Multi-product Airport Competition and Optimal Airport Charges*

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Abstract

This paper examines the importance of commercial revenue on optimal airport charges in a Hotelling-type duopoly airports competition. Each airport offers multi-products to heterogeneous consumers (airlines and passengers) and sets commercial and landing charges and serves. The airport-airline bundle competes for leisure and business passengers. The setting of landing charges under different regulatory regimes is investigated. We demonstrate that in the leisure travel market, which ignores schedule delay cost, the optimal landing fee is invariant to the regulatory scheme, and concession revenue is determined by an airport’s home market size. In the business travel market, the optimal landing charge is smaller if concession revenue is included in setting the landing fee than if it is not included. In the former case, increasing passenger volume does not guarantee increases in airports’ aeronautical revenue, and a negative impact may exist if the weight of concession profit out of total profit is small.

Keywords: Airport competition; airport regulation; landing fee; commercial charge.

JEL classification: L93, D43, L13, C72.

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1 Introduction

In recent years, the previous view that airports were natural monopolies has been changing. Airports are increasingly perceived as business entities that could stimulate the creation of a competing market structure. In fact, as Airport Council International (ACI) World reported, airports are a very competitive market. Airports differ substantially in terms of competitive position and can compete on different elements or in different markets, such as destination markets, locations for an airline base, and connecting traffic, as well as in the non-aviation market. Many cities have multiple airports, making airport competition very common. For example, in flying from London to Paris, a passenger can choose to depart from London City, Heathrow, Stansted, Gatwick, or Luton; and arrive at Paris-Charles de Gaulle or Orly. One can also refer to airport competition in adjacent cities or towns in a broader region. In Europe, approximately 63% of citizens live within two hours of at least two airports. Large metropolitan areas, for example in the USA, including Boston, Chicago, Los Angeles, New York, San Francisco, and Washington D.C., are typically served by several nearby airports that provide flights to common destinations. These airports differ in terms of accessibility, charges, and quality of service. This underscores the need to provide a theoretical framework to explore how airports compete with rivals for overlapping catchment areas.

The issue of choice among multiple airports in metropolitan areas has been addressed in previous studies (Başar and Bhat, 2004; Harvey, 1987; Hess and Polak, 2006; Ishii et al., 2009; Lian and Rønnevik, 2011; Pels et al., 2003). Among those, Pels et al. (2003) investigate both airport and airline competition in a metropolitan area with multiple departure airports and analyzed the effects of changes in accessibility on the airports’ and airlines’ competitive positions. Ishii et al. (2009) find that access time, frequency, arrival times, delays and airport–airline combinations strongly affect the choice of airport in the San Francisco Bay area. Hess and Polak (2006) find that flight frequency and access time are significant variables for the choice of airport in the same area. Lian and Rønnevik (2011) discover that travelers avoid using local airports in their vicinity and use more distant airports instead to benefit from lower airfares and more convenient airline services. De Palma et al. (2018) analyze rivalry between two airports that differ in geographical location and departure time, and examine the influence of differentiation in these two sources on airport fees and airline service prices. These studies highlight that understand-
ing airport competition requires taking into account primary determinants of travelers’ choice decisions, such as airport access time, flight frequency, and differences in airfare.

The current paper is closely related to Basso and Zhang (2007, 2008), who study airport competition and pricing in vertical structure settings. However, our contribution differs from theirs in several ways. Firstly, Basso and Zhang (2007, 2008) formally model downstream airline market, with equilibrium ticket price and airport demand being determined by airline competition. In contrast, we focus on airport-airline bundles where ticket price is predetermined, and derive airport pricing for leisure and business traveler markets. Secondly, we focus on how regulation, i.e., the weight of concession revenues that are used to cross-subsidize the aeronautical sector, affects aeronautical charge determination. Thirdly, unlike Basso and Zhang (2007), we do not consider airport capacity choice, though we take into account airline’s ability to increase frequency. The business travel market favors frequency as passengers incur schedule delay cost. The differentiation between business and leisure traveler markets is often overlooked in the existing literature on airport competition. For the sake of tractability, our model has simplified some assumptions from Basso and Zhang (2007).

Our paper extends existing studies on airport competition in such a way that a fixed profit-sharing regime can be studied for the airport industry which displays platform features, with heterogeneous consumer groups that have different valuations for flight frequencies. In the same vein as De Palma et al. (2018), we draw on Hotelling (1929) to develop a model that incorporates a vertical airport-airline-consumers framework in a two-airport system characterized by spatial differentiation. In contrast to De Palma et al. (2018), the focus of our paper is on the interaction between aeronautical fee and commercial charge, while commercial revenue is considered exogenous in their model.

The previous studies, such as Czerny (2006), Gillen and Mantin (2014), Ivaldi et al. (2015), Van Dender (2007), Zhang and Zhang (1997), Zhang and Zhang (2003), Flores-Fillol et al. (2018), did not take commercial revenue into airports’ optimal charges. In our model, airports provide multi-products for their consumers, set prices for both the airlines and passengers and could integrate a portion of commercial revenue into total revenue, based on which the airport optimally chooses per-passenger aeronautical charge (landing fee) and concession fee. Realistically, an airport does not dictate prices for retail services, which are actually determined by independent retailers. However, the airport could affect retail prices via two channels: the concession fee charged to each retailer, and the number of concessions, which could depress or foster competition among the concessionaires.
While the second channel is not explicitly modeled in this paper, the manipulation of competition can be alternatively realized by implementing a concession fee. As such, our study introduces a new dimension of analysis in explaining what has been observed in practice.

In comparison to other platforms, airport industry has its own peculiarity related to the one-way complementarity between the demand for aeronautical services (primary good) and non-aviation services (side good). Airport is increasingly perceived as a business entity that delivers both aeronautical services (transport-related) and non-aeronautical services, or retail, such as facilitating ancillary services occurring within terminals and on airport land, including terminal retail, duty-free shops, food and beverages, car parking and rentals (Oum et al., 2004; Starkie, 2001; Zhang and Zhang, 2003). The non-aviation business has become an important income source to airports within the last two decades, accounting for around half of all revenues (Graham, 2009). Given the two primary outputs (flights and retail services), the airport faces strategic decisions when pricing aeronautical services (charged to airlines) and concession services (charged to passengers). Since commercial services depend crucially on passenger throughput, the demand for aviation services and for concession services are complementary. Gillen and Mantin (2014) find the airport may lower the aeronautical charges to boost greater flight frequency in order to reduce airfares and attract passengers, which ultimately leads to an increase in concessions revenue. Intuitively, higher charges to airlines may have a positive effect on aeronautical revenues but a sizeable countervailing negative effect on commercial revenues due to the decrease in the number of flyers, as some flyers respond by not traveling while others switch to nearby rival airports or even other modes of travel.\(^2\) As consumers only buy retail products if they fly, to truly reap the benefits, airports must attract consumers first.

The one-way complementarity issue has been tackled by Flores-Fillol et al. (2018), who study how airports’ optimal behavior is affected by consumer foresightedness. Our paper differs from theirs in three ways. Firstly, consumers fully anticipate the surplus they will obtain from the retail service within the airport at the point they buy flight tickets. The complete anticipation is made possible by consumers taking into account whether one needs to park and dine at the airports, as well as, finding parking rates, restaurant brands and the availability of duty-free shops on airport website.\(^3\) Secondly, we differentiate heterogeneous consumer groups, with one group of consumers caring about product characteristic (flight frequency) from the primary goods. Thirdly, we examine explicitly

\(^2\) For multi-airport competition, see Mun and Teraji (2012) and Noruzoliaee et al. (2015).

\(^3\) With the spread of e-commerce, most airports display retail shops, restaurants, and parking facilities on their websites. For instance, Frankfurt Airport https://www.frankfurt-airport.com/>. 

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the spatial competition of two integrated airport-airline pairs, which is not part of Flores-Fillol et al. (2018)’s analysis.

We undertake a theoretical review of certain aspects of multiproduct airport competition, with a focus on conceptual issues and interpretation. In this paper, we propose a duopoly competition model to study the optimal pricing strategy of an airport that operates as a platform that generates revenues both from traditional aeronautical activities and from concession activities.

