal 1, i.e., when consumers have perfect foresight. While for wide parameter ranges it turns out

¹⁶In other non-airport settings, we often observe the symmetric problem of firms having to strategically determine the extent to which they should shroud the product/add-on attributes or prices: see, e.g., Gabaix and Laibson (2006) and Wenzel (2014), and the normative analysis of Kosfeld and Schüwer (2014).

¹⁷An interior solution to this optimal level of advertising could be granted by an increasing and sufficiently convex advertising cost, and would be dependent on the cost function parameters.

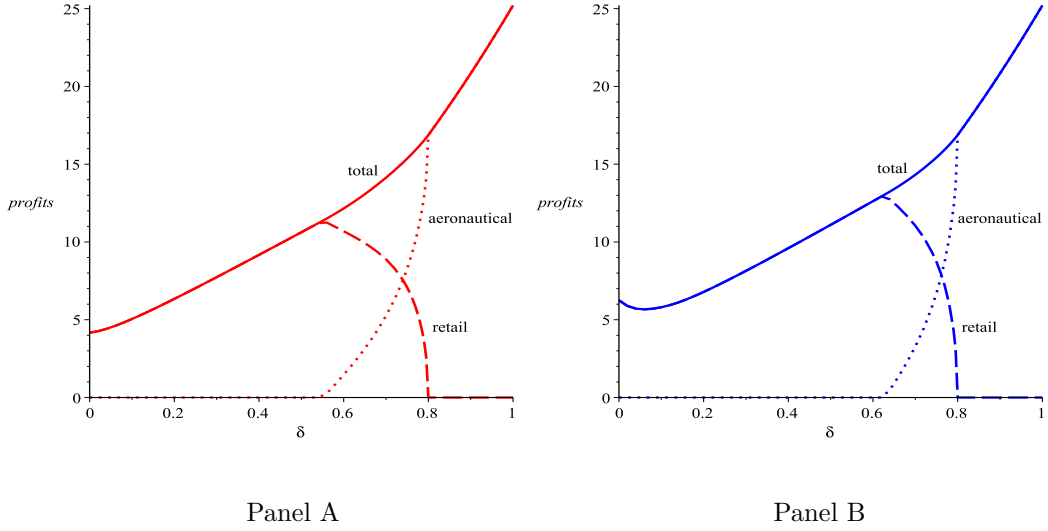


Figure 2: Equilibrium profits: panel A is for $t = 10$, and panel B is for $t = 15$ (when $v = 10$ and $n_A = 5$).

that profits increase with δ , this is not, however, a general result. In other words, while aggregate profits are always at their maximal value when δ is at its highest value, profits may locally decrease as δ goes up. This occurs for δ around 0 when v is sufficiently small relative to the other model's parameters (or, equivalently, when t is sufficiently large relative to the other models's parameters), as illustrated by the solid line in Panel B of Figure 2. Since this depends primarily on the features of the retail market, we separately discuss the interaction of δ with the retail and aeronautical profits in the next two paragraphs.

Retail profits are always strictly positive when consumers are perfectly myopic (since the airport chooses the most concentrated retail market) and are instead equal to zero when δ is sufficiently high (since the airport prefers the most dispersed retail market). The local effect of a change in the degree of consumer foresight is not uniquely determined. It is only when v is sufficiently large that a small increase in δ from 0 has a positive effect on retail profits (see Panel A of Figure 2). Instead, when v is sufficiently small (or, equivalently, when t is large), a local increase in δ from 0 reduces the airport retail profits (see Panel B of Figure 2). While a small increase of δ pushes up the demand for flights and, therefore, the number of retail customers, it also induces the airport to increase the number of concessions, as illustrated in Proposition 4. This, in turn, increases the competitiveness of the retail activities and depresses its profits. As it can be observed from (10), the demand expansion effect is largely proportional to v : when v is relatively small, so is the demand expansion effect, which is then outplayed by the

opposite effect due to the increasing number of concessions.

The dotted lines in Figure 2 illustrate the aeronautical profits. These are equal to zero when consumers are sufficiently myopic and t is large enough, since the pricing policy for the airport is to charge a landing fee equal to cost. In all other cases, they increase as consumer foresight also increases.

