Journal of Transport Economics and Policy, Volume 51, Part 4, October 2017, pp. 290–312

Airport Cities and Multiproduct Pricing

Tiziana D'Alfonso, Valentina Bracaglia, and Yulai Wan

Address for correspondence: Tiziana D'Alfonso and Valentina Bracaglia, Department of Computer, Control and Management Engineering, Sapienza Università di Roma, Via Ariosto 25, Rome, Italy (dalfonso@dis.uniroma1.it). Yulai Wan is at the Department of Logistics and Maritime Studies, Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong.

We gratefully acknowledge the useful suggestions made by the participants at the 2015 International Transport Economic Association (ITEA) Annual Conference, the Eureka Seminar Series at VU University, the Centre for Transportation Studies (CTS) Seminar Series at the University of British Columbia, and participants in the 2015 Italian Management Engineering Association (AiIG) Annual Conference. We also thank Achim Czerny, Ricardo Flores-Fillol, Robin Lindsey, Pierfrancesco Reverberi, Hugo E. Silva, and Anming Zhang for valuable discussions on previous drafts of this paper. This paper has been partly developed as a result of a mobility program funded by the Erasmus Mundus Programme of the European Commission under the Transatlantic Partnership for Excellence in Engineering (TEE Project). Financial support from Sapienza University of Rome (Grants No. C26N1339HR and C26N15NAZK) is also gratefully acknowledged.

Abstract

We study pricing of aviation and non-aviation products in a private monopolistic airport city and model two features. First, non-aviation goods are demanded by both air travellers and non-travellers. Second, the utility from consuming non-aviation goods may depend on whether the consumer travels or not. The impacts of these features on optimal aviation and non-aviation charges would depend on whether individuals foresee the utility of non-aviation goods or not while deciding to buy air tickets. It is profit maximising and welfare enhancing to manipulate the non-aviation product mix in a way that raises the extra surplus gained by travellers.

Final version: September 2017

1.0 Introduction

The growing importance of non-aviation revenues has been acknowledged as one of the most striking trends in the airport sector over the last 30 years (Graham, 2009; Gillen and Mantin, 2014; Czerny *et al.*, 2016a). Aviation (core) activities are associated with the usage of runways, aircraft parking stands, and terminals to handle air traffic, whereas non-aviation (side) activities include retailing, advertising, car rentals, car parking, and land rentals (Zhang and Czerny, 2012). On average, airports worldwide derive as much revenue from side activities as from core ones; at some medium- to large-sized airports, non-aviation business represents 75–80 per cent of the total revenues. In recent decades, many airports have further invested in non-aviation activities that lie outside the traditional boundary of goods and services complementary to the airside (Morrison, 2009). Such strategies are becoming increasingly prevalent as airports actively pursue initiatives for de-risking their aviation and passenger-dependent non-aviation businesses (Reiss, 2007; Poungias, 2009). For instance, from 1998 to 2008, operating revenues derived from leasing land and non-passenger terminal facilities grew by 58 per cent at large hubs, 54 per cent at non-hubs, 24 per cent at medium hubs, and 43 per cent at small hubs in the USA (Kramer, 2010).

Gradually, many commercially run airports have evolved into *airport cities* by expanding real estate development into the landside property zones of the airports. These airports have transformed their terminals into shopping malls and artistic venues, and have spawned clusters of hotels, corporate offices, convention, trade and exhibition facilities, retail complexes, and culture, entertainment, and recreation centres. As a result, many airports have become as much commercial destinations as places of departure (Kasarda, 2008), and have extended their offerings to new target groups, in addition to passengers (Poungias, 2009). These new airport users include not only the employees of airport authorities, airlines, and other air service providers and meeters-and-greeters, but also local residents (Jarach, 2001), strollers and half-day trippers who enjoy the international flair, the exciting atmosphere, and the variety of offerings found at the airport (Sulzmaier, 2001). In Europe, the concept of an airport city has been actively promoted by many airports, such as Amsterdam Airport Schiphol (Morrison, 2009), Zürich Airport (Orth *et al.*, 2015), Athens International Airport 'Eleftherios Venizelos' (Kasarda, 2008), and Munich Airport (Sulzmaier, 2001). Several airports have developed factory outlets on their land in Australia (Freestone and Baker, 2010), Taiwan (Wang and Hong, 2011), and China (Poungias, 2009). As a result, non-passengers form a significant customer base for these airports.[1]

[1] For instance, given the proximity and intermodal links to Amsterdam, Schiphol Airport attracts city residents along with approximately 58,000 people who work in the airport business district (Morrison, 2009). Indeed, under Schiphol management, Cairo International Airport plans to include an international airport hospital that will compete in the regional market for medical treatments and operations (Morrison, 2009). In 2013, Zurich Airport's 'The Circle' project attracted on a daily basis 68,000 air travellers and 55,000 non-travellers (20,000 commuters, 10,000 visitors, and 25,000 employees on site). This new development is forecasted to result in an additional 3,000 jobs (Orth *et al.*, 2015). See D'Alfonso and Bracaglia (2017) for more examples.

In this paper, we study the multiproduct pricing issue in the context of a monopoly airport city selling both aviation (core) and non-aviation (side) goods. Unlike a conventional airport, an airport city offers non-aviation goods to two groups of customers: travellers and non-travellers. The former use the transport infrastructure because their primary intent is to fly and, when at the facility, they may (or may not) purchase non-aviation goods. The latter may go to the airport city specifically to purchase non-aviation goods — simply because they know the stores are there.

Two novel features are explicitly modelled and studied in the paper. First, we relax the assumption that consumers buy non-aviation goods only if they buy the aviation goods as well. Although this assumption is common in the airport pricing literature, it does not apply to an airport city in which non-travellers play an important role. Second, we assume that the utility from consumption of non-aviation goods may depend on whether individuals travel or not. We explicitly model the interdependence between aviation and non-aviation goods by assuming the extra-surplus gained by travellers compared to non-travellers due to consuming the two products together. This setting is motivated by the following rationales: (i) certain non-aviation goods (for instance, car parking and car rental) are complementary to air travel, and the willingness to pay for such goods is lower, if not null, when the individual does not have to travel; and (ii) airports are unique retailing environments which can make travellers react in unusual ways and thus behave differently from ordinary shoppers (Sulzmaier, 2001; Crawford and Melewar, 2003; Geuens *et al*., 2004).

This study has important implications to airport pricing and operation. First, we re-examine a private (uncongested) airport's incentive to limit the aviation charge imposed on airlines in the presence of non-aviation goods by adding non-travellers' demand for non-aviation goods into the picture. We employ two major frameworks that have shaped the debate around airport pricing when non-aviation service activities matter. The first one assumes that travellers make air ticket and non-aviation purchasing decisions independently, and consequently demand for flights does not depend on the price of non-aviation goods (*one-sided complementarity*). The second framework assumes that travellers make decisions on buying both goods simultaneously, in the sense that demand for flights is affected by the prices of aviation as well as non-aviation goods (*two-sided complementarity*). The study also sheds some light on the most profitable airport strategy in the (landside) non-aviation business. In the context of an airport city, a natural question is whether the non-aviation goods offered by the airport should keep more features valued by travellers or become more user-friendly to non-travellers. This paper partially answers this question and provides policy makers its implication on airport charges, consumer surplus, and social welfare, in addition to the well-being of specific groups of individuals. Finally, although the study is motivated by the concept of airport city, other transport facilities, such as railway stations and cruise terminals, may also be fitted into our model, as travellers may catch a train or a cruise and end up buying side goods at these facilities, whereas non-travellers may go there just to shop.

The rest of the paper is organised as follows. Section 2 conducts the literature review. Section 3 describes the basic model and its extension to the case of two-sided complementarity. Section 4 discusses the role of non-travellers on airport charges, the profit and welfare implications of the interdependence between aviation and non-aviation goods, and the impacts of some assumptions. Section 5 presents the concluding remarks.

2.0 Literature Review

This paper relates to the literature on complementarity between aviation and non-aviation activities (see Czerny *et al.*, 2016a for a survey). It has been conjectured that airports may limit the aviation charges they impose on airlines in order to boost traffic and expand revenues from non-aviation goods. If this is true, the need for heavy-handed regulation on private airports should be alleviated (Starkie, 2002).

Analytically, Starkie's conjecture has been confirmed under the assumption of *one-sided complementarity* between aviation and non-aviation goods (Zhang and Zhang, 1997; 2003; 2010; Starkie, 2002; Yang and Zhang, 2011; D'Alfonso *et al.*, 2013). That is, while demand for non-aviation goods is determined by passenger numbers and hence the price of aviation goods, demand for flights is independent of the price of non-aviation goods. This may be the case, because purchasing of air tickets and non-aviation goods can be separated in time (Zhang and Zhang, 1997; 2003; 2010; Yang and Zhang, 2011; D'Alfonso *et al.*, 2013; Wan *et al.*, 2015). This strand of literature finds that the side business unambiguously causes downward pressure on the private aviation charge, even though the aviation charge set by a multiproduct private airport can still be above the social optimal level (Zhang and Zhang, 2003).

