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MARKET POWER OF HUB AIRPORTS: THE ROLE OF LOCK-IN EFFECTS AND DOWNSTREAM COMPETITION

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ABSTRACT

In this paper we develop a model of hub competition, which includes duopolistic Bertrand competition on the downstream market in order to analyze the incentives of hub airports to exploit market power in the transfer passenger market. We find evidence that downstream competition limits hub market power and moreover, that there are incentives for a hub airport and its respective network carrier to optimize profits of the overall network jointly. Therefore, strict economic regulation of the business relationship between hub airports and their respective network carrier is rendered unnecessary. Regulators should focus on supporting long-term profit sharing contracts of network carriers and hub airports or other contractual forms to ensure vertical cooperation.

Keywords: Airports, Regulation, Hub Competition

1 INTRODUCTION

The market-power of a hub airline at a hub airport has widely been discussed theoretically and empirically.[1] Much less emphasis has been laid upon the question, as to whether a hub airport has market power and is able to exploit the market power in its business relationship to the hub airline. The same notion is true for the regulatory consequences that arise from the nature of the relationship between hub airport and hub airline.

Hub airports are often considered to be monopolists in the business relationship with the respective network carrier.[2] This finding is a consequence of the lock-in effect that is assumed to arise for the network carrier at the airport. This lock-in effect might result from idiosyncratic investments in flight schedules or maintenance facilities. As these investments are sunk costs with high quasi-rents, they can be exploited by the airport by charging high

[1] See e.g. *Borenstein* (1989) Kahn (1993), Lijesen et al. (2000) or *van Dender* (2007).
[2] See e.g. *Beckers et al.* (2010) who only see a low level of network competition for German Airports.

prices for aviation services and/or offering poor service quality without having to fear that the airline shifts its hub operations to another airport.

However, employing such a strategy might not be profit maximizing, as it lowers the demand for the hub airline as passenger shift to other network airlines using other hubs and offering lower prices or better services, which, in turn, leads to lower demand for services of the hub airport that exploits market power. Competition in the downstream airline market drives the need for efficient and high quality services in the upstream market and, therefore, limits the incentives of hub airports to exploit market power.

In this paper we will give some insight into the incentives of a hub airport for using its market power from a game theoretical industrial economics perspective. In *section 2* we analyse the potential sources of market power for hub airports. In *section 3* we set up our basic model (*section 3.1*), identify the strategic options for airlines and airports within the framework (*section 3.2*) and derive possible market results (*section 3.3*). Based on these results*, section 4* analyses dominant strategies and profit distribution games in order to find stable market equilibrium. The characteristics of this equilibrium are used for giving recommendations on airport regulation. *Section* 5 concludes.

2 SOURCES OF MARKET POWER FOR HUB AIRPORTS

Airports are multi-product companies offering services in the aviation- and non-aviation market. It is generally agreed that non-aviation services of an airport such as lease of office or retail space are subject to strong competition from high-street locations, so that high prices for these services only reflect locational rents and no market power.[3]

In the aviation market, market power might occur due to the presence of monopolistic bottlenecks (essential facilities). These are facilities which are essential to the provision of airport services and which cannot be duplicated either because of cost reasons or because of entry barriers. These conditions are generally fulfilled for airport infrastructure like runways, taxiways or aprons.[4] Whereas, concerning costs, there is only empirical evidence for decreasing average costs of airport infrastructure up to 5 to 10m Work Load Units, [5] the presence of high sunk costs, public opposition against airport projects, and long judicial proceedings lead to high entry barriers for aviation services.[6]

With regard to hub airports, networks carriers often face lock-in effects at their hub airport. This is mainly linked to asset specificity: From the airline perspective, there is specificity due to the accumulation of traffic rights and slots at the airport,[7] the matching of the flight schedule on hub connections and idiosyncratic investments, for instance in maintenance facilities. The costs of switching hub operations to another airport are high as investments, which have been conducted at the present hub airport, have to be conducted at a new hub

[3] See e.g. *Malina* (2006), p. 182, Forsyth (2004), *de Wit* (2004), pp. 85f.
[4] See *Kunz* (1999), pp. 12f.
[5] See *Malina* (2006), pp. 142ff.
[6] See *Forsyth* (2006), pp. 350f and *Starkie* (2002), p. 65.
[7] The latter is mainly important if grandfathering is the main mode of slot distribution.