As observed before, our analysis has a limited nature due to the exclusions of the cost of advertising campaigns. Nevertheless, our results have some interesting managerial implications. First, they allow us to draw some lessons as to the most profitable activities in relation to the consumer's degree of foresight. Given the optimal pricing policies described in Section 4.2, a larger degree of consumer foresight has, in most cases, a positive effect on aeronautical profits and a negative effect on retail profits. When consumers are sufficiently myopic, the airport optimally charges a low landing fee to attract consumers to the airport and, by choosing a concentrated retail market, derives most of its profits from the retail activities. As δ becomes larger, the retail market becomes a better instrument to induce consumers to purchase a flight ticket: the number of concessions awarded increases and consumers appropriate a larger share of the surplus created in the retail activities. This leads to an increase in passengers, which benefits the airport as it can charge higher landing fees and derive most, if not all, of its profits from the aeronautical side alone.

Secondly, our results illustrate that small informative campaigns (to increase δ) may be counterproductive, when the consumers' foresight is very low and, importantly, the retail market is able to generate little profits because of the low consumers' willingness to spend. Yet, more ambitious (and costly) informative campaigns may actually be very profitable.

5 Concluding remarks and policy implications

Revenue at airports comes from two sources: aeronautical and retail activities. With an airport's optimal behavior, the relative importance of each one of them depends on the degree of consumer foresight about the ex post retail surplus when purchasing a flight ticket. We identify a clear trade-off between the retail market structure and the landing fee, depending on the degree of consumer foresight. When consumers are myopic, the airport awards very few retail concessions that turn out to be very lucrative, while landing fees are kept low to lure passengers in the airport terminal. As consumer foresight increases, the optimal retail structure becomes more fragmented while the landing fee increases, until the airport

optimally decides to earn money only from aeronautical services.

While airports represent the motivation for our analysis, we have argued that our model of platform pricing could be applied (with suitable adaptations) to other settings where a supplier offers a primary and a secondary good. We provided the example of shopping malls, hotel rooms, banking services and mobile phone operators. Albeit to a different degree, the questions of consumer foresight and (secondary good) market structure are present in all these examples.

Although the analysis undertaken in this paper adopts a positive perspective, some normative implications can be directly derived. Given that there are no set-up costs associated to retail activities and airlines compete imperfectly (in the absence of congestion), the first-best solution would require the most fragmented market structure on the retail side and the lowest possible landing fee (equal to zero) on the aeronautical side to minimize the effect of airlines' market power. In addition, a more thorough first-best analysis would require to taking a stance with respect to the socially-optimal degree of consumer foresight, a matter that is difficult to ascertain from first principles.

Therefore, comparing private and public incentives, we conclude the following. As consumers' foresight increases, the airport moves towards a socially-optimal fragmented market structure on the retail side, but this occurs at the expense of an inefficiently high landing fee. Conversely, higher values of consumers' myopia are associated with a more-efficient landing fee together with an inefficiently concentrated market structure in the retail sector.

Although we have dealt with an unregulated platform, some regulatory implications can be derived from our results. In the presence of perfectly myopic consumers, the airport's incentive to reduce the landing fee is well aligned with the one of a benevolent regulator with the same degree of myopia and, therefore, airport regulation should be soft (or even non-existent). In this particular case, our model provides some support for the recent airport claims in favor of a deregulation of charges on the basis of the two-sided nature of the airport business. However, in the presence of forward looking consumers, the landing fee may even exceed the monopoly price and, therefore, airport regulation of landing fees may be socially beneficial.

While our model illustrates that a single till regulation - where both aeronautical and retail activities are taken into account when setting the regulated landing fees - seems more appropriate than a dual till regulation, given the dual source of airport revenues (both aeronautical and commercial), it also highlights that current airport regulation is necessarily imperfect given that it is *one-sided* since

it only focuses on airlines' landing fees. In fact, our analysis shows that the retail market structure is as important and may be inefficiently chosen. Therefore, a more comprehensive view of the airport business as a platform, taking into account its two-sided nature and the decisions regarding the retail market structure, could be welfare enhancing.

