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Vertical relations between airports and airlines:
theory and implications

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Abstract

This dissertation provides new contributions on air transport economics with respect to the issue of vertical relations between airports and airlines.

Chapter 1 provides an interpretive review of models of airport-airline interaction. While assessing how deregulation of the airline market and privatization of airports create the incentives for airport-airline interaction, and which are the different forms of cooperation observed in practice, particular attention is payed on models used to represent formally vertical relations between airports and carriers. Moreover, if the vertical structure approach has become standard in air transport research, we discuss three elements that still seem to lack of understanding, but we think should be the lines of future research on airports-airlines interaction: (i) incomplete contracts and asymmetric information structure; (ii) upstream horizontal complementarities; (iii) airports as two sided platforms.

In Chapter 2 we study airport pricing with aeronautical and concession activities. While assuming that as congestion increases dwell time increases — and so the money spent in concession activities — we incorporate a positive relationship between delay and consumption of concession goods, and the effect of passenger types. We find that: (i) there is a downward correction on the congestion toll due to the positive externality of delay; (ii) the component relevant to the per-passenger benefit from concessions may be a mark-up depending on delay and the passengers' values of time. Furthermore, a welfare-maximizing airport may have more incentives to induce congestion than a profit-maximizing airport.

Chapter 3 investigates contracts between airports and airlines, in the context of two competing facilities and three types of agreements. The downstream market consists in

a route operated by one leader and *n-1* followers competing *à la* Stackelberg in each facility. We develop a multistage game where each airport and its dominant airline decide whether to enter into a contract and, if so, which one to engage in. We find that the airport and its dominant airline have incentive to vertical integration in each facility. The merger implies a downstream market foreclosure through a price-squeeze strategy but consumers' surplus and welfare increase with respect to the case in which no agreement occurs. Thus, the agreement exhibits a trade-off between competitiveness and welfare.

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Dedication

To my family. Loving, since curious.

Introduction

Airlines and airports involve vertical relationships since the airport is the provider of infrastructures and general services with the airlines as its consumer. Equivalently, airports constitute the upstream market which sells an essential input for the production of an output that is required by airlines – the downstream market – to move passengers: the travel. Thus, while airlines only view passengers as their customer group - and consider themselves as customers of the airports - airports regard both airlines and passengers as their key buyers.

Deregulation of airline market, privatization of airports and the recent phenomenon of low cost carrier have questioned the nature of airports-airlines relation.

On one hand, structural changes in the airport industry occurred. Competition between airports has been growing significantly, in the light of: (i) the liberalization process, which has increased the available routes in the network and, therefore, the numbers of competing routes and competing airports; (ii) the increasing number of small-medium secondary airports relying on the operations of LCCs which use a business model that has a relevant cost driver in airport costs and enables LCCs to shop around airports (Dresner et al., 1996; Pels et al. 2009); (iii) the privatization and the commercialization of the airport industry. Airports, many of which have been treated in the past as public service organizations directly controlled by government administrations, have increasingly been restructured to attract private investments, search for new sources of revenues, such as those form concessions, and attract the full service or low cost carriers competing within airports and for airports (Starkie, 2002).

On the other hand, liberalization has led to radical changes in the competitive structure of the airline market. The initial acts of deregulation (Airline Deregulation Act, 1978) have seen the entry of several carriers on the market. Nevertheless, structural, strategic and regulatory barriers persisted – such as the existence of high economics of density, strategic alliances and co-sharing agreements, slot allocation mechanisms based on grandfathering rules – and created the basis for the development of an oligopolistic market structure, centred around hub and spoke arrangements (Oum et al., 1996; Spiller, 1989; Zhang, 1996; Zhang and Wei, 1993). In other words, the degree of concentration among carriers has been increasing and airlines have been achieving higher and higher bargaining power (ICCSAI Factbook, 2011; OECD, 2009): as a consequence, the airport–airline relation turned into a bilateral-monopoly (monopoly–monopsony).

All these changes lead to increased opportunities for airports and airlines to engage in vertical relationships and develop new strategies to gain a competitive advantage: airlines and airports may have incentives to enter into cooperative relationships to create a win-win situation and compete successively with other pairs of airports and airlines (Fu et al., 2011; Starkie, 2012).

This dissertation provides new contributions on air transport economics with respect to the issue of vertical relations between airports and airlines.

There are two reasons why it is interesting to look at this topic. The first is that new and important insights have been derived during the last years for problems in these areas previously uninvestigated. This has been probably due to the fact that price discrimination on aviation services is prohibited by IATA and EU rules and the historical public utility status of most airports has often protected airports from anti-trust investigation until the recent privatization wave.

Second, it has been argued that regulation may be unnecessary – in that airport charges may be kept down and capacity investments may be more efficient – if deeper collaboration between airlines and airports was allowed and encouraged or, on the other hand, if airlines had enough countervailing power (Basso, 2008; Civil Aviation Authority UK, 2004; Forsyth, 2003; Starkie, 2001, 2002, 2005, 2012). Thus, the

analysis of different forms of cooperation between airports and airlines emerges as an obvious answer to this intuition.

In this framework, Chapter 1 seeks to review models on vertical relations between airports and carriers drawn in the literature during the last two decades, while assessing how deregulation of the air transport market created the incentives for airport-airline interaction as well as the different forms of cooperation observed in practice.

The work starts from the central insight of the recent research – that is airport economics and policy should incorporate strategic interactions between airlines with market power, thereby requiring examination of airports and airline-services in an integrated manner (Basso and Zhang, 2007; Czerny and Zhang, 2012b). The contribution of the survey is twofold. First, it seeks to provide an interpretive review of the main ideas developed by the literature on airport-airline interaction in a general unifying framework, with a particular attention on the models used to represent formally vertical relations. In this sense, through living on their findings and conclusions, the paper differs from previous contributions by Fu et al. (2011) and Starkie (2012) which examine forms of cooperation between airports and carriers but focus primarily on competition concerns as well as policy and regulatory implications. Second, if the vertical structure approach has become standard in air transport research, we discuss three elements – which are of particular importance for air transport markets – that still seem to lack of understanding with respect to airports-airlines interaction: (i) incomplete contracts and asymmetric information structure; (ii) upstream horizontal complementarities; (iii) airports as two sided platforms.

In the literature debate, the policy need to respond to increasing degree of concentration in the supply of air services and increasing congestion – which is likely to impose the dominant airline's control over key airport facilities and additional entry barriers to other potential competitors – has been driving new approaches in modeling the vertical relation between airports and carriers. Basically, the simplest vertical relationship between the airport (the provider of the facility – the input) and the airline (the user of the facility) can be seen in the input pricing mechanism. In order to provide aviation services, an airport incurs both operating and capital expenses: it charges carriers and collects these charges from airlines to cover these costs - or to make a return on capital

investments in the private airport case. Basso and Zhang (2007) review analytical models of airport pricing during the last 30 years and argue that the models in literature can be grouped into two broad approaches, the traditional approach and the vertical approach.

The key feature that divides these studies is whether to explicitly consider the market structure of downstream carriers and their market power. Literature finds a negative relationship between the socially optimal airport charge and airlines' market concentration. On the other hand, concession revenues exert a downward pressure on the aeronautical charge, in order to exploit complementarity between aviation and non-aviation services. However, in order to have a more complete picture of optimal airport pricing, two more aspects of the air transport business should be incorporated into the analysis. First, passengers may not be a homogeneous group of individuals. Czerny and Zhang (2010) find that, in the case of two types of passengers with different values of time, the socially efficient airport charge may exceed the residual share of the marginal congestion cost. Second, there is a positive correlation between the expenditure in the concessions area and the waiting time. This follows the common sense that more spare time gives more opportunity for browsing in the shops and induces the need to buy refreshment.

The research project presented in Chapter 2 starts investigating the issue of vertical relations between airports and airlines focusing on the basic mechanism of that relation – the airport pricing – and addressing the two aforementioned missing aspects.

The paper adds to literature as it takes into account the positive externality of congestion on concessions through its impact on dwell time, while incorporating the effect of passenger types. We think it is interesting to look at this topic, since non-aeronautical revenues have been growing significantly to the point that they have become the main income source for many airports. Specifically, we consider a model with one congestible airport serving a number of competing airlines and two types of passengers — business and leisure — with the former having a higher time value than the latter. We consider two types of airports, namely private airports maximising their profits and public airports maximising social welfare. We assume that only the extra surplus generated by airport concession services not attainable elsewhere is counted into the

social welfare function. In other words, we only include a proportion of the surplus from concession services. This reconciles two approaches to modelling the social welfare function in airport pricing literature: if the proportion is equal to one, all the surplus from concession activities is counted into social welfare (Yang and Zhang, 2011; Zhang and Zhang, 2003, 2010); if the proportion is equal to zero, surplus from concession activities is excluded (Czerny, 2011; Kratzsch and Sieg, 2011).

It is found that for both profit- and welfare-maximizing airports there is a downward correction for the congestion toll due to the positive externality of delay. Furthermore, as the passenger volume changes when the airport charge increases, there is a correction on the optimal airport charge. For some levels of delay this correction may not be a traditional mark-down but a mark-up. Finally, the comparison between privately and socially optimal airport charges shows that when concessions generate a sufficiently high proportion of extra surplus to total concession surplus, the welfare-maximizing airport can have more incentives than the profit-maximizing airport to decrease the congestion toll and induce delay.

In the light of recent dynamics, there are several forms of contracts observed in practice, such as concession revenues sharing agreements, airline ownership or control of airport facilities, long term use contracts, negotiated input charge, airport issuance of revenue bonds. Obviously, different contractual arrangements may exhibit different incentives to be signed, as well as be welfare-enhancing or not, pro or anti-competitive, depending on the competitive pressure in the upstream and downstream market.

At this purpose, in Chapter 3, three types of vertical contracts are considered in the context of two competing facilities and competing airlines. Specifically, we develop a multistage facility-rivalry game and we investigate the sub-game perfect Nash equilibria to analyze the incentives for vertical contracts and the effects in terms of welfare, consumer surplus and pro-competitiveness.

The first contract depicts the case of a vertical merger, that is the case of a negotiated fare between the airport and the dominant airline, depending on their bargaining power. The airport and the leader airline collude and maximize their joint profits: the negotiation aims at obtaining the highest joint profits for both partners and the solution

is the same of a vertical merger. The other airlines will pay a higher facility charge. In second case, long term leases on terminals are analyzed. The airport operates the runway for all airlines, while the leader airline leases and operates the terminal, using it and selling it to the followers. Finally, the third type of contract depicts the case of a two part tariff: the leader airline pays the airport the variable cost of its facility plus a part, which is agreed between the two partners, of its fixed costs.

The contributions of this paper to the literature are the following. With respect to the issue of airlines competition both consumer surplus and welfare increase with an increase in the number of followers: competitiveness in the airlines market has positive effects in social terms. With respect to the issue of airports competition, we found that the airport and the dominant airline at each facility may have incentives to vertical integration appear when competing with another pair. The result differs from the some previous contributions who find that no incentives for vertical merger agreements when both pairs of firms share the same market. In particular, the merger implies a downstream market foreclosure through a price-squeeze strategy and the equilibrium is anti-competitive. On the other hand, welfare increase with respect to the case in which no agreement occurs because of the internalization of vertical externalities due to a double-marginalization effect. Therefore, the agreement exhibits a trade-off between competitiveness and welfare.

The dissertation is organized as follows. Chapter 2 provides an interpretive review of models of airport-airline interaction. Chapter 3 studies the impact of concession activities on airport pricing, incorporating a positive relationship between delay and consumption of concession goods, and the effect of passenger types. Chapter 4 investigates three types of agreements between airports and airlines, including both upstream and downstream competition, and the effects in terms of welfare, consumer surplus and pro-competitiveness. Some concluding remarks summarize the dissertation, while outlining future research directions.

Chapter 1

A survey of models of airport-airline interaction[§]

1.1 Introduction

Deregulation of airline market, privatization of airports and the recent phenomenon of low cost carrier have questioned the nature of airports-airlines relation.

On one hand, structural changes in the airport industry occurred. Competition between airports has been growing significantly. In Europe, for example, the liberalization process – completed in 1997 – has formed a unique market where every European airline can provide a new route in the European network, i.e. a route having a European airport both as origin and destination (European Commission, 1992a,b,c). This has increased the available routes in the network and, therefore, the numbers of competing routes and competing airports[1].

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[1] This is particularly true in the case of airports located in different metropolitan areas sharing - at least in part - the same catchment area (e.g. the case of major hub-and-spoke airports as Fiumicino in Rome and Malpensa in Milan, the airports of Barcelona and Madrid, Brussels and Amsterdam or Brussels and Paris). Nevertheless, even if they are located in the same metropolitan area and are managed by the same company (notably, Paris ADP airports, London BAA airports, Rome ADR airports, Milan SEA Airports), some competitive issues may arise due to possible cross-subsidies and the ensuing distortions (Oum and Fu, 2008).

A positive influence of low-cost carriers' (LCCs) activity on airport competition is even well researched (Dresner et al., 1996; Pels et al. 2009): an increasing number of small-medium secondary and regional airports relies on the operations of LCCs which use a business model that has a relevant cost driver in airport costs and enables LCCs to shop around airports.

Running in parallel to the liberalization process, many airports were involved into a privatization process, starting in Europe in 1987 with the privatization of the seven major British airports - including London Heathrow, Gatwick, and Stansted - sold to the British Airports Authority plc. (BAA). Following this example, the majority stakes of Copenhagen Kastrup International Airport, Vienna International Airport, Rome's Leonardo Da Vinci Airport, and 49 per cent of Schiphol Airport, have been sold to private owners (Oum et al. 2004)[2].

Encouraged by the privatization process, there has been also the commercialization of the airport industry: non-aeronautical revenues have been growing significantly to the point that they have become the main income source for many airports. Airports, many of which have been treated in the past as public service organizations directly controlled by government administrations, have increasingly been restructured to attract private investments, search for new sources of revenues and attract the full service or low cost carriers competing within airports and for airports (Starkie, 2002).

Finally, besides these institutional changes, other sources of increasing competition pressure, as the development of high-speed rails, interregional bus transportation and transport networks, have been constituting additional factors influencing competition between airports (OECD, 2009).

On the other hand, liberalization has led to radical changes in the competitive structure of the airline market. The initial acts of deregulation (Airline Deregulation Act, 1978) have seen the entry of several carriers on the market: long haul airline markets served by local service carriers appeared to be basically contestable, that is even if actually served by only one firm they exhibited many of the desirable properties of competitive

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[2] In fact, more than 20 countries have completed the sale or lease of airport facilities so far. Some of them are: Argentina, Australia, Austria, Bahamas, Bolivia, Cambodia, Canada, Chile, China, Colombia, Denmark, Dominican Republic, Germany, Hungary, Italy, Japan, Malaysia, Mexico, New Zealand, Singapore, South Africa and Switzerland (Forsyth et al. 2010).

markets (Bailey and Panzar, 1981). Nevertheless, structural, strategic and regulatory barriers persisted, such as the existence of high economics of density, strategic alliances and *co-sharing* agreements, *frequent flyer* programs, global distribution systems (GDSs), access to comprehensive real time information on competitors' activity and, thus, the possibility to respond to competitors' initiatives more precisely and swiftly than firms in other industries (Starkie, 1999). Furthermore, the slot allocation mechanism based on *grandfathering* rules and the dominant airline's control over key airport facilities, such as gates, are likely to impose additional entry barriers to other potential competitors, that are even significant at congested airports (Morrison and Winston, 2000; Dresner, Windle and Yao, 2002)[3].

This created the basis for the development of an oligopolistic market structure, centred around hub and spoke arrangements (Oum et al., 1996; Spiller, 1989; Zhang, 1996; Zhang and Wei, 1993). A market polarization all around few carries with a relevant market share, challenged by smaller competitors, occurred and the expected competitive arrangement has not been reached (Fawcett and Farris, 1998). In other words, the degree of concentration among carriers has been increasing and airlines have been achieving higher and higher bargaining power (ICCSAI Factbook, 2011; OECD, 2009): as a consequence, the airport–airline relation turned into a bilateral-monopoly (monopoly–monopsony).

All these changes lead to increased opportunities for airports and airlines to engage in vertical relationships and develop new strategies to gain a competitive advantage: airlines and airports may have incentives to enter into cooperative relationships to create a win-win situation and compete successively with other pairs of airports and airlines (Fu et al., 2011; Starkie, 2012).

In the light of these recent dynamics, while assessing the incentives for airport-airline interaction as well as the different forms of cooperation observed in practice, we seek, in this survey, to review models on vertical relations between airports and carriers drawn in the literature during the last two decades.

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[3] Such a dominance of one airline at an airport allows the airline to obtain a substantial "hub premium" (Oum and Fu, 2008), even more evident for flights connecting two hubs of the same carriers.

To see how the present survey is related to previous surveys, note that Section 3 can be related to the survey papers by Basso and Zhang (2007) and Czerny and Zhang (2012b). The formers concentrated on airport pricing studies, grouped into two broad approaches: the *traditional approach* and the *vertical approach*. Basically, the key feature that divides these studies is whether to explicitly consider the market structure of downstream carriers and is the result, in the literature debate, of the policy need to respond to an increasing degree of concentration in the supply of air services. The latters, while covering issues related to airport congestion and pricing, further concentrate on airport regulation and privatization as well as airline alliances. Public versus private behaviors regarding airport pricing and capacity is discussed to motivate regulation of monopolistic airports in the presence or absence of airport concession revenues. Airline cooperation is discussed in order to give new insights on the social evaluation of airline alliances and on the rivalry between alliances.

While starting from the central insight of the recent research surveyed in these two papers – that is airport economics and policy should incorporate strategic interactions between airlines with market power, thereby requiring examination of airports and airline-services in an integrated manner (Czerny and Zhang, 2012b) – this paper differs from previous contributions as it concentrates on a specific topic, being the natural consequence of that insights: vertical relations between airports and airlines.

There are two reasons why it is interesting to look at this topic.

The first is, we believe, that new and important insights have been derived during the last years for problems in these areas previously uninvestigated. While airlines responded in a number of different fashions (hub-and-spoke network, frequent flyer programs, frequency/scheduling competition, yield management, alliances) to enhanced competitive pressures, the development of vertical cooperation with airports on the design of optimal contracts for inputs and the usage of facilities particularly surprised scholars and industry observers. Indeed, after the initial acts of deregulation, vertical relations between airports and airlines received little attention in the literature, probably due to the fact that price discrimination on aviation services is prohibited by IATA and EU rules: an airport is required to charge all airlines the same price for identical services (IATA, 1997; EU Directive 2009/12/EC-Art.3, EEC Treaty-Art.87/88, EEC Council

Regulation No. 95/93). In addition, the historical public utility status of most airports, has often protected airports from anti-trust investigation until the recent privatization wave.

Second, it has been argued that regulation may be unnecessary – in that airport charges may be kept down and capacity investments may be more efficient – if deeper collaboration between airlines and airports was allowed and encouraged or, on the other hand, if airlines had enough countervailing power (Basso, 2008; Civil Aviation Authority UK, 2004; Forsyth, 2003; Starkie, 2001, 2002, 2005, 2012). Thus, the analysis of different forms of cooperation between airports and airlines emerges as an obvious answer to this intuition.

In this picture, the contribution of the present survey is twofold. First, it seeks to provide an interpretive review of the main ideas developed by the literature on airport-airline interaction in a general unifying framework, with a particular attention on the models used to represent formally that vertical relations. In this sense, through living on their findings and conclusions, the paper differs from previous contributions by Fu et al. (2011) and Starkie (2012) which examine forms of cooperation between airports and carriers but focus primarily on competition concerns as well as policy and regulatory implications. Second, if the vertical structure approach has become standard in air transport research, we discuss three elements – which are of particular importance for air transport markets – that still seem to lack of understanding with respect to airports-airlines interaction: (i) incomplete contracts and asymmetric information structure; (ii) upstream horizontal complementarities; (iii) airports as two sided platforms.

The structure of the paper is as follows. Section 1.2 assesses the incentives for airport-airline interaction as well as the different forms of cooperation observed in practice. Section 1.3 reviews models in air transport research focusing on the difference between the traditional and the vertical approach, first, and on increasing cooperation between airports and carriers, second, as well as on the results in terms of pricing and welfare. Moreover, it provides insights on the role of concessions and the impact of low cost business models in creating new opportunities for cooperation. Section 1.4 discusses some elements that require, we think, further investigation, i.e. the issue of incomplete

contracts, scope for airport horizontal alliances and airports as two sided platforms. Section 1.5 contains some concluding remarks.

1.2 The economics of airport – airline vertical relations

1.2.1 Incentives for cooperation

Airlines and airports involve vertical relationships when the airport is seen providing infrastructure and general services with the airline as its consumer: while airlines only view passengers as their customer group and consider themselves as customers of the airports, airports regard both airlines and passengers as their key buyers. Equivalently, airports have to satisfy the demands of passengers and airlines simultaneously and to offer sufficient incentives to keep them as customers.

Indeed, evidence shows that when choosing between two airports, passengers choose a combination of airports and airlines, rather than airline services only: for instance, a Londoner flying in a low cost airline to Rome Ciampino may decide between Ryanair from Stanstead and Easyjet from Gatwick. Several studies model passenger travel choice over a region being served by multiple airports (Ashford and Bencheman, 1987; Ishii et al., 2009; Hess and Polack, 2006; 2007; Pels et al., 2001, 2003). Berry (1990) mentions that when passengers are choosing an airline, they consider if the airline has a dominant position at an airport in terms of flight frequency, as well as some other airline characteristics (e.g. frequent flyer programs, travel agent commission overrides). Pels et al. (2001) point out that an airline faces two types of competitors: those operating from the same airport and those operating from other airports. The formers may have conflicting interests as each tries to expand its market. But as opposed to the airlines operating from other airports, they may also have the same interest of making the airport attractive in order to attract more passengers to route their travel via the airport, and divide up those traffic among themselves. In facts, they find that a nested logit model with the airport choice at the upper level and the airline choice at the lower level best explained the joint airport–airline choice for both business and leisure

travelers in the San Francisco Bay Area. Ishii et al. (2009) and Hess and Polack (2006,2007) confirm, in the San Francisco bay Area and the Greater London Area cases respectively, that the availability of particular airport–airline combinations and the airline-airport allegiance – among other non-price characteristics like airport access time, airport delay or flight frequency – are found to strongly affect choice probabilities.

Graham (2008) identifies factors affecting the choice of airports for passengers: the destinations of flights, the image of the airport, the flight fare, availability and timings, the frequency of service, the image and reliability of airlines, airline alliance policy and frequent-flyer programs, range and quality of shops, catering and other commercial facilities, the surface access cost and ease of access to airport/car parking, On the other hand, the author identifies the slot availability, the network compatibility, airport fees and availability of discounts, other airport costs (e.g. fuel, handling), competition, marketing support, range and quality of facilities, ease of transfer connections, maintenance facilities, environmental restrictions, as factors affecting the choice of airports for airlines. Similarly, Tretheway and Oum (1992) identify the service and/or the price, the punctuality of flights, security, high number of flight destinations, high frequency of flights, fast and easy transfer connections, airline alliance policy and the reservation service (e-ticketing, seat reservation, car renting, etc.) as factors affecting the choice of airlines for passengers.

Thus, since the interests of passengers, airlines and airports overlap, it is in these areas of overlap where coordination of airports' and airlines' efforts has incentive to be developed in order to gain competitive advantage and potentially generate the greatest benefits (Albers et. al, 2005). From a strategic perspective, the basic motive for forming an alliance is gaining and sustaining competitive advantage for the participating companies (Fu et al. 2011; Oum and Fu, 2008; Stakie, 2008; Starkie, 2012). On a long term basis, this over-riding scope can be further differentiated into a main objective: reduce uncertainty for both partners.

The need of reducing risk relates to the traditional relationship between airport and airline having its core in a posted tariff for the use of the facility together with associated conditions of use. The interesting feature of this approach is its informality (Starkie, 2008): users do not need a contract with the airport but in paying the published

tariff they also accept the conditions of use. Under this arrangement the airport is, in effect, assuming the long-term traffic risk. This was not of concern to airport owners when air services were subject to general regulatory controls on route entry and thus operated in a less competitive, stable, environment. But liberalization of aviation has increased the risk of airport assets being subject to opportunistic behavior of airlines that are now free to change routes and switch airports. Consequently, there is now an incentive for the airport - facing competition from other airports, either an adjacent airport sharing the same catchment area, or another major airport competing for connecting traffic - to establish with its downstream airline customers negotiated long-term contracts for supply that achieve a better balance of risks.

In other words, the alliance formation expresses a long-term commitment of the airline to the airport and vice versa: the airport offers a safeguard for long-term traffic development and the airline can benefit from preferred treatment. On one hand, airports are protected against demand risk, obtain financial support and secure business volume, essential for ensuring daily operation as well as long term expansion. On the other hand, airlines would secure key airport facilities on favorable terms: they seek tailored-made facilities from airports, thus making long term commitment/investment possible. This is even particularly true for hub airlines, which prefer to have their own exclusive hub rather than to share a same airport with other carrier's hub function (Oum and Fu, 2008). Thus, partners commit to longer term business relationships and relation specific investments that, in the absence of such cooperation, would not have taken place: this enables partners to extract relational rents from their cooperation and to gain competitive advantage.