Our main findings are that if consumers care only about direct cost, i.e., airfare and commercial fees, and airports can charge the optimal landing charge and commercial fee independently of each other. Furthermore, the landing fee is independent of passenger volume, and concession fee is determined by home market size. Under a general setting, especially if airlines’ schedule delay is costly for consumers, the results are no longer clear-cut. Increasing in passenger volume does not guarantee an increase in airport’s total revenue regardless of the degree of complementarity.

In the remainder of this paper, we first present the model setting and notations in Section 2. Section 3 investigates the leisure travel market, which is indifferent to departure time and does not incur schedule delay costs. Section 4 examines the optimal landing charge in a business travel market for which schedule delay is costly. We conclude in Section 5.

2 The model setting and notations

Consider that two non-congested airports provide aviation and commercial services to airlines, and that airports maximize their profits. Following Hotelling (1929), we assume the passengers of the whole region are uniformly distributed, with density normalized to 1, along a line of length $l$ which is also normalized to 1, as shown in Figure 1. Airports $i$ ($i = A, B$) are located on this geographical line, and distance $a$ (respectively $b$) measures the distance from the remotest passenger to airport $A$ ($B$).\(^4\) There is only one airline operating at each airport.\(^5\)

\(^4\)It is worth noting that Basso and Zhang (2007) provide a more general setup where the remotest passengers of airport $A$ and $B$ ($a$ and $b$ in the current paper) are endogenously determined by consumer net benefit. While in our paper, the remotest passengers of each airport are exogenously given. Unlike in Basso and Zhang (2007), the current paper does not discuss airport capacity choice, hence the assumption of exogenous airport hinterland does not qualitatively affect our main results.

\(^5\)The set-up of a monopolistic downstream airline in a vertical airport-airline structure has been em-
To ease the notation, we use the same notation $i (i = A, B)$ to distinguish the airline that serves airport $i$. Each consumer purchases exactly one airline ticket, and to travel to the airport to take the flight each incurs a transportation cost equal to $k$ per unit distance. The distance shows how far each individual passenger’s most preferred airport is located from the actual airport. Suppose the whole market along the line is covered. The passenger who is indifferent to travel to either airport is termed indifferent passenger. The distance from the indifferent passenger and airport $A$ is denoted as $Y_A$ and similarly to airport $B$ is denoted as $Y_B$. We thus have $a \geq 0, b \geq 0$ and $a + b < 1$, where the last inequality guarantees that two airports coexist in the market.

![Figure 1: Spatial Competition à la Hotelling](image)

The sequence of the game is as follows. At the first stage, airports set out the per-flight landing charge, $x_i$, and airlines fix the flight frequency, $f_i$. At the second stage, airports choose the commercial fee $\tau_i$. Here we follow the convention in airport economics literature to assume that concessions are awarded to the private operators and perfect competition among bidders enables airport to absorb all rents through take-it-or-leave-it offers and that rent is set to maximize commercial profits (Czerny, 2013; D’Alfonso and Bracaglia, 2017). At the third stage, passengers choose an airport $i$ to fly from and make their retail purchases. Nonetheless, throughout this paper we assume that passengers have foresight: when they purchase an airline ticket, they already aware that they will

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6Basso and Zhang (2007), Kratzsch and Sieg (2011), Yan and Winston (2014), Flores-Fillol et al. (2018) also assume that airports set landing fee at the first stage in the sequential-move games. In practice, landing fee is part of airport charge schedules which are set by local airport operators or authorities. Generally, airport charge schedules are updated on an annual basis. Airports, such as Paris-Charles de Gaulle, San Francisco International Airport, Frankfurt International Airport, update charge schedules which include landing fees, annually. While others, for example, Marseille airport and Bremen airport, only update charge schedules after substantial changes are been made, which is much less frequent than annually.
incur commercial expenses at the airport. This assumption matches real-world evidence (Bracaglia et al., 2014; Evangelinos et al., 2021; Geuens et al., 2004) and shapes the models of Czerny (2006, 2013) and Flores-Fillol et al. (2018), among others. Geuens et al. (2004) report that 40% of a sample of Belgian travelers departing from Bruxelles airport pre-plan purchases at the airport. Evangelinos et al. (2021) find that airport parking costs may affect the overall passengers’ choice of the airport for multi-airport areas as they consider this cost a part of overall travel cost. The argument behind passengers’ pre-planned purchasing behavior is that the issue of the time-separation has been moderated over time by the e-commerce (airport website, Apps, etc) that enables the airports to advertise concession services online. Furthermore, frequent flyers are conscious of the surplus from concession goods.

Passenger decisions are made in a two-step process. First, they purchase their airline tickets; second, they make their retail purchases once at the airport. Only passengers who fly may also buy the retail goods, so the retail market is a pure complement to the airline market (but not vice versa).

The game contains full information, and we solve it by backward induction and obtain a subgame perfect equilibrium. The two airlines at corresponding airports charge ticket prices $P_A$ and $P_B$ respectively. As we focus on upstream airport competition, we do not formally model the airline market, other than perceiving $P_A$ and $P_B$ as parameters. We use superscripts $a$ and $c$ to distinguish aeronautical and commercial revenue, respectively, and denote the airport profit generated from aeronautical activities as $\Pi^a_i$ and non-aeronautical (commercial) activities as $\Pi^c_i$.

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7It is worth noting that there are two distinct assumptions on the nature of the demand complementarity between aeronautical and non-aeronautical services, our paper follows one strand, the other strand of the literature assumes that buying air tickets and concession services can be separated in time (Lin, 2006; Zhang and Zhang, 1997). These papers suppose that passengers decide the consumption of the concession goods after arriving at the airport, therefore passenger demand for air ticket is independent of the price of concession services, which differs from the scenario that shapes the current paper. We thank an anonymous referee for commenting on this point.

8A Swiss research agency (M1nd-Set) conducted a study that interviewed 75000 passengers world-wide in 2018, revealing that 81% global travelers plan their airport duty-free purchases to some extent. Pre-travel purchase planning is highlighted by the report data that shows 35% of travelers in Asia Pacific, 27% in the Americas, 29% in the Middle East and Africa and 32% in Europe decide they will purchase from duty-free shops while still at home. [https://www.dfionline.com/latest-news/travellers-asia-pacific-top-pre-travel-purchase-planners-m1nd-set-27-09-2018/](https://www.dfionline.com/latest-news/travellers-asia-pacific-top-pre-travel-purchase-planners-m1nd-set-27-09-2018/).

9In a similar setting with airport-airline vertical structure, Basso and Zhang (2007) assume Cournot behavior in modeling airline competition, with flight fares being determined by airline competition. Basso and Zhang (2008) discuss perfect competition in airline market in which case airlines behave as price takers and ticket price equals the full marginal cost (per passenger) of an airline. Following the idea, our setting of a single airline can alternatively be understood as an aggregate of atomistic homogeneous airlines.
Airport $i$, $i = \{A, B\}$ maximizes its profits $\Pi_i = \Pi_i^a + \Pi_i^c$ by optimally choosing a landing fee, $x_i$, and imposing a commercial charge, $\tau_i$. The assumption that airports possess market power in the two business branches is common in literature, see Zhang and Zhang (1997) and Czerny (2006) for example. The landing fee comes from facility usages, such as runway and terminal usage, which is indifferent to taking-off and landing.\footnote{Despite the longstanding call for more efficient runway pricing, due to the complexity and doubts on the grounds of fairness, in practice, taking-off and landing fees are still based on traditional aircraft maximum take-off weight, which is based per activity.} A commercial charge can be understood as the average revenue generated from each passenger. Airports generate concession revenues from providing services to passengers, for instance, car parking, restaurants and hotels, duty-free shops, and so on. Suppose airports select concession retailers via competitive auctions. Retailers bid non-cooperatively for concession contracts. As a result, an airport fully extracts all profits generated from the commercial side.

\subsection{Passenger concerns}

Business travelers often cannot predict their travel times and thus purchase refundable tickets that allow them to board the next flight. Hence, they value the convenience of a flight schedule with multiple departure times, which enables them to spend less time waiting to catch the next available flight closest to their desired departure time. By contrast, leisure guests have weaker preferences among flights, and thus, scheduling is less costly to them. To circumvent the complexities of the spatial approach, the present paper eliminates the relevance of particular departure times of individual flights and formalizes the model in a way that consumers care about overall flight frequency.