References

- ACI, 2012. ACI airport economics survey 2012.
- Armstrong, M., 2006. Competition in two-sided markets. *Rand Journal of Economics* 37 (3), 669-691.
- Arthur D. Little, 2009. Mastering airport retail. Available at: <http://www.adlittle.com/reports.html>.
- ATRS, 2013. Global airport benchmarking report 2013.
- Boudreau, K., 2010. Open platform strategies and innovation: Granting access vs. devolving control. *Management Science* 56 (10), 1849-1872.
- Brueckner, J. K., 1993. Inter-store externalities and space allocation in shopping centers. *Journal of Real Estate Finance and Economics* 7 (1), 5-16.
- Brueckner, J. K., 2002. Airport congestion when carriers have market power. *American Economic Review* 92 (5), 1357-1375.
- Brueckner, J. K., 2004. Network structure and airline scheduling. *Journal of Industrial Economics* 52 (2), 291-312.
- Busse, M. R., C. R. Knittel, and F. Zettelmeyer, 2013. Are Consumers Myopic? Evidence from New and Used Car Purchases. *American Economic Review* 103 (1), 220-256.
- Caillaud, B. and B. Jullien, 2003. Chicken and egg: Competition among intermediation service providers. *Rand Journal of Economics* 34 (2), 309-328.
- Carter, C. C., 2009. What we know about shopping centers. *Journal of Real Estate Literature* 17 (2), 165-180.
- Carter, C. C. and K. D. Vandelland, 2006. Store location in shopping centers: Theory and estimates. *Journal of Real Estate Research* 27 (3), 237-265.
- Casadesus-Masanell, R. and G. Llanes, forthcoming. Investment incentives in open-source and proprietary two-sided platforms. *Journal of Economics & Management Strategy*.
- Charles River Associates, 2013. Two sided market analysis in the context of the CAA's market power analysis - report for the CAA.
- Czerny, A. I., 2006. Price cap regulation of airports: Single till versus dual till. *Journal of Regulatory Economics* 30 (1), 85-97.
- Czerny, A. I., 2013. Public versus private airport behavior when concession revenues exist. *Economics of Transportation* 2 (1), 38-46.
- Czerny, A. I. and R. Lindsey, 2014. Multiproduct pricing with core goods and side goods. Mimeo, University of British Columbia.

- D'Alfonso, T., C. Jiang, and Y. Wan, 2013. Airport pricing, concession revenues and passenger types. *Journal of Transport Economics and Policy* 47 (1), 71-89.
- Daniel, J. I., 1995. Congestion pricing and capacity of large hub airports: a bottleneck model with stochastic queues. *Econometrica* 63 (2), 327-370.
- Economides, N. and E. Katsamakas, 2006. Two-sided competition of proprietary vs. open source technology platforms and the implications for the software industry. *Management Science* 52 (7), 1057-1071.
- Ellison, G., 2005. A model of add-on pricing. *Quarterly Journal of Economics* 120 (2), 585-637.
- Elmaghraby, W. and P. Keskinocak, 2003. Dynamic pricing in the presence of inventory considerations: Research overview, current practices, and future directions. *Management Science* 49 (10), 1287-1309.
- Erat, S. and S. Bhaskaran, 2012. Consumer mental accounts and implications to selling base products and add-ons. *Marketing Science* 31 (5), 801-818.
- Gabaix, X. and D. Laibson, 2006. Shrouded attributes and information suppression in competitive markets. *Quarterly Journal of Economics* 121 (2), 505-540.
- Gal-Or, E., 1997. Exclusionary equilibria in health care markets. *Journal of Economics & Management Strategy* 6 (1), 5-43.
- Gal-Or, E., 1999. Mergers and exclusionary practices in health care markets. *Journal of Economics & Management Strategy* 8 (3), 315-350.
- Gans, J. S., 2012. Mobile application pricing. *Information Economics and Policy* 24 (1), 52-59.
- Gans, J. S. and S. P. King, 2000. Mobile network competition, customer ignorance and fixed-to-mobile call prices. *Information Economics and Policy* 12 (4), 301-327.
- Gillen, D., 2011. The evolution of airport governance and ownership. *Journal of Air Transport Management* 17 (1), 3-13.
- Gillen, D. and B. Mantin, 2012. Transportation infrastructure management: One and two sided market approaches. *Journal of Transport Economics and Policy* 47 (2) 207-227.
- Hagiu, A., 2009. Two-sided platforms: Product variety and pricing structures. *Journal of Economics & Management Strategy* 18 (4), 1011-1043.
- Hagiu, A. and D. Spulber, 2013. First-party content and coordination in two-sided markets. *Management Science* 59 (4), 933-949.
- Hagiu, A. and J. Wright, forthcoming. Marketplace or reseller? *Management Science*.
- Haskel, J., A. Iozzi, and T. Valletti, 2013. Market structure, countervailing power and price discrimination: The case of airports. *Journal of Urban Economics* 74 (1), 12-26.