Conversely, if *two-sided complementarity* is assumed, Starkie's conjecture may not hold. This is because passengers make decisions about buying the aviation and non-aviation goods simultaneously rather than independently, and hence demand for aviation goods is affected by the price of non-aviation goods (Czerny, 2006; 2013; Bracaglia *et al.*, 2014; Flores-Fillol *et al.*, 2015; Czerny *et al.*, 2016b). The rationales behind this assumption are: (i) the issue of time-separation has been moderated over time by advancements in e-commerce (Bracaglia *et al.*, 2014); and (ii) many passengers, in particular business travellers, are frequent flyers, who are unlikely to be totally unaware of the surplus associated with non-aviation goods, such as car rental and car parking (Czerny, 2013). Under this assumption, a reduction in the price for side goods can be considered as an increase in airport 'quality' and the airport adjusts aviation charges upward to (partially) absorb the consumer surplus generated by the higher quality.

Empirically, there is no univocal evidence on the nature of complementarity between aviation and commercial goods. Therefore, it is necessary to assume both one-sided and two-sided complementarity in this paper, and compare their difference.[2]

Our paper is closely related to Kidokoro *et al.* (2016) and Czerny (2006). Kidokoro *et al.* (2016) incorporate both travellers and non-travellers in a general-equilibrium model that includes consumers, airlines, and airport, as well as shops outside of the airport in the city centre that involve perfect competition with shops at the airport. However, as the airport commercial rent is set to be an increasing function of passenger quantity only, it

[2]The two-sided nature of the airport business is widely cited (Gillen, 2011; Gillen and Mantin, 2012; D'Alfonso and Nastasi, 2014). Bilotkach *et al.* (2012) do not detect any significant relationship between the aviation charge and commercial revenues. However, Van Dender (2007) finds that commercial revenue per-passenger reduces in the number of passengers, which is consistent with two-sided complementarity (Zhang and Czerny, 2012). Czerny *et al.* (2016b) confirm that a one-dollar increase in the daily car rental price reduces passenger demand at 199 US airports by more than 0.36 per cent. Ivaldi *et al.* (2015) find that passengers fly more if the price of the daily car parking fee goes down.

explicitly assumes that non-travellers will not purchase at the airport and hence fails to capture the key feature of an airport city. Conversely, our work explicitly assumes that non-travellers might also buy non-aviation goods at the airport.

Although Czerny's (2006) modelling approach has been employed in our paper, Czerny takes into account neither non-travellers nor the difference between travellers and non-travellers in evaluating the non-aviation goods. As a result, in Czerny's (2006) setting, as long as the combined utility for aviation and non-aviation goods exceeds the total price of these two goods, individuals will consume aviation and non-aviation goods together, even if their utility for the flight alone is less than the ticket price. However, in our setting, such individuals may find it optimal to become a non-traveller while consuming non-aviation goods. This possibility is excluded by Czerny (2006). In a word, our paper includes three types of individuals ignored by Czerny (2006): (1) non-travellers who buy non-aviation goods; (2) those who derive a positive surplus from non-aviation goods only if they travel, constituting the *induced demand* for non-aviation goods; and (3) those who travel to enjoy the extra-surplus due to consuming aviation and non-aviation goods together, constituting the *induced demand* for aviation goods. Moreover, in our setting, the difference in travellers and non-travellers' utility for non-aviation goods plays a crucial role. If there is no such difference, the presence of non-aviation goods would not induce any demand for aviation goods and hence two-sided complementarity would reduce to one-sided complementarity. This feature is missing in Czerny (2006).

The assumption that travellers may value certain non-aviation goods more than non-travellers can be supported by a few arguments. First, some non-aviation goods or services are clearly related to the travel activities, or elicited by travel-related motivations. For instance, *ceteris paribus*, a traveller carrying heavy luggage might be willing to pay more for car parking than a non-traveller who goes to the airport simply to shop in the landside mall. Second, there is evidence that people derive extra-value from shopping when they travel. The motivations are inherent to travelling activities, and can be considered to be present from the start of the trip.[3]

3.0 The Model and Main Results

3.1 The base case: one-sided complementarity

Consider an airport complex (including the terminal and surrounding landside zone) managed by the airport authority with the objective to maximise profit.[4] For the sake of convenience, we assume that both the runway and terminal are uncongested. Thus, the

[3]They include '*to contrast day-to-day*' and '*to be out of place*' (Geuens *et al.*, 2004), or the '*I'm on my holidays syndrome*' (Crawford and Melewar, 2003). Other motivations are: *fear* — for some people, travelling causes fear or feelings of insecurity, leading them to search for comforting behaviours from shopping; w*aiting time* — waiting travellers shop because they are bored and seek entertainment in shopping (Geuens *et al.*, 2004); *search for exclusivity* — many products, such as specially designed gift boxes and travel kits, are developed exclusively for the retail travel channel of distribution, inducing purchases; and *disposal of foreign currency*; *forgotten items* — the need for day-to-day items that a person has forgotten to pack or items that have gone missing along with passengers' bags in transit (Crawford and Melewar, 2003).

[4]Starting with the privatisation of some UK airports in 1987, a growing number of airports around the world have been privatised, or partially privatised, especially in Europe, Australia, and New Zealand (Czerny *et al.*, 2016a).

airport's marginal cost of providing aviation goods is constant and further normalised to 0. In fact, airport operating costs are typically very low (especially in comparison to airport infrastructure costs) (Czerny *et al.*, 2016a). Let $p_c \geqslant 0$ be the per passenger aviation charge; that is, the price of core goods at the airport.[5] We further abstract away economies of traffic density and normalise airline operating costs except airport charge to 0. As a result, p_c is equivalent to air ticket price and will be referred to either price of aviation goods or price of taking a flight in the paper. Let $p_s \geqslant 0$ be the per customer charge levied by the airport authority on non-aviation service providers located within the terminal — before passport control — or in the surrounding land owned by the airport authority. We assume that side goods providers have zero operating cost in addition to the p_s paid to the airport and they conduct marginal cost pricing due to a competitive bidding process. Consequently, p_s equates the final price paid by individuals for non-aviation goods; that is, the price of side goods.

Following Czerny (2006), we consider a unit mass of individuals, each of them characterised by a pair of parameters (v_c, v_s), where v_c represents the valuation for the travel (that is, the gross utility derived from flying) and v_s represents the valuation for the non-aviation goods without travelling. The individuals are uniformly distributed with density $(v_c, v_s) \sim U([-k, 1] \times [-l, 1])$, where $k \geqslant 0$ and $l \geqslant 0$.[6] Unlike Czerny (2006), we do not require gross utilities to be bounded at zero, because our setting can avoid the full coverage of market when prices are set at zero and, more importantly, potential discontinuity of demand functions in the later part of the paper. As the utilities have an upper bound equal to one, we confine our analysis to the relevant case where $p_c \leqslant 1$ and $p_s \leqslant 1$ hold. Otherwise, there will be no aviation demand. When the non-aviation service is consumed jointly with the aviation service, an individual's valuation of the non-aviation good will be $v_{s,t} = v_s = a$, with $0 \leqslant a \leqslant 1$. The parameter a refers to the travellers' extra-surplus from the consumption of non-aviation goods in comparison to non-travellers, and it is determined by the interdependence between the utilities received from aviation and non-aviation goods. If non-aviation goods are perceived as unrelated to the travel activities, a is zero and travellers do not gain any extra-surplus compared to non-travellers when consuming aviation and non-aviation goods jointly. Thus, the value of a can also indicate the extent that the features of non-aviation goods fits the need for travellers better than non-travellers. We also assume that the extra-surplus a would not exceed the maximum valuation for the non-aviation goods, and hence is bounded above at one.

In our model, the distinction between travellers and non-travellers — as well as between those who buy non-aviation goods and those who do not — is endogenously determined by the price structure at the airport. That is, all individuals are potential travellers and consumers of non-aviation goods as long as they derive more net benefit from doing so. Thus, the demand functions for aviation and non-aviation goods are derived from each individual's

[5] We abstract away market structure and market power of downstream transport service providers. The inclusion of such elements in our model would be important if one wished to apply our framework to congested airports or to railway stations, where the provider of rail transport services is generally a monopolist (D'Alfonso *et al.*, 2015).

[6] We can interpret v_c as the utility for aviation goods deducting costs not reflected in airport charges, such as the opportunity cost of travel. We can interpret v_s as the utility for non-aviation goods deducting the time spent on searching and consuming the goods. As individuals' value of time varies, v_c and v_s can be negative, leading to positive values of k and l.

ranking on the following four alternatives: (1) buy nothing; (2) buy aviation goods alone; (3) buy non-aviation goods alone; and (4) buy both aviation and non-aviation goods. We assume that each consumer is willing to purchase at most one unit of each product, and that the person receives zero utility if no purchase is made.