The discrepancy between the preferred and actual departure time is called schedule delay (Brueckner and Flores-Fillol, 2007; Douglas and Miller III, 1974; Douglas and Miller, 1974; Richard, 2003). The dollar value of this time difference is termed schedule delay cost, reflecting the cost to the consumer of adapting travel plans to the flight’s departure time. Theoretical work has tended to specify this cost as inversely proportional to flight frequency. We follow Richard (2003) to express this cost by $\frac{\beta}{\sqrt{f}}$, where $\beta$ is a parameter reflecting a consumer’s valuation of the cost and $f_i$ is flight frequency.\footnote{This functional form implicitly assumes that flights are evenly placed along the 24h circle and desired departure times are uniformly distributed; thus, the distance to the closest departure time is on average proportional to $1/f_i$. However, Borenstein and Netz (1999) note that an airline usually groups some of its departure flights, so that a specification of $1/\sqrt{f_i}$ is a more appropriate description since the form is less convex in frequency. Moreover, the square root specification fits better empirically than a linear one.}
Consumers pay an effective price equal to

\[ P_i = P_i + \tau_i + \delta \frac{\beta}{\sqrt{f_i}}, \tag{1} \]

where \( P_i \) is airline \( i \)'s ticket price, and \( \tau_i \) is the commercial fee charged by airport \( i \). The effective price is modeled in Panzar (1979), Lederer (1993), Morrison and Winston (2010), Brueckner and Zhang (2001), among others.

The effective price to a consumer takes an additive separable form that includes an airline’s ticket price, commercial price and may include schedule delay cost, depending on the parameter \( \delta \in [0, 1] \). \( \delta \) describes whether and how much a passenger takes into account scheduling.\(^\text{12}\) If \( \delta = 0 \), the passenger is perfectly indifferent to the departure schedule of airlines. If \( \delta = 1 \), the passenger fully takes scheduling into account and attaches the same weight to schedule delay cost as with ticket price and commercial spending, while values between 0 and 1 denote intermediate cases of preference for departure time.

We use a Cobb-Douglas functional form to describe the composition of ticket price against costs, where the impact of landing fee on ticket price is denoted as \( \gamma \), \( \gamma \in [0, 1) \), and all other factors that determine ticket price aside from landing fee are denoted altogether as \( \Gamma > 0 \). This assumption of \( \gamma \) is in line with Sainz-González et al. (2011), who find evidence from the Spanish airline market that airlines pass the airport fees onto customers by raising fares.

\[ P_i(x_i) = \Gamma x_i^\gamma, \tag{2} \]

where \( \gamma \in [0, 1) \) shows decreasing returns in landing fee: an increase in one unit of landing fee induces less than one unit of increase in ticket price.

The indifferent passenger departing from airport \( A \) or \( B \) is determined by

\[ P_A + kY_A = P_B + kY_B, \]

in which \( Y_i \) measures the distance from the indifferent passenger to airports \( A \) and \( B \). Thus, we also have

\[ a + b + Y_A + Y_B = 1. \tag{3} \]

Since our analysis is limited to both airports coexisting and competing in the market, it is

\(^{12}\)The assumption that the schedule-delay cost of business travel market is higher than that of leisure travel market is common in literature, e.g., Arnott et al. (1994), Van den Berg and Verhoef (2011), Wan et al. (2015), among others.
legitimate to call $a$ and $b$ the home market (hinterland) of airport $A$ and $B$, respectively. Thus, the two airports (jointly with airlines using the airports) face Hotelling spatial competition.

In the following, we denote $q_i$ the expected passenger volume using airport $i$ and $Q_i$ the actual passenger volume. As previously mentioned, airport charges are revised on an annual or even less frequent basis. Flight activities, including frequency and size of aircraft, are determined based on airport charges, with some of the costs being passed on to passengers. In simpler terms, decisions regarding flight frequency are made using historical data and expectations, though the actual traffic may vary. As a result, instances of overbooking or empty flights can occur (Lan et al., 2015; Shepard, 2019). Given this scenario, we highlight the distinction between the projected traffic $q_i$ and actual traffic $Q_i$ in the subsequent analysis.

### 2.2 Airlines’ flight frequency

Ivaldi et al. (2012) shows that the optimal level of frequency depends on the number of passengers and landing fee charged by an airport. Following Ivaldi et al. (2012), we posit a simple specification for $f(x_i, q_i)$ as

$$f(x_i, q_i) = \left( \frac{\alpha q_i}{x_i} \right)^\epsilon,$$

where $q_i$ is the total passenger volume flying with airport $i$. Parameter $\alpha (> 0)$ reflects an airline’s ability to add an additional flight, which is constrained by airport capacity, environmental limits, or regulatory restrictions. A high $\alpha$ implies a higher ability to place more frequent flights. Equation (4) shows that the frequency depends on the passenger volume and the aeronautical fee charged by the airport, as well as on airline’s ability to expand frequency. Realistically, frequency is positively correlated with passengers and negatively correlated with aeronautical fee. Airlines’ demand for the airport depends both on the aeronautical fee and passenger volume. Obviously, the airport can affect

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13 We do not impose fixed proportion assumption in a traditional way as in Brueckner (2005), Zhang and Zhang (2006), Brueckner and Van Dender (2008) and Lin (2013, 2019), which says that given a constant aircraft size and (100%) load factor, the per-flight and per-passenger measurements are equivalent. Rather, this paper has different focus from these papers, we implicitly share the notion of fixed proportion in that aircraft size and load factor are constant, so that adjusting aircraft size is not a choice of the airline.

14 It can be understood that as airport becomes busier, $\alpha$ becomes smaller, as placing more flight activities become difficult when the airport faces capacity shortage, though here we do not explicitly model airport capacity decisions as in Basso and Zhang (2007).
airline’s frequency demand for airport either by adjusting the aeronautical fee or by man- 

ipulating the commercial fee. The former has a direct impact, while the latter has an 

indirect impact on airline demand via first affecting the passenger demand and then the 

airline demand. Moreover, parameter $\epsilon$ represents the elasticity of frequency to $\frac{x_i}{q_i}$:

$$-\epsilon = \frac{d \ln f(x_i, q_i)}{d \ln \left(\frac{x_i}{\alpha q_i}\right)}.$$ (5)

From (4), it is intuitive that the frequency increases in passenger volume, and the effect is 
greater when the passenger volume is larger: $\frac{\partial f(x_i, q_i)}{\partial q_i} > 0$, $\frac{\partial^2 f(x_i, q_i)}{\partial q_i^2} > 0$. Here, we stress 
that the airports studied are uncongested, so they have enough capacity to accommodate 
flight activities. At the airline level, because the two airlines are engaged in competition 
and flight frequency is perceived as the quality indicator by business travelers, it is 
natural that airlines tend to increase flight frequency to attract passengers. In addition, 
$\frac{\partial f(x_i, q_i)}{\partial x_i} < 0$, $\frac{\partial^2 f(x_i, q_i)}{\partial x_i^2} > 0$, frequency decreases with the landing fee, and the effect is more 
pronounced when the fee is already high.

### 3 The basic model and leisure travel - Benchmark case

This section develops the profit-maximization conditions for the simplest (benchmark) 
case where departure time is perfectly indifferent to passengers. This base case corre-

sponds to the leisure traveler market, which typically is not time-sensitive and has flexi-

ble travel times. This could be the case where two secondary airports compete, each has 
its exclusive Low Cost Carrier. We thank an anonymous referee for mentioning such an example.

Airports A and B offer respective charge pairs $(x_A, \tau_A)$ and $(x_B, \tau_B)$ to the two users - airlines and passengers.