- Heidhues, P. and B. Kőszegi, 2010. Exploiting naivete about self-control in the credit market. *American Economic Review* 100 (5), 2279-2303.
- Huang, P., M. Ceccagnoli, C. Forman, and D. Wu, 2013. Appropriability mechanisms and the platform partnership decision: Evidence from enterprise software. *Management Science* 59 (1), 102-121.
- Ivaldi, M., S. Sokullu, and T. Toru, 2012. Are airports two-sided platforms? A methodological approach. In J. Peoples (Ed.), *Advances in airline economics: Pricing behavior and non-price characteristics in the airline industry*. Bingley: Emerald Group Publishing.
- Karle, H. and M. Peitz, 2014. Competition under consumer loss aversion. *Rand Journal of Economics* 45 (1) 1-31.
- Klemperer, P., 1995. Competition when consumers have switching costs: An overview with applications to industrial organization, macroeconomics, and international trade. *Review of Economic Studies* 62 (4), 515-539.
- Kosfeld, M. and U. Schüwer, 2014. Add-on pricing in retail financial markets and the fallacies of consumer education. *SAFE Working Paper no. 47*.
- Kratzsch, U. and G. Sieg, 2011. Non-aviation revenues and their implications for airport regulation. *Transportation Research Part E* 47 (5), 755-763.
- Lal, R. and C. Matutes, 1994. Retail pricing and advertising strategies. *Journal of Business* 67 (3), 345-370.
- Mayer, C. and T. Sinai, 2003. Network effects, congestion externalities, and air traffic delays: or why not all delays are evil. *American Economic Review* 93 (4), 1194-1215.
- Miceli, T. J. and C. F. Sirmans, 1995. Contracting with spatial externalities and agency problems: The case of shopping center leases. *Regional Science and Urban Economics* 25 (3), 355-372.
- Oi, W. Y., 1971. A Disneyland dilemma: Two-part tariffs for a Mickey Mouse monopoly. *Quarterly Journal of Economics* 85 (1), 77-96.
- Parker, G. G. and M. W. Van Alstyne, 2005. Two-sided network effects: A theory of information product design. *Management Science* 51 (10), 1494-1504.
- Pashigan, B. P. and E. D. Gould, 1998. Internalizing externalities: The pricing of space in shopping malls. *Journal of Law and Economics* 41 (1), 115-142.
- Rochet, J.-C. and J. Tirole, 2003. Platform competition in two-sided markets. *Journal of the European Economic Association* 1 (4), 990-1029.
- Rochet, J.-C. and J. Tirole, 2006. Two-sided markets: Where we stand. *Rand Journal of Economics* 37 (3), 645-667.
- Rupp, N., 2009. Do carriers internalize congestion costs? Empirical evidence on the internalization question. *Journal of Urban Economics* 65 (1), 24-37.

- Shulman, J. D., A. T. Coughlan, and R. C. Savaskan, 2011. Managing consumer returns in a competitive environment. *Management Science* 57 (2), 347-362.
- Shulman, J. D. and X. Geng, 2013. Add-on pricing by asymmetric firms. *Management Science* 59 (4), 899-917.
- Starkie, D., 2001. Reforming UK airport regulation. *Journal of Transport Economics and Policy* 35 (1), 119-135.
- Strotz, R. H., 1995. Myopia and inconsistency in dynamic utility maximization. *Review of Economic Studies* 23 (3), 165-180.
- Verboven, F., 1999. Product line rivalry and market segmentation - with an application to automobile optional engine pricing. *Journal of Industrial Economics* 47 (4), 399-425.
- Wenzel, T., 2014. Consumer myopia, competition and the incentives to unshroud add-on information. *Journal of Economic Behavior and Organization* 98, 89-96.
- Wright, J., 2004. One-sided logic in two-sided markets. *Review of Network Economics* 3 (1), 44-64.
- Zhang, A. and Y. Zhang, 1997. Concession revenue and optimal airport pricing. *Transportation Research Part E* 33 (4), 287-296.
- Zhang, A. and Y. Zhang, 2006. Airport capacity and congestion when carriers have market power. *Journal of Urban Economics* 60 (2), 229-247.
- Zhang, A. and Y. Zhang, 2010. Airport capacity and congestion pricing with both aeronautical and commercial operations. *Transportation Research Part B* 44 (3), 404-413.

Appendix

In this Appendix, we provide the proofs of all Propositions.