From a legal point of view, incentives to incumbent or new entrant airlines to provide new air service are commonly referred to as *Air Service Incentive Programs* (FAA, 2010). It is important to understand that there are certain legal restrictions on the types of incentives that an airport operator can offer. In US, for example, an air service incentive program must be consistent with rules of the Federal Aviation Administration (FAA), such as the *FAA's Sponsor Grant Assurances*, the *FAA Rates and Charges Policy*, and the *FAA Revenue Use Policy*. Direct subsidy payments to airlines are forbidden. However, limited variations of airport fees may be allowed if they are: temporary, available to all qualifying airlines on a non-discriminatory basis, for new

airline services, not paid for (through offsetting increases in other fees) by the other airlines serving the market and not participating in the air service incentive program. Similarly, price discrimination is prohibited by IATA rules (IATA,1997) and European Commission rules: an airport is required to charge all airlines the same price for identical services (EU Directive 2009/12/EC-Art.3, EEC Treaty- Art.87/88, EEC Council Regulation No. 95/93). Since spring 2011, airport charges at 144 European airports[4] are also subject to the EU Airport Charges Directive. It generally outlaws *differential pricing* unless on the basis of clear differences in service levels offered. Airports are required to publish clearly their revenues, costs and methodology for price calculation. Discrimination in pricing on the basis of airline country of origin is outlawed (NERA, 2009). Charlton (2009) examines airport-airline legislation concerning charging practices and highlights anti-competitive behavior. The author points out some examples where airlines took airports to court: Virgin Blue against Sydney airport's charging practices or Air France against Geneva airport's plan to build a low cost terminal.

Thus, it is not surprising that, despite a growing tendency to engage in vertical relationships, most airport-airline agreements are not publicly disclosed. First of all, given that air service incentive programs must be temporary and generally do not represent a sustainable business arrangement, they are often established as temporary policies by airport operators rather than formalized in agreements. Second of all, as these contracts include clauses such as lower airport charges and priority of service for partner airlines, they often lead to price and service discrimination. Information on the existence of contracts between airports and airlines and on their outcomes is seldom available and it often comes to light whenever the case goes to appreciation by the EU Commission, motivated either by a breach of the contract or by illegal clauses.

1.2.2 A taxonomy of different types of contracts

Since the first acts of liberalization, literature started investigating different types of agreements in the aviation industry. Williams (1979) provides an overview of twenty-

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[4] Those airports where traffic is higher than one million per year.

seven long-term airport agreements used by seventeen different US airports. The author also analyses the nature of the entry barriers they represent to new entrants into a market. Phillips (1991) reviews and assesses several of the more important contractual relationships that influenced performance in the deregulated airline, railroad, and motor carrier industries. He concluded that average air fares at airports with significant entry barriers-majority-in-interest clauses or long-term exclusive-use leases are higher than they are at comparable airports that do not have such barriers. In more recent years, Albers et al. (2005) identified the potential for agreements between airports and airlines along with three basic classes: capacity-based agreements, in which the associated goals include purely operational issues[5]; marketing-based agreements, focusing mainly on image transfer between airline and airport and highly dependent on external influences, such as fluctuations in demand; and security-based agreements, which do not require long-term commitment and are, thus, not of a strategic nature[6]. FAA (2010), in a manual conceived as a tool to assist both airport operators and airlines during business arrangement negotiations, describes the range of business relationships between airports and airlines including the underlying rates and charges methodologies. It also presents a general negotiation process, identifying key information for a negotiation and various alternatives for resolving potential conflicts and issues. Fu et al. (2011) reviews six forms of vertical relationships between airports and airlines with a focus on the North American and European aviation markets, as well as their effects and policy implications. Starkie (2008) gives an overview of different types of contractual relationships between airport and airlines and argues for country – specific typologies: the European case, the Australian case and the US case.

Downline these contributions, in practice some specific relationships are found, which we here briefly review.

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[5] To achieve associated benefits, these activities – such as optimization of processes through improved process design, interface reduction and communication improvement – need to be redesigned on a longer-term basis, ensuring that partners are willing to engage in specific investments and in infrastructure-related tasks, ranging from inexpensive, easy to implement process and communication changes to capital intensive infrastructure investments.

[6] Security considerations can influence demand patterns, and this seems especially so following the events of September 11, 2001. Airlines, as well as airports, treat safety arrangements within their primary activity operations, thus an interface can be identified: an alliance between airlines and airports could be formed aimed at improving security before, during and after flights.

Many airport operators have entered into long terms contracts (fifteen- to thirty-year). Usually, if airport's gates are leased on an exclusive-use basis, a new entrant can only gain access by subleasing gates from incumbent carriers. While tenant airlines have subleased gates to new entrants, the fees charged (for both the gate and ground services provided by the lessor airline) are quite high, thus placing the entrant at a cost disadvantage. Nevertheless, there can be some positive effects. Many airlines choose to sign long-term contracts with airports to lock in favorable terms. Long-term contracts can also be beneficial to airports. They encourage airlines to make long-term investments and to develop more extensive networks, thus securing airport traffic in the long run. This practice is very common in US. For instance, US Airways has leased 37 gates at the Charlotte Airport until 2016. At Cincinnati, 50 gates are leased to Delta while at Minneapolis, 54 gates are leased to Northwest, with 22 of these leases due to expire in 2015 and 32 having been converted into preferential use leases in 1999 (Fu et al. 2011). In recent years, many secondary airports offer LCCs favorable usage terms to attract their traffic.

Signatory airlines at airports are carriers which sign a master use-and-lease agreement, becoming guarantors of the airport's financial structure. Such a service guarantee and use commitment reduces uncertainty related to airport revenue and thereby allows the airport to reduce its financing costs when securing long-term loans. In return, they are given varying degrees of influence over airport planning and operations, such as terminal usage, slot allocation, capacity expansion projects, and exclusive or preferential use of facilities. Aeronautical service charges are determined according to the 'residual cost' remaining after revenue from non-signatory airlines and non-aviation sources has been deducted from the airport's costs (debt service costs, interest, and operating expenses). As an example, Delta Airlines is the signatory airline at Atlanta Hartsfield Airport; in 2002 Melbourne airport and Virgin Blue reached a 10-year agreement for the airline to operate from the former Ansett Domestic Terminal.

Sometimes, airlines are owners – trough holding shares - or control of airport facilities, which allows carriers to optimize terminal operations and to share the revenue generated from concession services. Terminal 2 of Munich airport is a joint investment by FMG (60%) and Lufthansa (40%) (Albers et al., 2005). Lufthansa has also invested in Frankfurt airport, and holds a 29% share of Shanghai Airport Cargo Terminal. JetBlue

invested $80 million in Terminal 5 of the NewYork JFK Airport to be used by the airline under a 30-year lease agreement. Latvia's Riga Airport has offered a contract to the national airline Air Baltic to build and operate a 92 euro million terminal for seven million passengers per annum by 2014.

Airports sometimes issue special facilities revenue bond (SFRBs) to airlines to finance specific investement programs. In this case, airports retain asset ownership but transfer the right for exclusive usage to the bondholders airlines under long-term lease agreements. Usually, the bondholders have no access to liquidity to avoid default if the airline fails to make timely debt service payments. For example, Terminal E at Houston Airport was built for Continental Airlines. The airport issued a $323.5 million SFRB in 2001 and the rent paid by Continental secured the bonds. A similar agreement was signed between Dallas Love Field Airport and Southwest Airline (Fu et al., 2011), and Sydney Airport and Quantas Airlines.

Concession revenue sharing agreements are used to internalize the positive demand externality between aviation and non-aviation services: in this case airports usually share their revenue from commercial operations with airlines and thereby inducing them to bring in more passengers. Ryanair, as an example, in its negotiations with some airports has asked for a share of parking revenue as a condition of initiating services (Davy Securities, 2006).

Price rebate on the input charge usually implies a discount on landing fares, obtained through a negotiation process between the airport and the airline, depending on their bargaining power. The average charge paid by the airline in these contracts is usually much less than the average that would result from the use of the published tariff. Payments are also structured in such a way that traffic risks are shared, for example by using a per passenger charge only. The published tariff is, of course, still used for charging those airlines for which a negotiated contract is less suitable. This is a common practice in Europe. For instance, the EU Competition Authority has prohibited, in 1995, discriminatory charges for access to airport infrastructures in the case in the Zaventem/Brussels National Airport in favour of the National Flag Carrier Sabena.

It is worth to say that different forms of vertical agreements between airports and airlines often overlap in a specific contract negotiated between the partners, which need

to be analyzed case by case. For example, in many cases concession revenue sharing occurs when airports allow airlines to hold shares or control airport facilities: Tampa International Airport, as of 2005, shared 20% of its net revenue with the signatory airline, i.e. Continental Airlines, Inc. which continued to operate in the facility under an amended lease that expired in 2009. Starkie (2012) highlights how, besides specifying charges, a negotiated contract usually covers many other issues such as the quality of service the airport is to provide, for example minimum turn-round times; the amount of marketing support the airline is to receive; and a commitment by the airport to future investment, the nature of which is sometimes specified in detail. Conversely, as part of the agreement the airline may commit to basing a certain number of aircraft at the airport; to roll out, per schedule, a route network; and sometimes to guarantee a minimum level of traffic, effectively take-or-pay contracts[7].

1.3 An interpretative assessment of recent research on models of airport-airline interaction

In the literature debate, the policy need to respond to an increasing degree of concentration in the supply of air services has been driving new approaches in modeling the relation between airports and airlines. In this section, we first assess the scope of the vertical structure approach, which explicitly accounts for carrier market power and structure, that has become standard in air transport research. We then discuss some attempts in literature to model, formally, increasing cooperation between airports and airlines as a form of vertical integration.

1.3.1 From a traditional approach to a vertical approach

The relationship between the airport (the provider of the facility – the input) and airline (the user of the facility) has its base in what literature describes as the *airport pricing mechanism*. In order to provide aviation services, an airport incurs both operating and

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[7] This is the case, for example, of the agreement between Bmibaby and the Durham Tees Valley Airport.

capital expenses: it charges carriers and collects these charges from airlines to cover these costs - or to make a return on capital investments in the private airport case. Since airlines may not be atomistic carriers they may not be price takers. Thus, the basic mechanism and its outcome may change.

Basso and Zhang (2007) review analytical models of airport pricing during the last 30 years and argue that the models in literature can be grouped into two broad approaches, the *traditional approach* and the *vertical approach.* Basically, the key feature that divides these studies is whether to explicitly consider the market structure of downstream carriers.

The *traditional approach* follows a "partial equilibrium" analysis in which the airline market is not formally modeled, under the assumption that the airport charge would be completely passed to consumers, and so the delay costs if the airport is congested. In other words, passengers will perceive a full price consisting of the airport charge, flight delay costs, travel-time costs plus other airline charges (e.g., air ticket)[8]. Oum et al. (2004) argue that, in the case of perfect competition among carriers, airline tickets and other charges would be exogenous to the airport: the airport's demand is directly a function of a full price consisting of the airport charge and, when there is congestion, the flight delay cost, which includes the delay costs to both airlines and passengers. Czerny (2006), Lu and Pagliari (2004), Morrison (1987), Morrison and Winston (1989), Oum and Zhang (1990), Oum et al. (2004) and Zhang and Zhang (1997, 2001, 2003), among others, have been used this approach.

In the *vertical structure approach*, on the other hand, it is recognized that airlines may have market power. Airports are viewed as providing an essential input for the production of an output that is required by airlines to move passengers: the travel. Carriers are not price takers and engage in strategic rivalry with each other in the air

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[8] For a given capacity, as demand grows up at the facility, congestion can induce delays and extra costs on passengers and airlines. Passengers may also bear a schedule delay cost, which represents the monetary value of the time between the passenger's desired departure time and the actual departure time. Douglas and Miller (1974) introduce the schedule delay cost as the addition of two components: frequency delay cost - induced by the fact that flights do not leave at a passengers' request but have a schedule - and stochastic delay cost, which has to do with the probability that a passenger cannot board her desired flight because it was overbooked. Basso (2008) neglects overbooking, which arises in the presence of stochastic demands, and models the schedule delay cost corresponding only to the frequency delay cost.

travel market (Czerny and Zhang, 2012b). The airline market is formally modeled as an oligopoly, which takes airport charges as given: the airlines, observing the demands and understanding how consumers' decisions are made, choose their strategic variable in the output market[9]. Brueckner (2002) should undoubtedly be credited for starting this stream of literature and the approach has been used by, among others, Brueckner and Van Dender (2008), Pels et al (2004), Basso (2008), Basso and Zhang (2007), Czerny and Zhang (2011, 2012a), Raffarin (2004) and Zhang and Zhang (2006, 2010).

What the papers in the *vertical structure approach* have shown is that how airline decide ticket prices may not be exogenous to the airport because the downstream equilibrium depends on variables decided by the airport itself, the input charge and the capacity. In other words, how airport charges and airlines costs are passed to consumers is built inside the demand faced by the airport. Hence it depends on the nature of the equilibrium reached in the airline market: in this sense a full price model pertains more to the airline-market stage than the airport-market stage.

All these considerations have raised questions about the transferability of results between the two approaches. Basso (2008) and Basso and Zhang (2008) provided a theoretical support for their claim and boundaries for the use of the *traditional approach*. In particular, they prove, analytically, that the traditional approach to airport pricing is valid if air carriers are passive players, that is if they have no market power. This happens in two special cases. First, when airlines behave competitively and have constant marginal costs. Second, when airlines are atomistic, i.e. when the number of carriers tends to infinite, so each firm produces infinitesimal output[10]. Under these conditions, the airport demand can be expressed as a function of the full price perceived

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[9] Earlier studies that model a congestible airport serving air carriers with market power assume Cournot behavior (Basso and Zhang, 2007; Brueckner, 2002; Czerny, 2006; Pels and Verhoef, 2004; Zhang and Zhang 2006, 2010). Brander and Zhang (1990, 1993) find that the Cournot model seems much more consistent with the data than either the Bertrand or the cartel model. On the other hand, Neven et al. (1999) provide evidence that the estimated conduct in the airline market is consistent not with Cournot, but with Bertrand. However, there can be a theoretical justification for assuming Cournot behaviour: if firms first make pre-commitment of quantity, and then compete in prices, the equilibrium outcome will be equivalent to that of Cournot competition (Kreps and Scheinkman, 1983).

[10] The atomistic carriers case can exists only if airlines have no-fixed costs, which, under the Cournot conjecture, corresponds to the classical idea of perfect competition being the limiting case of oligopoly when the number of firms is very large.

by travelers, and the integral of the derived demand for airports will correspond to airlines' profits plus passengers surplus.

Thus, the debate shows that when the degree of concentration in the supply of air services is high, there may be some distortions if a *traditional approach* is used instead of a *vertical approach* in modeling the relationship between airports and airlines. Indeed, when carriers have market power, the *traditional approach* may result in a surplus measure that falls short of giving a true measure of social surplus. Furthermore, its use prescribes a traffic level that is, for given capacity, smaller than the socially optimal level. Thus, its use would generate deadweight losses that may be large if the degree of competition is low.

This is something that seems quite important to be explicitly taken into account if one is to apply to policy making what has been learned from analytical models.

1.3.2 Modeling increasing cooperation between airports and airlines

We discussed through the paper some forms of vertical contracts such as the revenues sharing, as well as related attempts in literature to model formally the results in terms of pricing and welfare.

Another specific form of vertical cooperation is vertical integration. Some countries like Australia have specific rules prohibiting pure vertical integration between airlines and airports and a maximum of five percent of the shares of an airport may be bought by an airline; in Argentina the regulatory framework do not establish any limit to vertical relations between the airport operator and airlines (Serebrisky, 2003). Nevertheless, there are certainly cases where co-investment in airport infrastructure could be viewed as a mechanism to share retail revenues and internalize costs as a form of implicit integration.

Conceptually the simplest way to model a vertical integration would involve two successive monopolies, with the airport being the upstream provider and an airline being the downstream producer. The airport-airline vertical structure is usually modeled

as a two stages game. In the first stage, the airport decides the aeronautical charge; in the second stage, taking that charge as given, airlines compete and choose their outputs, i.e. the number of passengers, or ticket prices. In this framework, a vertical integration between airports and carriers is modeling through the maximization of their joint profits, which is the procedure of a vertical merger. The only difference is that in this case aeronautical fares are negotiated between the two partners. Literature has pointed out two solutions that rely on symmetric or asymmetric power. The Wicksell and Bowley's solution depends on who has the power to set the input price. The Nash bargaining solution depends on the power of the product of two factors (profits with the transaction less profits without the transaction). Thus, instead of knowing if either the airport alone or the carrier alone has an incentive for merger, this procedure allows to consider the incentive of the airline and the airport together.

As discussed in the previous section, increasing concentration in the airline market has been inducing to be model the downstream market as an oligopoly market with product or price differentiation. Moreover, increasing competition between airports has been leading the need to model an airport market, with profit maximizing or welfare maximizing entities.

Gillen and Morrison (2003) were among the first to recognize the vertical relation between airports and carriers in a formal representation. They develop a model of product differentiation in which an airport located in the center of a market for bundled air travel products engages in price competition with another airport on the periphery of the market. Two important aspects are examined: horizontal product differentiation (between air travel bundles) and vertical integration between airlines and airports[11]. They conclude that: (i) when only one integrated pair of airport-airline covers the market, the merger firm will only charge its maximizing profit price if retail revenues per passenger are greater than the airport charges; (ii) this result holds for two competing pairs of airport-airline with symmetric airside costs.

A spatial model for horizontal differentiation is also used in Barbot (2009), who considers the scope for vertical integration to analyze incentives for vertical integration

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[11] The concept of horizontal differentiation can be employed to relate the services offered by FSCs and LCCs and their associated airports to some underlying distribution of consumer preferences that respond to the 'delivered' price of air travel. In this case the geographic location of airports necessarily defines differentiated bundles of attributes relating their distance from travelers' origins or destinations.

between one airport and one airline that compete with another airport and another airline. Interpreting the different transportation costs as inverse measures of quality, she obtain a model with vertical and horizontal differentiation. She finds that that market asymmetry, i.e. different market sizes, and, in some cases, airline vertical differentiation - when secondary airports and low cost airlines compete with main airports and full service airlines - are conditions for the existence of collusive agreements. The Nash equilibrium of a repeated game is also analyzed and it is found to depend, again, on the behavior of each pair, on the similarities of catchment areas and on the business model of each airline (low cost or full service).

The authors find that there is a clear incentive for airports and airlines to engage in vertical integration. Indeed, the greater the degree of vertical separation between airports and airlines, the greater is the potential that the attributes selected and/or the prices chosen for each attribute do not internalize the externalities created by independent decision-making at points in the vertical chain[12]. When vertically separated, the airport will want to mark-up its airside price over its airside cost per traveler, but then the airline will mark-up its ticket price over the airside price charged by the airport. The result is a ticket price that is higher than that charged by a perfectly integrated travel company.

Basso (2008) uses a model of vertical relations between two congestible airports, where round trips are serviced by an airline oligopoly to examine, both analytically and numerically, how deregulation may affect airports prices and capacities. He analyzes the case of a two part tariff, through which airports not only charge a per-flight price but also charge a fixed-fee to each airline. Airlines then compete but with this fee added to the cost function, which does not affect their quantity decisions but only whether they operate or not. The outcome is exactly that of maximization of the sum of profits but obtained in a non-cooperative fashion. With two-part tariffs, the airports use the variable price in order to maximize the profits of airlines when competing downstream, which are later captured through the fixed fee: the marginal price acts as an aligner of incentives while the fixed fee as transfer of surplus. The final result is that airlines run a

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[12] A simple example of this is the comparison between the desired turnaround time for an aircraft and the desired turnaround time for travelers in an airport. The optimal turnaround time between landing and taking-off for an airline (designed to minimize costs) is unlikely to maximize the retail revenues to the airport.

cartel for them and the upstream firm is rewarded with a share of the profits. Nevertheless, despite the fact that the result is as if airlines collude, social welfare increases because vertical double marginalizations are avoided.

Following these contribution, Barbot (2011) develops a model to analyze the effects of three types of vertical contracts, in what regards welfare, pro-competitiveness and the scope for regulation. She models a downstream oligopoly, with airlines competing in a Stackelberg fashion, but she does not focus on airport competition. Moreover, the airport only decided to sign the agreement with the leader airline. The vertical merger is found to imply a downstream market foreclosure through a price-squeeze strategy: the follower airlines are driven out of the market and the equilibrium is anti-competitive. On the other hand, consumers' surplus and welfare increase with respect to the case in which no agreement occurs: indeed, final quantities increase and final prices for consumers decrease because of the internalization of vertical externalities due to a double-marginalization effect. However, price regulation restores competitiveness and increases consumer surplus, even when allowing for the contract to persist. In the second case, the leader airline uses and lease to other airlines terminal facilities. Here, vertical restraints are anti-competitive but may increase welfare depending on airlines' efficiency in terminal operations. Price cap regulation may only restore competitiveness if is applied to the price airlines charge for leased terminals but not if it regulates airports' charges. A two part tariff case is also analyzed, but the fixed fee that the airport charges to the leader airline covers only a part of fixed costs. Thus the result of a joint maximization of profit is not perfectly repeated here. The contract is pro-competitive and also increases welfare, though only concession revenues may support the agreements. Additionally, in this case regulation is only useful if there are few airlines in the market: if markets are competitive enough, price cap regulation makes consumers worse-off.[13]

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[13] D'Alfonso and Nastasi (2012), by using a spatial model, extend the result of Barbot (2011) to the context of two competing facilities and multiple airlines. Specifically, they find that both the two competing pairs of airport and its dominant airline have incentive to a vertical integration, when they share the same market and the market itself is not covered.

1.3.3 Complementarity between aviation and non-aviation services

Commercial revenues have been growing faster than aeronautical revenues during the years of privatization and commercialization of airports (Graham, 2009; Morrison, 2009)[14]: at medium to large US airports, for instance, commercial business represents 75–80% of the total airport revenue (ATRS Airport Benchmarking, 2011). This has been a critical issue, since airports and airlines have more and more pressure to improve their financial performances, especially at congested facilities. Indeed, when carriers have market power, they will be able to internalize congestion costs – fully by a monopolist and partially by oligopolists – by setting a higher ticket price so that passengers will eventually bear the costs that they impose on each other (see Basso and Zhang, 2007). Such practice by the carriers can well serve the purpose of demand management, as the higher ticket price will curtail demand and reduce congestion. Nevertheless, it would effectively deprive the airport of an important source of funds for its capacity investment, which may lead to financial problems for the airport.

One of the main reasons of the growth of concession revenues is that commercial operations tend to be more profitable than aeronautical operations (Jones et al., 1993), owing partly to the locational rents enjoyed by a busy gateway airport and partly to prevailing regulations and charging mechanisms (Starkie, 2001). Indeed, while aeronautical operations are subject to various forms of regulation – either explicitly or implicitly – commercial operations are usually unregulated. One consequence of this profit disparity is that the profits made from commercial activities may be used to cross-subsidize aeronautical operations, thereby eliminating the need for government aid. Indeed, because these commercial operations depend greatly on the passenger throughput of an airport, there are complementarities between the demand for aviation services and the demand for concession services.

Literature has been widely investigating the impact of complementarity between aviation and non-aviation activities on airport pricing: since there exists a positive demand externality between the two types of services, the airport charge may be

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[14] Commercial operations refer to non-aeronautical activities occurring within terminals and on airport land, including terminal concessions, and car parking and rental.

reduced so as to induce a higher volume of passengers and increase the demand for concessions (Oum et al., 2004; Yang and Zhang, 2011; Zhang and Zhang, 2003, 2010)

As a result, airports and airlines now use various agreements – such as the commercial revenue sharing – to internalize the positive demand externality between the two types services: if airlines were unable to benefit from concession sale activities at airports, they would ignore such a demand externality in making their decisions.

Zhang et al. (2010) investigate the effects of concession revenue sharing between an airport and its airlines: Airport offers to share some part of its commercial revenue, generated by the concession activities, for a fixed fee with one or more airlines. Looking at both airports and airlines competition, the authors found that the degree of revenue sharing is higher when airport competition increases; while is affected by how airlines' services are related to each other (complements, independent, or substitutes) and it lower when airlines competition increases. Moreover, whether an airport is subject to competition is critical to the welfare consequences of alternative revenue sharing arrangements, in the form of pure sharing contracts or two-part sharing contracts.

On this basis, Fu and Zhang (2010) study the welfare implications when an airport offers airlines the option of sharing its concession revenue. By studying a non-congested airport whose aeronautical charge is regulated, they find that revenue sharing allows the airport and airlines to internalize the positive demand externality between aeronautical services and concession services. Importantly, this improve welfare but may cause a negative effect on airline competition: an airport may strategically share the revenue with its dominant airlines, which can further strengthen these firms' market power.

Saraswati and Shinya (2012), following these contributions, propose a game theory-network model that calculates outcomes of commercial revenue sharing for different combination of cooperation between airport and airlines, in the form of coalitions. They found that commercial revenue sharing increases cooperating airlines marginal revenue and so encourages airline to expand output, which in turn benefits travelers and improve welfare. Consistently with Fu and Zhang (2010), a positive effect on welfare is achieved because the agreement allows the airport and the airline to internalize the positive demand externality between aeronautical and non-aeronautical services. Nevertheless,

negotiation is found to favor an exclusive cooperation between the airport and the dominant airline - the airline that brings highest number of passengers. Again, a negative effect on airlines that do not participate in the cooperation exists, in terms of market share and profit.