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15See Section 4 for more detailed analysis.
16We thank an anonymous referee for mentioning such an example.
3.1 Leisure passengers’ choice

Passengers situated in the home market of each airport fly from the corresponding home airport, the market sizes are \( a \) and \( b \), respectively. Those who reside between the two airports may choose to fly with one of the two, depending on the factors depicted below. As explained earlier, the distance between the indifferent passenger and the two airports are \( Y_A \) and \( Y_B \), respectively. In the spirit of Hotelling (1929) and D’Aspremont and Thisse (1979), \( Y_A \) and \( Y_B \) can be identified in the standard way:

\[
Y_A = \frac{1}{2} \left( 1 - a - b + \frac{P_B + \tau_B - P_A - \tau_A}{k} \right), \quad Y_B = \frac{1}{2} \left( 1 - a - b - \frac{P_B + \tau_B - P_A - \tau_A}{k} \right).
\]

Straightforwardly, total passengers departing from the two airports are

\[
Q_A = a + Y_A = \frac{1}{2} \left( 1 + a - b + \frac{P_B + \tau_B - P_A - \tau_A}{k} \right), \quad Q_B = b + Y_B = \frac{1}{2} \left( 1 - a + b - \frac{P_B + \tau_B - P_A - \tau_A}{k} \right).
\]

3.2 Concession revenue in the leisure travel market

We assume concession cost away. Denote airport \( i \)'s concession revenue as \( \Pi_i^c, i = \{A, B\} \). On a single route segment, airports \( A \) and \( B \)'s profit maximization problem can be stated as

\[
\max_{\tau_A} \Pi_A^c = \tau_A Q_A = \frac{\tau_A}{2} \left( 1 + a - b + \frac{P_B + \tau_B - P_A - \tau_A}{k} \right), \quad \max_{\tau_B} \Pi_B^c = \tau_B Q_B = \frac{\tau_B}{2} \left( 1 - a + b - \frac{P_B + \tau_B - P_A - \tau_A}{k} \right).
\]

There exists a unique interior Nash equilibrium for commercial charge

\[
\tau_A^* = k \left( 1 + \frac{a - b}{3} \right) + \frac{P_B - P_A}{3}, \quad \tau_B^* = k \left( 1 - \frac{a - b}{3} \right) - \frac{P_B - P_A}{3},
\]

for \( a \) and \( b \) that fulfill

\[
(1 + \frac{a - b}{3})^2 \geq \frac{4}{3}(a + 2b), \quad (1 + \frac{b - a}{3})^2 \geq \frac{4}{3}(b + 2a).
\]
Airport \( A \)'s optimal commercial charge is increasing in its home market while decreasing in its rival's. All else equal, possessing location advantage (a larger home market) means enjoying greater market power, which enables the airport to charge a higher commercial fee. Moreover, \( \tau^*_A \) is decreasing in airline \( A \)'s ticket price. If airline \( A \) charges a lower ticket price, it could benefit from the higher passenger volume attracted to the airport and impose a higher commercial charge.

The difference between optimal commercial charges

\[
\tau^*_A - \tau^*_B = \frac{2}{3} [k(a - b) + (P_B - P_A)]
\]

(8)

is related to both the home market difference, \( a - b \), and the ticket price difference, \( P_B - P_A \), where ticket price difference outweighs commercial charge difference.

To illustrate the properties of the equilibrium, we undertake a comparative-static approach. Of additional interest, the optimal commercial fees charged by the two airports are characterized in two dimensions: home market size and airline ticket price. In the symmetric case, the two airports have home markets of the same size, i.e., \( a = b \), ticket price differential explains the differences in optimal commercial charge: \( \tau^*_A - \tau^*_B = \frac{2}{3} (P_B - P_A) \). The optimal commercial charge difference is narrower than the ticket price difference. In other words, if the home airline charges a lower ticket price, the airport by nature attracts more passengers and could therefore charge a higher commercial fee, but the difference in commercial fees does not compensate for the difference in ticket price, because the commercial fee affects both the passenger number and the airline. This point will be made explicit in the next section.

Finally, according to (8), if ticket prices at each individual airport are set to be equal, \( P_B = P_A \), the optimal commercial fee difference will be decided only by the home market size difference, \( \tau^*_A - \tau^*_B = \frac{2k(a - b)}{3} \), implying that the airport with a smaller home market should charge a lower fee than its rival.

**Proposition 1.** Suppose the conditions of (7) hold, then

- airport \( i \)'s optimal passenger volume is

\[
Q^*_A = \frac{1}{2} \left( 1 + \frac{a - b}{3} + \frac{P_B - P_A}{3k} \right), \quad Q^*_B = \frac{1}{2} \left( 1 - \frac{a - b}{3} - \frac{P_B - P_A}{3k} \right),
\]
• airport $i$’s optimal commercial revenue is

$$\Pi_A^c = \tau_A^* Q_A^* = \frac{1}{2k} (\tau_A^*)^2, \quad \Pi_B^c = \tau_B^* Q_B^* = \frac{1}{2k} (\tau_B^*)^2.$$  

(9)

The optimal passenger volume of an airport depends on home market size and ticket price. Hence, demand by the two airports is substitutable in the sense that one airport’s market share is increasing in another airline’s ticket price. Moreover, in putting (6) together with (9), we obtain

$$\frac{\partial \Pi_A^c}{\partial (a - b)} = \frac{\tau_A^*}{3} > 0, \quad \frac{\partial \Pi_B^c}{\partial (b - a)} = \frac{\tau_B^*}{3} > 0.$$  

All other things remaining unchanged, an airport’s concession profit is increasing in home market difference.

Combining (9) and (6), we generate the difference of airport optimal commercial revenues as

$$\Pi_A^c - \Pi_B^c = \tau_A^* - \tau_B^*.$$  

The following results are straightforward.

**Corollary 1.** Assume the conditions of (7) hold. Then, the difference between optimal total passenger flow is

$$Q_A^* - Q_B^* = \frac{\tau_A^* - \tau_B^*}{2k},$$

and the difference of optimal concession revenues is

$$\Pi_A^c - \Pi_B^c = \tau_A^* - \tau_B^*,$$

with $\tau_A^* - \tau_B^*$ given by (8).

The concession profit depends on both commercial charge and total passenger volume. Nevertheless, passenger volume difference is essentially determined by ticket price, which is exogenous. Therefore, concession profit difference relies solely upon that of commercial charge.
3.3 Aeronautical revenue in the leisure travel market

Suppose an airport incurs per-movement marginal operating cost $c_i$. Aeronautical profit for airport $i$ is generated from aeronautical revenue minus total cost, and is thus expressed as:

$$\Pi_i = (x_i - c_i) \cdot f_i(x_i, q_i) = (x_i - c_i) \left( \frac{\alpha q_i}{x_i} \right)^\epsilon, \quad i = A, B.$$  \hspace{1cm} (10)

In the current context, airport generates revenue from airport aeronautical facilities usage, which hinges on factors such as flight frequency, airport charge and operational cost. These factors consequently affect the projected passenger volume, as elucidated earlier.

The first-order condition with respect to $x_i$ yields:

$$\frac{\partial \Pi_i}{\partial x_i} = (\alpha q_i)^\epsilon x_i^{\epsilon-1} \left( (x_i(1-\epsilon) + \epsilon c_i) \right) = 0.$$  \hspace{1cm} (11)

Evaluated at the critical point, the second-order condition yields

$$\frac{\partial^2 \Pi_i}{\partial x_i^2} = (1-\epsilon)(\alpha q_i)^\epsilon x_i^{\epsilon-1},$$  \hspace{1cm} (12)

which is strictly negative when $\epsilon > 1$. We hereby impose the below assumption for the rest of the paper.

**Assumption 1.**

$$\epsilon > 1.$$  

Based on this assumption, airport $i$’s optimal charge is thus\(^{17}\)

$$x_i^* = \frac{\epsilon c_i}{\epsilon - 1} = c_i + \frac{c_i}{\epsilon - 1} > c_i,$$  \hspace{1cm} (13)

where $\frac{c_i}{\epsilon - 1}$ is a mark-up.

**Proposition 2.** Given airline frequency function (4), and Assumption 1 holds, then

- airport $i$’s ($i = A, B$) optimal landing fee is independent of total passengers and linearly increasing in airport operating cost,

\(^{17}\)Noticing that Ivaldi et al. (2012) assumes $0 < \epsilon < 1$. In their framework, the focus is on a monopoly airport that always operates at full capacity, and the aggregate frequency of all airlines is a fixed constant;
• airport i’s optimal aeronautical profit is

\[ \Pi_{a}^{i*} = \frac{\epsilon^{-\epsilon}}{(1 - \epsilon)^{1-\epsilon}} (\alpha q_i)^{\epsilon 1-\epsilon} \]

which is strictly increasing and convex in total passengers and strictly increasing and concave in operating cost.

The last statement claims that airport profit increases with operating cost. While it might seem counter-intuitive at first glance, the reason can be seen from (13). The airport fully transfers this cost to the airline, and moreover charges a mark-up term that is linearly increasing in operating cost.

### 3.4 Airport total profit in the leisure travel market

With the background laid out in previous subsections, this part discusses setting landing fee under different regulatory regimes, i.e., taking into account a certain portion of commercial operations profit. Under single-till regulation, revenues from both the aeronautical and commercial operations are considered to determine a price cap on aeronautical charges, therefore cross-subsidize the aeronautical charge with concession revenues. While under the dual-till approach, the aeronautical charges are determined based solely on aeronautical activities.