Proof of Proposition 1. Imposing symmetry (i.e., $p_i = p_j = p_R$), the first-order condition of retailer i 's problem (10) is

$$\frac{\partial \pi_i}{\partial p_i} = \frac{tn_R [4(1 - p_A + \delta v) - 3\delta p_R] - 4n_R^2 p_R (1 - p_A - \delta p_R + \delta v) - t(4p_R + t)}{4tn_R^2} = 0. \quad (\text{A-1})$$

We first prove the last part of the Proposition, i.e., the inequality in (12). First, note that (A-1) evaluated at $\delta = 0$ yields $\frac{\partial \pi_i}{\partial p_i} \Big|_{\delta=0} = \frac{(1-p_A)(t-n_R p_R)}{n_R t} = 0$. Solving with respect to p_R gives $p_R(p_A)|_{\delta=0} = \frac{t}{n_R}$, which is the standard price in a Salop model. Using (A-1), we can compute

$$\frac{\partial \pi_i}{\partial p_i} - \frac{\partial \pi_i}{\partial p_i} \Big|_{\delta=0} = \delta \frac{tn_R (4v - 3p_R) - 4n_R^2 p_R (v - p_R) - t(t + 4p_R)}{4tn_R^2}. \quad (\text{A-2})$$

Then (A-2), evaluated at the equilibrium price when $\delta \rightarrow 0$, yields $-\frac{t\delta}{n_R^3} < 0$, which proves the inequality in (12).

We now turn to establish the optimal retail price in (11). Solving (A-1) with respect to p_R and using γ , we obtain two solutions

$$p'_R, p''_R = \frac{\delta t(4 + 3n_R) + 4\gamma n_R^2 \pm \sqrt{16\delta t n_R^2 (\delta t - \gamma n_R) + [\delta t(4 + 3n_R) + 4\gamma n_R^2]^2}}{8\delta n_R^2}. \quad (\text{A-3})$$

To select the correct solution, first rewrite the first-order condition (A-1) as follows

$$\underbrace{4\delta n_R^2 p_R^2}_{Q(p_R)} = \underbrace{-\delta t(4vn_R - t) - 4tn_R(1 - p_A) + [4n_R^2(1 - p_A) + 4\delta t + 3\delta tn_R + 4\delta vn_R^2] p_R}_{L(p_R)}. \quad (\text{A-4})$$

Figure A-1 illustrates that (A-4) is satisfied at the intersection between two functions of p_R , one quadratic, $Q(p_R)$, and one linear, $L(p_R)$. Note that $L(p_R)$ has a negative intercept and that it is necessarily upward sloping. Notice also that, at the smallest solution in Figure A-1, $\frac{\partial Q(p_R)}{\partial p_R} < \frac{\partial L(p_R)}{\partial p_R}$, while, by contrast, at the largest solution in Figure A-1, $\frac{\partial Q(p_R)}{\partial p_R} > \frac{\partial L(p_R)}{\partial p_R}$.

The second-order condition of problem (10) is given by

$$\delta n_R(6p_R + t) - 4n_R^2(1 - p_A - \delta p_R + \delta v) - 4\delta t < 0, \quad (\text{A-5})$$

which can be rewritten as

$$\frac{\partial L(p_R)}{\partial p_R} - \frac{\partial Q(p_R)}{\partial p_R} > 2\delta n_R[2(t - n_R p_R) + 3p_R], \quad (\text{A-6})$$

where

$$\frac{\partial L(p_R)}{\partial p_R} = -\delta t(4vn_R - t) - 4tn_R(1 - p_A) + [4n_R^2(1 - p_A) + 4\delta t + 3\delta tn_R + 4\delta vn_R^2] \quad (\text{A-7})$$

and

$$\frac{\partial Q(p_R)}{\partial p_R} = -8\delta n_R^2 p_R. \quad (\text{A-8})$$

Noting that the right-hand side of (A-6) satisfies $2\delta n_R[2(t - n_R p_R) + 3p_R] > 0$ because $p_R < \frac{t}{n_R}$ as long as $\delta > 0$, one can conclude that, for (A-6) to be satisfied, $\frac{\partial L(p_R)}{\partial p_R} - \frac{\partial Q(p_R)}{\partial p_R} > 0$ must hold, which establishes that the smallest solution in Figure A-1 is the solution to the maximization problem (10). ■

Proof of Proposition 2. Substituting the equilibrium airfare in (16) into the retail price first-order condition in (A-1), we obtain

$$\Omega \equiv \frac{n_A \{tn_R[4(1 - \ell) - \delta(3p_R + 4v)] - 4n_R^2 p_R(1 - \delta p_R + \delta v - \ell) - \delta t(4p_R + t)\}}{4tn_R^2(n_A + 1)} - \frac{\delta p_R}{n_R^2(n_A + 1)} = 0. \quad (\text{A-9})$$