1.3.4 Low cost carriers and secondary airports

The low cost business model has now become a global phenomenon in the aviation industry. Following the example of Southwest, AirTran and Jet Blue have emerged in the US, with RyanAir, EasyJet, Buzz and Bimybaby emerging in Europe. WestJet has grown rapidly in Canada, as well as Virgin Blue in Australia.

Hub-and-spoke airlines are likely to develop a different relationship with their hub airports than low cost carriers will develop with their base secondary airports (Fuhr and Beckers, 2006; Gillen and Morrison, 2003). The main difference between the two business model is that, while low cost carriers are likely to provide short haul point to point services, in a hub-and-spoke network economies of density and scope are exploited by bundling traffic at a central hub airport (Brueckner and Spiller, 1994; Caves et al., 1984). When air services are concentrated at a transfer point, the significance of the agglomeration economies/network externalities may be such that they tie the individual dominant airline to the hub airport. Integration of the hub-and-spoke carrier's flight schedule with the networks of its airline alliance partners allows for further exploitation of these economies (Shy, 2001). As a consequence, there exists substantial relations-specific investment at a hub or 'base' airport. Indeed, it would seem most unlikely for a scheduled carrier, with a high level of transfer passengers to and from other airlines, to choose to forego the revenue and cost advantages of the hub by substituting a proximate, even adjacent, alternative airport (Starkie, 2002). British Airways or British Midland at Heathrow, Air France at Paris Charle De Gaulle or Alitalia at Rome Fiumicino provide an example in this sense. In addition, when the hub airport is congested, the airline may have incurred costs in acquiring take-off and landing slots which cannot be recovered if the airline ceases to provide services (Fuhr and Beckers, 2006; 2009).

On the other hand, the secondary airport's dependency on a particular low cost carrier often arises from a spot investment in dedicated terminal capacity. Similarly, low-cost carriers sometimes make some relationship specific investments in, say, building brand awareness and mobilizing customers in the catchment area of an airport (Fuhr and Beckers; 2006). Nevertheless, the sunk investment of non-networked air services operated by low cost carriers is likely to be lower, since they have more scope for switching operations between airports in order to reduce costs and they typically utilize airports that are not slot constrained. In other words, an airport with a dominant single low cost carrier is subject to more risk and low bargaining power. This stems from threat of shifting airports: airports that attract a single airline are subject to risk exposure from economic downturns if it is a legacy carrier and from airport switching if it is a low cost carrier carrier (Gillen and Lall, 2004). For these reasons, smaller secondary airports will furthermore require additional guarantees in the form of take-or-pay clauses or hostages prior to their investment decision.

In this scenario, Gillen and Morrison (2003) and Gillen and Lall (2004) recognize that the most important feature of the arrival of a low-cost carrier is that it leads to a permanent increase in traffic, so even if there are no differences in attributes of passengers that prefer low-cost carriers, there is an increase in revenue from concessions and parking just due to the numbers. Barrett (2004), while paying particular attention to the links that airlines have with airports, explores the nature of the demand function for the services of low cost carriers and contracts it to that of the more traditional European airlines. As opposite to full service carriers, airport requirements of low-cost airlines can be found in low airport charges as well as quick turnaround time and check-in or good facilities for ground transport; nevertheless, in most cases, good catering and shopping at airport is a critical requirement[15].

Thus, the low-cost model is increasingly motivating airlines to negotiate contracts that significantly reduce aeronautical revenues, leaving airports to compensate by seeking commercial revenues from the increase in passengers (Francis et al. 2003; Francis et al. 2004; Humphreys et al. 2006). Evidence shows that price rebate on the input charge is

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[15] At the same time the gains to the passenger from the combination of low-cost airline and low-cost airports negotiation may be summarized in lower air fares, using smaller airports with shorter waiting times for baggage, shorter walking times and less confusion at airports.

certainly the more common practice in negotiation between airports and LCCs. Since the average charge paid by the airline is usually much less than the average that would result from the use of the published tariff, these practices often have been prohibited by competition authorities. In 1999, the European Commission has condemned the Finnish airports of Helsinki, Vaasa, Turku, Pori and Tampere for a discount of 60% on landing fares on domestic flights (of domestic airlines) when compared with other services within the European Union. The same happened in Portugal, where ANA the airport authority, offered discounts of 50% on the same charges for domestic flights of domestic airlines in the airports of Lisbon, Faro and Porto (Barbot, 2009).

Fu et al. (2006) provide an analysis of airport pricing and regulation in the presence of competition between full service airlines and low cost carriers. In fact, the find that the level of competition in downstream airline markets will be reduced when an airport increases its airside service charges (such as aircraft landing fees) by the same amount to all airlines, because such an increase would reduce equilibrium outputs and profits of LCCs proportionally more than those of FSAs.

However, low cost carriers operations may be influenced by the availability of public funds (Francis et al. 2003; Oum and Fu. 2008). The European Commission has opened investigations on state aids possibly offered to LCCs by some airports such as Berlin Schoenefeld and Luebeck Blankensee in Germany, and Tampere Pirkkala in Finland. In November 2001, the Walloon region, owner of Charleroi airport, signed an agreement with Ryanair, stating special conditions for the use of the airport, involving a reduction in landing charges. In 2008 the Commission declared that the reductions on landing and handling charges were compatible with the common market, according to Article 87, and overturned the decision that Ryanair received state aid through its contract. This agreement is used as a basis for a formal model in Barbot (2006): she builds a vertical differentiation model to analyze the effects of subsidies, or lower aeronautical charges, for secondary airports on competition between a low cost carrier (LCC), supplying a no-frills service or lower quality flights, and a full scheduled carrier (FSC), supplying a high quality service. The difference in qualities is set by a few items, such as seat density of aircrafts and the provision (or not) of food and beverages during the flights.

Again, the main findings are that subsidization or lower airport charges benefit consumers but negatively affect incumbent airlines[16].

1.4 New insights on airport-airline interaction: what can still be done?

In the introduction, we already pointed out that the vertical structure approach, which explicitly accounts for carrier market power and structure, has become standard in air transport research. However, we think there are three elements – which are of particular importance for air transport markets – that still seem to lack of understanding with respect to airports-airlines interaction: (i) incomplete contracts and asymmetric information structure; (ii) upstream horizontal complementarities; (iii) airports as two sided platforms.

1.4.1 Incomplete contracts and asymmetric information

Airlines often need to make relationship-specific investments, such as the construction of customized facilities (such as terminals or maintenance bases), marketing of services to or from that airport, acquisition of take-off and landing slots, or the establishment of flight schedules, operating procedures, and staffing (Fuhr and Beckers, 2006, 2009; Goetsch and Albers, 2007; Niemeier, 2009). As widely discussed, throughout the paper, these investments are substantial especially at a hub or 'base' airport but even exists in the case of low-cost carriers.

Since these investments are relations-specific, they may give room for hold-up problems (Serebrisky, 2003). For instance, once that the investment is sunk, the airport can be motivated to ex post opportunistic behaviors and expropriate the value of the investment by raising its charges or reducing the quality of the service, thereby expropriating some of the value of the original investment. Therefore, downstream users

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[16] Moreover, the secondary airport may benefit from the aid more than the low cost airline. This is one of Ryanair's claims, stated in point (52) of the Commission's report.

are reluctant to make these investments unless they have some assurance that the value of their investment will not be expropriated in the future.

Vertical integration and contractual arrangements between airports and airlines are an important tool for protecting and promoting sunk investment by airlines. However, in most cases, negotiating long-term contracts between airports and airlines prior to the end-users making any sunk investment is simply not feasible[17]. Moreover, even if contractual arrangements can be signed, they are not perfect: the transactions costs of negotiating a long-term contract may outweigh the benefits; or the costs of negotiating over all possible contingencies may be such that contractual arrangements are inevitably incomplete, either limited in time, or limited in scope, or both. In either case, if the long-term contract is incomplete, there arises a risk of future negotiations after any necessary complementary investments have been sunk. Moreover, contracts may be signed within an asymmetric information structure, since one of the parties – or both – cannot directly observe the other party's effort.

A double hidden action/moral hazard situation is considered by Hihara (2011), who analyzes an airport-airline vertical relationship where both partners make efforts but neither can see the other's efforts. With a continuous-time stochastic dynamic programming model, they show that, if optimal effort costs are negligible and both parties are risk neutral, then they can agree on a single optimal contract, which is a linear function of final load factor depending on the productivities difference between the two parties. Hihara (2012) analyzes a risk sharing incomplete contract under which an airline agrees to serve an airport in exchange for payment to/from the airport based on the difference between a realized and a target load factor[18]. They show that, without the contractual commitment, there is an under effort problem and found the relevant conditions on payments and utilities under which the incomplete contract can achieve the first best level of effort and restore utility losses. Moreover, they show through numerical examples, that under high uncertainty and high risk aversion of the partners

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[17] For example, in Australia there are legal limits on vertical integration between airports and airlines, in order to prevent the competition problems, particularly foreclosure and exclusive dealing, that would arise if a major airline were to own one of the major airports in Australia (Biggar, 2012).

[18] The basic mechanism is described with respect to the Load Factor Guarantee Mechanism contract, which was agreed upon and is still binding at the Noto Airport in Japan.

the utility loss could be much severe and the utility loss restoration by these contracts is more imminently needed.

Biggar (2009, 2012) investigates the issues of the hold-up problem and long term contracts under a regulatory perspective. He suggests that creating an environment in which upstream and downstream customers of the monopoly facility have the assurances they need to make necessary sunk investments to extract the most value from the monopoly services should be the primary rationale for regulator. The author argues that the traditional neoclassical focus on deadweight loss is misplaced: public utility regulation is better viewed as an alternative governance arrangement - specifically a form of long term contract - within which the sunk investments of both sides, but especially the airline users, can be protected and thereby promoted[19].

In this framework, we think that attention to the airport–airline vertical relationship from the standpoint of hold-up and moral hazard problems - using an incomplete contract theory framework - still has not been sufficiently paid. Nevertheless, a better understanding is needed: results may justify, for example, incentive/risk mitigating payments by vertical contract from local or secondary airports to LCCs, even when the airport is owned by the local government, since these contracts may achieve the first best efficient effort levels and restore the first best utility levels.

1.4.2 Upstream horizontal complementarities and vertical externalities

Airport cooperation has a far shorter history than alliances in the airline industry, which have been largely studied in literature (see Czerny and Zhang, 2012b for a short recent survey). Some observers of the air transport industry had already stated that the formation of a few large groups and forms of cooperation among airports would be an

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[19] Public utility regulation is a form of long-term contract, administered by a permanent institution known as a public utility regulator, which seeks to recreate the contract that the parties would have written if they could have negotiated costlessly with each other before sinking any investment. The regulatory contract, by ensuring a long-term stable and non-discriminatory path of prices and services which broadly reflect the costs of providing the underlying services, protects and thereby promotes sunk investments by both the monopolist and its customers (Biggar, 2012).

inevitable result of airline deregulation and of privatization efforts since the mid1990s (Pal and Weil, 2005).

Airports are part of a large system where each facility is a node being connected by airline(s) to another node. Equivalently, airports provide complementary service to all of those airports to which they are connected. Indeed, they not only compete with airports that serve the same locational markets, but, as the providers of essential infrastructure facilities, they offer complementary services to airlines across airports that serve the same origin-destination markets. In this sense, airport infrastructure provision is characterized by horizontal complementarities as well as vertical market structures.

Failure to consider airports complementarities when looking for optimal pricing policies may, actually, result in social welfare losses (Basso and Zhang, 2007). Forysth et al. (2011) provide some stylized facts on different types of consolidation in the airport industry, such as airport alliances or multi-airport ownership[20]. They also explain that one rationale for consolidation among airports may be the elimination - through cooperation on service offerings and on the setting of airport charges - of market imperfections such as double marginalization in vertical related markets: by eliminating multiple price mark-ups on marginal costs, airport groups may improve their profits or social welfare while making their services more attractive to airlines.

Some papers, while pointing out that airlines typically have market power and are engaged in oligopolistic competition at different sub-markets, focus on airport complementarities and, in some cases of interest, on how the strategic airport behavior is affected by the extent of market power of the carriers serving those markets (Basso, 2008; Brueckner, 2005; Pels and Verhoef, 2004). Benoot, Brueckner and Proost (2012) focuses, in addition, on the role of regulatory authorities while looking at strategic interaction between international airports. Indeed, some distortions can arise given that different airports in an international network can be either regulated or not and, even if

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[20] One of the first airport holding companies has been the one operating Hochtief AG, a major private German construction company, and Aer Rianta, a division of the publicly owned Dublin Airport Authority, which together joined forces to create the consortium Airport Partners. Later on equity investment funds entered the market for airport shares like, e.g. Macquarie Airports which now holds equity shares of airports in Australia, Belgium, Denmark and the UK. In some cases airports formed strategic alliances, sush as Pantares Alliance between Shiphol and Frankfurt formed in 2001.

all regulated, they will typically not be regulated by the same authority. Martin (2012) focuses on airports complementarity and *welfare gravitation*[21] with the emphasis on examining the decision whether to keep an airport under government ownership or to privatize it.

Nevertheless, an important feature of vertically related industries is that there may be a trade between the upstream and the downstream firms and the trade is often determined through negotiation. Specifically, in the aviation industry, while at capacity constrained airports the landing fees charged are usually those at the price cap with no discounts, at other airports a bargaining process occurs (Competition Commission, 2009)[22].

In this context, what literature investigating airport alliances and complementarities still is missing is to explore the incentives to horizontal coordination in the upstream market, depending on downstream countervailing power: can airports serving serve the same origin-destination market have incentive to form an alliance to contrast the countervailing power of the dominant airline serving that market? And which are the effects in terms of welfare?

As an example, consider the simplest environment with two airports and two airlines that are locked in exclusive relations. The airports may decide whether or not they will merge and – after – choose their contract types to be traded with the two airlines. If the airports have merged, then the upstream monopolist bargains simultaneously and separately with each of the two airlines over their contract terms. If instead the airports

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[21] Welfare gravitation may be explained as follows. Consider a system of two airports where one is government owned and the other is private. The government owned airport sets low charges to stimulate demand and generate welfare for passengers and airlines from that location. The privately held airport may take advantage of the low charges set by the government owned airport and sets high charges that maximize its profit. These high charges extract some benefits available to passengers and airlines by the pricing behavior of the government owned airport. Since the airport extracts additional profit from the passengers and the airline of the other location, a *gravitation* of welfare from one location (the country with the government owned airport) to the other (the country with the private airport).

[22] Haskel, Iozzi and Valletti (2011) reviews some examples with respect to the English case. In all commercial UK airports, airlines are offered a preliminary discount to establish new routes, which then expire, typically after three years, when the airline is back to the published tariff. Ryanair reduced services from Leeds when the airport refused to lower their charges in 2004. In 2006, Ryanair also immediately switched its daily Dublin service to Bristol, when the discounts offered to Ryanair at Cardiff expired and were not renewed. In the same year, Jet2 moved from Manchester to Leeds following Manchester's refusals to continue introductory discounts that had expired. Likewise, in 2007, Flybe was operating twice weekly services from Bristol to Paris. Following the refusal of Bristol to lower its charges, it switched that route to Cardiff. Thomas Cook, by contrast, stayed at Bristol following an offer of a lower landing charge.

have remained separated, each of them bargains with its respective airline. In this environment, an upstream horizontal merger between the two airports may have potential effects on the ex post bargaining over the contract terms with the airlines. First, it changes the upstream bargaining position of the airports, by providing an outside option to the upstream merged airport group. Second, it allows the internalization of a competition externality, which refers to the fact that an increase in the airport charge to one airline leads to an increase in the rival airline's output[23].

Czerny and Zhang (2012b) started realizing this lack in literature. Some insights are derived by Fu and Zhang (2010) and Yan and Winston (2012). The formers find that market for privatized airports should facilitate bargaining between airports and airlines over airport charges, and encourage airports to price discriminate across different user classes.

However, both these contributions, tough considering the issue of airlines countervailing power, do not consider the effect of that power on the possibility of coordination among airports. One exception may be considered the work by Haskel et al. (2011), who study bargained input prices where up and downstream firms can choose alternative vertical partners[24]. They look at the impact of joint ownership of airports as well as the role of airline countervailing power in stopping airports raising fees. The find that an increased outside option for the airport will raise the input charge. So, if only one company owns airports, its outside option is increased. Thus, with increased concentration in airport ownership, or airports that are more dissimilar, the landing fees raises. Airports' outside options are also raised with discriminatory input pricing. Moreover, the effect of countervailing power, via an increase in downstream concentration, depends on the competition regime between airlines and whether airports can price discriminate.

Nevertheless, the outcome of the bargaining process between the upstream and the downstream firms may depend on the contract type through which trading is conducted. On these grounds, it may also be noteworthy to examine the differences between the outcomes of different types of contract, in terms of possible subsidization of passenger

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[23] Supposing airlines compete in the amount of passengers carried.

[24] They describe the case of two airports and two to four airlines.

traffic or distribution of profits among the players. As an example, in the simple environment described before, the subsidization may be due to the willingness of a separated airport to increase the aggressiveness - and thus the gross profits - of its airline, in the no merger case. In the merger case, instead, the subsidization results from the inability of an upstream monopolist to commit not to impose negative externalities to one airline by offering a discount to the other airline. Furthermore, the surplus of a negotiating pair of airport and airline can be maximized given the rival pair's strategy under a specific type of contract but not others. Finally, depending on the type of contract, the pie may be distributed among the vertically related chain according to their respective bargaining powers; or airports may receive a smaller share than the one corresponding to their bargaining power[25].

To the best of our knowledge, we are not aware of formal models of competition between vertical chains of airports and airlines dealing with bargaining process and different contract types, at the same time. Thus, we think literature may be innovative on this account.

1.4.3 Airports as two sided platforms

While airlines only view passengers as their customer group and consider themselves as customers of the airports, airports regard both airlines and passengers as their key buyers: airports have to satisfy the demands of passengers and airlines simultaneously and to offer sufficient incentives to keep them as customers.

In this scenario, two important features have to be recognized. First there exist externalities between carriers and passengers. Airlines demand depends on the airport charge and on the number of travelers using that airport. Passengers demand depends on the number of airlines serving at that airport, airline services - such as flights frequency and timing - accessibility of airport and availability of passenger services, such as

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[25]   Milliou and Petrakis (2007) analyze these issues with respect to vertically related industries when trading may take place through two-part tariff contracts or wholesale price contracts. They demonstrate that the contract types used can have significant implications for the equilibrium market structure and vice versa.

parking or shopping. Thus, the more the airport is chosen by passengers, the more an airline is interested in operate at that airport. The wider is the access to different airlines and destinations, as well as to an extensive range of shops, restaurants, convenient parkings and transportation facilities, the more passengers would chose that airport.

The second noticeable aspect is that the airport is able to internalize these existing network externalities - as well as complementarities between aviation and non-aviation services - whilst deciding on its pricing scheme. Indeed, while setting the price level for the aviation services – through the airport charge and negotiations with airlines – they decide on a price structure which allows them to cross-subsidize aeronautical revenues by non-aeronautical revenues, deduced from passengers via the commercial facilities such as parking, restaurants or stores.

Following this argument, airports are candidates to be considered as two sided platforms, that is markets with externalities in which they can cross-subsidize the two sides through the pricing structure. The end users are the airlines and the passengers, who both benefit from each other's existence and join the platform to interact. Airports add value to both sides by internalizing network effects which exist between the two demand groups.

Gillen (2011) points out that, given the transition which occurred both because of privatization of the industry and increasing importance of commercial revenues, it is indispensable to look at airports as two-sided platforms. These conclusions are drawn on the basis that the profit maximizing prices for the two sides of the market – airlines and passengers – are interlinked and depend on their demand elasticities, the nature and magnitude of the indirect network effects between the two groups, and the marginal costs for both sides. Following Wright (2004), he underlines some revelations and fallacies about one sided logic in two-sided markets, looking at the airport industry. In particular, he recognizes that airport charges should be externality based prices rather than cost based, which ignore the externality that exists between the customer groups on either side of the airport. This means that high price-cost margins do not necessarily indicate market power and an input charge below marginal cost does not necessarily indicate predation. For example, setting lower charges for certain types of carriers may make all carriers better off because the lower priced carriers attract more passengers to

the airport. As a consequence, competition between airports (the platforms) may lead to prices above costs since the competitive structure of charges will generally reflect the value placed on each side of the platform.

In a recent paper, Ivaldi et al. (2012) develop a structural model to examine airports under a two-sided market setting. They begin with a monopoly platform and estimate simultaneously the demand equations of passengers and pricing equations of airlines. By using data on US airports, empirical evidence about the two-sidedness is found through the significant coefficients of flight frequencies and airport characteristics, used as a measure of externality effects. The pricing scheme of airports shows that they can cross-subsidize the two sides with respect to their elasticities. In particular, they show that the airport: (i) takes into account the fact that aviation charge does not only affect the demand of airlines but also the demand of passengers for the airport; and (ii) internalizes the effect of a change in the concession price on airlines. This depends on the price elasticities for passengers and airlines, and the magnitude of externalities. Moreover, they find that airports do not maximize profits: either the marginal cost of aeronautical operations or non-aeronautical operations are computed under profit maximization scenario and, at each airport, they are found to be negative.

The two papers as a whole are a contribution to the air transport debate since airports have been considered as two-sided platforms neither theoretically nor empirically. Indeed, the correct definitions of market and market power is crucial for regulators: it is important to understand the business model of airports but this can be understood and tested only if the market structure is correctly identified. Nevertheless, literature still lacks maturity in this direction. For instance, in order to have a more complete picture of optimal airport pricing, one more aspect of the air transport business should be incorporated into the analysis.

Intuitively, there exists a trade-off relationship between the length of the connecting time and the consumption opportunities in the hub-airport. When the concession goods are not considered, the connecting time at the hub-airport has only a negative effect on the transfer passengers. Thus, the airport and airlines have an incentive to shorten the length of the connecting time to minimise the generalised cost (Encaoua et al., 1996). However, in a situation where the concession activities of the hub-airport are taken into

account, shortening the length of the connecting time would decrease the transfer passengers' consumption opportunities of concession goods. Smooth transits achieved on minimum connecting times mean less opportunity to spend money in hub-airport shops (Hanlon, 1999). Thus, besides the described negative effects, the length of the connecting time seems likely to have a positive effect on the levels of concession revenues. Indeed, some evidence shows that, once the decision has been made to make a purchase or spend money, the expenditure increase as the waiting time increases (Castillo-Manzana, 2010; Guens et al., 2004; Torres et al., 2005)[26]. In this scenario, a more complete picture can be drawn adopting a two side market thinking: modeling the connection between aeronautical and non-aeronautical services through cross-price relationships - instead of through the time component only - allows to evaluate the impact of the externalities on the price structure.

These considerations question the existing approaches to airport regulation. Some contributions take the view that single till may give wrong incentives in terms of investment: they show, crucially, that the dual-till approach is desirable when the airport capacity is close to saturation or suffers congestion, while the single-till approach is better when there is spare capacity (Starkie, 2002; Starkie and Yarrow, 2000; Zhang and Zhang 2003, Lu and Pagliari 2004). Empirical results from Ivaldi et al. (2012) show that, in a two-sided market setting, the airport may not maximize profits and can clearly do cross-subsidization between the two sides: it is the single-till price cap regulation that can capture this cross-subsidization. Thus, regulators should take into account that airports even with market power could have less incentive to use or abuse this power because of the complementarity between airside and non-airside revenues and this is a

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[26] D'Alfonso et al. (2013) catch the positive externality of waiting time on concessions, through the impact of congestion on the dwell time, while incorporating the effect of passenger types. Bruinsma, Brons and Rietveld (2000) indicates that in a transfer market, passengers will pay attention to two quality aspects of the aviation services: services offered by the airlines using the airport (e.g. air-fares, frequencies, convenient departure times), and the additional concession goods/services of the airport such as tax-free shopping, restaurants, internet facilities, casino. Nevertheless, the quality aspect concerning concession goods is not formally included in the model. Lin, M.H. (2006) develops a network model to analyze competition between hub-airports. Focusing on the tradeoff relationship between the length of the connecting time in the hub-airport and the consumption opportunities of the transfer passengers, he demonstrate theoretically that even though the hub-airport bears a cost disadvantage over its rival in providing the hub-airport service, it still has a chance to earn more profits than its rival by the setting of the connecting time to maximize the total profits obtained from both concession and aeronautical activities.

good example of two-sided platform thinking: the debate of single-till versus dual-till can be reconsidered under this thinking[27].

1.5 Concluding remarks

This survey provides an interpretive review of the main ideas developed by the literature on airport-airline interaction, with a particular attention on the models used to represent formally vertical relations during the last two decades. This is done while assessing how deregulation of the air transport market created the incentives for airport-airline interaction as well as the different forms of cooperation observed in practice.

The work starts from the central insight of the recent research – that is airport economics and policy should incorporate strategic interactions between airlines with market power, thereby requiring examination of airports and airline-services in an integrated manner.