airport again in order to ensure the functionality of the network.[8] This lock-in effect might lead to market power of hub airports in their business relationship to the airline, which the airport might use in order to charge higher prices or offer lower service quality, so that the quasi-rents of airline investment is (at least) partially transferred to the airport operator. However, airports might be prevented from abusing market power due to idiosyncratic investment into hub-specific airport infrastructure as well. In general, the airport operator depends on the network carrier feeding flights into the airport, as the only option of generating the throughput, which is needed for a sufficient utilization of airport infrastructure. This is due to restrict bilateral agreements, which prevent carriers from other countries from operating 7th freedom flights from the hub airport and possibly due to a lack of market knowledge and market reach of those carriers. Moreover, the incentives of abusing market power in its relationship to the hub carrier might further be reduced because of competition between different airline-airport networks. By increasing airport charges or decreasing service quality, a hub airport operator increases costs and decreases the service level and, therefore, weakens the competitiveness of its hub carrier. This leads to lower demand for the hub airline as passenger shift to other network airlines using other hubs and offering lower prices or better services, which, in turn, leads to lower demand for services of the hub airport that exploits market power.[9]

There is only scarce empirical evidence on market power of hub airports in the relationship to the hub airline. Moreover, the degree of market power which is identified varies quite substantially. Based on an analysis of ticket prices and journey time, *Malina* (2006) argues that the two German hub airports Frankfurt and Munich face substantial competition for transfer passengers from other European hubs such as Paris Charles de Gaulle, Amsterdam, London Heathrow or Madrid which mitigates market power in relation to the hub carrier.

Van Dender (2007) uses a data set of 55 US airports from 1998 to 2002 to analyze the determinants of airport revenues and ticket prices. He applies a simultaneous equations approach in order to account for different endogenous variables of demand, fare, delay, and revenue. He finds that ticket prices are significantly higher at hub airport routes, which is consistent to previous results by *Borenstein,* who finds that dominant positions of an airline at an airport lead to higher prices.[10] *Van Dender* shows that higher concentration of airlines at an airport results in higher aeronautical revenues per passenger. However, he does not provide evidence that hub airports charge significantly higher aeronautical charges than non-hub airports, as the aeronautical revenues per departure are not influenced significantly by the hub status.[11]

Research by *Bel* / *Fageda* (2010) focus on explaining airport charges for 100 European airports in 2008 using a sample aircraft (Airbus A320) and a sample load factor of 70 % (105 passengers). They find that airport charges are higher, if the share of traffic of airline alliances increases at a particular airport.

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[8] See *Malina* (2006), pp. 136ff or *Fuhr / Beckers* (2006), p. 394.
[9] See *Oum / Fu* (2008), p. 13.
[10] See *Borenstein* (1989).
[11] See *van Dender* (2007), p. 327.

3 A MODEL OF HUB COMPETITION

In this section we develop a model of hub competition in order to analyze the incentives of airports to exploit market power in relation to the hub airline. We first discuss the general model framework and its assumptions (*section 3.1*). Afterwards, we identify the strategic options for airlines and airports within this framework (*section 3.2*). In *section 3.3* we find the market equilibria.

3.1 Basic Model Set-up

The basic model comprises two market stages and two airline-airport systems as shown in *figure 1:*