Hereby, we analyze an airport’s profit maximization under different regulatory regimes, i.e., with various weights of commercial activities being integrated into the derivation of optimal landing charge

\[ \max_{x} [\Pi_{a}^{i} + \omega \Pi_{c}^{i}] \]

where parameter \( \omega \in [0, 1] \) indicates the degree of integration of concession revenue in the airport revenue. When \( \omega = 0 \), the regulation scheme is such that the airport is restrained from subsidizing its aeronautical services with commercial revenue, and the two profit segments are taken separately, resembling a dual-till regulatory approach. When \( \omega = 1 \), the regulation scheme allows the airport to utilize both business branches to determine landing fee, resembling a single-till regulatory approach. Any \( \omega \) value locating in (0, 1) indicates a hybrid scheme that lies between the two schemes.

\[ \text{hence, } 0 < \epsilon < 1. \] Our setting, however, involves duopoly airport competition, and the airport has not reached full capacity. Hence, we are concerned with a different range of \( \epsilon \).
We start with $\omega = 0$. In this case, only aeronautical profit is used to calculate landing charge. Aeronautical and commercial operations are regarded as two independent sources of airport profit, and thus, we maximize each segment separately. Combining Proposition 1 and 2, the profit maximization of airport $i$ from the two segments is thus

$$\max_{\{x_i, r_i\}} \Pi_i = \max_{x_i} \Pi_{a}^i + \max_{r_i} \Pi_{c}^i.$$ 

**Proposition 3.** Given the airline frequency function and that both Assumption 1 and the conditions of (7) hold, airport $i$’s optimal profits from the two markets are

$$\Pi_A^* = \Pi_A^a + \Pi_A^c$$
and
$$\Pi_B^* = \Pi_B^a + \Pi_B^c$$
respectively, where $q_i$ in Proposition 2 is replaced by $Q_i^*$ as given in Proposition 1.

We then look at the case where $\omega \neq 0$. The regulation scheme here allows the airport to incorporate a portion $\omega \neq 0$ of concession revenue into the determination of aeronautical charge. As indicated by (6) and Proposition 1, concession revenue is irrelevant to the landing charge for leisure travelers. Therefore, in this market, the regulatory regime does not affect an airport’s choice of optimal landing charge.

Thus far, our attention has been devoted to a framework with a straightforward and tractable functional form. More precisely, the optimal landing fee depends only on the parameter and airport operating cost, while the optimal commercial fee relates to home market size and ticket price, which are both exogenously given. To examine both the complementarity and cross-subsidization between the two sides, we complement the current framework setting by generalizing model specifications and adding more sophisticated features.

### 4 Business travelers market

Until now, we have confined attention to the leisure traveler market where fliers overlook scheduling. We now look into the business traveler market, which could mirror the case where competition is between two major airports with their exclusive carriers.\(^{18}\) This

\(^{18}\)For example, Xiaoshan airport (HGH) in Hangzhou, China and Hongqiao airport in Shanghai (SHA) each has over 10 million annual passenger throughput, HGH is hub for XiamenAir and SHA is hub for China Eastern. The two cities are easily accessible to each other within 1-2 hours by public transportation.
demand segment represents fliers who prefer to travel on flights that meet their schedule requirements. It is important to note that we consider leisure and business travel markets as different scenarios rather than different passenger groups that embark on one flight.\textsuperscript{19}

To account for the simplicity of the current approach, the precise departure times of individual flights are taken to be irrelevant. Business travelers incorporate valuation of ticket price, commercial fee and flight frequency combined. We use a tilde on top of variables to denote the business travel market, as differentiated from the leisure market.

Taking into account the form of $P_i$ with the presence of schedule delay cost, or equivalently, $\delta = 1$ (from (1)), effective price for business travelers is:

$$
\tilde{P}_i = P_i(\tilde{x}_i) + \tilde{\tau}_i + \frac{\beta}{\sqrt{f_i(\tilde{x}_i, \tilde{q}_i)}}.
$$

(14)

Here, $\tilde{x}_i$ denotes landing fee and $\tilde{q}_i$ is the total number of passengers using airport $i$. We impose the natural assumption that both airports at least cover their home markets and no airline could win all the markets, $\tilde{q}_A \geq a$ and $\tilde{q}_B \geq b$ with $\tilde{q}_A + \tilde{q}_B = 1$. We retain the assumption that airlines stick with frequency function (4). We solve this three-stage game via backward induction.

4.1 Business passengers’ choice

Analogous to Subsection 3.2, the indifferent passenger is identified by equating the utility derived from departures at the two airports, which are

$$
\tilde{Y}_A = \frac{1}{2} \left( 1 - a - b + \frac{\tilde{P}_B - \tilde{P}_A}{k} \right), \quad \tilde{Y}_B = \frac{1}{2} \left( 1 - a - b - \frac{\tilde{P}_B - \tilde{P}_A}{k} \right).
$$

(15)

\textsuperscript{19}Leisure traveler market can be distinguished from business traveler market by travel destination and airline characteristics, among other factors. Airlines flying to typical holiday spots such as Mediterranean and the Caribbean region is an example of leisure travel market (Papatheodorou and Lei, 2006). Another example is some Low-Cost Carriers that fly to less expensive but remote secondary airport destinations, such as Ryanair. We thank one anonymous referee for pointing this out.
Putting (14) together with (15), the total passenger volumes departing from the two airports, respectively, are thus

\[
\tilde{Q}_A = a + \tilde{Y}_A = \frac{1}{2} \left( 1 + a - b + \frac{(P_B + \tilde{\tau}_B + \frac{\beta}{\sqrt{f_B}}) - (P_A + \tilde{\tau}_A + \frac{\beta}{\sqrt{f_A}})}{k} \right),
\]

\[
\tilde{Q}_B = b + \tilde{Y}_B = \frac{1}{2} \left( 1 - a + b - \frac{(P_B + \tilde{\tau}_B + \frac{\beta}{\sqrt{f_B}}) - (P_A + \tilde{\tau}_A + \frac{\beta}{\sqrt{f_A}})}{k} \right).
\] (16)

Keeping airline A’s commercial charge fixed, the above expression shows that a marginal increase in airline B’s commercial charge attracts an additional \(1/2k\) portion of passengers to A. The ticket price has an impact on the user number of the passenger side.

### 4.2 Revenues in the business travel market

In practice, airlines often experience profit losses due to unoccupied seats, which is why last-minute airfare deals can be quite affordable. Nevertheless, business and first-class tickets typically aren’t subject to discounts. This is because historical data provides a reliable basis for predicting the number of business travelers. As previously explained, this paper considers business and leisure traveler markets as different scenarios rather than mixed, as the model feature is unable to separate the two types of travelers if they embark on one flight. Given these considerations, we maintain the assumption that \(q_i\) equals \(Q_i\) throughout the remainder of this study.

**Commercial Revenues** Airport \(i\)'s concession profit maximization problem can be stated as

\[
\max_{\tilde{\tau}_i} \tilde{\Pi}_i^c = \tilde{\tau}_i \tilde{q}_i, \quad i = A, B.
\] (17)

The solution\(^{20}\) to the above optimization problem yields, under conditions (7), the unique interior Nash equilibrium in terms of commercial fee

\[
\tilde{\tau}_A(\tilde{x}_A, \tilde{x}_B) = k \left( 1 + \frac{a - b}{3} \right) + \frac{P_B(\tilde{x}_B) + \frac{\beta}{\sqrt{f_B(\tilde{x}_B)}} - P_A(\tilde{x}_A) - \frac{\beta}{\sqrt{f_A(\tilde{x}_A)}}}{3},
\]

\[
\tilde{\tau}_B(\tilde{x}_B, \tilde{x}_A) = k \left( 1 - \frac{a - b}{3} \right) - \frac{P_B(\tilde{x}_B) + \frac{\beta}{\sqrt{f_B(\tilde{x}_B)}} - P_A(\tilde{x}_A) - \frac{\beta}{\sqrt{f_A(\tilde{x}_A)}}}{3}.
\] (18)

\(^{20}\)As mentioned in the last subsection, commercial charge influences passengers’ choice of airport and
Business passengers know in advance their preferred departure time, are aware of their scheduled delay cost and would count the monetary value of the waiting time into the effective price. The optimal commercial fee charged by the airport under this circumstance should contain a schedule delay term, which, in turn, depends on flight frequency set by airlines. Implicit in the expressions is the idea that if passengers are aware of time cost, airports’ optimal commercial fees are dependent on landing fees.