A major conclusion of this survey is that the problem of vertical relations constitutes a fundamental issue because of the ensuing regulatory requirements: airport-airline interaction matters and need to be investigated very carefully since there can be negative as well as positive outcomes in terms of welfare and competitiveness. Starkie (2011) argues that the use of long-term contracts between airlines and airports is beneficial for passengers and that application of competition law should be favored over sector specific regulation. Fu et al. (2011) conclude that the beneficial effects of vertical cooperation need to be weighed against the negative effects. Such practices can improve welfare but may cause a negative effect on airline competition: an airport may strategically cooperate with its dominant airlines, which can further strengthen these firms' market power.

Within the scope of policy implications, the main insights can be derived as follows: on one hand, how regulation might balance the trade-off raised by the vertical agreements,

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[27] Malavolti (2009), in an unpublished draft, shows using a two-sided market approach that the aeronautical tax can be either higher or lower under single till depending on whether the impact of the passengers demand or of the waiting time is the more important for the shops.

by giving room for the merger, so leaving consumers better-off, but not for market foreclosure; on the other hand, how regulation could provide incentives, both to airports and dominant airline, for welfare enhancing agreements.

If the vertical structure approach has become standard in air transport research, one of the main contributions of the survey is that it discussues three elements – which are of particular importance for air transport markets – that still seem to lack of understanding with respect to airports-airlines interaction.

First, there is the issue of incomplete contracts and asymmetric information structure. Vertical integration and contractual arrangements between airports and airlines are an important tool for protecting and promoting sunk investment by airlines. However, in most cases, negotiating long-term contracts between airports and airlines prior to the end-users making any sunk investment is simply not feasible, or inevitably incomplete, either limited in time, or limited in scope, or both. Finally, contracts may be signed within an asymmetric information structure, since one of the parties – or both – cannot directly observe the other party's effort. In this framework, we think that attention to the airport–airline vertical relationship from the standpoint of hold-up and moral hazard problems still has not been sufficiently paid.

Second, airport infrastructure provision is characterized by horizontal complementarities as well as vertical market structures. What literature investigating airport alliances and complementarities still is missing is to explore the incentives to horizontal coordination in the upstream market, depending on downstream countervailing power: can airports serving serve the same origin-destination market have incentive to form an alliance to contrast the countervailing power of the dominant airline serving that market? And which are the effects in terms of welfare? It may also be noteworthy to examine the differences between the outcomes of different types of contract, in terms of welfare, possible subsidization of passenger traffic or distribution of profits among the players.

Finally, we point out that airports are candidates to be considered as two sided platforms, that is markets with externalities in which they can cross-subsidize the two sides through the pricing structure. The end users are the airlines and the passengers,

who both benefit from each other's existence and join the platform to interact. Airports add value to both sides by internalizing network effects which exist between the two demand groups.

Researches in these directions are a contribution to the air transport debate since the correct definitions of market and market power is crucial for regulators: it is essential to understand the business model of airports but this can be understood and tested only if the market structure is correctly identified.

These considerations also question the existing approaches to airport regulation. It has been argued that regulation may be unnecessary – in that airport charges may be kept down and capacity investments may be more efficient – if deeper collaboration between airlines and airports was allowed and encouraged or, on the other hand, if airlines had enough countervailing power. Thus, the analysis of different forms of cooperation between airports and airlines emerges as an obvious answer to this intuition. Some contributions take the view that single till may give wrong incentives in terms of investment: they show, crucially, that the dual-till approach is desirable when the airport capacity is close to saturation or suffers congestion, while the single-till approach is better when there is spare capacity. Regulators should take into account that airports even with market power could have less incentive to use or abuse this power because of the complementarity between airside and non-airside revenues and this is, for instance, a good example of two-sided platform thinking: the debate of single-till versus dual-till can be reconsidered under this thinking.

On the theoretical side, evaluating how and why airports and airlines use contracts to coordinate their activities is crucial to analyzing the organization and efficiency of economic contractual exchange, as well as policy implications. Nevertheless, we regret the absence of empirical verification of the economics of contracts: for policy makers understanding and testing the functions and the implications of various contract terms is a prerequisite to distinguish between efficient and anti-competitive practices and to developing appropriate policies. In addition, while usually theoretical conclusions indicated qualitative effects of airport-airline bargaining, it is not clear how significant these effects are in practice.

Great efforts have been made to ensure the applicability of analytical investigation. Still, to make the model tractable, works usually make routine simplifications such as symmetric airlines and constant marginal costs. Therefore, even greater efforts should be make in building empirical: they allow one to verify the analytical conclusions, and to quantify the actual impacts of airport-airline vertical relationships[28].

This is a difficult and complex task, since, despite this growing tendency to engage in vertical relationships, most airport-airline agreements are not publicly disclosed. Indeed, as these contracts include clauses such as lower airport charges and priority of service for partner airlines, they often lead to price and service discrimination, which is prohibited by EU and IATA rules: an airport is required to charge all airlines the same price for identical services (EU Directive 2009/12/EC-Art.3, EEC Treaty- Art.87/88, EEC Council Regulation No. 95/93). Thus, it is not surprising that information on the existence of contracts between airports and airlines and on their outcomes is seldom available. Evidence is given by the considerable number of cases gone to appreciation by the European Commission, motivated either by a breach of the contract or by illegal clauses.

Such data limitations make it difficult to test the effects of vertical contracts between airports and airlines, and, even if a few recent airport competition and regulation cases provide good samples for researchers to study, making statistical inference from such a small and special sample would be difficult and likely be biased.

However, this is something that seems quite important to be explicitly taken into account if one is to apply to policy making what has been learned from analytical models.

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[28] Barbot et al. (2013) make some improvements in this direction. They develop a test for vertical collusion between airports and airlines, based on the evaluation of price-costs gross margins. They tested 36 pairs of airports-airlines in the case of non competing airports and they find evidence for vertical collusion with respect to: (i) main national carriers in small airports (ii) low cost carriers in secondary airports.

Chapter 2

Airport pricing, concession revenues and passenger types[§]

2.1 Introduction

Air traffic delay has been growing dramatically since the end of the 1990s. The delay problem has been widely discussed in policy circles: increasing the capacity of congested airports by investing in new runways or improving air traffic control technology is one possible remedy. Another solution is the imposition of congestion pricing, according to which the landing fees paid by airlines would vary with the level of congestion at the airport. Meanwhile, non-aeronautical revenues have been growing significantly to the point that they have become the main income source for many airports (Graham, 2009; Morrison, 2009). For these reasons, the impact of non-aeronautical revenues on airport pricing is of increasing concern for airport and airline management.

With respect to the issue of airport congestion pricing, literature finds a negative relationship between the socially optimal airport charge and airlines' market concentration (Basso, 2008; Basso and Zhang, 2007; Brueckner, 2002; Brueckner and Van Dender, 2008; Pels and Verhoef, 2004; Zhang and Zhang, 2006). The socially optimal charge should include only the residual share of the marginal congestion cost[29] that is not internalized by monopoly or oligopoly carriers and it should be reduced to correct for market power of airlines. On the other hand, concession revenues exert a downward pressure on the aeronautical charge (Oum et al., 2004; Starkie 2002, 2008; Yang and Zhang, 2011; Zhang and Zhang, 2003, 2010). Commercial operations tend to be more profitable than aeronautical operations (Jones et al. 1993; Starkie, 2001); therefore, the aeronautical charge should be reduced so as to induce a higher volume of passengers and increase the demand for concessions. However, in order to have a more complete picture of optimal airport pricing, two more aspects of the air transport business should be incorporated into the analysis.

First, passengers may not be a homogeneous group of individuals. Literature finds that, in the case of a single passenger type, the socially optimal charge never exceeds the residual share of the marginal congestion cost (Basso and Zhang, 2007; Brueckner, 2002; Zhang and Zhang, 2006). Czerny and Zhang (2010) find that, in the case of two types of passengers with different values of time, the socially efficient airport charge may exceed the residual share of the marginal congestion cost. Intuitively, their result implies that it can be useful to increase airport charge so as to protect business passengers with higher time value from excessive congestion caused by leisure passengers with lower time value.

Second, there is a positive correlation between the expenditure in the concessions area and the dwell time, that is, the time available between the security check and the boarding: it is during that time that passengers will have higher chance to shop. This follows the common sense that more spare time gives more opportunity for browsing in the shops and induces the need to buy refreshment. Hence, the expenditure increases as the dwell time increases. Congestion levels may have an impact on the dwell time, and therefore on the expenditure in the commercial area; but, without solid empirical studies

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[29] The residual share is equal to $(1 - 1/n)$ where n represents the number of airlines.

in the literature, it is unclear whether increased congestion has a negative or positive effect. The higher the volume of passengers the longer the time needed for check-in and security check. As a result, on one hand, it would be obvious that dwell time decreases as congestion goes up, since passengers spend more time in queues. However, on the other hand, higher congestion may force travelers to arrive in advance at airport terminals because they anticipate longer waiting time in queues (Appold et al., 2006; Buendia and de Barros, 2008). This can happen when air travellers are risk averse, especially when the cost of missing a flight is relatively high: business passengers may miss important business opportunities; leisure passengers may have to cancel hotel and trip reservations whose costs cannot be fully recovered. In this context, if this amount of extra time they spend in the airport is disproportionally longer than the expected extra time they need to go through check-in and security checks, dwell time will increase: passengers will have more captive time in terminals and more time to spend money in shops. Specifically, in this paper, we *assume* that passengers will exaggerate waiting time and therefore dwell time increases. In other words, we *assume* that as congestion increases dwell time increases and so the money spent in concession activities; equivalently, that there is a positive externality of congestion on concession activities. Hence, under this assumption, when concessions are taken into account, there can be some incentives for the airport to increase congestion in order to drive up the expenditure in the commercial area.

There is a stream of empirical literature trying to explore this issue. Geuens et al. (2004) find that waiting time influences consumption of concession goods. Castillo-Manzana (2010) finds that the dwell time prior to embarking is positively correlated with the decisions of consuming food/beverages and making a purchase at a significance level of 99 percent in both cases. Besides, he finds that being on vacation increases the likelihood of consuming concession goods. Moreover, the average expenditure of these passengers is greater than that of business passengers. Torres et al. (2005) show that the more time spent in the airport, the more consumption made by passengers. In addition, he finds that those flying on business consume more than those on vacation, if they are in the airport for less than 45 minutes. In the range of 45–170 minutes, leisure travellers consume more. When staying longer than 170 minutes, business travelers consume more. Graham (2008) finds that young leisure passengers are high spenders, while

business passengers are unlikely shoppers. However, to the best of our knowledge, there is no contribution in literature analyzing, from a theoretical point of view, the effects of congestion and passenger types on consumption of concession goods.

This paper adds to literature on airport pricing as it takes into account the positive externality of congestion on concessions, through its impact on dwell time, while incorporating the effect of passenger types. Specifically, we consider a model with one congestible airport serving a number of competing airlines and two types of passengers, business and leisure, with the former having a higher time value than the latter. We consider two types of airports, namely private airports maximizing their profits and public airports maximizing social welfare. We assume that only the extra surplus generated by airport concession services not attainable elsewhere is counted into the social welfare function. In other words, we only include a proportion of the surplus from concession services. This reconciles two approaches to modeling the social welfare function in airport pricing literature: if the proportion is equal to 1, all the surplus from concession activities is counted into social welfare (Yang and Zhang, 2011; Zhang and Zhang, 2003, 2010); if the proportion is equal to 0, surplus from concession activities is excluded (Czerny, 2011; Kratzsch and Sieg, 2011).

We find that for both profit and welfare maximizing airports there is a downward correction for the congestion toll, equal to the marginal airport concession profit and passengers concession surplus, respectively, due to the positive externality of delay. Furthermore, as the passenger volume changes when the airport charge increases, there is a correction on the optimal airport charge equal to the average concession profit and expected concession surplus for profit and welfare maximizing, respectively, weighted for different passenger types. For some levels of delay this correction may not be a traditional mark-down but a mark-up. Finally, the comparison between privately and socially optimal airport charges shows that: (i) when concessions generate a sufficiently high proportion of extra surplus to total concession surplus, the welfare maximizing airport can have more incentives than the profit maximizing airport to decrease the congestion toll and induce delay; and (ii) depending on the difference in the passengers' values of time and the proportion of extra surplus generated by airport concessions, the profit maximizing airport may or may not impose a higher charge than the welfare maximizing airport.

The structure of the paper is as follows. Section 2.2 sets up the model. Section 2.3 and 2.4 discuss, respectively, airlines' and airport's equilibrium behaviors. Section 2.5 contains the concluding remarks.

2.2 The model

Consider a single airport, n competing airlines and two types of passengers, one of which has a higher time value than the other. For sake of convenience, in our analysis we refer to them as business and leisure passengers, because Morrison (1987) and Pels et al. (2003), among others, provide empirical evidence that business passengers have a greater value of time than leisure passengers. We denote the business and leisure passengers' value of time as v_B and v_L, respectively, with $v_B \geq v_L > 0$. Let Q_B and Q_L be the number of business and leisure passengers at the airport. Moreover, $B_B(Q_B)$ and $B_L(Q_L)$ represent the gross benefit from traveling, for business and leisure passengers, respectively, where $B_h' > 0$ for $h \in \{B, L\}$. For analytical tractability, we assume linear demand functions, which give

$$B_h'(Q_h) = a_h - b_h Q_h, \tag{2.1}$$

where $a_B \geq a_L > 0$, that is, the willingness to pay of business passengers for air travel is greater than that of leisure passengers; and $b_B \geq b_L > 0$, that is, the leisure passengers are more price sensitive than business passengers. The airport is congestible: the average congestion delay, $D(\tilde{Q}, K)$, depends on the total number of flights, $\tilde{Q}$, and the airport's capacity, K. With these specifications, we have

$$B_h'(Q_h) = p_h + v_h D(\tilde{Q}, K), \tag{2.2}$$

where p_h is the airline ticket price for type h passengers. We use the same linear delay function as the one in Basso and Zhang (2007) and De Borger and Van Dender (2006).[30] That is, $D(\tilde{Q}, K) = \theta(\tilde{Q}/K)$, where θ is a positive parameter. Specifically, let Q be the number of passengers of all airlines. We assume, as is common in the airport pricing

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[30] Such a linear delay function make the analytical work more feasible, but it may lead to the problem that an interior solution may not exist, that is we may have a corner solution. Nevertheless, we assume an interior solution.

literature, a fixed proportion condition. That is, all the flights use identical aircraft and have the same load factor (Basso, 2008; Basso and Zhang, 2007; Brueckner, 2002; Pels and Verhoef, 2004; Zhang and Zhang, 2006, 2010). Therefore, each flight has an equal number of passengers, denoted by S. Then, $Q/S = \tilde{Q}$ and we obtain

$$D(\tilde{Q}, K) = \theta \frac{Q}{KS}. \tag{2.3}$$

Furthermore, without loss of generality, we normalize $KS = 1$. Therefore, we can use, in what follows, $D(Q)$ instead of $D(\tilde{Q}, K)$. From (2.1)-(2.3), it follows that

$$p_h(Q_B, Q_L) = a_h - b_h Q_h - v_h \theta Q. \tag{2.4}$$

Carriers are ex ante symmetric and offer a homogeneous good/service, that is, the flight. Let q_h^i denote the number of type h passengers served by airline i, for $h \in \{B, L\}$ and $i = 1, 2, \ldots, n$. Let q^i be airline i's output, that is, the total number of passengers who fly with airline i. Therefore, $q^i = \sum_{h \in \{B,L\}} q_h^i$, $Q_h = \sum_{i=1}^{n} q_h^i$, for $h \in \{B, L\}$ and $Q = \sum_{h \in \{B,L\}} Q_h = \sum_{h \in \{B,L\}} \sum_{i=1}^{n} q_h^i$.

Next, we specify the passengers' demand for concessions. In particular, we assume that demand for retail services depends on travel activities. In other words, we suppose that passengers make two separate decisions sequentially. First, they book the air tickets from the airlines, based on their perceived full prices; second, after arriving at the airport, they make decisions on purchasing concession goods. Our specification of the concession demand is related to, but different from, Yang and Zhang (2011), according to whom a passenger will consume one unit of the concession goods if her valuation is greater than the concession price. We suppose that the passengers' valuation for the concession goods has a positive support on the interval $[0, \bar{u}]$, where $\bar{u}$ is the highest valuation for the concession goods. We consider two random variables, u_B and u_L, representing, respectively, the valuations for the concession goods of business passengers and leisure passengers. We assume that u_h is distributed with probability density function $g_h(u; T)$, given a specific level of dwell time, T. As we noted in the introduction, we assume that as congestion increases dwell time increases as well because passengers will exaggerate waiting time. Equivalently, we assume that the dwell time, $T = T(D)$, is an increasing function of congestion. Therefore, we can use, in what follows, $g_h(u; D)$ instead of $g_h(u; T(D))$. Let $G_h(u; D)$ be the cumulative

distribution function of type h passengers' valuation. In this scenario, the probability that a type h passenger buys the concession goods at the price p_c is equal to the probability that her valuation for the good is greater than p_c, that is, $\int_{p_c}^{u_h} g_h(p; D)\, dp = \bar{G}_h(p_c; D)$, where $\bar{G}_h(u; D) = 1 - G_h(u; D)$. With this setup we want to catch the relationship between congestion and the probability of purchasing, through the dwell time. As noted by an anonymous referee, it is possible that at some point concession revenues are adversely affected by congestion and waiting time: firstly, congestion may reduce the comfort level of shopping, affecting patronage of shops and restaurants; secondly, it may increase the stress level of passengers, that is, passengers may get unnerved by waiting. A congested airport may simply not make the passengers relaxed enough to shop (Graham, 2009). On the other hand, for some people waiting may cause annoyance just leading them to search for comfort from shopping. In this paper, we assume that the impact of people finding relaxation in shopping is enough to offset that of unnerved passengers, that is, the extra dwell time leads to more retail activity. This is equivalent to assume that the probability of purchasing increases as the delay increases. In other words, $G_h(u; D)$ satisfies the first order stochastic dominance property (FOSD) with respect to D, that is, $\partial G_h(u; D)/\partial D \leq 0$, with a strict inequality for some value of u.[31] From the FOSD property, we have that $\bar{G}_h(p_c; D) \geq \bar{G}_h(p_c; \widetilde{D}), \forall D > \widetilde{D}$, that is, the probability of purchasing a unit of concession goods increases with the delay. We further assume that the positive externality of delay decreases when the concession price increases, that is $\partial^2 \bar{G}_h(p_c; D)/\partial p_c \partial D < 0$. Therefore, the concession demand function of the type h passengers, x_h, is given by

$$x_h(p_c, Q_h, Q_{-h}) = Q_h \bar{G}_h(p_c; D(Q_h, Q_{-h})). \qquad (2.5)$$

In other words, the demand for non-aviation activities of type h passengers depends on the number of type h travelers, Q_h, the concession price, p_c, and the delay, $D(Q_h, Q_{-h})$.

The airport charges airlines a price per passenger, denoted as p_a. For simplicity of presentation, the case where the airport has zero fixed costs is considered, that is, the

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[31] This property means that for all $\tilde{u} \in [0, \bar{u}]$ the probability that $u \leq \tilde{u}$ is weakly and sometimes strictly decreasing in delay, that is, $g_h(\cdot; D)$ shifts rightward when delay increases.

only cost the airport bears is the operating cost per passenger[32], c_a. Since we consider ex ante symmetric carriers, the cost function of carrier i is given by $C^i(q^i, q^{-i}) = (c + p_a + \beta D(Q))q^i$ where c is the (constant) marginal operating cost and β is the value of time of carriers. Suppose that the airport provides concessions to (homogeneous) retailers and that the airport itself determines the concession price p_c. Finally, we assume that the airport captures all the rents from the retailers and that the unit cost of the concession goods is constant and denoted by c_c.

The airport-airline vertical structure is modeled as a two stages game. In the first stage, the airport decides both the aeronautical charge, p_a, and the concession price, p_c. In the second stage, taking p_a as given, airlines compete in Cournot fashion[33] and simultaneously choose their outputs, that is, the number of passengers.

2.3 Airlines' equilibrium behavior

In the second stage, each airline chooses its output to maximize its profit:

$$\pi^i = \sum_{h \in \{B,L\}} q_h^i [p_h(Q_B, Q_L) - c - p_a - \beta D(Q)]. \tag{2.6}$$

To focus on the effect of the positive externality of congestion, we abstract away the possibility of price discrimination: all passengers pay a uniform airfare, p. Therefore, at the equilibrium, the condition $p_B = p_L = p$ must be satisfied. That is,

$$p(Q_B, Q_L) = a_h - b_h Q_h - v_h \theta Q. \tag{2.7}$$

The equilibrium outputs are determined by the first-order conditions:

$$\frac{\partial \pi^i}{\partial q_h^i} = p + \left(\frac{\partial p}{\partial Q} - \beta\theta\right)q^i - \beta\theta Q - c - p_a = 0, \qquad \forall i, h. \tag{2.8}$$

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[32] The qualitative results of this analysis, however, are unchanged since we assume there are no economies of scale as well economies of scope.

[33] Earlier studies that model a congestible airport serving air carriers with market power assume Cournot behavior (Basso and Zhang, 2007; Brueckner, 2002; Czerny, 2006; Pels and Verhoef, 2004; Zhang and Zhang 2006; 2010). Brander and Zhang (1990, 1993) find that the Cournot model seems much more consistent with the data than either the Bertrand or the cartel model. On the other hand, Neven et al. (1999) provide evidence that the estimated conduct in the airline market is not consistent with Cournot, but with Bertrand. However, there is a theoretical justification for assuming Cournot behavior: if firms first make pre-commitment of quantity, and then compete in prices, the equilibrium outcome will be equivalent to that of Cournot competition (Kreps and Scheinkman, 1983).

Symmetry implies that

$$p + \frac{1}{n}\frac{p}{\varepsilon} - \left(1 + \frac{1}{n}\right)\beta\theta Q - c - p_a = 0, \tag{2.9}$$

where $Q/n = q^i$ and $\varepsilon = -(\partial Q/\partial p)(p/Q)$ is the elasticity of demand for airline services with respect to the ticket price. The effect of the ticket price p on Q, Q_B and Q_L is summarized in Lemma 2.1.

Lemma 2.1

$\frac{dQ}{dp} < 0$, $\frac{dQ_L}{dp} < 0$, while the sign of $\frac{dQ_B}{dp}$ is ambiguous.

Therefore, an increase in the ticket price leads to a decrease in the total number of passengers and the number of leisure passengers, but it can lead to an increase or a decrease in the number of business passengers. The proof of Lemma 2.1 is given in the Appendix A. Let $Q^*(p_a)$ denote the equilibrium total number of passengers, $Q_B^*(p_a)$ the equilibrium number of business passengers, $Q_L^*(p_a)$ the equilibrium number of leisure passengers and $p^*(p_a)$ the equilibrium airlines ticket price. The comparative static of these equilibrium outcomes with respect to the airport charge, p_a, is summarized in Lemma 2.2.

Lemma 2.2

$\frac{dQ^*}{dp_a} < 0$, $\frac{dQ_L^*}{dp_a} < 0$, $\frac{dp^*}{dp_a} > 0$, while the sign of $\frac{dQ_B^*}{dp_a}$ is ambiguous.

Therefore, an increase in the airport charge leads to a decrease in the equilibrium total number of passengers and the number of leisure passengers, an increase in the equilibrium airlines ticket price but it can lead to an increase or a decrease in the equilibrium number of business passengers. The proof of Lemma 2.2 is given in the Appendix A.

2.4 Airport pricing

Taking the second stage airlines behavior into account, the airport chooses p_c, the concession price, and p_a, the charge for airlines. We consider two types of airports, namely a private airport which maximizes its profit and a public airport which is a welfare maximizer.

2.4.1 Profit maximizing airport

Consider a private airport maximizing its profit:

$$\pi_A = (p_a - c_a)Q + (p_c - c_c) \sum_{h\in\{B,L\}} Q_h \bar{G}_h(p_c; D(Q)). \tag{2.10}$$

The optimal concession price is characterized by the first-order condition with respective to p_c:

$$p_c^{\Pi} = c_c - \frac{Q_B^* \bar{G}_B(p_c^{\Pi}; D(Q^*)) + Q_L^* \bar{G}_L(p_c^{\Pi}; D(Q^*))}{Q_B^* \dfrac{\partial \bar{G}_B(p_c; D(Q^*))}{\partial p_c} + Q_L^* \dfrac{\partial \bar{G}_L(p_c; D(Q^*))}{\partial p_c}}, \tag{2.11}$$

where the superscript Π represents the profit maximization case. Since $\partial \bar{G}_h(p_c; D(Q))/\partial p_c < 0$ with $h \in \{B, L\}$, a profit maximizing airport sets the optimal concession price above the marginal concession cost and, in particular, equal to the monopoly price. The profit maximizing airport charge is characterized by the first-order condition with respective to p_a:

$$p_a^{\Pi} - c_a = \theta \left[\left(1 + \frac{1}{n}\right) \beta Q^* + \left(1 + \frac{1}{n}\right) \frac{v_B b_L + v_L b_B}{b_L + b_B} Q^* \right] + \left(1 + \frac{1}{n}\right) \frac{b_L b_B}{b_L + b_B} Q^*$$

$$-\theta(p_c^{\Pi} - c_c) \sum_{h\in\{B,L\}} Q_h^* \frac{\partial \bar{G}_h(p_c^{\Pi}; D(Q^*))}{\partial D} - (p_c^{\Pi} - c_c) \frac{dp}{dQ} \sum_{h\in\{B,L\}} \frac{dQ_h}{dp} \bar{G}_h(p_c^{\Pi}; D(Q^*))$$

(2.12).