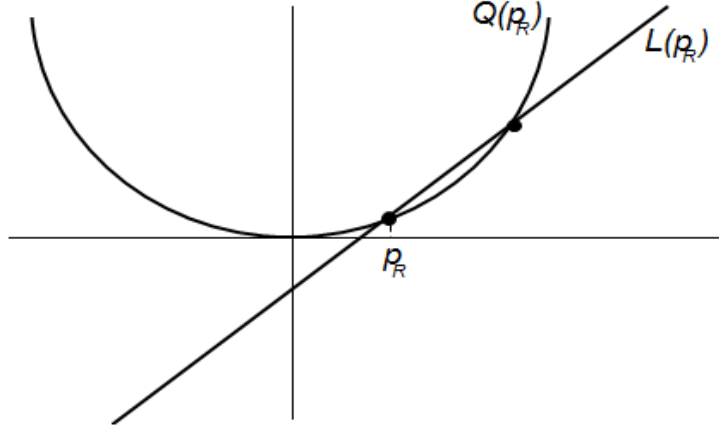


Figure A-1: The first-order condition of retailer i 's maximization problem

Implicitly differentiating it, we obtain

$$\begin{aligned} \frac{\partial p_R}{\partial \ell} &= -\frac{\partial \Omega / \partial \ell}{\partial \Omega / \partial p_R} \\ &= \frac{4n_A n_R (n_R p_R - t)}{n_A [4n_R^2 (1 - 2\delta p_R + \delta v - \ell) + 3\delta t n_R + 4\delta t] + 4\delta t}, \end{aligned} \quad (\text{A-10})$$

$$\begin{aligned} \frac{\partial p_R}{\partial n_R} &= -\frac{\partial \Omega / \partial n_R}{\partial \Omega / \partial p_R} \\ &= \frac{t \{2n_A [\delta(t - 2vn_R) - 2n_R(1 - \ell)] + \delta p_R [3n_A n_R + 8(n_A + 1)]\}}{n_R \{n_A [4n_R^2 (1 - 2\delta p_R + \delta v - \ell) + 3\delta t n_R + 4\delta t] + 4\delta t\}}. \end{aligned} \quad (\text{A-11})$$

As to (A-10), the numerator is positive since Proposition 1 establishes that $p_R < \frac{t}{n_R}$ when $\delta > 0$. The denominator is negative because it is smaller than the second-order condition in (A-5) after replacing the equilibrium airfare in (16), which is negative.

As to (A-11), the denominator is again negative because of the second-order condition (A-5). The numerator is decreasing in p_R , hence it takes a lower bound at $p_R = \frac{t}{n_R}$, in which case the numerator simplifies to

$$-\frac{t}{n_R} \{8t\delta + n_A [8t\delta + 5n_R t\delta - 4n_R^2 (1 - \ell + v\delta)]\}. \quad (\text{A-12})$$

When this last expression is positive, then (A-11) is negative overall. From (A-12), a *sufficient* condition is therefore that

$$v > -\frac{1 - \ell}{\delta} + \frac{5t}{4n_R} + \frac{2(1 + n_A)t}{n_A n_R^2}. \quad (\text{A-13})$$

This condition is always satisfied when δ is low enough. From (4), recall also that $v > \frac{5t}{8}$, which ensures that v is always greater than the second term on the RHS of (A-13). Hence we expect that $\frac{\partial p_R}{\partial n_R} < 0$ in most cases. However, the third term of the RHS of (A-13) is a countervailing effect that may change the sign of $\frac{\partial p_R}{\partial n_R}$: a necessary (but still not sufficient) condition for $\frac{\partial p_R}{\partial n_R}$ to be positive overall is that δ is large, n_A is

small, and v is also small. ■

Proof of Proposition 3. Directly in the text and therefore omitted. ■

Proof of Proposition 4. Substituting the values of q_A , $\frac{\partial q_A}{\partial \ell}$, $\frac{\partial q_A}{\partial p_R}$, $\frac{\partial q_A}{\partial n_R}$, $\frac{\partial p_R}{\partial \ell}$, and $\frac{\partial p_R}{\partial n_R}$ into (18) and (19), we obtain