Equation (16) along with (18) give us concession profits evaluated at critical point

\[ \tilde{\Pi}^c_i = \tau_i Q_i = \frac{1}{2k}(\tau_i)^2, \quad i = A, B. \]  

(19)

We conclude the above findings in the following proposition.

**Proposition 4.** For given ticket prices, assume that effective prices are given by (14). Then

- there exists a unique interior Nash equilibrium for commercial charges which is given by (18),
- airports’ optimal concession profits are given by (19),
- if it is further assumed that (4) and (2) hold, then both commercial charge and airport profit increase with the competing airport’s landing fee but decrease with own landing fee.

**Aeronautical Revenues** Aeronautical profit remains the form as in leisure traveler case (10), with variables now being replaced by corresponding variables with tilde mark to identify business travel market, and can be expressed as

\[ \tilde{\Pi}^a_i = (\tilde{x}_i - c_i) \left( \frac{\alpha \tilde{q}_i}{\tilde{x}_i} \right)^\epsilon, \quad i = A, B. \]  

(20)

### 4.3 Airport total profit in the business travel market

Combining (19) and (20), airport \( i \)’s optimization problem can be characterized as

\[ \max_{\tilde{x}_i} \left[ \tilde{\Pi}^a_i + \omega \tilde{\Pi}^c_i \right] = \max_{\tilde{x}_i} \left[ (\tilde{x}_i - c_i) f(\tilde{x}_i, \tilde{q}_i) + \omega \frac{\tau_i^2(\tilde{x}_i, \tilde{x}_j)}{2k} \right], \]

airline, and consequently the total passenger volume, but flight frequency was determined at a prior step.
where \( i, j = A, B \) and \( \tilde{x}_i \neq \tilde{x}_j \) with \( \tilde{q}_A \geq a \) and \( \tilde{q}_B \geq b \).

In the rest of the paper, we first study the optimal choice of landing fee under regulation, after which we investigate the impact of the optimal passenger volume on the aeronautical and commercial profits; we close this section by analyzing total profit.

### 4.3.1 Optimal Landing Fee

The optimal choice of landing fee is derived from the first-order condition with respect to \( \tilde{x}_i \), which yields

\[
\frac{\partial \tilde{\Pi}_i}{\partial \tilde{x}_i} = \frac{\partial \tilde{\Pi}_i^a}{\partial \tilde{x}_i} + \omega \frac{\partial \tilde{\Pi}_i^c}{\partial \tilde{x}_i} = (\alpha \tilde{q}_i)^\epsilon \tilde{x}_i^{-\epsilon - 1} \left[c_i \epsilon + (1 - \epsilon) \tilde{x}_i \right] + \omega \frac{\tilde{\tau}_i}{k} \frac{\partial \tilde{\tau}_i}{\partial \tilde{x}_i} = 0. \tag{21}
\]

In the ensuing analysis, to guarantee the second-order conditions for optimization, whose proof is provided in the Appendix A, we impose the following assumption:

**Assumption 2.** Parameter \( \epsilon \) and \( \omega \) satisfy

1. \( 1 < \epsilon < 2 \),
2. at the critical point defined by (21), \( \omega \) fulfills

\[
0 < \omega < \omega \equiv \min \left\{ 1, \left( \frac{\partial^2 \tilde{\Pi}_i^a}{\partial \tilde{x}_i^2} \right) \left/ \left( -\frac{\partial^2 \tilde{\Pi}_i^c}{\partial \tilde{x}_i^2} \right) \right., i = A, B \right\}.
\]

Weight parameter \( \omega \) is bounded by the ratio of the curvatures of two profit functions. Intuitively, it should be smaller than one by definition. Although explicit solution to the first-order condition (21) is difficult to obtain, because \( \frac{\partial \tilde{\tau}_i}{\partial \tilde{x}_i} < 0 \), whose proof is relegated to Step 2 of Appendix A, it follows that the first term of (21) must be positive, and therefore

\[
c_i \epsilon + (1 - \epsilon) \tilde{x}_i > 0,
\]

Thus, at this stage, not only the passengers but also the airports take as given the flight frequency.

\( ^{21} \)Given our focus is not on the choice of \( \epsilon \), condition \( \epsilon < 2 \) simplifies the calculation and it is not essential for either the existence and uniqueness of optimal choices or the properties we study thereafter.
which is equivalent to

\[ \tilde{x}_i < \frac{\epsilon}{1 - \epsilon} c_i = x_i^*. \]

Because the landing charge will be partially or fully added to a ticket price and consequently has impact on the flight frequency, the optimal landing charge is chosen to maximize aeronautical and concession profits combined, although the weight of the latter may vary. The optimal landing fee should be lower than the case where only aeronautical profit is used to derive landing fee.

**Proposition 5.** Suppose Assumption 2 holds. There is a unique optimal solution, \( \tilde{x}_i \), given by the first-order condition (21):

\[ \tilde{x}_i \leq x_i^*. \]

Equality holds if and only if \( \omega = 0 \).

The intuition behind this result can be explained by the complementary nature of demand for the two sides of services. When facing demand complementarities between aeronautical and commercial activities, in equilibrium an airport sets a lower charge for aeronautical services. In particular, a rise in landing charge leads to a fall in the demand for both aeronautical services and commercial services. Under a hybrid scheme, landing charge magnifies the impact of passenger demand on the airport. Following this reasoning the airport may not seek to increase the landing charge, which supports the viewpoint that airport regulation is not necessary.

### 4.3.2 Impact of passenger volume on optimal landing charge

In the last section, we considered a setting where optimal landing fee is independent of the passenger volume. We now take into account the impact on the other market and discuss the case where optimal landing fee and passenger volume are intertwined.

Recall the optimal choice of \( \tilde{x}_i \) is given by first-order condition (21). Applying implicit function theorem to (21) yields

\[
\frac{d\tilde{x}_i}{dq_i} = -\left( \frac{\partial}{\partial \tilde{x}_i} \left( \frac{\partial \Pi_i}{\partial \tilde{x}_i} \right) \right) / \left( \frac{\partial^2 \Pi_i}{\partial \tilde{x}_i^2} \right).
\] (22)
Thus, we can conclude the following

\[
\begin{align*}
\frac{d\tilde{x}_i}{d\tilde{q}_i} & \begin{cases} 
> 0, & 0 < \omega < \bar{\omega}, \\
< 0, & \omega < \omega < \bar{\omega} \end{cases}
\end{align*}
\]

(23)

where \(\bar{\omega}\) is given in Assumption 2 and \(\omega\) is defined as

\[
\omega = \frac{3(\epsilon c_i \epsilon + (1 - \epsilon)\bar{x}_i)}{\gamma} f(\bar{x}_i, \bar{q}_i) q_i \rho_i(\bar{x}_i).
\]

(23) reflects the fact that the optimal landing fee can either rise or fall with passenger volume. The reason is the following. As concession profit is increasing with passenger volume (for a proof, see equation (B.2) in Appendix B), if \(\omega\) is large, concession profit puts downward pressure on the aeronautical revenue and eventually the landing fee. Hence, the relationship between passenger volume and landing fee is negative. The reverse holds for a relatively small \(\omega\).

Using (23), we proceed to study the impact of passenger volume on both aeronautical and concession profits.