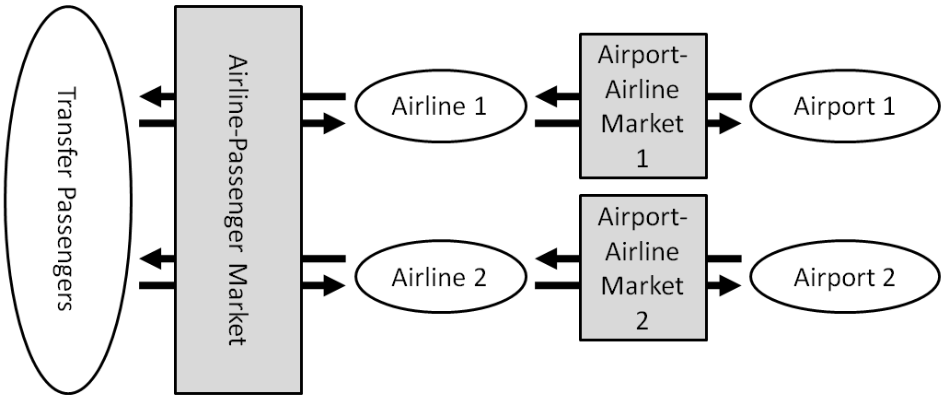

Figure 1 – Market Structure

- *Airline-Passenger market (downstream market)*

On this airline-passenger-market we model the interaction between passengers and network airlines. Passengers choose the relevant airline based on their preferences and airline prices. Thus, in this market, prices are used as the profit optimizing parameter for airlines.
We limit the scope of this market to transfer passengers who use feeder flights into a hub airport and continue their flight to their destination from the hub airport. Passengers who use direct flights from or to the hub (hub O/D traffic) are not taken into account. The market between airlines and passengers is modelled as an oligopolistic market, which is, given the current airline market structure, a realistic assumption. The number of carriers and networks is limited to two as a larger number would only add complexity without providing additional value to the analysis.

- *Airport-Airline market (upstream market)*

The market between airlines and airports is modelled as a monopolistic market. Hence, we account for lock-in effects of the network carrier. Each airport only serves one network carrier and the network carrier focuses its traffic to one hub airport which he cannot change. Furthermore, we do not account for the possibility of countervailing power by the airlines. As a consequence, if we find that a hub airport has no incentive to exploit market power in relation to the hub carrier in this very rigid market framework, it will not do either in more competitive market environments.

Based on the model framework, we define demand and cost functions. Let x_i denote the passenger demand directed to airline i, p_i the ticket price of airline i and $a, b, d > 0$ we define the following demand function:

$$x_i = a - b \cdot p_i + d \cdot p_j \quad \forall\ i, j \in \{1; 2\}; i \neq j.$$

In the analysis, we assume that the decline of demand due to a 1 € raise in ticket prices by airline i is higher than the additional demand for airline i due to a 1 € raise in ticket price by airline j: $b > d$. As the model is symmetric, this implies, furthermore, that overall volumes in the transfer passenger market grow as the level of ticket prices in this market decreases. Parameter e is the marginal passenger cost of the airport and c the marginal passenger cost of the airline (without airport fees). The airport fee per passenger at airport i, the airport which network carrier i uses, is q_i. Airport fixed costs are F, airline fixed costs are A. We define the cost function of the airport i $K_{Airport,i}$ and the cost function of the airline i $K_{Airline,i}$:

$$K_{Airport,i} = e \cdot x_i + F \quad \forall\ i \in \{1; 2\},$$
$$K_{Airline,i} = (c + q_i) \cdot x_i + A \quad \forall\ i \in \{1; 2\}.$$

Airlines and airports maximize profits Π. Their strategic parameters are airport fees (for airports) and ticket prices (for airlines). We do not account for non-aviation revenues of the airport. From a regulatory point of view we, therefore, model a worst-case scenario. If we find that a hub airport operator has no or only limited incentives to exploit market power in the relationship to the hub carrier without incorporating the effect of non-aviation revenues, it will have even lower incentives, if non-aviation revenues are accounted for.

The airline networks are modelled as being heterogeneous for passengers. This is realistic, as the networks differ in flight time and service quality. Thus, the market is a market with heterogeneous products and Bertrand competition. The market equilibrium is described as a Nash equilibrium. As the airlines' costs are influenced by pricing decisions on the upstream market, the market equilibrium is also determined by the charges which are set by the airports. From the equilibrium on the downstream market we derive the demand functions for the airports. The model is designed as a symmetric model without differences concerning cost structures for airlines and airports as well as concerning demand structures.

3.2 Identification of Strategic Options for airlines and airports

Airlines and airports maximize their profits by setting prices on the upstream and downstream market. However, they are also able to influence profits by the level of cooperation between the market partners.