$$\frac{\partial \Pi}{\partial \ell} = \underbrace{\left(1 - 2\ell - \frac{t}{n_R}\right)}_A + \underbrace{4n_R n_A (n_R p_R - t)}_B \Upsilon + \underbrace{\left[\frac{t(4 - \delta)}{4n_R} + \delta v - p_R(1 + \delta)\right]}_C = 0, \quad (\text{A-14})$$

$$\frac{\partial \Pi}{\partial n_R} = -\underbrace{\frac{tn_A(1 - \ell)}{(n_A + 1)n_R^2}}_D + \underbrace{\frac{tn_A}{(n_A + 1)n_R}}_E \Psi = 0, \quad (\text{A-15})$$

with $\Upsilon \equiv \frac{1 - \ell + \delta(v - 2p_R - \ell - \frac{t}{4n_R})}{n_A[4n_R^2(1 - 2\delta p_R + \delta v - \ell) + 3\delta t n_R + 4\delta t] + 4\delta t}$ and $\Psi \equiv \frac{4(1 - \ell) + \delta(\ell + p_R)}{4n_R} + \Upsilon\{8\delta p_R + n_A[2\delta(4p_R + t) - n_R(4 - 3\delta p_R + 4\delta v - 4\ell)]\}$.

From (20) and (21), we have that $A = \frac{\partial \Pi}{\partial \ell}\big|_{\delta=0}$ and $D = \frac{\partial \Pi}{\partial n_R}\big|_{\delta=0}$. Notice also that both A and D do not depend on δ , so that $\frac{\partial A}{\partial \delta} = \frac{\partial D}{\partial \delta} = 0$. Also, we observe that $\frac{\partial B}{\partial \delta}\big|_{\delta \rightarrow 0} = 0$, given that, for $\delta = 0$, $p_R = \frac{t}{n_R}$ and the denominator of B takes on a strictly positive value. Hence, $\frac{\partial^2 \Pi}{\partial \ell \partial \delta}\big|_{\delta=0} = \frac{\partial C}{\partial \delta}\big|_{\delta=0}$ and $\frac{\partial^2 \Pi}{\partial n_R \partial \delta}\big|_{\delta=0} = \frac{\partial E}{\partial \delta}\big|_{\delta=0}$.

Since our analysis is limited to δ infinitesimally close to 0, it is legitimate to approximate the first-order conditions by their first order Taylor's expansions. Hence, (A-14) and (A-15) become

$$\begin{aligned} \frac{\partial \Pi}{\partial \ell} &\cong \frac{\partial \Pi}{\partial \ell}\bigg|_{\delta=0} + \delta \frac{\partial^2 \Pi}{\partial \ell \partial \delta}\bigg|_{\delta=0} = A + \delta \frac{\partial C}{\partial \delta}\bigg|_{\delta=0} \\ &= 1 - 2\ell - \frac{t}{n_R} + \delta \left(v - \frac{5t}{4n_R}\right) = 0, \end{aligned} \quad (\text{A-16})$$

$$\begin{aligned} \frac{\partial \Pi}{\partial n_R} &\cong \frac{\partial \Pi}{\partial n_R}\bigg|_{\delta=0} + \delta \frac{\partial^2 \Pi}{\partial n_R \partial \delta}\bigg|_{\delta=0} = D + \delta \frac{\partial E}{\partial \delta}\bigg|_{\delta=0} \\ &= \frac{1}{n_R^2} \left\{ -\frac{tn_A(1 - \ell)}{(n_A + 1)} + \delta t \frac{n_A[n_R^2(5\ell - 4v) + 2t(5n_R + 6)] + 12t}{4n_R^2(n_A + 1)} \right\} = 0. \end{aligned} \quad (\text{A-17})$$

It is then immediate to see that (A-16) is negative when $t > \hat{t}_1 \equiv \frac{4n_R(1 + \delta v)}{4 + 5\delta}$. When instead $t \leq \hat{t}_1$, solving (A-16) with respect to ℓ gives the expression for the optimal ℓ given in the Proposition.

As to (A-17), solving it with respect to n_R gives

$$\hat{n}_R = \frac{5\delta t n_A + \sqrt{\delta t n_A \{25\delta t n_A + [48(1 + \delta v - \ell) - 60\delta \ell](n_A + 1)\}}}{n_A[4(1 + \delta v) - \ell(5\delta + 4)]}, \quad (\text{A-18})$$

where there are also other solutions but none of them admissible. Notice that $\hat{n}_R \geq 2$ when $t \geq \hat{t}_2 \equiv \frac{n_A[4(1 + \delta v) - \ell(4 - 5\delta)]}{\delta(3 + 8n_A)}$.