### 4.3.3 Impact of passenger volume on aeronautical profit

From the expression of aeronautical profit (20), we can derive

\[
\frac{d\tilde{\Pi}_i^a}{d\tilde{q}_i} = f(x_i, q_i) \frac{d\tilde{x}_i}{d\tilde{q}_i} + (\tilde{x}_i - c_i) \frac{df}{d\tilde{q}_i}.
\]

(24)

For given frequency function \(f(x_i, q_i) = \left(\frac{a q_i}{x_i}\right)^\epsilon\), total differential of \(f\) shows

\[
\frac{df}{d\tilde{q}_i} = \frac{\partial f}{\partial \tilde{x}_i} \frac{d\tilde{x}_i}{d\tilde{q}_i} + \frac{\partial f}{\partial \tilde{q}_i} = \epsilon \frac{f}{q_i} \left(1 - \frac{d\tilde{x}_i}{d\tilde{q}_i} / \tilde{x}_i\right).
\]

(25)

Substituting the first expression into (24) and rearranging terms, it follows

\[
\frac{d\tilde{\Pi}_i^a}{d\tilde{q}_i} = f(x_i, q_i) \tilde{x}_i^{-1} [1 - \epsilon] \tilde{x}_i + c_i \epsilon \frac{d\tilde{x}_i}{d\tilde{q}_i} + (\tilde{x}_i - c_i) \frac{\partial f}{\partial \tilde{q}_i}.
\]

(26)

As we have assumed change of aircraft away, flight frequency does not decrease with
passenger volume; thus, \( \frac{\partial f}{\partial \tilde{q}_i} > 0 \). The second expression in (25) implies that \( \frac{\tilde{x}_i}{\tilde{q}_i} > 0 \). The second expression in (25) implies that \( \frac{\partial f}{\partial \tilde{q}_i} > 0 \), which says the optimal landing charge must be inelastic with respect to passenger volume. This condition puts no restraint on the sign of \( \frac{\tilde{x}_i}{\tilde{q}_i} \). If \( \frac{\tilde{x}_i}{\tilde{q}_i} > 0 \), it follows straightforwardly from equation (26) that \( \frac{\partial \tilde{x}_i}{\partial \tilde{q}_i} > 0 \). If \( \frac{\tilde{x}_i}{\tilde{q}_i} < 0 \) otherwise, the first term in (26) is negative, while the second term is positive. Passenger volume affects aeronautical profit in two opposite directions and the joint effect is not straightforward. This analysis is summarized in the following result.

**Proposition 6.** Given frequency function (4) and ticket price expression (2), as well as Assumption 2, the following results hold

1. when \( 0 < \omega < \omega \)
   (1.a) passenger volume positively affects aeronautical profit,
   (1.b) optimal landing charge must be inelastic with respect to passenger volume,
2. when \( \omega < \omega < \omega \), passenger volume has an ambiguous impact on aeronautical profit.

The ambiguity comes from the fact that, on the one hand, larger passenger volume leads to more frequent flights, \( \frac{df}{d\tilde{q}_i} > 0 \); on the other hand, it directly implies larger non-aeronautical profit, \( \frac{\partial \Pi_i^c}{\partial \tilde{q}_i} > 0 \); thus, the airport can afford to decrease its landing charge, i.e., \( \frac{dx_i}{d\tilde{q}_i} < 0 \). In other words, airlines can transfer the lower landing charge via ticket price to the passengers, thus increasing the competitive advantage of the airport-airline bundle together.

**4.3.4 Impact of passenger volume on concession profit**

The aggregate effect of passenger volume on concession profit depends on both passenger volume and commercial charge

\[
\frac{d\tilde{\Pi}_i^c}{d\tilde{q}_i} = \tilde{r}_i + \tilde{q}_i \frac{d\tilde{r}_i}{d\tilde{q}_i},
\]

which can be rewritten, using (18), as

\[
\frac{d\tilde{\Pi}_i^c}{d\tilde{q}_i} = \left( \tilde{r}_i + \tilde{q}_i \frac{\partial \tilde{r}_i}{\partial \tilde{q}_i} \right) + \tilde{q}_i \frac{\partial \tilde{r}_i}{\partial \tilde{x}_i} \frac{d\tilde{x}_i}{d\tilde{q}_i},
\]

(27)
the bracket term is always positive and the second term is ambiguous. Our results are summarized in the following Proposition.

**Proposition 7.** Under the same conditions as in Proposition 6. The following are true

- when \( 0 < \omega < \omega \), passenger volume has an ambiguous impact on concession profits,
- when \( \omega < \omega < \omega \), concession profits increase with passenger volume.

Here, ambiguity arises from a different source. It is still true that larger passenger volume leads to larger concession profit; at the same time, however, it also enables the airport to impose higher landing charges, \( \frac{\partial \tilde{\Pi}}{\partial q_i} > 0 \). Given that the airline can partially pass the charge on to passengers through ticket prices, airlines reduce commercial charges imposed on the passengers to remain attractive.

### 4.3.5 Impact of passenger volume on airport total profit

To sum up the previous two subsections, we conclude the following

\[
\begin{cases}
\frac{\partial \Pi^a}{\partial q_i} > 0 \text{ and } \frac{\partial \Pi^c}{\partial q_i} \geq 0, & \text{if } 0 < \omega < \omega, \\
\frac{\partial \Pi^a}{\partial q_i} \geq 0 \text{ and } \frac{\partial \Pi^c}{\partial q_i} > 0, & \text{if } \omega < \omega < \omega.
\end{cases}
\] (28)

If the regulation scheme allows a higher portion of concession revenue to cross subsidize the aeronautical sector, a rise in traffic increases the commercial sector’s revenue, while its impact on the aeronautical sector is ambiguous. If the regulatory scheme restricts the portion of concession revenue to be integrated into the airport’s total revenue, then a rise in traffic has a positive impact on aeronautical revenue, but an ambiguous impact on commercial revenue.

While it may seem intuitive to think that an increase in passenger volume would increase an airport’s revenue, we have shown that regulatory scheme in terms of the portion of concession used to cross subsidize the aeronautical sector has a different impact on the revenue of the two sectors. If the regulatory scheme is less stringent, i.e., allows for a higher portion to be integrated into airport total revenue, passenger volume increases concession revenue, while its impact on the aeronautical sector may be positive or negative. If the regulatory scheme is stringent such that the shared portion is small, then an
increase in passenger volume does not necessarily translate into higher concession profit, but its impact on aeronautical revenue is positive.

5 Conclusion

The aim of this paper is to provide new insights into the theoretical outcome of airport competition. The originality of our approach is that we model duopoly competition of multiproduct airports, who at the same time serve and charge both passengers and airlines, a la Hotelling. The model demonstrates that if passengers only care about direct cost, i.e., airline tickets and commercial fees, and airports can treat the markets separately, the optimal landing charge and commercial fee are independent of each other. The landing fee is also independent of passenger volume, although commercial fees are determined by home market size. Under a general setting, the above clear-cut results are no longer true. More importantly, increasing passenger volume does not guarantee increases in airports' aggregate revenue regardless of whether the duopoly competing airports are single-till or dual-till regulated.

In analyzing concessions, Bracaglia et al. (2014) assume that commercial services sold online generate extra surplus. These services mostly include car rental, car parking or hotel reservations that might stimulate the demand for travel and are thus welfare enhancing (Czerny, 2013). The current paper is built upon the assumption of consumer foresight as a result of enhanced price observability via nowadays e-commerce. In the strand of the literature that considers that consumers may make decisions about buying the ticket and concession services simultaneously rather than independently, a reduction in concession goods prices can be considered as an increase in airport service quality, which improves consumer surplus and boosts travel demand (Czerny and Lindsey, 2014).

It is worth pointing out that our results are based on tractable and simplified model settings and functional forms that ignore some aspects of airport-airline integration. The current framework does not formally model the downstream airline market. In a vertical structure setting, what seems to be an interesting and feasible avenue for future research, is to consider downstream airline market structure and competition (e.g., oligopoly airlines versus monopoly airline), in a passenger-based aeronautical and commercial charge set-up.
References


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**Appendix A: Proof of second order conditions in Subsection 4.3**

Recall

\[
\max_{\tilde{x}_i} \tilde{\Pi}_i = \max_{\tilde{x}_i} [\Pi_i^a + \omega \Pi_i^c] \\
= \max_{\tilde{x}_i} [(\tilde{x}_i - c_i) f(\tilde{x}_i, \tilde{q}_i) + \omega \frac{\tilde{\tau}_i^2 (\tilde{x}_i, \tilde{x}_j)}{2k}],
\]

and

\[
\tilde{\tau}_A(\tilde{x}_A, \tilde{x}_B) = k \left(1 + \frac{a - b}{3}\right) + \frac{P_B(\tilde{x}_B) + \frac{\beta}{\sqrt{f_B(\tilde{x}_B)}} - P_A(\tilde{x}_A) - \frac{\beta}{\sqrt{f_A(\tilde{x}_A)}}}{3},
\]

\[
\tilde{\tau}_B(\tilde{x}_B, \tilde{x}_A) = k \left(1 - \frac{a - b}{3}\right) - \frac{P_B(\tilde{x}_B) + \frac{\beta}{\sqrt{f_B(\tilde{x}_B)}} - P_A(\tilde{x}_A) - \frac{\beta}{\sqrt{f_A(\tilde{x}_A)}}}{3}.
\]