In the base case, as one-sided complementarity is assumed, passenger demand for flights, D_c, does not depend on the price of non-aviation goods. Individuals buy a flight as long as they derive a positive utility from travelling. Thus, the demand for aviation goods is:

$$D_c(p_c) = Prob(v_c \geqslant p_c) = A + B_1 + B_2 = \frac{1 - p_c}{1 + k}, \quad (1)$$

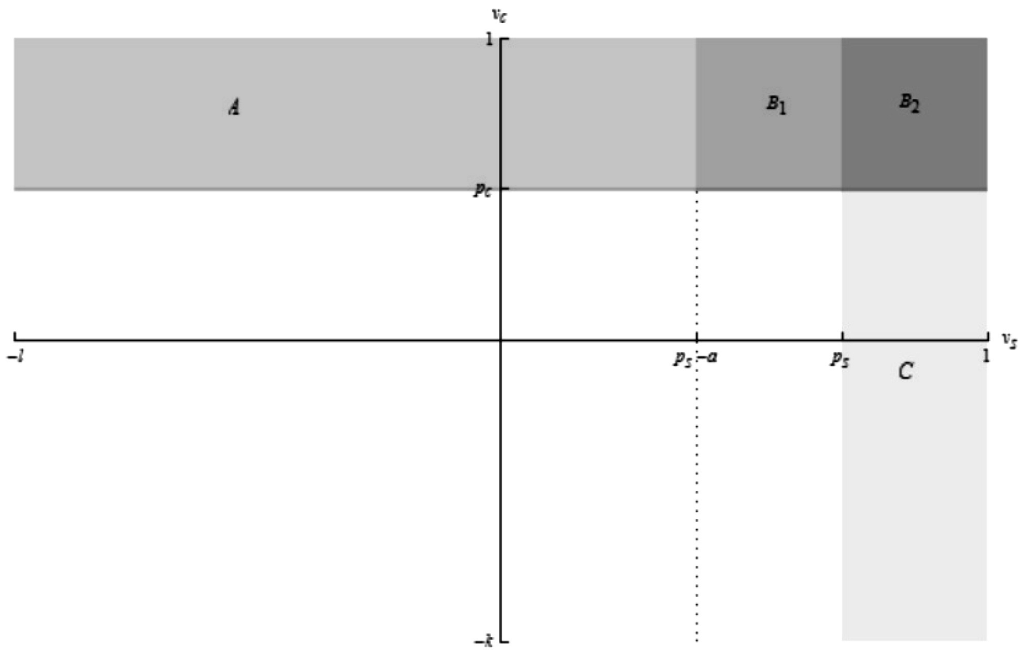
where A, B_1, and B_2 are the areas depicted in Figure 1.

We now derive the demand function for non-aviation goods. An individual who derives a positive utility from buying non-aviation goods (that is, $v_s \geqslant p_s$) is going to demand such goods irrespective of travelling or not. These individuals constitute the *non-induced demand* for non-aviation goods:

$$D_{s,ni}(p_s) = Prob(v_s \geqslant p_s) = B_2 + C = \frac{1 - p_s}{1 + l}, \quad (2)$$

where the areas B_2 and C are depicted in Figure 1. However, an individual who derives a negative utility from buying only non-aviation goods (that is, $v_s < p_s$) is going to demand them if the utility from consuming non-aviation goods jointly to the flight is

Figure 1
Structure of the Demand: One-sided Complementarity



positive (that is, $v_s + a - p_s > 0$). These individuals constitute the *induced demand* for non-aviation goods:

$$D_{s,i}(p_c) = Prob(p_s - a \leqslant v_s \leqslant p_s, v_c \geqslant p_c) = B_1 = \frac{a(1 - p_c)}{(1 + l)(1 + k)}. \tag{3}$$

Overall, we can write the demand functions for non-aviation goods as:

$$D_s(p_c, p_s) = D_{s,ni}(p_s) + D_{s,i}(p_c) = B_1 + B_2 + C = \frac{(1 - p_s)(1 + k) + a(1 - p_c)}{(1 + l)(1 + k)}. \tag{4}$$

When $a = 0$, the *induced demand* for non-aviation goods is zero. Since the demands for aviation and non-aviation goods are independent of each other's price when $a = 0$, we also call parameter a the 'degree of complementarity' in the paper. When $a \neq 0$, D_s is a function of both p_s and p_c, while $\forall a, 0 \leqslant a \leqslant 1$, D_c only reacts to changes in p_c. In other words, the offer of flights is able to stimulate the demand for non-aviation goods, while the reverse is not true.

The demand structure can be described alternatively. It is easy to note that $Prob(v_s \geqslant p_s, v_c < p_c)$ represents the non-travellers' demand for non-aviation goods, $D_{s,nt}(p_c, p_s)$, which is made up of those people who purchase non-aviation goods at the airport but are not willing to fly. Conversely, $Prob(v_s + a \geqslant p_s, v_c \geqslant p_c)$ represents the travellers' demand for non-aviation goods, $D_{s,t}(p_c, p_s)$. This results in:

$$D_{s,t}(p_c, p_s) = B_1 + B_2 = \frac{(1 - (p_s - a))(1 - p_c)}{(1 + l)(1 + k)}, \tag{5}$$

$$D_{s,nt}(p_c, p_s) = C = \frac{(1 - p_s)(p_c + k)}{(1 + l)(1 + k)}. \tag{6}$$

Interestingly, the non-travellers' demand for side goods also depends on the aviation charge. In particular, it is easy to check that $\partial D_s(p_c, p_s)/\partial p_c = -a/((1 + l)(1 + k)) \leqslant 0$, and since $p_s \in [0, 1]$, $\partial D_{s,t}(p_c, p_s)/\partial p_c = -((1 - p_s) + a)/((1 + l)(1 + k)) \leqslant 0$, while $D_{s,nt}(p_c, p_s)/\partial p_c = (1 - p_s)/((1 + l)(1 + k)) \geqslant 0$.

Observation 1. The aviation price affects non-aviation demands in the following ways: (i) $\partial D_s(p_c, p_s)/\partial p_c = \partial D_{s,i}(p_c)/\partial p_c \leqslant 0$, $\partial D_{s,t}(p_c, p_s)/\partial p_c \leqslant 0$ and $\partial D_{s,nt}(p_c, p_s)/\partial p_c \geqslant 0$; and (ii) $\partial^2 D_s(p_c, p_s)/\partial p_c \partial a = \partial^2 D_{s,i}(p_c)/\partial p_c \partial a \leqslant 0$.

When $a > 0$, consistent with Starkie (2002), part (i) of Observation 1 implies that a reduction in the price of aviation goods induces a higher demand for non-aviation goods. However, such increase is driven by the increase in the demand from travellers, to the detriment of demand from non-travellers. There are two impacts on the travellers' non-aviation demand. First, some non-travellers who consume non-aviation goods become travellers as the price of a flight reduces. This impact does not increase the total non-aviation demand, but is a mere transfer of consumer status from non-travellers to travellers. Second, some individuals who buy neither aviation goods nor non-aviation goods become travellers and they start to purchase non-aviation goods as well, since the extra-surplus from joint consumption makes consuming non-aviation goods a better choice, leading to the socalled induced non-aviation demand, $D_{s,i}(p_c)$. This impact causes the net increase in total demand for non-aviation goods. However, when $a = 0$, the second impact (due to the induced non-aviation demand) disappears and hence the demands for aviation and non-aviation goods become independent; that is, $\partial D_s(p_c, p_s)/\partial p_c = 0$. Part (ii) of Observation 1 suggests that an increase in the degree of complementarity a will enhance the impact of aviation price on the demand of non-aviation goods.

The airport maximises its profits by simultaneously choosing the charges for both sides of its business. Analytically, the airport solves the following problem:

$$max_{p_c,p_s}\pi(p_c, p_s) = p_c D_c(p_c, p_s) + p_s D_s(p_c, p_s). \tag{7}$$

Based on equations (1), (4), and (7), it is straightforward to obtain Lemma 1.

Lemma 1. $\partial^2\pi/\partial p_c\partial p_s = \partial D_s(p_c, p_s)/\partial p_c = \partial D_{s,i}(p_c)/\partial p_c \leqslant 0.$

The first two equal signs in Lemma 1 come from the fact that p_s has no impact on the marginal profit with respect to p_c, $\partial\pi/\partial p_c$, generated from aviation goods due to one-sided complementarity, but it affects the marginal profit generated from the induced demand for non-aviation goods. Therefore, following Observation 1(i), when $a = 0$, $\partial^2\pi/\partial p_c\partial p_s = 0$. That is, when there is zero degree of complementarity, a variation in the non-aviation charge does not induce any change in the aviation charge as demands for these two goods are independent. However, when $a > 0$, an increase in the price for non-aviation goods induces a reduction in the marginal profit, because an increase in p_s exaggerates the non-aviation profit loss owing to higher p_c and hence lower induced non-aviation demand.