They either conduct profit maximization separately. In this strategy, the airport would exert a profit maximizing strategy on its demand function, which is defined by the market equilibrium on the downstream market. Thus, the airport tries to exploit market power to the maximal extend which is possible in the given market framework. The equilibrium is determined by the Nash equilibrium on the upstream market which affects the level of the equilibrium on the oligopolistic airline-passenger downstream market.

Alternatively, the hub airline and its hub airport can also jointly optimize profits of the overall network and distribute the profits to the partners afterwards. Thus, the structure of the market is changed as airlines and airports use joint profit maximization within their network. Vertical integration or hybrid forms of cooperation between airlines and airports might be used as a contractual basis for joint profit maximization. Obviously, hub airports do not exploit market power in this situation as they engage in joint profit maximization of the system.

In the following *section 3.3* we analyze the market equilibria dependent on the different strategies to design the business relationship between network carriers and their hubs airports. We compare the market results to a reference scenario of perfect competition on the upstream market. In this scenario, airports set their fee level at the level of marginal cost to $q_i = e \;\; \forall \;\; i \in \{1;2\}$. Because we assume that airport fixed cost F are high, this level of fees results in long-term losses for the airports. Hence, we only use this market result as a reference to evaluate the implications on market power and social welfare in different market settings.

3.3 Market Results for different strategic options

Having identified the different strategic options for airlines and airports in the market framework, we present the market results for different combinations of these strategic options. At first, we present the reference scenario, in which airports choose a price level at marginal costs. Afterwards, we develop the market results, if airports try to exploit market power by separate profit maximization and compare it with the reference scenario. Last, we derive the market equilibrium, if one or two networks conduct joint profit maximization within their network.

3.3.1 Reference Scenario: Perfect Competition on the Upstream Market

In the downstream market between airlines and passengers, we model profit maximizing airlines with given airport fees q_i and profits:

$$\max_{p_i} \Pi_{Airline,i} \;\forall\;\; i \in \{1;2\}.$$

This yields the best response for airline i on a given ticket price level of airline j:

$$p_i = \frac{a + dp_j + bc + bq_i}{2b} \;\forall\;\; i,j \in \{1;2\}, i \neq j.$$

By substituting the best response functions we find the Nash equilibrium in the downstream market:

$$p_i = \frac{(2q_i + 2c)b^2 + \left((c + q_j)d + 2a\right)b + da}{4b^2 - d^2} \;\forall\;\; i,j \in \{1;2\}, i \neq j.$$

In the reference situation, we assume that there is perfect competition on the upstream market between the network carrier and its hub airport. Thus, airports fix the level of charges in the upstream market at marginal costs:

$$q_i = e \;\; \forall \;\; i \in \{1; 2\}.$$

Substitution into the Nash equilibrium function yields

$$p_i^{Ref} = \frac{a + b(e + c)}{2b - d} \;\; \forall \;\; i \in \{1; 2\}.$$

As a consequence the level of passenger demand in the system is

$$x_i = \frac{b(a - be - bc + de + dc)}{2b - d} \;\; \forall \;\; i \in \{1; 2\}.$$

This situation is hypothetical. It is only discussed in order to find a reference for the upstream market, in which social welfare is maximized due to perfect competition on the upstream market. This strategic option does not reflect rational behaviour in the given market framework. Moreover, fees for the airport infrastructure at marginal costs are impossible in our model framework in the long-run, as the airports would suffer long-term losses due to high fixed costs, i.e. the cost of capital appropriation.

3.3.2 Separate profit maximisation

Compared to the reference situation, we do not change the structure of the downstream market, which is presented in *section 3.3.1*. However, we substitute the downstream equilibrium price into the downstream demand functions:

$$x_i = \frac{b(2ab + da + (d^2 - 2b^2)q_i + dbc + dbq_j - 2b^2c + d^2c}{4b^2 - d^2} \;\; \forall \;\; i, j \in \{1; 2\}, i \neq j$$

The result is the upstream demand function. It shows that the number of passengers, who use airport i, depends on the level of fees at airport i as well as on the level of fees at airport j.[12] Thus, although we account for lock-in effects of the airlines, hub airports do not hold a monopoly position in this traffic segment, because high airport fees cause a disadvantage in airline costs and thus, result in higher ticket prices in the respective network. Hence, passengers change network or do not travel at all. As a consequence, market power of hub airports is limited in this respect by downstream competition between network carriers.