The first line on the right hand side (RHS) of equation (2.12) can be reduced to the results in earlier literature where only one passenger type is considered (Zhang and Zhang, 2006). The second line consists of two terms which are the focus of this paper.

The first term is a correction for the congestion toll equal to the marginal airport concession profit due to the positive externality of congestion on concession activities. Since $\partial \bar{G}_h(p_c; D(Q))/\partial D > 0$, this term is negative. Therefore, the airport has incentives to reduce the congestion toll so as to increase the passenger volume and the passengers' waiting time. This means that, in contrast with previous literature, the congestion toll may become a "subsidy", when the positive externality of congestion is taken into account. The above discussion leads to Proposition 2.1.

Proposition 2.1

In the case of a profit maximizing airport, there is a downward correction for the congestion toll which is equivalent to the marginal concession profit due to the positive externality of delay. Therefore, the airport has incentives to reduce the aeronautical charge so as to increase passengers' waiting time and so their consumption of concession goods.

The last term is a correction on the optimal airport charge equal to the per passenger concession profit weighted for different passenger types, where the weight is the ratio of the marginal change in the number of type h passengers over the marginal charge in the total number of passengers. This term takes into account the change in the passenger volume and hence the pool of potential consumers of concession services when the airport charge increases. When passengers have the same value of time, this term is always negative as shown in previous literature (for example, Yang and Zhang, 2011; Zhang and Zhang, 2010), but the sign of this term is no longer clear-cut when more than one type of passengers is considered. In particular, when $dQ_B/dp > 0$, that is, $(v_B - v_L)\theta > b_L$, and

$$\frac{\bar{G}_L(p_c^\Pi; D(Q))}{\bar{G}_B(p_c^\Pi; D(Q))} < -\frac{\frac{dQ_B}{dp}}{\frac{dQ_L}{dp}}, \tag{2.13}$$

it becomes positive, that is, a mark-up on the privately optimal airport charge. Specifically, $\bar{G}_h(p_c^\Pi; D(Q))$ represents the probability of purchasing the concession good for type h passengers when the concession price is p_c^Π. Therefore, when this

probability is sufficiently higher for business passengers than for leisure passengers, inequality (2.13) is satisfied and the last term on the RHS of equation (2.12) is a mark-up on the airport charge. According to Torres et al. (2005), those flying on business can consume more than those on vacation under high levels of delay. Therefore, for these levels of delay the private airport can have incentives to induce more business passengers with higher time value - and let them buy in the commercial area – by protecting them from excessive congestion caused by leisure passengers with lower time value. This leads to

Observation 2.1

In the case of a profit maximizing airport and two types of travelers, for some levels of delay the correction on the optimal airport charge due to the impact of the changes in passenger volume on concession profit may not be a traditional mark-down but a mark-up. Therefore, the privately optimal airport charge can be higher than what would prevail if passengers are treated as a single type.

In summary, whenever we consider the positive externality of congestion alone, there is always a downward correction on the congestion toll to exploit the higher probability of purchasing induced by longer waiting time and a mark-down to increase the pool of potential consumers for concession goods. On the other hand, if, in addition, we consider two types of travelers, resulting from a trade-off between business and leisure passengers, the aforementioned mark-down may become a mark-up. Intuitively, such a mark-up is likely to occur when the level of delay is high.

2.4.2 Welfare maximizing airport

Consider a public airport whose mandate is to maximize social welfare (SW). It is the sum of two parts, namely, surplus from aeronautical services, S^a, and a proportion, $\delta \in [0,1]$, of the surplus from concession services, S^c, which are given by $S^a =$

$$\int_0^{Q_B} \rho_B(y)dy + \int_0^{Q_L} \rho_L(y)dy - \theta Q(v_B Q_B + v_L Q_L) - \theta\beta Q^2 - (c + c_a)Q \quad \text{and} \quad S^c =$$

$$\sum_{h\in\{B,L\}} \int_{p_c}^{u_h} Q_h \bar{G}_h\big(z; D(Q)\big) dz + (p_c - c_c)\Big(Q_B \bar{G}_B\big(p_c; D(Q)\big) + Q_L \bar{G}_L\big(p_c; D(Q)\big)\Big).$$

In our formulation, if $\delta = 1$, all the surplus generated by the concession services is extra surplus (that is, surplus which is unattainable elsewhere), which is commonly assumed in the literature (Yang and Zhang, 2011; Zhang and Zhang 2003, 2010). If $0 < \delta < 1$, only part of the concession surplus is extra surplus. If $\delta = 0$, none of the concession services generate extra surplus (Czerny, 2011; Kratzsch and Sieg, 2011). The reason why only a proportion, δ, of the surplus from concession services is counted into the social welfare function is that only under certain occasions concession services generate extra surplus. In other words, a difference may exist between the types of concession services at the airport. For example, the overall demand for food and beverages may not depend much on whether individuals fly or not fly. On the other hand, there are some other types of concession services which may be elicited by travel-related motivations. Geuens et al. (2004) find that there are specificities for airport shopping, such as motivation ''to contrast day-to-day'' and ''to be out of place''. Several authors agree that the shopping and purchasing habits of a tourist often vary considerably from her normal pattern at home (Brown, 1992; Huang and Kuai, 2006). Another motivation is that travelers leaving a certain country shop in order to spend their remaining foreign currencies. Furthermore, the habit of buying souvenirs and presents motivates travelers to shop (Sulzmaier, 2001). Large international brands design new product lines exclusively for duty-free shops in order to seduce travelers to buy an unique souvenir (Vlitos Rowe, 1999). Moreover, for some people traveling causes fear or feelings of insecurity, leading them to search for comforting and reassuring behaviors from shopping (Dube and Menon, 2000).

As a result, the social welfare function can be written as follows.

$$SW = \sum_{h\in\{B,L\}} \int_0^{Q_h} \rho_h(y)dy - \theta Q \sum_{h\in\{B,L\}} v_h Q_h - \theta\beta Q^2 - (c + c_a)Q$$

$$+ \delta \sum_{h\in\{B,L\}} \int_{p_c}^{u_h} Q_h \bar{G}_h\big(z; D(Q)\big) dz + \delta(p_c - c_c) \sum_{h\in\{B,L\}} Q_h \bar{G}_h\big(p_c; D(Q)\big)$$

(2.14).

The airport maximizes social welfare with respect to p_c, the concession price, and p_a, the charge for airlines. The first-order condition with respective to the concession price is

$$\frac{\partial SW}{\partial p_c} = (p_c - c_c) \sum_{h \in \{B,L\}} Q_h^* \frac{\partial \bar{G}_h(p_c; D(Q^*))}{\partial p_c} = 0. \tag{2.15}$$

Equation (2.15) is only satisfied when

$$p_c^W = c_c, \tag{2.16}$$

where the superscript W is used to denote results for the welfare maximization case. Therefore, for a welfare maximizing airport, the optimal concession price is equal to the marginal concession cost. The welfare maximizing airport charge is characterized by

$$\frac{\partial SW}{\partial p_a} = \frac{\partial SW}{\partial p} \frac{dp}{dp_a} = 0. \tag{2.17}$$

From Lemma 2.2, we have $dp/dp_a > 0$. Therefore, equation (2.17) is satisfied if and only if $\partial SW/\partial p = 0$, that is

$$p = (c + c_a) + \theta \left[v_B Q_B^* + v_L Q_L^* + 2\beta Q^* - \delta \sum_{h \in \{B,L\}} Q_h^* \int_{p_c^W}^{\bar{u}} \frac{\partial \bar{G}_h(z; D(Q^*))}{\partial D} dz \right]$$

$$- \delta (p_c - c_c) \sum_{h \in \{B,L\}} Q_h^* \frac{\partial \bar{G}_h(p_c^W; D(Q^*))}{\partial D} - \frac{\delta}{\frac{dQ}{dp}} \left[\sum_{h \in \{B,L\}} \frac{dQ_h}{dp} \int_{p_c^W}^{\bar{u}} z g_h(z; D) \, dz - c_c \bar{G}_h(p_c^W; D(Q)) \right]$$

(2.18).

Substituting equation (2.9) into equation (2.18), we derive the optimal airport charge, p_a^W:

$$p_a^W - c_a = \theta \left[\left(1 - \frac{1}{n}\right) \beta Q^* + v_B Q_B^* + v_L Q_L^* - \frac{1}{n} \frac{v_B b_L + v_L b_B}{b_L + b_B} Q^* \right] - \frac{1}{n} \frac{b_L b_B}{b_L + b_B} Q^*$$

$$- \theta \delta \sum_{h \in \{B,L\}} Q_h^* \int_{c_c}^{\bar{u}} \frac{\partial \bar{G}_h(z; D(Q^*))}{\partial D} dz - \frac{dp}{dQ} \delta \sum_{h \in \{B,L\}} \frac{dQ_h}{dp} \int_{c_c}^{\bar{u}} (z - c_c) g_h(z; D) dz.$$

(2.19).

The first line on the RHS of (2.19) is the sum of the uninternalized marginal congestion cost for airlines, the marginal congestion cost for passengers, a correction for the

internalized marginal congestion cost for passengers and a correction for airlines' market power. Similar to the case of a profit maximizing airport, the second line of (2.19) also contains two terms of interest when > 0. The first term is again a downward correction for the congestion toll to internalize the positive externality of congestion on concessions, but this time it stems from the marginal increase in passenger concession surplus rather than the marginal increase in profit. Therefore, the airport can have incentives to reduce the congestion toll so as to increase the passenger volume and their waiting time. The above discussion can be summarized in Proposition 2.1.

Proposition 2.1

In the case of a welfare maximizing airport, when concession services generate extra surplus, there is a downward correction for the congestion toll which is equal to the marginal passenger concession surplus due to the positive externality of delay. Therefore, it can be useful to decrease the airport charge so as to increase passengers' waiting time and so their consumption of concession goods.

The last term accounts for the per passenger expected concession surplus, weighted for different passenger types. Unlike previous literature where this term is always negative, this is again no longer clear-cut when more than one type of passenger is considered. This can be seen as follows. Let $\Gamma(D) = \sum_{h\in\{B,L\}} \frac{dQ_h}{dp} \int_{c_c}^{\bar{u}} (z - c_c) g_h(z; D) dz$.

Consider the case in which $dQ_B/dp > 0$. Since $dQ/dp < 0$, from Lemma 2.2, we have $dQ_B/dp < - dQ_L/dp$. It follows that $\Gamma(D) > 0$ when

$$\Lambda(D) = \frac{\int_{c_c}^{\bar{u}} (z - c_c) g_L(z; D) dz}{\int_{c_c}^{\bar{u}} (z - c_c) g_B(z; D) dz} < -\frac{\frac{dQ_B}{dp}}{\frac{dQ_L}{dp}} . \tag{2.20}$$

In other words, when (2.20) is satisfied the last term becomes a mark-up. Specifically, from the definition of $\Lambda(D)$ we have $\Lambda(D)$ decreases with the delay if and only if at the equilibrium

$$\int_{c_c}^{\bar{u}} \frac{\partial \bar{G}_L(z; D)}{\partial D} dz - \int_{c_c}^{\bar{u}} \frac{\partial \bar{G}_B(z; D)}{\partial D} dz < 0 . \tag{2.21}$$

The left hand side (LHS) of (2.21) is the difference between the impacts of delay on the expected concession surplus of one leisure passenger and one business passenger. When (2.21) is satisfied, condition (2.20) is more likely to be fulfilled. Therefore, for high levels of delay it is more likely to have a mark-up. As in the profit maximizing case, findings from Torres et al. (2005) support the idea that for these levels of delay it can be useful, for the welfare maximizing airport, to increase the airport charge to protect the business passengers from excessive congestion. This is consistent with Czerny and Zhang (2010) but from another perspective: it is welfare-enhancing to induce more business passengers and let them buy in the commercial area, gaining more extra surplus. Summarizing the above discussion leads to:

Observation 2.2

In the case of a welfare maximizing airport and two types of travelers, when concession services generate extra surplus, the correction on the optimal airport charge due to the impact of changes in passenger volume on concession surplus is a mark-up, not a mark-down, for some levels of delay. Therefore, the socially efficient airport charge can be higher than what would prevail if passengers are treated as a single type.

Comparing (2.13) and (2.20), Observations 2.1 and 2.2 differ in the following sense: the profit maximizing airport cares about the difference between the probability of purchase of business and leisure passengers at the monopoly concession price p_c^{Π}; while the welfare maximizing airport cares about the difference between the concession surplus of business and leisure passengers.

2.4.3 Comparison between profit and welfare maximizing airports

In this section, we concentrate on the comparison between the pricing rules of profit and welfare maximizing airports derived above. Specifically, comparing equations (2.12) and (2.19), the first lines on the RHS of both equations are consistent with previous

literature; therefore, we focus on the remaining parts – consisting of two terms – which highlight the effects of the positive externality of delay and passenger types on concessions. The first term takes into account the marginal increase in concession profit (passenger concession surplus) due to delay in the case of a profit (welfare) maximizing airport. This term is negative and comes from the positive externality of congestion on concessions. The second term takes into account the impact of different passenger types on the per passenger concession profit (expected concession surplus), in the case of a profit (welfare) maximizing airport. This term may be positive or negative, that is, a mark-up or a mark-down, according to the difference in the values of time between travelers and the level of delay.

Proposition 3.1

    (1)   *There exists a $\bar{\delta} \in (0,1)$ such that $\forall \delta \in [0, \bar{\delta})$ the (downward) correction for the congestion toll due to the positive externality of delay is higher for a profit maximizing airport than a welfare maximizing airport; $\forall \delta \in (\bar{\delta}, 1]$ this correction is higher for a welfare maximizing airport than a profit maximizing airport.*

    (2)   *When the difference in the values of time between passenger types is small and there is mark-down due to concessions, there exists a $\hat{\delta} \in (0,1)$ such that $\forall \delta \in [0, \hat{\delta})$ the mark-down is higher for a profit maximizing airport; $\forall \delta \in (\hat{\delta}, 1]$ it is higher for a welfare maximizing airport. When the difference in the values of time between passenger types is large, the comparison is ambiguous.*

The proof of Proposition 3.1 is given in the Appendix A. The first part of Proposition 3.1 suggests that in some situations a welfare maximizing airport can have more incentives to decrease the congestion toll and induce congestion - so as so to increase the passengers' probability of purchasing concession goods - than a profit maximizing airport. This is more likely to happen in those airports which provide unique and more desirable shopping experiences that are not available elsewhere and thus generate a

sufficiently high proportion of extra surplus. The second part of Proposition 3.1 implies that in some situations a welfare maximizing airport can subsidize more than a profit maximizing airport, so as to decrease the aeronautical charge and increase the pool of passengers who are potential consumers of concession goods. This is true when the difference in passengers' value of time is small and the proportion of extra surplus generated by airport concession activities is sufficiently large. However, when the difference in passengers' value of time is large the comparison is no longer clear-cut. Specifically, we may have a charge or a subsidy for both types of airports and three different scenarios can happen depending on two conditions

$$-\frac{\frac{dQ_B}{dp}}{\frac{dQ_L}{dp}} < \frac{E_L^W - E_L^\Pi}{E_B^W - E_B^\Pi}, \tag{2.22}$$

$$-\frac{\frac{dQ_B}{dp}}{\frac{dQ_L}{dp}} < \frac{E_L^\Pi}{E_B^\Pi}, \tag{2.23}$$

where $E_h^\Pi = (p_c^\Pi - c_c)\bar{G}_h(p_c^\Pi; D)$ is the per passenger concession profit and $E_h^W = \int_{c_c}^{\bar{u}}(z - c_c)\,g_h(z; D)dz$ is the per passenger concession surplus. In the first scenario, when only (22) holds, the welfare maximizing airport charges less[34] than the profit maximizing airport. This happens because business passengers generate sufficiently high profit for concessions while leisure passengers generate sufficiently high consumer surplus from concessions. Therefore, the profit maximizing airport has higher incentives to retain business passengers than the welfare maximizing airport. In the second scenario, when only (2.23) holds, the profit maximizing airport charges less and the situation is just reversed. In the last scenario, when both (2.22) and (2.23) hold, there exists a $\tilde{\delta} \in (0,1)$ such that $\forall \delta \in [0, \tilde{\delta})$ the profit maximizing airport charges less; $\forall \delta \in (\tilde{\delta}, 1]$ the welfare maximizing airport charges less. This happens because leisure passengers generate sufficiently high profit in the profit maximizing case and sufficiently high consumer surplus in the welfare maximizing case, that is when concession activities produce a sufficiently high proportion of extra surplus, the welfare

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[34] Note that it is possible that both airports subsidize, in which case "charge less" means "subsidize more". It is also possible that one airport subsidizes while the other airport charges.

maximizing airport has a stronger incentive to decrease the aeronautical charge and induce more leisure passengers.

2.5 Concluding remarks

This paper focuses on the impact of concessions on airport congestion pricing. In particular, it adds to literature by taking into account the positive relationship between congestion and the consumption of concession goods, through dwell time, while incorporating the effect of passenger types.

We find that for both profit and welfare maximizing airports there is a downward correction for the congestion toll equivalent to the marginal concession profit and passenger concession surplus, respectively, due to the positive externality of delay. This correction may even turn the congestion toll into a subsidy, which is in contrast with previous literature on airport pricing. Therefore, the airport can have incentives to reduce the aeronautical charge so as to increase passengers' dwell time and their consumption of concession goods. Furthermore, we show that there is a correction on the optimal airport charge equal to the per passenger concession profit and expected concession surplus, weighted for different passenger types, for profit and welfare maximizing airports, respectively. We find that in the case of two types of travelers, for some levels of delay this correction may be a mark-up rather than the traditional mark-down. Therefore, the optimal airport charge can be higher than what would prevail if passengers are treated as a single type. Finally, the comparison between privately and socially optimal airport charges highlights two results. First, when concession activities generate a sufficiently high proportion of extra surplus, the welfare maximizing airport can have more incentives to decrease the congestion toll and induce congestion, so as to increase the passengers' dwell time and the probability of purchasing concession goods. Second, the profit maximizing airport may impose a lower charge than the welfare maximizing airport, so as to adjust the impact of changes in the pool of potential consumers for concession services, depending on both the difference in the passengers' values of time and the proportion of extra surplus generated by airport concessions.

Non-aeronautical revenues have become the main income source of many airports and studies on the impact of commercial revenues on airport pricing are of increasing concern. Our findings, therefore, can be useful for both academics and practitioners because of their implications for the operation of the industry and the ensuing regulatory requirements. In this sense, further developments of the present work may go in two directions. First of all, in this paper we abstract away the possibility of price discrimination and assume that all passengers are charged a uniform airfare. Hence a natural extension is to check whether our results still hold when price discrimination is allowed. Second, within the scope of policy implications, the impact of different types of regulation, such as single-till or dual-till, should be investigated under our framework. It is of interest to explore whether considering the positive externality of congestion will contribute new insights to the policy debate.

Chapter 3

Vertical relations in the air transport industry: A facility-rivalry game[¥]

3.1 Introduction

Vertical relations in the aviation industry are of increasing concern and source of debate for both academics and practitioners, constituting a fundamental issue because of its implications for the operation of the industry and the ensuing regulatory requirements. Indeed, evidence suggests that there may be strong incentives, which need to be analyzed, for airports and their respective dominant airlines to vertical cooperation: (i) airports can obtain financial support and secure business volume, essential for ensuring daily operation as well as long term expansion; (ii) airlines can secure key airport facilities on favorable terms, thus making long term commitment/investment at an airport possible ; (iii) since concession revenues are increasingly important, airports and airlines now use various agreements to internalize the positive demand externality between aviation services and concession services. This has been a crucial issue since airports have had more and more pressure to improve their financial performances.

Moreover such airline-airport cooperation raises anticompetitive concerns. Vertical restraints may harm competition in the downstream airline market: such a dominance of

one airline at an airport allows the airline to obtain a substantial "hub premium", even more evident for flights connecting two hubs of the same carriers. Moreover, the dominant airline's control over key airport facilities, such as slots and gates, is likely to impose significant entry barriers to other potential competitors, especially at congested airports.

Different forms and types of agreement have been observed in practice. For example: (i) master use-and-lease agreements, where airlines become guarantors of the airport's financial structure; in return, they are given varying degrees of influence over airport planning and operations (i.e. terminal usage); (ii) concession revenue sharing agreement, where the sharing airline can internalize positive demand externality, and benefits from its competitors' output expansion in terms of getting more concession revenue. In many cases it occurs when airports allow airlines to hold shares or control airport facilities; Tampa International Airport, as of 2005, shares 20% of its net revenue with the signatory airline, i.e. Continental Airlines, Inc. which continued to operate in the facility under an amended lease that expired on September 30, 2009; (iii) airlines owning or controlling airport facilities (i.e. Terminal 2 of Munich airport is a joint investment by FMG (60%) and Lufthansa (40%); Lufthansa has also invested in Frankfurt airport, and holds a 29% share of Shanghai Airport Cargo Terminal); (iv) long term usage contract, as service guarantee and usage commitment (i.e. in 2002 Melbourne airport and Virgin Blue reached a 10-year agreement for the airline to operate from the former Ansett Domestic Terminal; (v) airport revenue bond, where airports retain asset ownership but transfer the right for exclusive usage to the bondholders airlines under long-term lease agreements.

Despite the above agreements, vertical relations between airports and airlines have received little attention in the literature so far, probably due to the fact that price discrimination on aviation services is prohibited by IATA and EU rules: an airport is required to charge all airlines the same price for identical services (EU Directive 2009/12/EC-Art.3, EEC Treaty-Art.87/88, EEC Council Regulation No 95/93). In addition, the historical public utility status of most airports, has often protected airports from anti-trust investigation until the recent privatization wave. Therefore, research documented in the literature appears to lack maturity in this direction.

Pels et al. (2003) analyze the correlation among the dimensions of passengers' choice, namely access mode, airport and airline. They find that the set "airport and airline" is considered but not the facility alone. Basso and Zhang (2007) focus on both airport rivalry and airline competition with respect to the issue of congestion delays. Basso (2008) considers the issue of facility rivalry and finds that an increasing cooperation between airports and airlines provides some improvements, even if the resulting airport pricing strategy (two part tariff) leads to a downstream airline cartel. Nevertheless, he does not analyze other different forms of vertical relations. Starkie (2008), Oum and Fu (2008) give an overview of airport-airline vertical relationships and policy implications, but they do not build a model to analyze different types of contracts or the effects in terms of competitiveness, social welfare and consumer surplus. Barbot (2009) focuses on the issue of facility rivalry: she analyzes the incentives to vertical collusion for an airport-dominant airline system if the other airport and dominant airline also engage in agreement, finding that they exist when airports and airlines have different market sizes or, in some cases, when there is a secondary airport and LCC carriers. Nevertheless, she does not analyze the issue of airlines competition within each airport. Barbot (2011) develops an airport-airlines model to examine the effects of three types of contracts, according to Starkie (2008): the European case, the Australian case and the US case. The European case, namely "Vertical Collusion", depicts the case of a negotiated fare between the airport and the dominant airline, depending on their bargaining power (i.e. Charleroi – Ryanair, Finnish or Portuguese airports contracts). The airport and the leader airline collude and maximize their joint profits: the negotiation aims at obtaining the highest joint profits for both partners and the solution is the same of a vertical merger. The other airlines will pay a higher facility charge. In the Australian case, i.e. "Airlines in the upstream market", long term leases on terminals are analyzed (i.e. Sydney, Melbourne, Dallas Forth Worth). The airport operates the runway for all airlines, while the leader airline leases and operates the terminal, using it and selling it to the followers. Finally, the US case depicts the case of "Price discrimination" (i.e. Atlanta, Orlando): the leader airline pays the airport the variable cost of its facility plus a part, which is agreed between the two partners, of its fixed costs. Specifically, the competitive pressures in the airlines market on the incentives to the three types of vertical contracts are analyzed and it is found that: (i) two of them are anti-competitive

and (ii) in all of them consumers are better-off. Nevertheless, in this context, facility rivalry is not investigated. Zhang et al. (2010) deal with the issue of both airports and airlines competition, but with respect to the case of a single type of contract: concession revenue sharing. They find that: (i) the degree of revenue sharing will be affected by how airlines' services are related to each other; (ii) airport competition is critical to the welfare consequences of alternative revenue sharing arrangements.

In this paper, the three types of vertical contracts analyzed in Barbot (2011) are considered in the context of two competing facilities: in this sense, the paper adds to literature as it considers the issue of vertical alliances with respect to both airports competition and airlines competition. Specifically, we develop a multistage facility-rivalry game and we investigate the sub-game perfect Nash equilibria to analyze the incentives for vertical contracts and the effects in terms of welfare, consumer surplus and pro-competitiveness.

The paper is organized as follows. Section 3.2 sets up the model. Section 3.3 describes the different cases according to the different types of vertical agreements between airports and airlines. In Section 3.4, we find the airports and airlines optimal strategies for each case. Section 3.5 contains the concluding remarks.