First-order necessary optimality conditions for unconstrained optimisation can be expressed as follows:

$$\begin{aligned} \left.\frac{\partial\pi}{\partial p_c}\right|_{p_c=p_c^*,p_s=p_s^*} &= D_c(p_c^*) + p_c^*\left.\frac{\partial D_c(p_c)}{\partial p_c}\right|_{p_c=p_c^*} + p_s^*\left.\frac{\partial D_{s,i}(p_c)}{\partial p_c}\right|_{p_c=p_c^*} = 0, \\ \left.\frac{\partial\pi}{\partial p_s}\right|_{p_c=p_c^*,p_s=p_s^*} &= D_{s,ni}(p_s^*) + D_{s,i}(p_c^*) + p_s^*\left.\frac{\partial D_{s,ni}(p_s)}{\partial p_s}\right|_{p_s=p_s^*} = 0, \end{aligned} \tag{8}$$

where the superscript * indicates the optimum. The unique interior solution (p_c^*, p_s^*), with $p_j^* \in [0, 1]$ for $j = c, s$, and $a \in [0, 1]$, is described below:[7]

$$\begin{pmatrix} p_c^* \\ p_s^* \end{pmatrix} = \begin{pmatrix} \dfrac{2(1+l)(1+k) - a^2 - a(1+k)}{4(1+l)(1+k) - a^2} \\ \dfrac{(1+l)(2(1+k)+a)}{4(1+l)(1+k) - a^2} \end{pmatrix}. \tag{9}$$

It is easy to see that $\partial^2\pi/\partial p_s\partial a = \partial D_{s,i}(p_c)/\partial a \geqslant 0$, while Observation 1(ii) and Lemma 1 give $\partial^2\pi/\partial p_c\partial a = p_s\partial^2 D_{s,i}(p_c)/\partial p_c\partial a \leqslant 0$, which leads to Proposition 1.

[7] The eigenvalues of the Hessian of the objective function are negative; thus second-order necessary optimality conditions for unconstrained optimisation are always satisfied. We solved the decision problem by relaxing the constraint that prices must be in the range [0,1] and checked that this constraint is satisfied.

Proposition 1. At the optimum, an increase in the degree of complementarity between aviation and non-aviation activities, a, leads to an increase of the non-aviation charge and to a reduction of the aviation charge; that is, $\partial p_s^*/\partial a \geqslant 0$ and $\partial p_c^*/\partial a \leqslant 0$. The equal signs hold when $a = 0$.

In other words, when both travellers and non-travellers buy non-aviation goods, the airport reacts to an increase in a by raising the price for non-aviation goods to the detriment of non-travellers, and reduces the price for aviation goods. This can be explained by looking at the elasticity of demand for non-aviation goods; that is, $\varepsilon_s = -\left(\partial D_s(p_c, p_s)/\partial p_s\right) \cdot \left(p_s/D_s(p_c, p_s)\right)$. It is easy to note that $\partial \varepsilon_s/\partial a \leqslant 0$, because $\partial D_s(p_c, p_s)/\partial a = \partial D_{s,t}(p_c, p_s)/\partial a = \partial D_{s,i}(p_c)/\partial a \geqslant 0$. Since an increase in the extra-surplus a causes the demand for non-aviation goods less elastic to price, the airport will raise the non-aviation price when a increases. Conversely, $\partial \varepsilon_c/\partial a = 0$, where $\varepsilon_c = -\left(\partial D_c(p_c)/\partial p_c\right) \cdot \left(p_c/D_c\right)$ is the elasticity of demand for aviation goods, and therefore an increase in a has no direct impact on the aviation charge. However, based on Lemma 1, a marginal increase in the non-aviation price produces an incentive to reduce p_c, so as to induce higher demand for non-aviation goods from travellers.

3.2 Extension: two-sided complementarity

In this section, we focus on the case in which individuals, when purchasing the flight ticket, fully take into account the surplus they will get from the consumption of non-aviation goods; that is, the case of *two-sided complementarity* between aviation and non-aviation goods.[8] Again, we assume that each individual is willing to purchase at most one unit of each product, and receives zero utility if no purchase is made. The individual is fully informed about the non-aviation offerings and, when buying the flight tickets, fully anticipates the surplus that can be obtained by purchasing non-aviation goods at the airport (Czerny, 2006; 2013). In this new setting, people will buy the flight ticket if $v_c + max\{CS_{s,t}(p_s), 0\} - p_c \geqslant 0$. Here, $CS_{s,t}(p_s) = v_s - p_s + a$ is the surplus that travellers can gain from the consumption of non-aviation goods. In the rest of the paper, we assume the lower bounds of gross utilities are large enough (that is, $k \geqslant a$ and $l \geqslant a$) to avoid discontinuity of demand functions.

In the literature (Czerny, 2006; 2013), it is assumed that travellers consume both aviation and non-aviation goods as long as the total net benefit is positive. However, in our setting, an individual may only buy one type of goods if it leads to higher net utility than consuming both of them. Thus, except for buying nothing, there are three cases. In the first case, individuals will buy the flight alone. This occurs if and only if the net benefit from this choice is greater than the net utility from buying the two products together or buying nothing. Analytically, this is the case in which $v_c - p_c \geqslant 0$ and $v_c - p_c \geqslant v_c - p_c + (v_s + a - p_s)$, which corresponds to individuals located in area A of

[8]As noted by an anonymous referee, it is still unclear to what extent concession activities can affect travel decisions since information about products and non-aeronautical services available at the terminals can be limited. Indeed, we have also analysed the case in which consumers have imperfect foresight on the non-aviation goods surplus when purchasing the flight tickets. To achieve this, we apply the approach of Flores-Fillol *et al.* (2015), where the demand for air travel depends on a fraction, representing the degree of foresight, of the surplus from non-aviation goods. Then, it can be shown that both an increase in consumer foresight and an increase in traveller extra-surplus for non-aviation goods shift the demand for flights (and the induced demand for non-aviation goods). A technical appendix is available upon request.

Figure 2
Structure of the Demand: Two-sided Complementarity

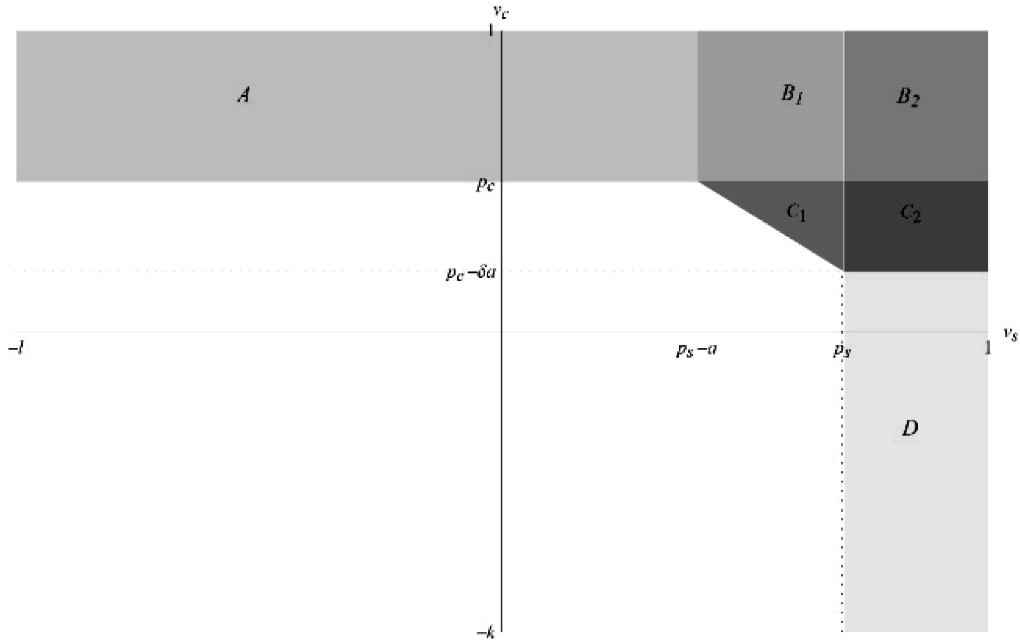


Figure 2. In the second case, individuals will buy the two products together, which happens when the net utility received from this alternative is positive and greater than that from buying the aviation or the non-aviation goods alone. That is, $v_c - p_c + (v_s + a - p_s) \geqslant 0$, $v_c - p_c + (v_s + a - p_s) \geqslant v_s - p_s$, and $v_c - p_c + (v_s + a - p_s) \geqslant v_c - p_c$ should hold simultaneously. This is true for individuals located in area $B_1 + B_2 + C_1 + C_2$ of Figure 2. Those located in B_2 will buy both goods regardless of the extra-surplus from joint consumption of aviation and non-aviation goods, while those in C_1 have both aviation and non-aviation demands induced from joint consumption. Those located in B_1 have only the non-aviation demand induced from joint consumption, while those in C_2 have only the aviation demand induced. In the third case, an individual will only buy the non-aviation good and this occurs when doing so brings greater benefit than buying the two products together or buying nothing. That is, $v_s - p_s \geqslant 0$ and $v_s - p_s \geqslant v_c - p_c + (v_s + a - p_s)$ should both hold. This is the case for individuals located in area D of Figure 2.