It is easy to establish that $\hat{t}_1 < \hat{t}_2$, by simply checking for the sign of their difference when δ goes to zero. Therefore, both in \hat{t}_2 and (A-18), it is possible to substitute $\ell = 0$ to obtain t_2 and the expression for the optimal n_R given in the Proposition; similarly, in \hat{t}_1 , it is possible to substitute $n_R = 2$ to obtain t_1 given in the Proposition. ■

Proof of Proposition 5. Let us initially assume $n_R \rightarrow \infty$. Then we can compute explicitly the optimal landing fee, which is given by $\ell^*|_{n_R \rightarrow \infty} = \frac{1}{2}(1 + \delta v)$, as indicated in the Proposition. Then the rest of the proof consists in showing that indeed it is optimal to set $n_R \rightarrow \infty$ for $\delta \geq 4/5$.

Using (A-15) and taking into account that $\ell^*|_{n_R \rightarrow \infty} = \frac{1}{2}(1 + \delta v)$, it can be computed $\frac{\partial \Pi^2}{\partial n_R \partial v}$ which takes a long expression (omitted here for the sake of brevity), where it can be shown that $\frac{\partial \Pi^2}{\partial n_R \partial v} < 0$. Then we can compute $\frac{\partial \Pi}{\partial n_R} \Big|_{v \rightarrow \infty}$ (using de l'Hôpital Rule), which constitutes a lower bound for $\frac{\partial \Pi}{\partial n_R}$. More precisely, $\frac{\partial \Pi}{\partial n_R} \Big|_{v \rightarrow \infty} = \frac{\delta t n_A (5\delta - 4)}{8 n_R^2 (n_A + 1)}$, which is non-negative for $\delta \geq 4/5$. Therefore, $\frac{\partial \Pi}{\partial n_R} > 0$ for $\delta \geq 4/5$, which directly implies $n_R^* \rightarrow \infty$. ■

Proof of Proposition 6. From Proposition 3, $\pi^*|_{\delta=0} = \frac{n_A(t+2)^2}{16(n_A+1)}$ when $t < 2$, and $\pi^*|_{\delta=0} = \frac{t n_A}{2(n_A+1)}$ when $t \geq 2$. Similarly, from Proposition 5, $\pi^*|_{\delta \geq \frac{4}{5}} = \frac{n_A(1+\delta v)^2}{4(n_A+1)}$, which is clearly increasing in δ . Comparing the two profits, it obtains that $\pi^*|_{\delta=0} > \pi^*|_{\delta \geq \frac{4}{5}}$ when $v < \frac{t}{2\delta}$ (when $t < 2$) or $v < \frac{\sqrt{2t-1}}{\delta}$ (when $t \geq 2$), where both limiting values are below the smallest admissible value for v , which is $\frac{5t}{8}$, from (4). Hence the highest profit that can be achieved is $\pi^*|_{\delta \geq \frac{4}{5}}$, in particular when $\delta = 1$.

As for the results for δ around 0, using the envelope theorem, we simply take the derivative of the airport's profits with respect to δ , plug into it the optimal values $\ell^*|_{\delta=0}$ and $n_R^*|_{\delta=0}$ and evaluate it at $\delta = 0$. This gives $\frac{\partial \pi^*}{\partial \delta} \Big|_{\delta=0} = \frac{8v n_A(t+2) - t(9t n_A + 10n_A + 4t)}{32(n_A+1)}$, $\frac{\partial \pi_R^*}{\partial \delta} \Big|_{\delta=0} = \frac{t[8v n_A - t(7n_A + 2)]}{16(n_A+1)}$, and $\frac{\partial \pi_A^*}{\partial \delta} \Big|_{\delta=0} = \frac{n_A[(8v-5t)(2-t)]}{32(n_A+1)}$ when $t < 2$; and $\frac{\partial \pi^*}{\partial \delta} \Big|_{\delta=0} = \frac{\partial \pi_R^*}{\partial \delta} \Big|_{\delta=0} = \frac{t[8v n_A - t(7n_A + 2)]}{16(n_A+1)}$ and $\frac{\partial \pi_A^*}{\partial \delta} \Big|_{\delta=0} = 0$ when $t \geq 2$. Solving these expressions with respect to v gives the critical values and the results in the Proposition. ■