3.2 The model

We consider the case of an infinite linear city where potential consumers are uniformly distributed with a density of one consumer per unit length. There are two airports, A^0 and A^1, respectively located at 0 and 1. The locations of the facilities are exogenous. We assume there are consumers also beyond the airports: facility 0 also captures the consumers at its immediate left side and facility 1 those at its immediate right side. In each airport the downstream market consists in a route operated by one leader and *n-1* followers, which offer a homogeneous good/service, the flight. Let L^h and F_i^h stand for the leader and the *i-th* follower, respectively, which operate in airport A^h, with $h = 0,1$ and $i = 1, ..., n-1$. The number of carriers at each facility is exogenous. The airlines cannot choose which facility they operate, but they are bound to a certain airport: they

do not compete for the airport where to operate. Hence, each follower-leader set of airlines will supply the demand for only one airport, which they do not choose. In this sense, airports do not compete for the airlines but compete through airlines to get passengers: each airport gets the number of passengers the carriers are able to capture.

In each airport the leader and the followers compete *à la* Stackelberg. Moreover, the leader L^0 competes in quantities with the leader L^1 in a Cournot fashion; the followers compete in quantities with the followers at the same facility and with the followers at the other facility in a Cournot fashion. Therefore, the followers take into account the strategic choices of the leader at the same airport and the ones of the leader at the other airport. Airlines sell tickets directly to consumers, at prices-per-passenger p_0 and p_1. Demand at each facility, Q_0 and Q_1 respectively, is measured by the total number of flights offered. In the downstream market, the only cost both the leader and the followers incur is the airport aeronautical fare, varying with respect to the type of contract the leader and the airport have entered in. Other variable airline costs are constant and normalized to zero. The airports have a constant marginal operating cost per flight, c, and a fixed cost F_h, with $h = 0,1$. Potential consumers have unit demand for flights and they care for their "full price". Indeed, passengers may not necessarily choose the airport with the cheaper fare, but may go to an airport that is nearer and has a shorter total travel time. As a result, the full price is the sum of the ticket price and the travel cost to the facility.

The vertical structure of airport-airlines behavior is represented by a multistage game: in the first stage, the airport A^0 and its dominant carrier L^0 decide, simultaneously with the airport A^1 and its dominant carrier L^1, whether to enter into a contract and, if so, which one to engage in; prices for the input to be used by carriers are decided; in the second stage, L_0 competes with L^1 in the output market choosing quantities; in the third stage, F_i^0 competes in quantities with F_j^0, $j \neq i$, at the same facility, and F_i^1, at the other facility, with $i = 1, \dots, n-1$ and $j = 1, \dots, n-1$; finally, passengers decide whether to fly or not and if so, which facility to go to.

There are two main reasons why we assume there is an infinite linear city with consumers also beyond the airports. First, the case where potential consumers are spread over a line with airports located at the endpoints, i.e. the usual Hotelling model,

would have limited the application of the model to regions where population is only concentrated in coastal areas, as it is the case of Porto and Galicia's airports or JFK and Newark, as an example. Second, such a framework allows to examine situations where there can be some consumers for whom the sum of the flight's price plus the total transportation costs would exceed their reservation price. Hence, we do not assume a priori that each consumer decides to fly or, in other words, that the market is covered as in the usual Hotelling address model. Earlier studies that have modeled a general demand structure generated through explicit considerations of passenger behavior have assumed an infinite linear city[35] (Basso and Zhang, 2007; Zhang et al. 2010).

According to Barbot (2011), the application of Stackelberg quantity leadership to the downstream market seems realistic: the dominant carriers may be considered as quantity leaders because, as first comers, they choose the quantity and leave the remaining slots for other carriers. Table 3.1 shows a high concentration, in terms of Available Seat Kilometers[36] (ASK) of airlines' flights in the 20 largest airports in Europe, for 2009, and high shares belonging to flag carriers (i.e. Air France at Paris CDG, Alitalia at Rome Fiumicino, SN Brussels Airlines at Brussels National) or to carriers that established their bases at particular airports (i.e. Lufthansa at Frankfurt and München F.J. Strauss or Spanair at Barcelona).

In our model, the leader and the followers at each airport are assumed to charge a homogenous fare, even though it is well known that leader and followers can charge passengers different prices. On one hand, the dominance of one airline at an airport allows the airline itself to obtain a substantial "hub premium", even more evident for flights connecting two hubs of the same carriers: an airline with 50% of the traffic at

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[35] As noted by an anonymous referee, assuming potential consumers are uniformly distributed may not be the best way to reflect the reality in some situations, as the cases of inter- or intra- metropolitan area competitions. For inter-metropolitan competition, demand for each airport primarily stems from the respective metropolitan area; for intra - metropolitan competition, demand may be concentrated at one airport. Airport demand patterns can be affected by many factors such as easiness/convenience of ground access (e.g. availability of multimodal transfer at the airport) and proximity of the airport to the population mass.

[36] Available seat kilometer (ASK) is a measure of an airline flight's passenger carrying capacity. It is equal to the number of seats available multiplied by the number of kilometers flown.

each endpoint of a route is estimated to charge high-end prices about 12% above those of a competitor with 10% of the traffic at each endpoint. (Oum and Fu, 2008).

Table 3.3. ASK (%) of the top five carriers in the 20 biggest European airports.

			ASK (%) First Carrier	ASK (%) Top Two Carriers	ASK (%) Top Three Carriers	ASK (%) Top Four Carriers	ASK (%) Top Five Carriers
	ASK (%) of the top five carriers in the 20 biggest European airports						
Rank	**Airport**	**First carrier**					
1	Roma Fiumicino	Alitalia	37,2%	42,2%	47,0%	49,5%	51,9%
2	Parigi Charles De Gaulle	Air France	54,6%	57,4%	59,9%	62,3%	64,3%
3	Francoforte	Lufthansa	53,3%	59,2%	62,0%	64,6%	67,1%
4	Londra Heathrow	British Airways	40,1%	45,5%	50,9%	54,4%	57,6%
5	Milano Malpensa	Alitalia	31,4%	37,7%	43,3%	47,6%	51,5%
6	Amsterdam-Schiphol	KLM	49,6%	62,3%	66,5%	69,7%	72,1%
7	Madrid Barajas	Iberia	51,8%	57,3%	62,8%	65,9%	68,8%
8	München F.J. Strauss	Lufthansa	56,1%	62,1%	67,0%	70,2%	73,0%
9	Barcellona	Spanair	13,7%	23,7%	32,3%	39,5%	45,4%
10	Londra Gatwick	British Airways	26,4%	43,3%	50,7%	56,2%	61,4%
11	Atene Eleftherios	Olympic Airlines	30,9%	41,6%	47,1%	51,6%	55,3%
12	Brussels National	SN Brussels Airlines	24,7%	41,5%	51,3%	55,8%	60,2%
13	Zurigo	SWISS	58,0%	64,0%	67,3%	70,5%	73,6%
14	Vienna	Austrian	59,4%	63,7%	68,0%	71,3%	73,6%
15	Manchester	Emirates	9,0%	17,5%	25,1%	31,8%	37,0%
16	Copenhagen	SAS	51,7%	58,2%	61,2%	64,0%	66,6%
17	Geneva-Cointrin	Easyjet Switzerland	14,4%	28,5%	36,8%	44,9%	50,9%
18	Stoccolma-Arlanda	SAS	39,9%	48,0%	52,8%	57,6%	62,2%
19	Dusseldorf	Air Berlin	22,6%	44,3%	63,3%	68,5%	73,6%
20	Malaga	easyJet	21,3%	28,6%	34,8%	40,7%	45,5%

Source: ICCSAI- Fact Book 2010.

On the other hand, non-dominant carriers, attempting to gain a foothold at the airport, may be forced to offer lower fares in order to attract passengers. In this paper, we have

abstracted away from the possibility of airlines charging different prices in order to concentrate on the incentives for vertical contracts and the effects in terms of welfare, consumer surplus and pro-competitiveness[37].

In our model we assume airlines are bound to a certain airport. It can be argued that airlines could, actually, decamp all or part of their operations to an alternative site. In particular, this is true once we take into account non-networked air services operated by charter or low cost carriers which have more scope for switching operations between airports in order to reduce costs[38]. Yet, when air services are concentrated at a transfer point, i.e. at a hub airport, the significance of the agglomeration economies/network externalities may be such that they tie the individual dominant airline to the hub airport. It would seem most unlikely, in this case, for a scheduled carrier, with a high level of transfer passengers to and from other airlines, to choose to forego the revenue and cost advantages of the hub by substituting a proximate, even adjacent, alternative airport (Starkie, 2002). British Airways or British Midland at Heathrow, Air France at Paris Charle De Gaulle or Alitalia at Rome Fiumicino provide an example in this sense. Moreover, some airlines own or control airport facilities: Lufthansa has invested in Frankfurt airport and Munich airport; Latvia's Riga Airport has offered a contract to the national airline Air Baltic to build and operate a 92 euro million terminal for seven million passengers per annum by 2014. This means that the costs of switching airports are higher for the dominant airlines. The assumption seems also reasonable once the presence of followers aligned with the leaders in co-sharing or alliance agreements, within a given airport, is taken into account. Actually, this occurs in particular with respect to the case of regional subsidiary carriers[39] (Table 3.2).

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[37] This allows us to establish a benchmark case and is consistent with the uniform pricing case in the literature, i.e. the leader and the followers charge homogenous fares. Allowing airlines charging passengers different prices is certainly important (and is consistent with the existing airline practice) and can represent an extension of the analysis presented here.

[38] Competition between Luton and Stansted in the early 1990s for the custom of Ryanair provides an example in this sense.

[39] As noted by an anonymous referee, the assumption of not allowing one airline to serve two airports may seem also restrictive when considering the case of different facilities dominated by the same carrier. For inter-metropolitan case, for instance, Roma Fiumicino and Milano Malpensa are both dominated by Alitalia. For intra-metropolitan case, London Heathrow and London Gatwick are both dominated by British Airways. The same argument could be applied in terms of follower airlines. Our framework

Finally, it is assumed airlines choose quantities, i.e. the number of flights. It ought to be noted that airlines' quantity choice should be subject to airport capacity constraints: for example, if the number of scheduled flights exceeds airport runway capacity, a significant level of congestion will occur, which, in turn, will increase airline operating costs and reduce the attractiveness of the airport. However, for sake of simplicity, we assume there is spare capacity and there is no congestion at both facilities[40].

Table 3.4. Alliance agreements between national and regional consociate carriers within some European hubs.

Alliance	First Carrier	Consociate	Hub
SkyTeam	Air France	Brit Air Régional	Paris-Orly Lion-Saint Exupéry
	KLM	KLM Cityhopper	Amsterdam-Schipol
	Alitalia	Airone CAI-Second (i.e.Volare Airlines)	Milano Malpensa
		Airone Cityliner CAI-First (i.e. Alitalia Express)	Rome Fiumicino
Star Alliance	Lufthansa	Lufthansa Regional	Frankfurt München F.J. Strauss
Oneworld	Iberia	Iberia Regional Vueling ClickAir	Madrid Barajas

Source: www.skyteam.com, www.staralliance.com, www.oneworld.com.

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implies a perfect alignment between the interests of the airport and the airlines operating at the airport itself: in this sense our results are restricted to the cases just discussed, that is when the carries have no incentives to shift form one facility to another (high switching costs, etc.). If this is not case, the equilibrium of the game may change, given that airports would compete between each other for airlines and not through airlines to get passengers.

[40] We can allow for airport capacity constraints assuming each of the facilities chooses its capacity and prices for the input to be used by carriers to maximize their own profit. We could investigate both a closed-loop game, in which capacities are chosen prior to prices, and an open-loop game in which capacities and prices are decided simultaneously, that is equivalent to a game in which decisions are sequential but the capacity decision is not observable by the rival. In general, both the two settings can be relevant in the context of airports. Indeed, we can consider airport capacity expansions through: (i) runways construction that would be easily observable; or (ii) technological improvements of air traffic control systems that would not be observed as easily. Privatized and more commercialized airports may be dynamic innovators in discovering new technologies, but they would have no incentive to share them with its competitors (Basso, 2008).

We investigate the subgame perfect Nash equilibria of the game. For this purpose, we first focus on airline's demand. For a consumer located at $0 \leq z \leq 1$ and who goes to facility 0, the full price is given by:

$$p_0 + 4tz$$

(3.1)

where $4t$ is a parameter capturing consumers' transportation cost, assumed to be positive[41]. If the consumer decides to fly she derives a net utility:

$$U_0 = U - p_0 - 4tz$$

where U is denoting the gross benefit. Similarly, if the consumer goes to facility 1, then she derives a net benefit:

$$U_1 = U - p_1 - 4t(1 - z)$$

In addition to ground transportation cost, other aspects of facility differentiation could be captured by extending the formulation of the full price supported by passengers: for instance, the two facilities may have different ground access costs[42] (Pels et al. 2004). We could further specify additional service quality components, as the flight delay (of both take-off and landing) because of congestion at airport, or the schedule delay cost, i.e. the monetary value of the time between the passenger's desired departure time and the actual departure time[43].

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[41] The parameter *4t* is chosen to simplify equations in the model.

[42] We can allow for this specification in two ways. First, we can interpret the two different ground access costs as inverse measures of quality, obtaining a model with vertical and horizontal differentiation (Ferreira and Thisse, 1996). Following them, we can specify the qualities of the facilities' services by unit of distance be, respectively, R_0 and R_1, with $R_0 \lessgtr R_1$ and let $t_0 = 1/R_0$ and $t_1 = 1/R_1$ be the inverse measures of quality, by unit of distance, $t_0 \gtrless t_1$. Alternatively, we can introduce a parameter, x_1, to the net utility function such that $U_1 = U - p_1 - 4tx_1(1 - z)$, where $x_1 > 1$ ($0 < x_1 < 1$, respectively) if facility 1 has a higher (lower, respectively) access cost for consumers than facility 0.

[43] The congestion delay, i.e. $D_h(Q_h, K_h)$, depends on the total number of passengers, Q_h, and the airport's (runway) capacity, at facility h. We can use a linear delay function as the one in De Borger and Van Dender (2006) and Basso and Zhang (2007): such a linear delay function make the analytical work more feasible, but it may lead to the problem that an interior solution may not necessarily exist, that is a solution in which capacity is exceeded may subsist. To avoid this problem, we can alternatively use a convex delay function, i.e. delay approaches infinity when output approaches capacity. A convex delay function was proposed by the US Federal Aviation Administration (1969) and is further discussed in Horonjeff and McKelvey (1983). It has been used by Morrison (1987), Zhang and Zhang (1997), Oum et al. (2004) and Basso (2008). The schedule delay cost was introduced by Douglas and Miller (1974) as the sum of two components: (i) frequency delay cost, induced by the fact that flights do not leave at a passengers' request but have a schedule; (ii) stochastic delay cost, which is related to the probability that a passenger cannot board her desired flight because it was overbooked. Oum et al. (1995) and Basso (2008) also considered schedule delay cost in analytical models.

Assuming that everyone in the [0,1] interval decides to fly and both airports receive consumers from [0,1], then the indifferent consumer $\tilde{z} \in (0,1)$ is determined by $U_0 = U_1$, or

$$\tilde{z} = \frac{1}{2} + \frac{p_1 - p_0}{8t}$$

Thus the number of [0,1] consumers going to facility 0 increases in p_1 and decreases in p_0. Since with positive t, facility 0 also captures the consumers at its immediate left side and facility 1 those at its immediate right side. Let z^l be the last consumer on the left side of the city, who decides to fly and goes to facility 0, and z^r the last consumer on the right side of the city, who decides to fly and goes to facility 1. Given the uniformity and unit density of consumers, z^l and z^r are determined [44] as:

$$z^l = -\frac{U - p_0}{4t} \qquad\qquad z^r = 1 + \frac{U - p_1}{4t}$$

The points z^l, z^r and $\tilde{z}$ define the catchment areas of each airport as shown in Fig. 3.1. Hence, the demands for flight at each facility are given by $Q_0 = \tilde{z} + |z^l|$ and $Q_1 = (1 - \tilde{z}) + (z^r - 1)$, or:

$$Q_0 = \frac{1}{2} + \frac{2U - 3p_0 + p_1}{8t}$$
$$Q_1 = \frac{1}{2} + \frac{2U - 3p_1 + p_0}{8t} \qquad\qquad (3.2)$$

In order to have everyone in the [0,1] interval decides to fly we need $U_0 \geq 0$ and $U_1 \geq 0$ or:

$$2U \geq p_0 + p_1 + 4t$$

Similarly to have both airports receive consumers from [0,1] or, in other words, to have at least one consumer in both of the two airports, we need $0 \leq \tilde{z} \leq 1$ or:
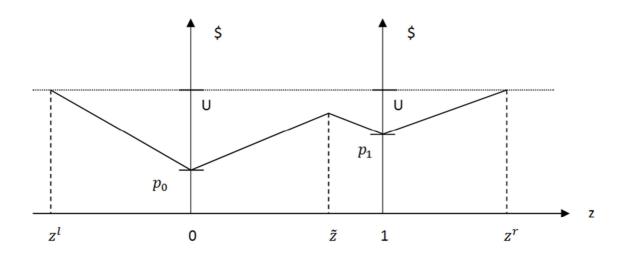
$$\left| p_{1-p_0} \right| < 4t$$

which remain maintained assumptions.

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[44] If consumer z^l decides to fly she derives a net utility $U - p_0 - 4t(-z^l) = 0$. Similarly, if the consumers goes to facility 1, then she derives a net benefit $U - p_1 - 4t(z^r - 1) = 0$

Fig 3.2. Consumers distribution and facilities' catchment areas.

Inverting the demand system (3.2) in   , we obtain the inverse demand functions faced by

carriers at each airport:

Hence, in the output market the demands depend on both   and   : each carrier faces direct competition from the others carriers at the same airport and indirect competition from the airlines in the other one. To save notations we shall, in what follows, simply use   and   , for   and   respectively. Given the structure of the downstream market, the total demand for flight at facility h can be rewritten as:

where   is the demand for flights faced by the leader and   is the demand for flights faced by the *i-th* follower, with   and   . In considering the choices of carriers at facility h, we shall use   and   to indicate the demand for flights faced by the leader and the *i-th* follower, respectively, at the other facility.

In order to analyse the effects in terms of welfare and consumer surplus we specify the two functions. Given the uniformity and unit density of consumers, (see Fig. 1), the consumers' surplus is given by:

$$CS = \int_0^{|z^l|} [U - p_0 - 4tz]dz + \int_0^{\tilde{z}} [U - p_0 - 4tz]dz + \int_0^{1-\tilde{z}} [U - p_1 - 4tz]dz$$

$$+ \int_0^{z^r-1} [U - p_1 - 4tz]dz$$

Using (3.3) to replace p_0 and p_1 both in the integrands and in z^l, z^r and $\tilde{z}$, and solving the integrals we get:

$$CS = \frac{(-4 + 3Q_0^2 + 2Q_0Q_1 + 3Q_1^2)t}{2} \tag{3.5}$$

Since there are three groups of stakeholders in the model – passengers, airlines and airports – the social welfare (W) is the sum of passengers (consumers) surplus, airline profits, and airports' profit. With this specification, the welfare function is given by:

$$W = CS + \sum_{h=0}^{1} \pi_A^h + \sum_{h=0}^{1} \pi_L^h + \sum_{h=0}^{1} \sum_{i=1}^{n-1} \pi_i^h \tag{3.6}$$

where CS is the consumers' surplus as defined in equation (3.5), π_A^h is the profit of airport h, with $h = 0,1$, while π_L^h and π_i^h, respectively, are the profit of the leader airline and of the *i-th* follower at facility h.

We find the subgame perfect Nash equilibria to analyze the incentives for vertical contracts and the effects in terms of welfare, consumer surplus and pro-competitiveness.

3.3 Analysis of the different types of vertical agreements

In this section we analyze both the symmetric cases and the asymmetric cases, according to the different choices of the two airport – dominant airline systems. In section 3.3.1 we analyze the symmetric cases, that is, the choice of the airport and its respective leader airline at facility 0 is the same of that at facility 1. We refer to these cases with the wording "two sided". In section 3.3.2 we specify the asymmetric cases, that is, the choice of the airport and its respective dominant airline at facility 0 is different from that at facility 1.

3.3.1 Symmetric cases

In section 3.3.1.1 we specify the basic case in which no agreement occurs in both the two facilities; then, in sections 3.3.1.2, 3.3.1.3 and 3.3.1.4, we analyze the cases in which at each facility the airport and the respective dominant airline both sign the same type of contract. Since there are so many variables, a table of nomenclature can be found in Appendix B.

3.3.1.1 *"Two sided No-Agreement"*. The airport and the leader airline do not sign any type of contract. Both the leader and the followers will pay the facility charge T_h, an input price, at facility h. Each follower competes in quantities with the followers at the same airport and with the followers at the other airport. The profit function for follower i at facility h, can be written as:

$$\pi_i^h = (p_h - T_h)q_i^h \qquad (3.7)$$

for $h = 0,1$ and $i = 1, \dots, n-1$, where p_h is given by (3.3) and (3.4). The equilibrium is characterized by $2(n-1)$ first-order conditions[45]:

$$\frac{\delta \pi_i^h}{\delta q_i^h} = U + 2t - 3tq_L^h - tq_L^{-h} - 3t(n-2)q_i^h - 6tq_i^h - t(n-1)q_i^{-h} - T_h = 0$$

We derive the best reply functions (BRF) of the followers, i.e. $q_i^h(q_L^h, q_L^{-h}, T_h, T_{-h})$. The leader L_0 competes in quantities with the leader L_1. They maximize simultaneously their profit:

$$\pi_L^h = (p_h - T_h)q_L^h \qquad (3.8)$$

for $h = 0,1$, where p_h, again, is given by (3.3) and (3.4). Substituting the followers' BRF into (3.4) and solving the 2-first order conditions system, i.e. $\delta \pi_L^h / \delta q_L^h = 0$, with $h = 0,1$, we derive $q_L^h(T_0, T_1)$ and so the quantities $q_i^h(T_0, T_1)$ of the followers. In the first stage, the airports compete choosing the input prices, T_h. The profit function for airport h can be written as:

$$\pi_A^h = (T_h - c)Q_h - F_h \qquad (3.9)$$

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[45] As costs are identical $q_i^h = q_j^h$

for $h = 0,1$, where Q_h is given by (3.4). Substituting $q_i^h(T_0, T_1)$ and $q_L^h(T_0, T_1)$ into (3.9), we solve the 2-first order conditions system, i.e. $\delta\pi_A^h/\delta T_h = 0$, with $h = 0,1$, finding solutions for all variables. The superscript NA is used to denote them. Specifically, for facility $h = 0,1$ and $i = 1, ..., n-1$ we obtain:

$$T_h^{NA} = \frac{(-3 + 9n + 48n^2)c + (-1 + 14n + 32n^2)(2t + U)}{-4 + 23n + 80n^2}$$

$$p_h^{NA}$$

$$= \frac{\left(12(-2 - 5n + 16n^2)(-1 + 3n + 16n^2)\right)c + \left(-4 + n(-119 + 64n(3 + 34n + 32n^2))\right)(2t + U)}{(-1 + 4n)(5 + 16n)(-4 + 23n + 80n^2)}$$

$$q_L^{h\,NA} = \frac{3\left((-1 + 4n)(-1 + n + 22n^2 + 32n^3)\right)(2t + U - c)}{\left((-1 + 4n)(5 + 16n)(-4 + 23n + 80n^2)\right)t}$$

$$q_i^{h\,NA} = \frac{3\left((1 + 8n)(-1 + 3n + 16n^2)\right)(2t + U - c)}{\left((-1 + 4n)(5 + 16n)(-4 + 23n + 80n^2)\right)t}$$

Analytical results for profits are shown in the Appendix B, as a function of parameters depending on n, so on the number of followers in the downstream market. The parameters are defined in the Appendix B.

3.3.1.2 "Two sided Vertical Collusion". At each facility, the airport and the leader airline negotiate the aeronautical fare $T_{L,h}$ depending on their bargaining power: the two partners maximize their joint profits and both of them, through the negotiation, obtain the highest joint profit so that the outcome is the same of a vertical merger[46]. The other *n-1* followers will pay the facility charge T_h, with $T_{L,h} < T_h$. Furthermore, we assume that there are no transaction costs of colluding.

Given the structure of the downstream market, the total demand for flight at facility h can be rewritten now in the form:

$$Q_h = q_C^h + \sum_{i=1}^{n-1} q_i^h \tag{3.10}$$

where q_C^h is the demand for flights faced by the colluded firm and q_i^h is the demand for flights faced by the *i-th* follower, with $i = 1, ..., n-1$ and $h = 0,1$.

---

[46] For our purposes, it does not matter which will be the negotiated fare $T_{L,h}$. The market solution for $T_{L,h}$ depends on the bargaining power of each contracting party, thus, within our framework, it is impossible to know if either the airport or the leader airline alone has an incentive for collusion: the only possibility is to consider the incentive of the two partners together.