Therefore, we can write the demand function for aviation goods as follows:

$$D_c(p_c, p_s) = \underbrace{A + B_1 + B_2}_{D_{c,ni}} + \underbrace{C_1 + C_2}_{D_{c,i}} = \underbrace{\frac{1 - p_c}{1 + k}}_{D_{c,ni}} + \underbrace{\frac{a^2 + 2a(1 - p_s)}{2(1 + l)(1 + k)}}_{D_{c,i}}. \tag{10}$$

Different from the base case, now the aviation demand has two parts. The first part, denoted as $D_{c,ni}(p_c)$, is the non-induced aviation demand. This part is the same as the aviation demand in the base case and hence is independent of parameter a and p_s. The second part, $D_{c,i}(p_s)$, only exists with two-sided complementarity. It is the induced demand for flights, as surplus from non-aviation goods is taken into account, and hence this part of the aviation demand increases in parameter a and decreases in p_s. If the consumption of non-aviation goods together with aviation goods did not lead to extra-surplus, individuals located in C_2 would consume non-aviation goods alone, while those located in C_1 would purchase neither aviation goods nor non-aviation goods. Thus, when individuals anticipate the surplus from the consumption of non-aviation goods, the degree of complementarity a will positively affect the demand for flights. That is, $\partial D_c(p_c, p_s)/\partial a = \partial D_{c,i}(p_s)/\partial a \geqslant 0$, and $\partial \varepsilon_c/\partial a \leqslant 0$. Unlike the modelling approach applied by Czerny (2006), our approach links the impact of two-sided complementarity assumption on the demand for aviation goods to the extra-surplus generated from joint consumption. That is, joint consumption would induce aviation demand if and only if there is positive extra-surplus (that is, $a > 0$). However, in Czerny's (2006) setting, joint consumption will induce aviation demand although there is no extra-surplus. This difference stems from the inclusion of non-travellers' demand for non-aviation goods. Since Czerny (2006) abstracted away the alternative of consuming non-aviation goods alone, some of the individuals in C_2 are forced to jointly consume aviation and non-aviation goods, even though they receive lower net utility than consuming non-aviation goods alone.

Similarly, we may write the demand for non-aviation goods as:

$$D_s(p_c, p_s) = \underbrace{B_2 + C_2 + D}_{D_{s,ni}(p_s)} + \underbrace{B_1 + C_1}_{D_{s,i}(p_c)} = \underbrace{\frac{1 - p_s}{1 + l}}_{D_{s,ni}(p_s)} + \underbrace{\frac{a(1 - p_c)}{(1 + l)(1 + k)} + \frac{a^2}{2(1 + l)(1 + k)}}_{D_{s,i}(p_c)}. \tag{11}$$

The non-induced demand for non-aviation goods, $D_{s,ni}$, remains the same as in the base case. However, the induced demand for non-aviation goods, $D_{s,i}$, includes: (i) Those individuals (in B_1) who would have only bought the aviation goods if there were no extra-surplus from jointly consuming both aviation and non-aviation goods; and (ii) individuals (in C_1) who would have bought neither aviation nor non-aviation goods if they were not jointly consumed. In the base case, $D_{s,i}(p_c)$ only includes individuals located in B_1 but not C_1. Thus, with two-sided complementarity, an increase in a raises the induced non-aviation demand even more than the base case and similarly $\partial \varepsilon_s/\partial a \leqslant 0$ holds again. It is straightforward to see that when $a = 0$, one-sided and two-sided complementarity is equivalent. The non-aviation demand can be rewritten as follows:

$$\begin{aligned} D_s(p_c, p_s) &= \underbrace{D}_{D_{s,nt}} + \underbrace{B_1 + B_2 + C_1 + C_2}_{D_{s,t}} \\ &= \underbrace{\frac{(1 - p_s)(p_c - a + k)}{(1 + l)(1 + k)}}_{D_{s,nt}} + \underbrace{\frac{(2(1 - p_c) + a)(1 - p_s + a)}{2(1 + l)(1 + k)}}_{D_{s,t}}. \end{aligned} \tag{12}$$

Equation (12) shows the distinction between travellers' and non-travellers' demand for non-aviation goods. Similar to the base case, the former decreases in p_c while the latter increases in p_c. The main difference is that with two-sided complementarity, non-travellers' demand for non-aviation goods decreases (rather than remaining unchanged) as the degree of complementarity increases, because higher interdependence between aviation and non-aviation goods induces more people to switch from non-travellers to travellers, even if their net utility from travel alone is negative.

Again the airport maximises profit by choosing p_c and p_s:

$$max_{p_c,p_s} \pi(p_c, p_s) = p_c D_c(p_c, p_s) + p_s D_s(p_c, p_s). \tag{13}$$

The first-order necessary optimality conditions for unconstrained optimisation are:

$$\begin{aligned} \left.\frac{\partial \pi}{\partial p_c}\right|_{p_c=p_c^*, p_s=p_s^*} &= D_{c,ni}(p_c^*) + D_{c,i}(p_s^*) + p_c^* \left.\frac{\partial D_{c,ni}(p_c)}{\partial p_c}\right|_{p_c=p_c^*} + p_s^* \left.\frac{\partial D_{s,i}(p_c)}{\partial p_c}\right|_{p_c=p_c^*} = 0, \\ \left.\frac{\partial \pi}{\partial p_s}\right|_{p_c=p_c^*, p_s=p_s^*} &= p_c^* \left.\frac{\partial D_{c,i}(p_s)}{\partial p_s}\right|_{p_s=p_s^*} + D_{s,ni}(p_s^*) + D_{s,i}(p_c^*) + p_s^* \left.\frac{\partial D_{s,ni}(p_s)}{\partial p_s}\right|_{p_s=p_s^*} = 0. \end{aligned} \tag{14}$$

Solving equation (14) and following the same procedure as in Section 3.1, we obtain the unique interior solution (p_c^*, p_s^*), with $p_j^* \in [0, 1]$ for $j = c, s$:

$$\begin{pmatrix} p_c^* \\ p_s^* \end{pmatrix} = \begin{pmatrix} \dfrac{a^3 - 2(1+l)(1+k) + a^2(1-k)}{4(a^2 - (1+l)(1+k))} \\ \dfrac{a^3 - 2(1+l)(1+k)}{4(a^2 - (1+l)(1+k))} \end{pmatrix}. \tag{15}$$

As mentioned above, since two-sided complementarity causes the induced aviation demand, we have both $\partial \varepsilon_c / \partial a \leqslant 0$ and $\partial \varepsilon_s / \partial a \leqslant 0$. An increase in a gives more incentives for the airport to raise both aviation and non-aviation charges, which leads to Proposition 2.

Proposition 2. At the optimum, an increase in the degree of complementarity between aviation and non-aviation goods, a, leads to an increase of both aviation and non-aviation charges, that is $\partial p_s^* / \partial a \geqslant 0$ and $\partial p_c^* / \partial a \geqslant 0$. The equal signs hold when $a = 0$.

The impact of a on the marginal profit with respect to the non-aviation price is $\partial^2 \pi / \partial p_s \partial a = p_c \partial^2 D_{c,i}(p_s) / \partial p_s \partial a + \partial D_{s,i}(p_c) / \partial a$. Although $\partial^2 D_{c,i}(p_s) / \partial p_s \partial a \leqslant 0$ and $\partial D_{s,i}(p_c) / \partial a \geqslant 0$, it is straightforward to show that the second effect dominates the first one and hence $\partial^2 \pi / \partial p_s \partial a \geqslant 0$ always holds. Therefore, the equilibrium non-aviation price increases in a. Moreover, the impact of a on the marginal profit with respect to the aviation price is $\partial^2 \pi / \partial p_c \partial a = \partial D_{c,i}(p_s) / \partial a + p_s \partial^2 D_{s,i}(p_c) / \partial p_c \partial a$ with $\partial D_{c,i}(p_s) / \partial a \geqslant 0$ and $\partial^2 D_{s,i}(p_c) / \partial p_c \partial a \leqslant 0$. Unlike the base case, now the first effect leads to the reduced elasticity of the demand for flights, which pushes up the aviation price, while the second effect tends to reduce aviation price as in the base case. It can be proved that at the equilibrium, the first effect always dominates the second one.

4.0 Implications and Discussion

4.1 Impacts of non-aviation and non-traveller demands on the abuse of market power

In this section, we discuss how the provision of non-aviation goods and the existence of non-travellers' demand for non-aviation goods affect airport charges. We compare the equilibrium airport charges with two benchmark cases widely assumed in the literature. The first benchmark case depicts a situation in which only aviation goods are available at the airport. This case is denoted as SP in the rest of the paper. The second describes the case in which only travellers will purchase non-aviation goods at the airport (though they may abstain from consuming any of these goods), which is later denoted as I. In particular, we want to answer the following question: does a private uncongested airport ask for a higher aviation charge compared to the case in which non-travellers are excluded?

4.1.1 One-sided complementarity

When only aviation goods are available at the infrastructure, the airport maximises its profits by choosing the aviation charge:

$$max_{p_c} \pi^{SP}(p_c) = p_c D_c(p_c), \tag{16}$$

where $D_c(p_c)$ is given in (1). The optimal solution is given below:

$$p_c^{SP} = \tfrac{1}{2}. \tag{17}$$

Observation 2 compares (9) with the airport charge described in (17).

Observation 2. Compared to the case where only aviation goods are available at the infrastructure, having non-aviation goods makes the airport charge a lower aviation price (that is, $p_c^* \leqslant p_c^{SP}$) where the equal sign holds when $a = 0$. Moreover, such a price difference increases as a increases; that is, $\partial(p_c^{SP} - p_c^*)/\partial a > 0$.