Obviously, the first-order condition with respect to $\tilde{x}_i$ yields:

\[
\frac{\partial \tilde{\Pi}_i}{\partial \tilde{x}_i} = \frac{\partial \tilde{\Pi}_i^a}{\partial \tilde{x}_i} + \omega \frac{\partial \tilde{\Pi}_i^c}{\partial \tilde{x}_i} = (\alpha \tilde{q}_i)^{\epsilon - \epsilon - 1} [c_i \epsilon + (1 - \epsilon) \tilde{x}_i] + \omega \frac{\tilde{\tau}_i}{k} \frac{\partial \tilde{\tau}_i}{\partial \tilde{x}_i} = 0,
\]

and the second order derivative is

\[
\frac{\partial^2 \tilde{\Pi}_i}{\partial \tilde{x}_i^2} = \frac{\partial^2 \tilde{\Pi}_i^a}{\partial \tilde{x}_i^2} + \omega \frac{\partial^2 \tilde{\Pi}_i^c}{\partial \tilde{x}_i^2}.
\]
In the following, in order to check and impose conditions for the second order sufficient condition to hold, we study the two terms in the above equation one by one.

**Step 1.** The sign of $\frac{\partial^2 \tilde{\Pi}^a}{\partial x_i^2}$.

From the first order condition, there is internal critical point if and only if at the critical point

$$c_i \epsilon + (1 - \epsilon) \tilde{x}_i > 0.$$ 

Then it is straightforward that

$$\frac{\partial^2 \tilde{\Pi}^a}{\partial x_i^2} = (\alpha q_i)^{\epsilon} \left[ (-\epsilon - 1) \tilde{x}_i^{-\epsilon - 2} (c_i \epsilon + (1 - \epsilon) \tilde{x}_i) + \tilde{x}_i^{-\epsilon - 1} (1 - \epsilon) \right] < 0.$$ 

**Step 2.** The sign of $\frac{\partial^2 \tilde{\Pi}^c}{\partial x_i^2}$.

Direct calculation yields

$$\frac{\partial \tilde{\tau}_i}{\partial x_i} = -\frac{1}{3} \left[ \frac{\partial P_i}{\partial x_i} - \frac{\beta}{2} (f_i(x_i))^{-3/2} \frac{\partial f_i}{\partial x_i} \right]$$

$$= -\frac{1}{3} \left[ \Gamma \gamma x_i^{\gamma - 1} + (\epsilon - 1) (\alpha q_i)^{\epsilon - \frac{\epsilon}{2}} x_i^{\epsilon - \frac{1}{2}} \right] < 0.$$ (A.1)

It is easy to see

$$\frac{\partial \tilde{\Pi}^c}{\partial x_i} = \frac{\tilde{x}_i}{k} \frac{\partial \tilde{\tau}_i}{\partial x_i} < 0$$

and

$$\frac{\partial^2 \tilde{\Pi}^c}{\partial x_i^2} = \frac{1}{k} \left( \frac{\partial \tilde{\tau}_i}{\partial x_i} \right)^2 + \frac{\tilde{x}_i}{k} \frac{\partial^2 \tilde{\tau}_i}{\partial x_i^2}$$

where

$$\frac{\partial^2 \tilde{\tau}_i}{\partial x_i^2} = -\frac{1}{3} \left[ \Gamma \gamma (\gamma - 1) x_i^{\gamma - 2} + \frac{\epsilon \beta}{2} \left( \frac{\epsilon}{2} - 1 \right) (\alpha q_i)^{\epsilon - \frac{\epsilon}{2}} x_i^{\epsilon - \frac{1}{2}} \right].$$

Depending on parameter setting, $\frac{\partial^2 \tilde{\tau}_i}{\partial x_i^2}$ could be positive or negative. For simplicity, we assume that

$$1 < \epsilon < 2,$$
then \( \frac{\partial^2 \tilde{x}_i}{\partial \tilde{x}_i^2} > 0 \) is always true. Therefore at the critical point, \( \tilde{x}_i \):

\[
\frac{\partial^2 \tilde{\Pi}_i^c (\tilde{x}_i)}{\partial x_i^2} > 0, \quad \forall \epsilon \in (1, 2).
\]

**Step 3.** We now turn to prove the second order condition.

The second order sufficient condition for optimization at the critical point (which satisfies the first order condition)

\[
\frac{\partial^2 \tilde{\Pi}_i (\tilde{x}_i)}{\partial x_i^2} = \frac{\partial^2 \tilde{\pi}_i^a (\tilde{x}_i)}{\partial x_i^2} + \omega \frac{\partial^2 \tilde{\pi}_i^c (\tilde{x}_i)}{\partial x_i^2} < 0
\]

holds if and only if

\[
\frac{\partial^2 \tilde{\pi}_i^a (\tilde{x}_i)}{\partial x_i^2} < -\omega \frac{\partial^2 \tilde{\pi}_i^c (\tilde{x}_i)}{\partial x_i^2},
\]

which is equivalent to

\[
\omega < \left( \frac{\partial^2 \tilde{\Pi}_i^a (\tilde{x}_i)}{\partial \tilde{x}_i^2} \right) / \left( -\frac{\partial^2 \tilde{\Pi}_i^c (\tilde{x}_i)}{\partial \tilde{x}_i^2} \right), \quad i = A, B.
\]

Furthermore, if parameter setting is established such that

\[
\frac{\partial^2 \tilde{\Pi}_i^c (\tilde{x}_i)}{\partial x_i^2} < 0, \quad \forall \epsilon,
\]

as a weighted variable, we still need to impose that

\[
\omega < 1.
\]

That completes the proof of the second order condition as we stated in the Assumption 2.

**Appendix B: Proof of Subsection 4.3.2**

It is then immediate to see that under Assumption 2, the second order condition states that the denominator is always negative. The sign of the numerator, which captures the mixed effects of landing fee and passenger volume on airport’s aggregate profit, is am-
biguous. Using (21), the numerator of (22) can be written as

$$\frac{\partial}{\partial \tilde{q}_i} \left( \frac{\partial \tilde{\Pi}_i}{\partial \tilde{x}_i} \right) = \frac{\partial^2 \tilde{\Pi}_i}{\partial \tilde{x}_i \partial \tilde{q}_i} + \omega \frac{\partial^2 \tilde{\Pi}_i}{\partial \tilde{x}_i \partial \tilde{q}_i}, \quad \text{(B.1)}$$

where the first term on the right hand side is

$$\frac{\partial^2 \tilde{\Pi}_i}{\partial \tilde{x}_i \partial \tilde{q}_i} = \epsilon \left( \alpha \tilde{q}_i \right)^{\epsilon-1} \tilde{x}_i^{-\epsilon-1} (c_i \epsilon + (1 - \epsilon) \tilde{x}_i) > 0.$$

Marginal aeronautical profit of landing charge always increases with passenger volume. To study the second term, we recall the definition of concession revenue (17), it is thus straightforward that

$$\frac{\partial \tilde{\Pi}_i}{\partial \tilde{q}_i} = \tau_i + q_i \frac{\partial \tau_i}{\partial \tilde{q}_i} > 0. \quad \text{(B.2)}$$

Increase in passenger volume has a positive, direct effect on concession revenue. After rearranging terms and simplification, we obtain

$$\frac{\partial^2 \tilde{\Pi}_i}{\partial \tilde{x}_i \partial \tilde{q}_i} = \frac{\partial \tau_i}{\partial \tilde{x}_i} + q_i \frac{\partial \tau_i}{\partial \tilde{x}_i} \frac{\partial \tau_i}{\partial \tilde{q}_i} = - \frac{\Gamma \gamma}{3} \tilde{x}_i^{\gamma - 1} < 0.$$

(B.1) can now be rewritten as

$$\frac{\partial^2 \tilde{\Pi}_i}{\partial \tilde{q}_i \partial \tilde{x}_i} = \left[ \epsilon (c_i \epsilon + (1 - \epsilon) \tilde{x}_i) \frac{f(x_i)}{\tilde{q}_i} - \omega \frac{\Gamma \gamma}{3} \tilde{x}_i^{\gamma - 1} \right] \tilde{x}_i^{-1}.$$

That finishes the proof.