Each follower competes in quantities with the followers at the same airport and with the followers at the other airport. The profit function for follower i at facility h, can be written as:

$$\pi_i^h = (p_h - T_h)q_i^h \tag{3.11}$$

for $h = 0,1$ and $i = 1, \ldots, n - 1$, where p_h is given now by (3.3) and (3.10). The equilibrium is characterized by $2(n - 1)$ first-order conditions:

$$\frac{\delta \pi_i^h}{\delta q_i^h} = U + 2t - 3tq_C^h - tq_C^{-h} - 3t(n - 2)q_i^h - 6tq_i^h - t(n - 1)q_i^{-h} - T_h = 0$$

We derive the best reply functions (BRF) of the followers, i.e. $q_i^h(q_L^h, q_L^{-h}, T_h, T_{-h})$. The colluded firm at facility 0 competes with the colluded firm at facility 1; they choose q_C^h and T_h maximizing simultaneously their profit:

$$\pi_C^h = (p_h - c)q_C^h + (T_h - c)(n - 1)q_i^h - F_h \tag{3.12}$$

for $h = 0,1$, where p_h, again, is given by (3.3) and (3.10). Substituting the followers' BRF into (3.12) and solving the 4-first order conditions system, i.e. $\delta \pi_C^h / \delta q_C^h = 0$ and $\delta \pi_C^h / \delta T_h = 0$, with $h = 0,1$, we find solutions for all variables. The superscript C is used to denote them. Specifically, for facility $h = 0,1$ and $i = 1, \ldots, n - 1$ we obtain:

$$T_h^C = \frac{12nc + (1 + 8n)(2t + U)}{1 + 20n}$$

$$p_h^C = \frac{12nc + (1 + 8n)(2t + U)}{1 + 20n}$$

$$q_i^{hC} = 0$$

$$q_C^h = \frac{3n(2t + U - c)}{(1 + 20n)t}$$

Analytical results for profits are shown in the Appendix B, as a function of parameters depending on n, so on the number of followers in the downstream market. The parameters are defined in the Appendix B.

3.3.1.3 "Two sided Airlines in the Upstream Market". The airport h operates the runways for all airlines, both the leader and the followers, at a price T_h^r; the leader airline operates and leases the terminal, using it at the marginal cost and selling it to the followers at a price T_h^t. Terminals have a constant marginal cost of *tm*, and runways a constant marginal cost of *r*. Previous to the agreement *c=tm+r*, but afterwards the

leader airline may have a higher (or lower) efficiency in the terminal operation: if there are no efficiency improvements *c=tm+r,* while if the leader improves (worsens) enough the terminal operations efficiency *c>(<)tm+r* . Furthermore, we assume that there are no transaction costs of signing this type of contract.

Each follower competes in quantities with the followers at the same airport and with the followers at the other airport. The profit function for follower i at facility h, can be written as:

$$\pi_i^h = (p_h - T_h^r - T_h^t)q_i^h \tag{3.13}$$

for $h = 0,1$ and $i = 1, \dots, n - 1$, where p_h is given by (3.3) and (3.4). The equilibrium is characterized by $2(n - 1)$ first-order conditions:

$$\frac{\delta \pi_i^h}{\delta q_i^h} = U + 2t - 3tq_L^h - tq_L^{-h} - 3t(n - 2)q_i^h - 6tq_i^h - t(n - 1)q_i^{-h} - T_h^r - T_h^t = 0$$

We derive the best reply functions (BRF) of the followers, i.e. $q_i^h(q_L^h, q_L^{-h}, T_h^r, T_h^t, T_{-h}^r, T_{-h}^t)$. The two leaders compete choosing q_L^h and T_h^t, the terminal charge. They maximize simultaneously their profit:

$$\pi_L^h = (p_h - T_h^r - tm)q_L^h + (T_h^t - tm)(n - 1)q_i^h \tag{3.14}$$

for $h = 0,1$, where p_h, again, is given by (3.3) and (3.4). Substituting the followers' BRF into (3.14) and solving the 4-first order conditions system, i.e. $\delta\pi_L^h/\delta q_L^h = 0$ and $\delta\pi_L^h/\delta T_h^t = 0$, with $h = 0,1$, we derive T_0^t, T_1^t, $q_L^h(T_0^r, T_1^r)$ and so the quantities $q_i^h(T_0^r, T_1^r)$ of the followers. In the first stage, the airports compete choosing the runways charge T_h^r. The profit function for airport h can be written as:

$$\pi_A^h = (T_h^r - r)Q_h - F_h \tag{3.15}$$

for $h = 0,1$, where Q_h is given by (3.4). Substituting $q_i^h(T_0^r, T_1^r)$ and $q_L^h(T_0^r, T_1^r)$ into (3.15), we solve the 2-first order conditions system, i.e. $\delta\pi_A^h/\delta T_h^r = 0$, with $h = 0,1$, finding solutions for all variables. The superscript AUM is used to denote them. Specifically, for facility $h = 0,1$ and $i = 1, \dots, n - 1$ we obtain:

$$T_h^{r\,AUM} = \frac{(1 + 17n)r + (1 + 14n)(2t + U - tm)}{2 + 31n}$$

$$T_h^{t\,AUM} = \frac{(1 + 46n + 484n^2)tm + (1 + 25n + 136n^2)(2t + U - r)}{(2 + 31n)(1 + 20n)}$$

$$p_h^{AUM} = \frac{12n(1 + 17n)(r + tm) + (2 + n(59 + 416n))(2t + U)}{(2 + 31n)(1 + 20n)}$$

$$q_i^{h\,AUM} = 0$$

$$q_L^{h\,AUM} = \frac{3n(1 + 17n)(2t + U - r - tm)}{(2 + 31n)(1 + 20n)t}$$

Analytical results for profits are shown in the Appendix B, as a function of parameters depending on n, so on the number of followers in the downstream market. The parameters are defined in the Appendix B.

3.3.1.4 "Two sided Price Discrimination". The leader airline pays the airport the variable cost of its facility, c, plus a part k, which is agreed between the two partners, of its fixed costs. This situation depicts the case of a two-part tariff. The other $n - 1$ followers will pay the facility charge T_h. Furthermore, we assume that there are no transaction costs of signing this type of contract.

With these specifications, each follower competes in quantities with the followers at the same airport and with the followers at the other airport. The profit function for follower i at facility h, can be written as:

$$\pi_i^h = (p_h - T_h)q_i^h \tag{3.16}$$

for $h = 0,1$ and $i = 1, \dots, n - 1$, where p_h is given by (3.3) and (3.4). The equilibrium is characterized by $2(n - 1)$ first-order conditions:

$$\frac{\delta \pi_i^h}{\delta q_i^h} = U + 2t - 3tq_L^h - tq_L^{-h} - 3t(n - 2)q_i^h - 6tq_i^h - t(n - 1)q_i^{-h} - T_h = 0$$

We derive the best reply functions (BRF), i.e. $q_i^h(q_L^h, q_L^{-h}, T_h, T_{-h})$. The leader L_0 competes in quantities with the leader L_1. They maximize simultaneously their profit:

$$\pi_L^h = (p_h - c)q_L^h - kF_h \tag{3.17}$$

for $h = 0,1$, where p_h, again, is given by (3.3) and (3.4). Substituting the followers' BRF into (3.17) and solving the 2-first order conditions system, i.e. $\delta \pi_L^h / \delta q_L^h = 0$, with $h = 0,1$, we derive $q_L^h(T_0, T_1)$ and so the quantities $q_i^h(T_0, T_1)$ of the followers. In the first stage, the airports compete choosing the input prices, T_h. The profit function for airport h can be written as:

$$\pi_A^h = (T_h - c)(n - 1)q_i^h - (1 - k)F_h \tag{3.18}$$

for $h = 0,1$. Substituting $q_i^h(T_0, T_1)$ into (3.18), we solve the 2-first order conditions system, i.e. $\delta\pi_A^h / \delta T_h = 0$, with $h = 0,1$, finding solutions for all variables. The superscript PD is used to denote them. Specifically, for facility $h = 0,1$ and $i = 1, ..., n-1$ we obtain:

$$T_h^{PD} = \frac{\left(2 + n\left(-155 + 64n(3 + n(37 + 32n))\right)\right)c + \left(3(1 + 2n)(1 + 8n)(-1 + 16n)\right)(2t + U)}{-1 + n\left(-137 + 16n(39 + 4n(49 + 32n))\right)}$$

$$p_h = \frac{\delta^{PD}c + (\theta^{PD} - \delta^{PD})(2t + U)}{\left((-1 + 4n)(5 + 16n)(-1 - 137n + 624n^2 + 3136n^3 + 2048n^4)\right)}$$

$$q_i^{h\,PD} = \frac{(1 + 8n)(-2 - 91n + 240n^2 + 1664n^3 + 1024n^4)(2t + U - c)}{\left((-1 + 4n)(5 + 16n)(-1 - 137n + 624n^2 + 3136n^3 + 2048n^4)\right)t}$$

$$q_L^{h\,PD} = \frac{3(-1 + 4n)(1 + 2n)(-2 - 91n + 240n^2 + 1664n^3 + 1024n^4)(2t + U - c)}{\left((-1 + 4n)(5 + 16n)(-1 - 137n + 624n^2 + 3136n^3 + 2048n^4)\right)t}$$

where:

$\delta^{PD} \coloneqq 4(-1 + n(276 + n(3 + 64n(-124 + n(-123 + 16n(33 + 32n))))))$

$\theta^{PD} \coloneqq \left((-1 + 4n)(5 + 16n)(-1 - 137n + 624n^2 + 3136n^3 + 2048n^4)\right)$

Analytical results for profits are shown in the Appendix B, as a function of parameters depending on n, so on the number of followers in the downstream market. The parameters are defined in the Appendix B.

Two types of agreements are anti-competitive: (i) "Vertical Collusion", where the merger implies a downstream market foreclosures by setting the ticket price equal to the input charge, $p_h^C = T_h^C$, i.e. price-squeeze; (ii) "Airlines in the upstream market", where $q_i^{h\,AUM} = 0$ as well and the followers are driven out of the market. With respect to the case of "Price Discrimination", the airport will never make $p_h^{PD} = T_h^{PD}$, or it would lose all revenues except kF_h, which only covers part of the fixed costs and is not relevant for the determination of T_h^{PD}. Therefore, this type of contract does not foreclosure the downstream market.

With respect to the case of "Airlines in the upstream market", it is possible to find that, if the leader does not improve efficiency in the airport facilities it operates, the agreement may only be interesting for both partners if the leader airline pays a rent to the airport that compensates it for its losses: there is an interval in which values for this

rent exist. Moreover, with respect to the case of "Price Discrimination", it is possible to find that there are no incentives for airports and airlines to sign it: there is not a value for the rent the leader airline pays to the airport that is interesting for both parties. Specifically, the rent the leader airline pays to the airport, kF_h, must, at least, compensate the airport for its losses, i.e., $\pi_A^{h^{PD}} \geq \pi_A^{h^{NA}}$, that is:

$$kF_h \geq \left(T_h^{NA} - c\right)Q_h^{NA} - \left(T_h^{PD} - c\right)(n-1)q_i^{h^{PD}} \qquad (3.19)$$

On the other hand the leader will only pay a rent kF_h that does not diminish its profits, that is:

$$kF_h \leq (p_h^{NA} - T_h)q_L^{h^{NA}} - (p_h^{PD} - c)q_L^{h^{PD}} \qquad (3.20)$$

Substituting the equilibrium values for all variables into (3.18) and (3.19) we obtain:

$$kF_h \geq M \frac{(-c+2t+U)^2}{t} \qquad \text{and} \qquad kF_h \leq N \frac{(-c+2t+U)^2}{t}$$

where M and N are parameters depending on the number of followers in the downstream market, as defined in Appendix B. We find that for every fixed value of $(U + 2t - c)^2/t > 0$ given $n > 1$, i.e., at least one follower is present in the downstream market, there is no value of kF_h that matches the above conditions, i.e. that makes the agreement interesting for both partners[47].

With respect to the symmetric cases, in each scenario we find that the input charges increase with the marginal cost of the facilities, namely c in the cases of "No – Agreement", "Vertical Collusion" and "Airlines in the upstream market", or $(r + tm)$ in the case of "Airlines in the upstream market". Specifically, we find $T_h^C < T_h^{NA}$, for $h = 0,1$, that is at each facility the input charge in the case of "Two sided Vertical Collusion" is smaller than the input charge in the case of "Two sided No Agreement". Indeed, $Q_h^C \geq Q_h^{NA}$ and $p_h^C \leq p_h^{NA}$, because of the internalization of vertical externalities due to a double-marginalization effect; therefore, a smaller value for T_h^C is sufficient for the colluded firm to engage in price squeezing. For a similar reason, even in the case of "Two sided Price Discrimination" we find $T_h^{PD} \leq T_h^{NA}$: the internalization of vertical externalities occurs since the leader airline pays the airport a part kF_h of its fixed costs and the variable cost of its facility, i.e. two-part tariff.

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[47] As an example, for n=2, i.e. only one follower is present in the downstream market, we obtain $kF_h \geq 0,045(U + 2t - c)^2/t$ and $kF_h \leq 0,028(U + 2t - c)^2/t$. For n=3, we obtain $kF_h \geq 0,049(U + 2t - c)^2/t$ and $kF_h \leq 0,021(U + 2t - c)^2/t$

In each case, final prices for consumers, p_h, increase with the marginal cost of the facilities, as well as with the gross benefit U of consumers and the transportation cost t, thus reflecting adjustments in consumer behavior to the changing; the quantities of carriers, both the leader and the followers, decrease with the marginal cost of the facilities; moreover, they increase with the gross benefit U and decrease with the transportation cost t, when $c - U < 0$, i.e. when the consumers' willingness to pay is greater than the airport marginal cost. The reason for this is that when the transportation cost increases providing services is less effective than before, as passengers' responsiveness is reduced by lower accessibility: indeed, passengers may not necessarily choose the airport with cheaper fare, but may go to an airport that is nearer and has a shorter total travel time.

Finally, with respect to the issue of airlines competition, we find an increase in the number of followers in the downstream market leads to a decrease in the equilibrium prices at each facility. Demand measured by the total number of flights offered, increase at each facility as a consequence of the decreasing prices. Both consumer surplus and welfare increase with an increase in the number of followers: competitiveness in the airlines market has positive effects in social terms.

3.3.2 Asymmetric cases

In this section we specify six cases with respect to the choices of the airport and its dominant airline at facility 0: (i) "No Agreement" – "Vertical Collusion"; (ii) "No Agreement" – "Airlines in the upstream market"; (iii) "No Agreement" – "Price Discrimination"; (iv) "Vertical Collusion" – "Airlines in the upstream market"; (v) "Vertical Collusion" – "Price Discrimination"; (vi) "Airlines in the upstream market" – "Price Discrimination". Specifically, in each case, the first choice refers to the one of the airport and its dominant airline at facility 0; the second choice refers to the one at facility 1.

In each case, the profit functions of the airports, the dominant airline and the followers are defined as in the previous sections, according to the different choices in the two

facilities. Backward induction is used to find solutions for all variables, as in the previous section: specifically, closed-form solutions for prices, input charges, quantities, profits and welfare are obtained as a function of parameters depending on the number of followers in the downstream market[48]. Moreover, results with respect to the choices of the airport and its dominant airline at facility 1 are symmetric to those obtained with respect to the choices at facility 0.

3.4 The optimal strategies of airports and airlines

We find the Nash equilibrium of the game where airports and their dominant airline decide whether to enter into a contract and, if so, which one to engage in among the three different types of agreements analyzed in the previous section.

In the cases of "No – Agreement" (NA), "Airlines in the upstream market" (AUM) and "Price Discrimination" (PD) we consider the sum of the airport's and leader airline's profits and we compare it with the profit of the merged firm in the case of "Vertical Collusion" (C)[49]. With respect to "Airlines in the upstream market", we suppose that $c = r + tm$, i.e., the leader airline does not improve the terminal operations efficiency. Hence, a direct comparison of the profits obtained in all the cases is possible. In particular, we find that given $n > 1$, i.e., at least one follower is present in the downstream market, it is:

$$\pi_h(C, x_{-h}) \geq \pi_h(x_h, x_{-h}) \quad \forall\, h = 0,1 \quad \forall x_h \in X_h \quad \forall x_{-h} \in X_{-h}$$

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[48] The results are available from request by the author. Superscripts NA, C, AUM and PD will be used to denote the parameters according to the different choices in the two facilities. In each case, the first superscript refers to the one of the airport and its dominant airline at facility 0, the second to the one at facility 1

[49] Such a framework implies a perfect alignment between the interests of the two agents, namely the airport and the dominant airline in each facility. This is the case, because we assume there are no transaction costs of colluding or signing any other type of contract. Clearly, if the agents are subject to transaction costs, if they can benefit from informational advantages, or if there are situations in which irreversible investments must be made, then it is reasonable to expect that a perfect alignment between the interest of the two parts does not occur and the equilibrium of the game may change: a contract economics approach would be more suitable to evaluate if each part alone has an incentive for vertical collusion.

where $X_h = \{NA, C, AUM, PD\}$ is the action set of the player h, namely the airport – dominant airline system in the facility h, and $\pi_h(x_h, x_{-h})$ is the payoff [50] of the system h when its choice is x_h and the choice of the other system is x_{-h}.

Therefore, an iterated dominant strategy equilibrium exists, $s^* = (C, C)$, that is, in each facility the airport and the dominant airline have incentive to collude. The result can be summarized as follows.

Proposition 3.1

In the context of an infinite linear city and two competing facilities, if both the two airport-leader airline systems share the same market and anticipate that her rival plays the best strategy, both of them have incentive to collude, given at least a follower is present in the downstream market.

The equilibrium input charges, quantities, final prices, payoffs, consumer surplus and welfare are:

$$T_h = \frac{12nc + (1 + 8n)(2t + U)}{1 + 20n} \qquad p_h = \frac{12nc + (1 + 8n)(2t + U)}{1 + 20n}$$

$$q_i^h = 0 \qquad q_h^C = \frac{3n(2t + U - c)}{(1 + 20n)t}$$

$$\pi_i^h = 0 \qquad \pi_h^C = \frac{3n(1 + 8n)(2t + U - c)^2}{(1 + 20n)^2 t} - F_h$$

$$CS = \frac{1}{2}t\left(-4 + \frac{72n^2(2t + U - c)^2}{(1 + 20n)^2 t^2}\right) \qquad W = \frac{(6n + 84n^2)(2t + U - c)^2}{(1 + 20n)^2 t} - 2t - F_0 - F_1$$

The results hold under our maintained assumptions, that is $2U \geq p_0 + p_1 + 4t$, i.e. everyone in the [0,1] interval decides to fly, and $|p_1 - p_0| < 4t$, i.e. both airports receive consumers from [0,1]. Substituting the equilibrium final prices, we derive[51]:

$$U - c - 5t \geq 0$$

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[50] The payoff $\pi_h(x_h, x_{-h})$ of the system h is equal to the colluded firm's profit when "Vertical Collusion" is signed, i.e. when its choice is $x_h = \{C\}$, while it is equal to the sum of the airport h's profit and its dominant airline's profit when no agreement or any other type of agreement is signed, i.e. i.e. when its choice is $x_h \in \{NA, AUM, PD\}$.

[51] We obtain $U - c - t((1 + 14n)/3n) \geq 0$: given $-(1 + 14n)/3n$ is an increasing function of n, with $n>0$, if the relationship is satisfied for n=1, then it is $\forall$ $n>0$.

The result differs from the findings of Barbot (2009), where there are no incentives for collusive agreements when both pairs of firms share the same market. Our results depend on the hypothesis that in the model, i.e. infinite linear city, there would be some consumers for whom the sum of the flight's price plus the total transportation costs would exceed their reservation price: in other words, we do not assume that the market is covered, or that $Q_0 + Q_1 = 1$, as in the usual Hotelling address model. In the case of a one sided vertical collusion, i.e. when only a pair of firms decide to engage in vertical collusion, the colluded firm's demand, Q_1 (or Q_2) increases by a larger amount and the left-alone firm's demand, Q_2 (or Q_1) also increases, depending on the price elasticities of demands. The same applies to the case of a "Two sided Vertical Collusion", with both merged firms disputing in identical conditions the demand from the consumers that did not fly before the collusion.

Finally, with respect to the consumer surplus and to the social welfare, we find that:

$$CS^C = \frac{1}{2}t\left(-4 + \frac{\delta^{C^2}(2t+U-c)^2}{\theta^{C^2}t^2}\right)$$

$$W^C = \frac{\phi^C(2t+U-c)^2}{\theta^{C^2}t} - 2t - F_0 - F_1$$

$$CS^{PD} = \frac{1}{2}t\left(-4 + \frac{\delta^{PD^2}(2t+U-c)^2}{2\theta^{PD^2}t^2}\right)$$

$$W^{PD} = \frac{\phi^{PD}(2t+U-c)^2}{\theta^{PD^2}t} - 2t - F_0 - F_1$$

where:

$\delta^C = \sqrt{72}n$,

$\delta^{PD} = -4 + 1104n + 12n^2 - 31744n^3 - 31488n^4 + 135168n^5 + 131072n^6$,

$\theta^C = 1 + 20n$

$\theta^{PD} := (-1 + 4n)(5 + 16n)(-1 - 137n + 624n^2 + 3136n^3 + 2048n^4)$

$\phi^C = 6n + 84n^2$

$\phi^{PD} = 4.2 \times 10^9(-0.43 + n)(-0.20 + n)(-0.19 + n)(-0.06 + n)(-0.014 + n)(0.028$
$\qquad + n)(0.27 + n)(0.34 + n)(0.38 + n)(0.5 + n)(0.93 + n)(1.54 + n)$

Given $n > 1$ we get:

$$\frac{\delta^{PD^2}}{2\theta^{PD^2}} > \frac{\delta^{C^2}}{\theta^{C^2}} \qquad \text{and} \qquad \frac{\phi^{PD}}{\theta^{PD^2}} > \frac{\phi^C}{\theta^{C^2}} \qquad\qquad (3.21)$$

From inequality (3.21), when $c - U < 0$, i.e. when the consumers' willingness to pay is greater than the airport marginal cost, it follows that:

$$\frac{\delta^{PD^2}(2t+U-c)^2}{2\theta^{PD^2}t^2} > \frac{\delta^{C^2}(2t+U-c)^2}{\grave{e}^{C^2}t^2} \qquad \text{and} \qquad \frac{\phi^{PD}(2t+U-c)^2}{\theta^{PD^2}t} > \frac{\phi^C(2t+U-c)^2}{\theta^{C^2}t}$$

Therefore, we conclude that:

$$CS^{PD} > CS^C \qquad \text{and} \qquad W^{PD} > W^C$$

that is both consumer surplus and social welfare are lower in the case of "Two sided Vertical Collusion".

Hence, the Nash equilibrium is not efficient in social terms: indeed consumer surplus and social welfare are maximized at $s' = (PD, PD)$, namely in the case of "Two sided Price Discrimination". Indeed, as we noted previously, internalization of vertical externalities occurs since the leader airline pays the airport a part kF_h of its fixed costs and the variable cost of its facility, i.e. two-part tariff. Nevertheless, the result of the "Two sided Vertical Collusion" case is not perfectly repeated here: in the case of "Two sided Price Discrimination", the airport will never make $p_h^{PD} = T_h^{PD}$, or it would lose all revenues except kF_h, which only covers part of the fixed costs. Therefore, this type of contract does not foreclosure the downstream market, i.e. $q_i^{h^{PD}} > 0$ and $Q_h^{PD} \geq Q_h^C$ or $p_h^{PD} \leq p_h^C$.

However, there are no incentives for airports and airlines to sign it; therefore there is a misalignment between private and social incentives.

3.5 Concluding remarks

In this paper, vertical contracts between airports and airlines in the context of two competing facilities and three different types of agreements have been considered. Specifically, we have developed a multistage facility-rivalry game and we have investigated the Nash equilibrium to analyze the incentives for vertical contracts and the effects in terms of welfare, consumer surplus and pro-competitiveness. The paper adds to existing literature as it considers the issue of vertical contracts both in airports and airlines competition: indeed, we have analyzed the case of a leader and *n-1* followers at each facility. Moreover, airports do not compete for the airlines but compete through airlines to get passengers.

The contributions of this paper to the literature are the following. With respect to the issue of airlines competition, results show that with an increase in the number of followers in the downstream market there is a decrease in the equilibrium prices at each facility. The total number of flights offered increase at each facility as a consequence of the decreasing prices. Both consumer surplus and welfare increase with an increase in the number of followers: competitiveness in the airlines market has positive effects in social terms. With respect to the issue of airports competition, we have found that the airport and the dominant airline at each facility may have incentives to collude. The result differs from the findings of Barbot (2009), where there are no incentives for collusive agreements when both pairs of firms share the same market. Our findings depend on the hypothesis that in the model, i.e., infinite linear city, there would be some consumers for whom the sum of the flight's price plus the total transportation costs would exceed their reservation price: in other words, we do not assume that the market is covered.

The results raise some policy issues and avenues for future research. In particular, the merger implies a downstream market foreclosure through a price-squeeze strategy: the follower airlines are driven out of the market and the equilibrium is anti-competitive. On the other hand, consumers' surplus and welfare increase with respect to the case in which no agreement occurs: indeed, final quantities increase and final prices for consumers decrease because of the internalization of vertical externalities due to a double-marginalization effect. Therefore, the agreement exhibits a trade-off between competitiveness and welfare. In addition, the equilibrium is not efficient in social terms: consumer surplus and social welfare, though increasing with respect to the case in which no-agreement occurs, are maximized in the case of another type of agreement, that is "Price Discrimination". The problem is that there are no incentives for airports and airlines to sign it: therefore there is a misalignment between private and social incentive.