When both aviation and non-aviation goods are available at the airport, with the latter being consumed only by travellers, the airport maximises its profits by simultaneously choosing its charges on both sides of the business:

$$max_{p_c, p_s} \pi^I(p_c, p_s) = p_c D_c(p_c) + p_s D_{s,t}(p_c, p_s), \tag{18}$$

where $D_c(p_c)$ and $D_{s,t}(p_c, p_s)$ are defined in equations (1) and (5), respectively. The only difference between equations (7) and (18) is the addition of non-traveller demand for non-aviation goods, $D_{s,nt}$, in equation (7). After taking first-order conditions and following the same procedure as mentioned in Section 3, we obtain the following optimal prices:

$$\begin{pmatrix} p_c^I \\ p_s^I \end{pmatrix} = \begin{pmatrix} \dfrac{3 - 2a - a^2 + 4l}{8(1 + l)} \\ \dfrac{(1 + a)}{2} \end{pmatrix}, \tag{19}$$

where the superscript I stands for the case in which the demand for non-aviation goods is included in the demand for aviation goods. Proposition 3 compares the optimal aviation and non-aviation charges in this case with the one described in equation (9).

Proposition 3. Compared to the case in which non-travellers are excluded, when both travellers and non-travellers demand non-aviation goods, (i) the airport charges a higher (lower) aviation (non-aviation) price — that is, $p_c^* \geqslant p_c^I$ and $p_s^* \leqslant p_s^I$; and (ii) an increase in the degree of complementarity raises an airport's incentive to increase (reduce) the aviation (non-aviation) charge — that is, $\partial\left(p_c^* - p_c^I\right)/\partial a \geqslant 0$ and $\partial\left(p_s^I - p_s^*\right)/\partial a \geqslant 0$.

In fact, when both travellers and non-travellers demand non-aviation goods, the airport has an incentive to reduce the non-aviation price in order to earn more profits from non-travellers; that is, $\partial D_{s,nt}\left(p_c, p_s\right)/\partial p_s \leqslant 0$. Furthermore, the marginal benefit from aviation price reduction decreases, since higher aviation charges induce higher demand for non-aviation goods from non-travellers; that is, $\partial D_{s,nt}\left(p_c, p_s\right)/\partial p_c \geqslant 0$.

The above analysis leads to important policy implications. Although our finding is consistent with the prediction made by the literature of one-sided complementarity that airports have incentives to restrain the aviation charge in order to boost traffic and expand non-aviation goods revenues (Observation 2), such an impact could be overstated in the case of airport city. In particular, when non-travellers also play an important role in the airport's business, the presence of non-aviation business may only exert a mild or even limited downward pressure on the private aviation charge if the extra-surplus gained by travellers, as compared to non-travellers, induces demand for non-aviation activities (Proposition 3), leading to a higher aviation charge than an ordinary airport without a focus on non-travellers.[9] Moreover, as the degree of complementarity increases, an airport's tendency to charge a higher aviation price (compared to the case in which only travellers demand non-aviation goods) is even reinforced. This is because an increase in a leads to an increase in travellers' demand for non-aviation goods, while non-travellers' demand remains unchanged, leading to lower marginal benefits from reducing aviation charges.

Proposition 3 also appears to be consistent with Waguespack's (2015) notion of street pricing (or value), according to which non-aviation charges should be reduced to approach the level equivalent to what a consumer/passenger would pay for the same item outside the airport; that is, in a traditional retail store located in a 'street'. In some cases, street pricing is accompanied with evidence that airports are coming up with a plan that allows retailers to sell goods at kiosks in the publicly accessible civic amenities. The goal is to draw more non-travellers to the airport shopping area, which could translate into more sales for concessionaires.

4.1.2 Two-sided complementarity

The first benchmark case with only aviation goods available at the airport is irrelevant when two-sided complementarity is under concern. Thus, only the second benchmark case — when both aviation and non-aviation goods are sold at the airport and non-traveller demand is absent — is compared with our results derived in Section 3.2.

In this case, the structure of the benchmark problem will change. In analogy to the previous section, when both services are available at the facility, people will buy the air ticket if the benefit $v_c + max\left\{v_s - p_s + a, 0\right\} - p_c$ is greater than 0. However, only travellers may purchase side goods. Thus, we can derive the demands for the two goods as follows. Customer (v_c, v_s) will buy the air ticket alone if and only if the net benefit he or she gains from this choice is greater than the utility he or she expects to gain from buying nothing or

[9] Literature on one-sided complementarity used to abstract away this mechanism, since demand for non-aviation goods has always been assumed to come from travellers only, and thus to be a decreasing function of aviation prices.

the two products together. Analytically, this is the case in which $v_c - p_c \geqslant 0$ and $v_c - p_c \geqslant v_c - p_c + (v_s + a - p_s)$. Conversely, the customer will buy the two products together if and only if the utility that he or she expects to receive from this alternative is positive and greater than the utility gained from taking the flight alone; that is, if $v_c - p_c + (v_s + a - p_s) \geqslant 0$ and $v_c - p_c + (v_s + a - p_s) \geqslant v_c - p_c$. Thus, in this scenario, the benchmark decision problem of the airport is:

$$max_{p_c,p_s} \pi^I(p_c, p_s) = p_c D_c^I(p_c, p_c) + p_s D_{s,t}^I(p_c, p_s), \tag{20}$$

where $D_c^I(p_c, p_c)$ and $D_{s,t}^I(p_c, p_s)$ are the demands for aviation and non-aviation services, respectively, in this setting, as derived from previous assumptions.[10]

Since the highly non-linear nature of the problem at hand prevents us from fully characterising the optimal airport pricing decisions analytically, we turn to numerical methods. Table 1 shows the optimal airport charges (that is, p_c^I and p_s^I) for a set of values of a in the range [0, 1] and two specific values of l ($l = 1$ and $l = 5$), while parameter k can be any value larger than a.

When individuals foresee the surplus they will gain from the consumption of non-aviation goods at the time of air ticket purchase, an increase in travellers' extra-surplus for non-aviation goods shifts out the demand for flights (and the induced demand for non-aviation goods). Thus, the airport finds it profit maximising to set a lower aviation charge and higher non-aviation charge compared to the benchmark case in which non-travellers are not taken into account.

However, the incentive to reduce (increase) aviation (non-aviation) charge is moderated as the degree of complementarity increases. In addition, such incentive is: (i) moderated by high values of k, since $\partial p_c^*/\partial k \geqslant 0$ and $\partial p_s^*/\partial k \leqslant 0$; and (ii) moderated by high values of l. In fact, when a, k, and l are large, the airport finds it profit maximising to charge a higher aviation price and lower non-aviation price, compared to the benchmark case in which non-travellers are not taken into account.

4.2 Profit and welfare implications

Although our model treats the degree of exogenous complementarity, the airport might affect it by, for instance, choosing the right types of retailers in the terminals or in the surrounding land parcels, or creating a unique environment that stimulates travellers to buy non-aviation goods. Thus, in this section, we discuss the impact of the degree of complementarity on airport profit, social welfare, and the surplus of specific groups of individuals.

4.2.1 Airport profits

Let π^*, π_c^*, π_s^* be the airport's equilibrium total profit, aviation profit, and non-aviation profit, respectively; that is, $\pi^* = \pi_c^* + \pi_s^* = p_c^* D_c(p_c^*, p_s^*) + p_s^* D_s(p_c^*, p_s^*)$. Moreover, let $\pi_{s,t}^*$ and $\pi_{s,nt}^*$ be the airport's equilibrium non-aviation profits from travellers and non-travellers, respectively; that is, $\pi_{s,t}^* = p_s^* D_{s,t}(p_c^*, p_s^*)$ and $\pi_{s,nt}^* = p_s^* D_{s,nt}(p_c^*, p_s^*)$. Prices p_c^* and p_s^* are the optimal charges given in (9) if one-sided complementarity holds, or in equation (15) if two-sided complementarity holds. Equivalently, $D_{s,t}(p_c^*, p_s^*)$ and $D_{s,nt}(p_c^*, p_s^*)$ are given in equations (5) and (6) if one-sided complementarity holds, or in

[10] For the sake of space, we did not report here the full expression for demand functions in this benchmark scenario, but they are available upon request from the authors.

Table 1
Comparison Between Optimal Charges (with l = 1 and l = 5) Under Two-sided Complementarity

	p_c^I	p_s^I	$p_c^I - p_c^*$	$p_s^I - p_s^*$
		$l = 1$		
$a = 0.00$	0.544	0.203	>0	<0
$a = 0.10$	0.546	0.227	>0	<0
$a = 0.20$	0.553	0.250	>0	<0
$a = 0.30$	0.562	0.273	>0	<0
$a = 0.40$	0.571	0.296	>0	<0
$a = 0.50$	0.581	0.317	>0	<0
$a = 0.60$	0.593	0.337	>0	<0
$a = 0.70$	0.607	0.355	>0	<0
$a = 0.80$	0.623	0.371	>0	<0
$a = 0.90$	0.642	0.383	>0	<0
$a = 1.00$	0.667	0.391	>0	<0
		$l = 5$		
	p_c^I	p_s^I	$p_c^I - p_c^*$	$p_s^I - p_s^*$
$a = 0.00$	0.510	0.225	>0	<0
$a = 0.10$	0.512	0.253	>0	<0
$a = 0.20$	0.514	0.282	>0	<0
$a = 0.30$	0.515	0.311	>0	<0
$a = 0.40$	0.517	0.341	>0	<0
$a = 0.50$	0.518	0.370	>0	<0
$a = 0.60$	0.520	0.400	>0	<0
$a = 0.70$	0.522	0.430	>0	<0
$a = 0.80$	0.524	0.460	>0	<0
$a = 0.90$	0.525	0.490	<0 if $k > 3.068$ ≥ 0 otherwise	<0 if $k > 7.853$ ≤ 0 otherwise
$a = 1.00$	0.527	0.520	<0 if $k > 1.564$ ≥ 0 otherwise	>0 if $k > 9.719$ ≤ 0 otherwise

equation (12) if two-sided complementarity holds. The effects of a on the airport's various equilibrium profits are presented in Proposition 4.

Proposition 4. When non-travellers demand non-aviation goods, the following holds for equilibrium airport profits: (i) $\partial\pi^*/\partial a \geqslant 0$; (ii) $\partial\pi_s^*/\partial a \geqslant 0$ with $\partial\pi_{s,t}^*/\partial a \geqslant 0$ but $\partial\pi_{s,nt}^*/\partial a \leqslant 0$; and (iii) $\partial\pi_c^*/\partial a \leqslant 0$ under one-sided complementarity, but $\partial\pi_c^*/\partial a \geqslant 0$ under two-sided complementarity.

Proof. See Appendix.

Proposition 4 has implications for the airport's non-aviation business strategy, although we do not seek to characterise the optimal non-aviation goods supplied by the airport. First, regardless of travellers' foresight on the benefit from non-aviation goods, strategies aiming at raising the interdependence between aviation and non-aviation goods will bring more revenues to the airport. Thus, airports would benefit by activating different stimuli that makes travellers perceive a higher extra-surplus from purchasing at airports, which might be achieved through effective communication.[11] From an airport manager's point of view, when an airport implements the airport city model, it might be beneficial to raise the degree of complementarity by manipulating the non-aviation product mix and providing a sufficient share of side goods or services specialised for air travellers, such as travel kits and hotels. Thus, the airport management team should be disciplined to avoid overemphasis on ordinary consumer goods that attract non-travellers, although the group size of non-travellers tends to be much larger than the group size of travellers.

Second, the above-mentioned strategy tends to be more effective in the case of *two-sided* complementarity than one-sided complementarity, as in the former case some aviation demand will be induced by a as well. In other words, the airport has incentives to stimulate both a high level of a and passenger foresight as long as it is not too expensive to do so. However, since the increase in non-aviation revenue is also driven by an increase in the non-aviation price (Propositions 1 and 2), we stress that this strategy might not be sustainable in the presence of tough competition from outside retailers, which is not modelled in this paper and thus deserves further analysis in the future.[12]

4.2.2 Social welfare and consumer surplus

Given that all costs are normalised to zero, social welfare is the sum of the surplus generated by aviation and non-aviation activities, and can be evaluated as follows:

$$
\begin{aligned}
W(p_c, p_s) = \frac{1}{(1+l)(1+k)} \Bigg(& \int_{-l}^{1} \int_{p_c}^{1} v_c dv_c dv_s + \int_{p_s}^{1} \int_{p_c-\delta a}^{p_c} v_c dv_c dv_s \\
& + \int_{p_s-a}^{p_s} \int_{p_c-\delta(v_s+a-p_s)}^{p_c} v_c dv_c dv_s + \int_{p_c-\delta a}^{1} \int_{p_s}^{1} (v_s + a) dv_s dv_c \\
& + \int_{p_c-\delta(v_s+a-p_s)}^{1} \int_{p_s-a}^{p_s} (v_s + a) dv_s dv_c + \int_{-k}^{p_c-\delta a} \int_{p_s}^{1} v_s dv_s \Bigg),
\end{aligned} \tag{21}
$$

where $\delta = 0$ under one-sided complementarity and $\delta = 1$ under two-sided complementarity. Policy makers may be more concerned about consumer surplus than producer surplus. Moreover, two types of consumers may buy goods at the airport: travellers and non-travellers. For these reasons, we analyse consumer surplus, $\mathrm{CS}(p_c, p_s)$, distinguishing between the surplus that travellers gain from aviation and non-aviation goods, $\mathrm{CS}_t(p_c, p_s)$, and the surplus that non-travellers gain from non-aviation goods, $\mathrm{CS}_{nt}(p_c, p_s)$:

$$
\begin{aligned}
CS_t(p_c, p_s) = \frac{1}{(1+l)(1+k)} \Bigg(& \int_{-l}^{1} \int_{p_c}^{1} (v_c - p_c) dv_c dv_s + \int_{p_s}^{1} \int_{p_c-\delta a}^{p_c} (v_c - p_c) dv_c dv_s \\
& + \int_{p_s-a}^{p_s} \int_{p_c-\delta(v_s+a-p_s)}^{p_c} (v_c - p_c) dv_c dv_s + \int_{p_c-\delta a}^{1} \int_{p_s}^{1} (v_s + a - p_s) dv_s dv_c \\
& + \int_{p_c-\delta(v_s+a-p_s)}^{1} \int_{p_s-a}^{p_s} (v_s + a - p_s) dv_s dv_c \Bigg),
\end{aligned} \tag{22}
$$

[11] Crawford and Melewar (2003) describe different strategies in order to increase the surplus that browsers may obtain from airport purchases such as: (i) *Increase excitement* (chocolate production demonstration by Lindt at the Belgium Sky Shops); (ii) *reduce boredom* (the world's first airport casino at Amsterdam Duty Free); and (iii) *'Happy hour' syndrome* (the 'Cigar Bar' for customers at Beirut Duty free).

[12] Further studies on airport choice of the marketing mix of non-aviation goods should also incorporate the cost of alternative marketing strategies.

$$\mathrm{CS}_{nt}(p_c, p_s) = \frac{1}{(1+l)(1+k)}\left(\int_{-k}^{p_c-\delta a}\int_{p_s}^{1}(v_s - p_s)dv_s dv_c\right), \tag{23}$$

where $\mathrm{CS}(p_c, p_s) = \mathrm{CS}_t(p_c, p_s) + \mathrm{CS}_{nt}(p_c, p_s)$ and, again, $\delta = 0, 1$.

Let $W^* = W(p_c^*, p_s^*)$ be the equilibrium social welfare and $CS_t^* = CS_t(p_c^*, p_s^*)$ and $CS_{nt}^* = CS_{nt}(p_c^*, p_s^*)$ be the equilibrium travellers and non-travellers surplus, respectively. They are evaluated by p_c^* and p_s^*, as described given in equation (9) if $\delta = 0$, or given in equation (15) if $\delta = 1$. The following proposition illustrates how social welfare and consumer surplus vary when the degree of complementarity varies.

Proposition 5. At the equilibrium, the following results hold:
(i) social welfare: $\partial W^*/\partial a \geqslant 0$;
(ii) consumer surplus: $\partial CS^*/\partial a \geqslant 0$, with $\partial CS_t^*/\partial a \geqslant 0$ while $\partial CS_{nt}^*/\partial a \leqslant 0$.

Proof. See Appendix.

Part (i) of Proposition 5 is intuitive, as an increase in a can be interpreted as an increase in the quality of non-aviation goods supplied by the airport and, in our setting, there are no costs associated with quality a. Part (ii) suggests that the gain in consumer surplus owing to the increase in quality a is larger than the loss in consumer surplus due to the increase in prices (p_s in the basic model and p_s and p_c in the extension to two-sided complementarity). Moreover, travellers' consumer surplus increases in a, because some non-travellers become travellers under two-sided complementarity and their surplus increases slightly, even though they pay a higher p_s. However, people who buy only non-aviation goods are worse off.

Proposition 5 leads to some important policy implications. In particular, moving the non-aviation product mix towards a more traveller-oriented business (that is, to increase a) may be not only profitable for the airport (Proposition 4), but also social welfare and traveller surplus enhancing. However, such positive effects occur to the detriment of non-travellers, who end up paying a higher price for non-aviation goods. Thus, policy makers should be aware that, although some airport strategy may be valuable for society as a whole, one group of individuals might end up being worse off.

5.0 Concluding Remarks

In this paper, we focused on the issue of multiproduct pricing of aviation and non-aviation goods in the case of airport cities where non-aviation goods, supplied within the terminal or in the surrounding land parcels of the airport, are available to two groups of customers — travellers and non-travellers. In our model, the utility from the consumption of non-aviation goods depends on whether individuals travel or not. We explicitly model the degree of complementarity arising from the joint consumption of aviation and non-aviation goods (or, equivalently, the extra-surplus gained by travellers compared to non-travellers from consuming non-aviation goods). Such a degree of complementarity could be interpreted as the level of interdependence between aviation and non-aviation goods or the extent of traveller-orientation in the non-aviation goods provided at the airport. As a result, there are individuals who derive a positive surplus from consuming non-aviation goods only if they travel. These individuals constitute the *induced demand* for non-aviation goods, which increases in the degree of complementarity.