In this sense, the problem of vertical relations constitutes a fundamental issue because of the ensuing regulatory requirements and further developments of the present work may go along two directions within the scope of policy implications: on one hand, how regulation might balance the trade-off raised by the vertical collusive agreement, by

giving room for the merger, so leaving consumers better-off, but not for market foreclosure; on the other hand, how regulation could provide incentives, both to airports and dominant airline, for other types of agreements, namely those that maximize social welfare, (i.e. "Price Discrimination" in this framework).

Conclusions

This dissertation provides new contributions on air transport economics with respect to the issue of vertical relations between airports and airlines.

Chapter 1 seeks to review models on vertical relations between airports and carriers drawn in the literature during the last two decades, while assessing how deregulation of the air transport market created the incentives for airport-airline interaction as well as the different forms of cooperation observed in practice. The contribution of this chapter is twofold. First, we provide an interpretive review of the main ideas developed by the literature on airport-airline interaction with a particular attention on the models used to represent formally vertical relations. In this sense, the paper differs from previous contributions by Fu et al. (2011) and Starkie (2012) which do examine forms of cooperation between airports and carriers but focus primarily on competition concerns as well as policy and regulatory implications. Second, we discuss in a general unifying framework three elements that still seem to lack of understanding with respect to airports-airlines interaction: (i) incomplete contracts and asymmetric information structure; (ii) upstream horizontal complementarities; (iii) airports as two sided platforms.

The research project presented in Chapter 2 investigates the issue of vertical relations between airports and airlines focusing on the basic mechanism of that relation – the airport pricing. The paper adds to literature by taking into account the positive relationship between congestion and the consumption of concession goods, through dwell time, while incorporating the effect of passenger types. We confirm a positive externality of concession activities on the aeronautical charge: the airport can have

incentives to reduce the aeronautical charge so as to increase passengers' dwell time and their consumption of concession goods. Indeed, there is a downward correction for the congestion toll due to the positive externality of delay. Nevertheless, this correction may even turn the congestion toll into a subsidy, and this is in contrast with previous literature on airport pricing. Furthermore, we show that there is a correction on the optimal airport charge, as the passenger volume changes when the airport charge increases. In the case of two types of travelers, for some levels of delay this correction may be a mark-up rather than the traditional mark-down. Therefore, the optimal airport charge can be higher than what would prevail if passengers are treated as a single type. Finally, the comparison between privately and socially optimal airport charges highlights two interesting results. First, in some cases the welfare maximizing airport can have more incentives, with respect to a profit maximizing airport, to induce congestion. Second, the profit maximizing airport may impose a lower charge than the welfare maximizing airport, so as to adjust the impact of changes in the pool of potential consumers for concession services.

In Chapter 3, three types of vertical contracts are considered in the context of two competing facilities and competing airlines. Indeed, there are several forms of contracts observed in practice, such as concession revenues sharing agreements, airline ownership or control of airport facilities, long term use contracts, negotiated input charge, airport issuance of revenue bonds. Obviously, different contractual arrangements may exhibit different incentives to be signed, as well as be welfare-enhancing or not, pro or anti-competitive, depending on the competitive pressure in the upstream and downstream market. Hence, the research project develops a multistage facility-rivalry game to analyze the incentives for vertical contracts and the effects in terms of welfare, consumer surplus and pro-competitiveness, including both airports and airlines competition. We find that both consumer surplus and welfare increase with an increase in the number of followers: hence, competitiveness in the airlines market has positive effects in social terms. Moreover, we find that the airport and the dominant airline at each facility may have incentives to vertical integration when competing with another pair. The result differs from the some previous contributions who find that no incentives for vertical merger agreements appear when both pairs of firms share the same market. Finally, the merger implies a downstream market foreclosure through a price-squeeze

strategy: the follower airlines are driven out of the market and the equilibrium is anti-competitive. On the other hand, welfare increase with respect to the case in which no agreement occurs. Therefore, the agreement exhibits a trade-off between competitiveness and welfare.

A major conclusion is that the problem of vertical relations constitutes a fundamental issue because of the ensuing regulatory requirements: airport-airline interaction matters and need to be investigated very carefully since there can be negative as well as positive outcomes in terms of welfare and competitiveness. Starkie (2011) argues that the use of long-term contracts between airlines and airports is beneficial for passengers and that application of competition law should be favored over sector specific regulation. Fu et al. (2011) conclude that the beneficial effects of vertical cooperation need to be weighed against the negative effects. Such practices can improve welfare but may cause a negative effect on airline competition: an airport may strategically cooperate with its dominant airlines, which can further strengthen these firms' market power.

Within the scope of policy implications, the main insights can be derived as follows: on one hand, how regulation might balance the trade-off raised by the vertical agreements, by giving room for the merger, so leaving consumers better-off, but not for market foreclosure; on the other hand, how regulation could provide incentives, both to airports and dominant airline, for welfare enhancing agreements.

Vertical integration and contractual arrangements between airports and airlines are an important tool for protecting and promoting sunk investment by airlines. However, in most cases, negotiating long-term contracts between airports and airlines prior to the end-users making any sunk investment is simply not feasible. Even if contractual arrangements can be signed, they are not perfect: the transactions costs of negotiating a long-term contract may outweigh the benefits; or the costs of negotiating over all possible contingencies may be such that contractual arrangements are inevitably incomplete, either limited in time, or limited in scope, or both. Finally, contracts may be signed within an asymmetric information structure, since one of the parties – or both – cannot directly observe the other party's effort. In this framework, we think that attention to the airport–airline vertical relationship from the standpoint of hold-up and moral hazard problems still has not been sufficiently paid. Nevertheless, a better

understanding is needed: results may justify, for example, incentive/risk mitigating payments by vertical contract from local or secondary airports to LCCs, even when the airport is owned by the local government, since these contracts may achieve the first best efficient effort levels and restore the first best utility levels.

Airport infrastructure provision is characterized by horizontal complementarities as well as vertical market structures. Indeed, airports provide complementary services to all of those airports to which they are connected and, as the providers of essential infrastructure facilities, to airlines across airports that serve the same origin-destination markets. Literature explains that one rationale for consolidation among airports may be the elimination - through cooperation on service offerings and on the setting of airport charges - of market imperfections such as double marginalization in vertical related markets: by eliminating multiple price mark-ups on marginal costs, airport groups may improve their profits or social welfare while making their services more attractive to airlines. In this context, what literature investigating airport alliances and complementarities still is missing is to explore the incentives to horizontal coordination in the upstream market, depending on downstream countervailing power: can airports serving serve the same origin-destination market have incentive to form an alliance to contrast the countervailing power of the dominant airline serving that market? And which are the effects in terms of welfare?

Moreover, the outcome of the bargaining process between the upstream and the downstream firms may depend on the contract type through which trading is conducted. On these grounds, it may also be noteworthy to examine the differences between the outcomes of different types of contract, in terms of welfare, possible subsidization of passenger traffic or distribution of profits among the players. To the best of our knowledge, we are not aware of formal models of competition between vertical chains of airports and airlines dealing with bargaining process and different contract types, at the same time. Thus, we think literature may be innovative on this account.

Finally, we point out that airports are candidates to be considered as two sided platforms, that is markets with externalities in which they can cross-subsidize the two sides through the pricing structure. The end users are the airlines and the passengers, who both benefit from each other's existence and join the platform to interact. Airports

add value to both sides by internalizing network effects which exist between the two demand groups.

Researches in this framework are a contribution to the air transport debate since airports have been considered as two-sided platforms either theoretically or empirically only in very few works. This is really important, since the correct definitions of market and market power is crucial for regulators: it is essential to understand the business model of airports but this can be understood and tested only if the market structure is correctly identified.

These considerations also question the existing approaches to airport regulation. It has been argued that regulation may be unnecessary – in that airport charges may be kept down and capacity investments may be more efficient – if deeper collaboration between airlines and airports was allowed and encouraged or, on the other hand, if airlines had enough countervailing power. Thus, the analysis of different forms of cooperation between airports and airlines emerges as an obvious answer to this intuition. Some contributions take the view that single till may give wrong incentives in terms of investment: they show, crucially, that the dual-till approach is desirable when the airport capacity is close to saturation or suffers congestion, while the single-till approach is better when there is spare capacity. In a two-sided market setting, for example, the airport may not maximize profits and can clearly do cross-subsidization between the two sides: it is the single-till price cap regulation that can capture this cross-subsidization. Thus, regulators should take into account that airports even with market power could have less incentive to use or abuse this power because of the complementarity between airside and non-airside revenues and this is a good example of two-sided platform thinking: the debate of single-till versus dual-till can be reconsidered under this thinking .

On the theoretical side, evaluating how and why airports and airlines use contracts to coordinate their activities is crucial to analyzing the organization and efficiency of economic contractual exchange, as well as policy implications. Nevertheless, we regret the absence of empirical verification of the economics of contracts: for policy makers understanding and testing the functions and the implications of various contract terms is a prerequisite to distinguish between efficient and anti-competitive practices and to

developing appropriate policies. In addition, while usually theoretical conclusions indicated qualitative effects of airport-airline bargaining, it is not clear how significant these effects are in practice.

Great efforts have been made to ensure the applicability of analytical investigation. Still, to make the model tractable, works usually make routine simplifications such as symmetric airlines and constant marginal costs. Therefore, even greater efforts should be make in building empirical: they allow one to verify the analytical conclusions, and to quantify the actual impacts of airport-airline vertical relationships.

This is something that seems quite important to be explicitly taken into account if one is to apply to policy making what has been learned from analytical models.

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Appendix A

Proof of Lemma 2.1

Differentiating equation (2.7) on both sides with respect to the ticket price p, we have:

$$\frac{dQ_L}{dp} = \frac{1}{\psi}[-b_B - (v_B - v_L)\theta]$$

$$\frac{dQ_B}{dp} = \frac{1}{\psi}[-b_L + (v_B - v_L)\theta]$$

$$\frac{dQ}{dp} = \frac{dQ_B}{dp} + \frac{dQ_L}{dp} = \frac{1}{\psi}[-b_B - b_L]$$

where $\psi = [b_B b_L + (v_B b_L + v_L b_B)\theta] > 0$. Since $v_B > v_L$, we obtain $dQ_L/dp < 0$ while the sign of dQ_B/dp is undetermined. Since $b_B > 0$ and $b_L > 0$, we obtain $dQ/dp < 0$.

Proof of Lemma 2.2

Differentiating equation (2.8) on both sides, we have:

$$\frac{dQ^*}{dp_a} = \frac{n}{(1+n)\frac{dp}{dQ} + Q\frac{d^2p}{dQ^2} - (1+n)\beta\theta} < 0$$

where $d^2p/dQ^2 = 0$ as the inverse demand for air travel is linear and $dp/dQ < 0$ from Lemma 2.1. Therefore,

$$\frac{dp^*}{dp_a} = \frac{dp}{dQ}\frac{dQ^*}{dp_a} > 0$$

From equations (2.7) and (2.8) we derive:

$$q_L^{i\,*} = \frac{(a_L - c - p_a)\big((1+n)(b_B + \theta(\beta + v_B))\big) - (a_B - c - p_a)\big(n\theta(\beta + v_L) + \theta(\beta + v_B)\big)}{H}$$

$$q_B^{i\,*} = \frac{(a_B - c - p_a)\big((1+n)(b_L + \theta(\beta + v_L))\big) - (a_L - c - p_a)\big(n\theta(\beta + v_B) + \theta(\beta + v_L)\big)}{H}$$

where:

$$H = (1+n)^2\big(b_B + \theta(\beta + v_B)\big)\big(b_L + \theta(\beta + v_L)\big)$$
$$- \big(n\theta(\beta + v_B) + \theta(\beta + v_L)\big)\big(n\theta(\beta + v_L) + \theta(\beta + v_B)\big)$$

Therefore we obtain:

$$\frac{dq_L^{i\,*}}{dp_a} = \frac{1}{H}[n\theta(v_L - v_B) - b_B(1+n)]$$

$$\frac{dq_B^{i\,*}}{\partial p_a} = \frac{1}{H}[n\theta(v_B - v_L) - b_L(1+n)]$$

From the concavity condition of airlines' profit function, we derive:

$$\pi_{BB}^i \pi_{LL}^i - \pi_{LB}^i \pi_{BL}^i = 4[b_B + \theta(\beta + v_B)][b_L + \theta(\beta + v_L)] - [\theta(\beta + v_B) + \theta(\beta + v_L)]^2 > 0$$

with $\pi_{BB}^i \pi_{LL}^i - \pi_{LB}^i \pi_{BL}^i|_{n=1} = H|_{n=1} = \partial H/\partial n\,|_{n=1}$. Therefore, when $n = 1$, $H > 0$.
Moreover,

$$\frac{d^2 H}{dn^2} = 2[b_B + \theta(\beta + v_B)][b_L + \theta(\beta + v_L)] > 0$$

that is, $\partial H/\partial n$ is an increasing function of n. Therefore, we derive that $H > 0 \ \forall \ n \geq 1$.
Since $v_B > v_L$, we have that $dq_L^{i\,*}/dp_a < 0$ but the sign for $dq_B^{i\,*}/dp_a$ is undetermined.

Proof of Proposition 2.3

(1) Let Δ_1 be the difference between the first terms of the second line of equations (12) and (19).

$$\Delta_1 = (p_c^{\Pi} - c_c) \sum_{h \in \{B,L\}} Q_h \frac{\partial \bar{G}_h(p_c^{\Pi}; D(Q))}{\partial D} - \delta \sum_{h \in \{B,L\}} Q_h \int_{c_c}^{\bar{u}} \frac{\partial \bar{G}_h(z; D(Q))}{\partial D} dz$$

If $\delta = 1$ we have

$$\Delta_1 = \sum_{h \in \{B,L\}} Q_h \int_{c_c}^{p_c^\Pi} \frac{\partial \bar{G}_h(p_c^\Pi; D(Q))}{\partial D} dz - \sum_{h \in \{B,L\}} Q_h \int_{p_c^\Pi}^{\bar{u}} \frac{\partial \bar{G}_h(z; D(Q))}{\partial D} dz - \sum_{h \in \{B,L\}} Q_h \int_{c_c}^{p_c^\Pi} \frac{\partial \bar{G}_h(z; D(Q))}{\partial D} dz$$

$$< \sum_{h \in \{B,L\}} Q_h \int_{c_c}^{p_c^\Pi} \frac{\partial \bar{G}_h(p_c^\Pi; D(Q))}{\partial D} dz - \sum_{h \in \{B,L\}} Q_h \int_{c_c}^{p_c^\Pi} \frac{\partial \bar{G}_h(z; D(Q))}{\partial D} dz$$

Given $\partial^2 \bar{G}_h(p_c; D)/\partial p_c \partial D < 0$, we have that

$$\sum_{h \in \{B,L\}} Q_h \int_{c_c}^{p_c^\Pi} \frac{\partial \bar{G}_h(p_c^\Pi; D(Q))}{\partial D} dz < \sum_{h \in \{B,L\}} Q_h \int_{c_c}^{p_c^\Pi} \frac{\partial \bar{G}_h(z; D(Q))}{\partial D} dz$$

Therefore, $\Delta_1 < 0$.

If $\delta = 0$ we have

$$\Delta_1 = (p_c^\Pi - c_c) \sum_{h \in \{B,L\}} Q_h \frac{\partial \bar{G}_h(p_c^\Pi; D(Q))}{\partial D} > 0$$

Therefore, since Δ_1 is linear in δ, there must exist some $\bar{\delta} \in (0,1)$ such that $\Delta_1 = 0$.

(2) Let Δ_2 be the difference between the second terms of the second line of equations (2.12) and (2.19).

$$\Delta_2 = (p_c^\Pi - c_c) \sum_{h \in \{B,L\}} \frac{dQ_h}{dp} \bar{G}_h(p_c^\Pi; D(Q)) - \delta \sum_{h \in \{B,L\}} \frac{dQ_h}{dp} \int_{c_c}^{\bar{u}} (z - c_c) g_h(z; D) dz$$

If $\delta = 1$ we have

$$\Delta_2 = \sum_{h \in \{B,L\}} \frac{dQ_h}{dp} \int_{p_c^\Pi}^{\bar{u}} (p_c^\Pi - c_c) g_h(z; D) dz - \sum_{h \in \{B,L\}} \frac{dQ_h}{dp} \int_{c_c}^{\bar{u}} (z - c_c) g_h(z; D) dz$$

Let $E_h^\Pi = \int_{p_c^\Pi}^{\bar{u}} (p_c^\Pi - c_c) g_h(z; D) dz$ and $E_h^W = \int_{c_c}^{\bar{u}} (z - c_c) g_h(z; D) dz$. Then

$$\Delta_2 = \frac{dQ_B}{dp}(E_B^\Pi - E_B^W) + \frac{dQ_L}{dp}(E_L^\Pi - E_L^W)$$

Since

$$E_h^W = \int_{p_c^\Pi}^{\bar{u}} (z - c_c) g_h(z; D) dz + \int_{c_c}^{p_c^\Pi} (z - c_c) g_h(z; D) dz > \int_{p_c^\Pi}^{\bar{u}} (z - c_c) g_h(z; D) dz$$

$$> E_h^\Pi$$

when $dQ_B/dp < 0$, that is, $(v_B - v_L)\theta < b_L$, we have $\Delta_2 > 0$. When $dQ_B/dp > 0$, $\Delta_2 > 0$ if and only if

$$-\frac{\dfrac{dQ_B}{dp}}{\dfrac{dQ_L}{dp}} < \frac{E_L^W - E_L^\Pi}{E_B^W - E_B^\Pi}$$

If $\delta = 0$ we have

$$\Delta_2 = \frac{dQ_B}{dp} E_B^\Pi + \frac{dQ_L}{dp} E_L^\Pi$$

when $dQ_B/dp < 0$, we have $\Delta_2 < 0$. When $dQ_B/dp > 0$, $\Delta_2 < 0$ if and only if

$$-\frac{\dfrac{dQ_B}{dp}}{\dfrac{dQ_L}{dp}} < \frac{E_L^\Pi}{E_B^\Pi}$$

Therefore, when $dQ_B/dp < 0$, since Δ_2 is linear in δ, there must exist some $\hat{\delta} \in (0,1)$ such that $\Delta_2 = 0$.

Appendix B

Table 3.3 Nomenclature

Case	Nomenclature	Variable	Description
"Two sided No Agreement"	NA	T_h^{NA}	Input charge at facility h
		p_h^{NA}	Ticket price per passenger at airport h
		$q_L^{h^{NA}}$	Number of flight offered by the leader at airport h
		$q_i^{h^{NA}}$	Number of flight offered by the follower i at airport h
		$\pi_L^{h^{NA}}$	Profit of the leader at airport h
		$\pi_i^{h^{NA}}$	Profit of the follower i at airport h
		$\pi_A^{h^{NA}}$	Profit of the airport h
		CS^{NA}	Consumer surplus
		W^{NA}	Social welfare
"Two sided Vertical Collusion"	C	T_h^C	Input charge at facility h
		p_h^C	Ticket price per passenger at airport h
		q_C^h	Number of flight offered by the colluded firm at facility h
		$q_i^{h^C}$	Number of flight offered by the follower i at airport h
		π_C^h	Profit of the colluded firm at facility h
		$\pi_i^{h^C}$	Profit of the follower i at airport h
		CS^C	Consumer surplus
		W^C	Social welfare
"Two sided Airlines in the upstream market"	AUM	$T_h^{r^{AUM}}$	Input charge for the use of the runway at facility h
		$T_h^{t^{AUM}}$	Input charge for the use of the terminal at facility h
		p_h^{AUM}	Ticket price per passenger at airport h
		$q_L^{h^{AUM}}$	Number of flight offered by the leader at airport h
		$q_i^{h^{AUM}}$	Number of flight offered by the follower i at airport h

		$\pi_L^{h^{AUM}}$	Profit of the leader at airport h
		$\pi_i^{h^{AUM}}$	Profit of the follower i at airport h
		$\pi_A^{h^{AUM}}$	Profit of the airport h
		CS^{AUM}	Consumer surplus
		W^{AUM}	Social welfare
"Two sided Price Discrimination"	PD	T_h^{PD}	Input charge at facility h
		p_h^{PD}	Ticket price per passenger at airport h
		$q_L^{h^{PD}}$	Number of flight offered by the leader at airport h
		$q_i^{h^{PD}}$	Number of flight offered by the follower i at airport h
		$\pi_L^{h^{PD}}$	Profit of the leader at airport h
		$\pi_i^{h^{PD}}$	Profit of the follower i at airport h
		$\pi_A^{h^{PD}}$	Profit of the airport h
		CS^{PD}	Consumer surplus
		W^{PD}	Social welfare

Profits

Two sided No Agreement

$$\pi_i^{h^{NA}} = \frac{27\sigma^{NA^2}(2t + U - c)^2}{\theta^{NA^2}t}$$

$$\pi_L^{h^{NA}} = \frac{\varepsilon^{NA}(2t + U - c)^2}{\theta^{NA^2}t}$$

$$\pi_A^{h^{NA}} = \frac{\eta^{NA}(2t + U - c)^2}{\theta^{NA^2}t} - F_h$$

Two sided Collusion

$$\pi_i^{h^{C}} = 0$$

$$\pi_C^h = \frac{\eta^C(2t + U - c)^2}{\theta^{C^2}t} - F_h$$

Two sided Airlines in the Upstream market

$$\pi_i^{h^{AUM}} = 0$$

$$\pi_L^{h^{AUM}} = \frac{\varepsilon^{AUM}(2t + U - r - tm)^2}{\theta^{AUM^2}t}$$

$$\pi_A^{h\,AUM} = \frac{\eta^{AUM}(2t + U - r - tm)^2}{\theta^{AUM^2}t} - F_h$$

Two sided Price Discrimination

$$\pi_i^{h\,PD} = \frac{3\sigma^{PD^2}(2t + U - c)^2}{\theta^{PD^2}t}$$

$$\pi_L^{h\,PD} = \frac{\varepsilon^{PD}(2t + U - c)^2}{\theta^{PD^2}t} - kF_h$$

$$\pi_A^{h\,PD} = \frac{\eta^{PD}(2t + U - c)^2}{\theta^{PD^2}t} - (1 - k)F_h$$

Value of parameters for profits

$$\theta^{NA} := (-1 + 4n)(5 + 16n)(-4 + 23n + 80n^2)$$

$$\sigma^{NA} := (1 + 8n)(-1 + 3n + 16n^2)$$

$$\varepsilon^{NA} := 27(1 + 2n)(-1 + 4n)(1 + 8n)(-1 + 3n + 16n^2)^2$$

$$\eta^{NA} := 3(1 + 2n)(-1 + 4n)(5 + 16n)(-1 + 16n)(-2 - 5n + 16n^2)(-1 + 3n + 16n^2)$$

$$\theta^C := 1 + 20n$$

$$\eta^C := 3n(1 + 8n)$$

$$\theta^{AUM} := (2 + 31n)(1 + 20n)$$

$$\varepsilon^{AUM} := 3n(1 + 8n)(1 + 17n)^2$$

$$\eta^{AUM} := 3n(1 + 14n)(1 + 17n)(1 + 20n)$$

$$\theta^{PD} := (-1 + 4n)(5 + 16n)(-1 - 137n + 624n^2 + 3136n^3 + 2048n^4)$$

$$\sigma^{PD} := (1 + 8n)(-2 - 91n + 240n^2 + 1664n^3 + 1024n^4)$$

$$\varepsilon^{PD} := 27(1 + 2n)(-1 + 4n)(1 + 8n)(1 - 55n + 24n^2 + 896n^3 + 1024n^4)^2$$

$$\eta^{PD} := 3(-1 + n)(1 + 2n)(-1 + 4n)(-1 + 16n)(5 + 16n)(1 + 8n)^2(-2 - 91n + 240n^2 + 1664n^3$$
$$+ 1024n^4)$$

Value of parameters for the rent

$$M = \frac{3(1 - 16n)^2(1 + 2n)^3(-1 + 4n)}{\left(-4 + n(23 + 80n)\right)^2\left(-1 + n\left(-137 + 16n(39 + 4n(49 + 32n))\right)\right)^2} \cdot$$

$$\frac{\left(6 + n\left(305 + n\left(-2335 + 64n\left(-148 + n(505 + 16n(115 + 64n))\right)\right)\right)\right)}{\left(-4 + n(23 + 80n)\right)^2\left(-1 + n\left(-137 + 16n(39 + 4n(49 + 32n))\right)\right)^2}$$

$$N = \frac{27(1+2n)^2(1+8n)(-1+16n)\big(-1+n(7+24n)\big)}{(5+16n)\big(-4+n(23+80n)\big)^2\left(-1+n\left(-137+16n\big(39+4n(49+32n)\big)\right)\right)^2} \cdot$$

$$\frac{\left(-3+n\left(377+4n\left(-583+2n\left(-1361+8n\big(559+64n(37+28n)\big)\right)\right)\right)\right)}{(5+16n)\big(-4+n(23+80n)\big)^2\left(-1+n\left(-137+16n\big(39+4n(49+32n)\big)\right)\right)^2}$$