The impacts of the degree of complementarity on airport pricing are compared between two plausible scenarios: (i) one-sided complementarity which assumes individuals make decisions about buying aviation and non-aviation goods independently; and (ii) two-sided complementarity which assumes individuals determine the consumption of non-aviation goods at the time of air ticket purchase. Although these two scenarios are equivalent if the degree of complementarity is zero, raising the degree of complementarity would have different impacts on airport prices in these two scenarios. In particular, under one-sided complementarity, the airport is incentivised to reduce the aviation charge but raise the non-aviation charge, because the increased extra-surplus gained by travellers consuming non-aviation goods only induces more demand for non-aviation goods from existing travellers. However, under two-sided complementarity, the airport would raise both aviation and non-aviation charges, because an increase in the degree of complementarity not only induces non-aviation demand from existing travellers, but also shifts out demand for flights — which further induces demand for non-aviation goods from new travellers, making consumers less sensitive to both aviation and non-aviation prices.

This study also reveals the important role of non-travellers on airport pricing. Under one-sided complementarity, the presence of non-travellers demanding for non-aviation goods incentivises the airport to ask for relatively high (low) aviation (non-aviation) charges in comparison to the case in which only travellers may purchase non-aviation goods, and this tendency is stronger as travellers' extra-surplus increases. However, the opposite holds under two-sided complementarity. On the other hand, models excluding non-traveller demand predict that non-aviation business has downward (upward) pressure on aviation charge under one-sided (two-sided) complementarity. Therefore, the main lesson is that providing goods or services to non-travellers may moderate the impacts of non-aviation business on a private aviation charge in both scenarios.

Despite the importance of non-travellers, an airport city should not overlook the travellers' special needs in non-aviation goods, because raising the interdependence between aviation and non-aviation goods will bring more revenues to the airport. Thus, when an airport moves towards the airport city model, it would benefit from activating different stimuli that make travellers perceive a higher extra-surplus from purchasing at airports, which might be achieved through effective communication. From a social welfare point of view, such strategy may be welfare-enhancing overall, although the travellers' gain in consumer surplus outweighs the non-travellers' loss in surplus, as the latter would have to pay a higher price for non-aviation products.

The above suggestion about making non-aviation goods more traveller-oriented is based on some simplifications to preserve tractability. Future studies might consider relaxing some of them, leading to a different suggestion on the product mix strategy of non-aviation goods. First, travel demand could be uncertain, which is one major reason for airports to develop business with non-travellers so that the airport can keep a relatively stable revenue source to maintain its operation.

Second, we did not model the commercial services supplied to passengers at the airside; that is, after security screening and passport controls.[13] We assume that the airport offers

[13] Following the suggestion of an anonymous referee, a preliminary way to incorporate this feature is to add a fixed add-on profit per passenger, τ, to the profit function (Zhang and Zhang, 1997, 2003, 2010; Oum *et al.*, 2004). In such a scenario, the airport's profit function in equation (7) would become $\pi(p_c, p_s) = (p_c + \tau)D_c(p_c, p_s) +$

the same level of traveller-orientation for non-aviation goods, but it is possible that different traveller-orientation levels can be chosen at the airside versus landside. Indeed, non-aviation services supplied airside (that is, after passport control) are only available to travellers, while non-aviation services sold landside within the terminal or in the surrounding land parcels are available to both travellers and non-travellers. Thus, non-aviation services sold landside and airside are imperfect substitutes for travellers. Whether the travellers buy at the landside or airside depends on many things, such as the prices, the types of goods sold, the dwell time, and the availability of such information about airside goods before travellers enter the airside. A more complex and complete framework should include all the above aspects and require a better understanding on travellers' shopping behaviour. It might even be possible to price-discriminate between travellers and non-travellers, as the former hold a boarding pass.

Third, our model assumes a monopoly profit-maximising airport free from any regulatory constraint. However, many airports are under various regulatory restrictions in setting prices (especially the price for aviation goods), and therefore have strong incentives to expand non-aviation business by attracting non-travellers. Moreover, competition from outside retailers may reduce the offering of traveller-oriented business so that the non-aviation price can be kept competitively low.

Fourth, in our model, costs of supplying aviation and non-aviation goods are both normalised to zero. Given that the marginal traveller contributes to both aviation and non-aviation revenues if the interdependence between aviation and non-aviation goods increases and the non-traveller only contributes to non-aviation revenue, naturally increasing traveller-orientation is a better choice. However, the cost of serving a traveller tends to be higher than serving a non-traveller, as the former requires more services and facilities. Therefore, increasing traveller-orientation will become less beneficial if the cost difference is considered.

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$p_s D_s(p_c, p_s)$. Under one-sided complementarity, it can be proved that $\forall (a,k,l) \in I$, where $I = \{(a,k,l): 0 \leqslant a \leqslant 1, k \geqslant a, l \geqslant a\}$, there exists $\tau^*(a,k,l) > 0$ such that $\forall \tau \leqslant \tau^*$, the higher τ, the higher the incentive to increase profits through a reduction of the aviation charge. This is because the additional profit, τ, is linked to the growth of passenger demand. As a consequence, the price for non-aviation goods would increase. In the case of two-sided complementarity, higher τ also leads to lower aviation charge, but it has no impact on non-aviation goods price.

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Appendix

To save notation, we resort on x to indicate the elements $(a,k,l) \in I$, where $I = \{(a,k,l)\colon 0 \leqslant a \leqslant 1, k \geqslant a, l \geqslant a\}$.

Proof of Proposition 4

Let π^*_a, $\pi^*_{s,a}$, $\pi^*_{s,t,a}$, $\pi^*_{s,nt,a}$, and $\pi^*_{c,a}$ denote, respectively, $\partial\pi^*/\partial a$, $\partial\pi^*_s/\partial a$, $\partial\pi^*_{s,t}/\partial a$, $\partial\pi^*_{s,nt}/\partial a$, and $\partial\pi^*_c/\partial a$. The proof follows immediately, given that:

(i) $\pi^*_a \geqslant 0$ when $k = a$ and $\partial\pi^*_a/\partial k \geqslant 0\ \forall x \in I$.

(ii) $\pi^*_{s,a} \geqslant 0$ when $l = a$. Moreover, it results in $\partial\pi^*_{s,a}/\partial l \geqslant 0\ \forall x \in I$. Indeed, let $\pi^*_{s,a,l}$ denote $\partial\pi^*_{s,a}/\partial l$. It results in $\pi^*_{s,a,l} \geqslant 0$ when $l = a$, $\partial\pi^*_{s,a,l}/\partial l\big|_{l=1} \geqslant 0$, and $\partial^2\pi^*_{s,a,l}/\partial l^2 \geqslant 0\ \forall x \in I$; $\pi^*_{s,nt,a} \leqslant 0$ when $l = a$, $\partial\pi^*_{s,nt,a}/\partial l\big|_{l=1} \leqslant 0$, $\partial^2\pi^*_{s,nt,a}/\partial l^2\big|_{l=1} \leqslant 0$, $\partial^3\pi^*_{s,nt,a}/\partial l^3\big|_{l=1} \leqslant 0$, and $\partial^4\pi^*_{s,nt,a}/\partial^4 l \leqslant 0\ \forall x \in I$. Finally, $\pi^*_{s,a} = \pi^*_{s,nt,a} + \pi^*_{s,t,a}$, which implies that $\pi^*_{s,t,a} = \pi^*_{s,a} - \pi^*_{s,nt,a} \geqslant 0\ \forall x \in I$.

(iii) It results in $\pi^*_{c,a} \geqslant 0\ \forall x \in I$. ■

Proof of Proposition 5

Let W^*_a, CS^*_a, $CS^*_{nt,a}$ and $CS^*_{t,a}$ denote, respectively, $\partial W^*/\partial a$, $\partial CS^*/\partial a$, $\partial CS^*_{nt}/\partial a$, and $\partial CS^*_t/\partial a$. The proof follows immediately, given that:

(i) $CS^*_a \geqslant 0$ when $k = a$, $\partial W^*_a/\partial k\big|_{k=1} \geqslant 0$, $\partial^2 W^*_a/\partial k^2\big|_{k=1} \geqslant 0$ and $\partial^3 W^*_a/\partial k^3 \geqslant 0\ \forall x \in I$.

(ii) $CS^*_a \geqslant 0$ when $k = a$, $\partial CS^*_a/\partial k\big|_{k=1} \geqslant 0$, $\partial^2 CS^*_a/\partial k^2\big|_{k=1} \geqslant 0$, and $\partial^3 CS^*_a/\partial k^3 \geqslant 0\ \forall x \in I$. Moreover, it results $CS^*_{nt,a} \leqslant 0$ when $k = a$, $\partial CS^*_{nt,a}/\partial k\big|_{k=1} \leqslant 0$, $\partial^2 CS^*_{nt,a}/\partial k^2\big|_{k=1} \leqslant 0$, $\partial^3 CS^*_{nt,a}/\partial k^3\big|_{k=1} \leqslant 0$ and $\partial^4 CS^*_{nt,a}/\partial k^4 \leqslant 0\ \forall x \in I$. Finally, $CS^*_a = CS^*_{nt,a} + CS^*_{t,a}$, which implies that $CS^*_{t,a} = CS^*_a - CS^*_{nt,a} \geqslant 0\ \forall x \in I$. ■