We find the profit maximization condition of an airport i as follows:

$$\max_{q_i} \Pi_{Airport,i} \; \forall \;\; i \in \{1; 2\}.$$

From this condition we yield best responses for each airport to a given price level of the airport of the antagonist system:

[12] Demand at airport i depends negatively on q_i for $b, d > 0, b > d$ and positively on q_j for $b, d > 0$.

$$q_i = \frac{2ab + da + dbc + dbq_j - 2b^2c + d^2c + 2eb^2 - ed^2}{4b^2 - 2d^2} \quad \forall\ i,j \in \{1;2\}, i \neq j.$$

By substituting the best response functions we find the Nash equilibrium in the upstream market:

$$q_i = \frac{2ab + da + dbc - ed^2 - 2b^2c + d^2c + 2eb^2}{4b^2 - db - 2d^2} \quad \forall\ i \in \{1;2\}.$$

Substituting this result into the downstream market equilibrium we find the overall equilibrium in this market framework:

$$p_i^{Sep} = \frac{2b^3e + 2b^3c + 6ab^2 - bed^2 + bd^2c - 2d^2a}{(2b-d)(4b^2 - db - 2d^2)} \quad \forall\ i \in \{1;2\}.$$
$$x_i = \frac{2(b^2 - 0.5d^2)\big((-e-c)b + (e+c)d + a\big)b}{(2b-d)(4b^2 - db - 2d^2)} \quad \forall\ i \in \{1;2\}.$$

For our analysis we also calculate the profits of airlines, airports and the overall profits of the system of airlines and airport. We calculate the following results:

$$\Pi_{Airport,i}^{Sep} = \frac{b(2b^2 - d^2)(-be - bc + de + dc + a)^2(2b+d)}{(2b-d)(4b^2 - db - 2d^2)^2} - F \quad \forall\ i \in \{1;2\};$$
$$\Pi_{Airline,i}^{Sep} = \frac{(2b^2 - d^2)^2(-be - bc + de + dc + a)^2 b}{(2b-d)^2(4b^2 - db - 2d^2)^2} - A \quad \forall\ i \in \{1;2\};$$
$$\Pi_{System,i}^{Sep} = \frac{2(2b^2 - d^2)(-be - bc + de + de + a)^2 b(3b^2 - d^2)}{(2b^2 - d)^2(4b^2 - db - 2d^2)^2} - (A+F) \quad \forall\ i \in \{1;2\}.$$

Although a downstream duopoly results in a lower level of market power for hub airports as the airport's demand function is not only dependent on the level of charges of the airport itself but also of the level of charges of the airport in the antagonist system, we suppose that there is at least some market power of hub airlines. Thus we analyse:

$$p_i^{Sep} > p_i^{Ref}$$
$$\Leftrightarrow \frac{b(2b+d)(a - b(e+c) + d(e+c))}{(2b-d)(4b^2 - db - 2d^2)} > 0.$$

For $b, d > 0$ this conditions holds, if three additional conditions are true:

1. $\big(a - b(e+c) + d(e+c)\big) > 0$. This condition implies that there is positive passenger demand, if airlines and airports use marginal costs as prices. If this condition is not true, nobody can serve the passengers without operational losses.

2. $b > \frac{1}{2}d$. This condition holds if $b > d$ which implies that the decline of demand due to a 1 € raise in ticket prices by airline i is higher than the additional demand for airline i due to a 1 € raise in ticket price by airline j.

3. $(4b^2 - db - 2d^2) > 0$, which holds if $b > \frac{1+\sqrt{33}}{8}d$ for $b, d, > 0$. This condition is true, if $b > d$ for $b, d > 0$.

We can, therefore, conclude that in a market setting, in which airlines and airports conduct independent profit maximization, ticket prices are higher compared to our reference situation of perfect competition on the upstream market. Thus, independent profit maximization of airlines and airports has negative impacts on social welfare which stem from lock-in effects of network carriers at the hub airport.

3.3.3 System Optimization

Airlines and airports may also have an incentive to conduct joint profit maximization. Hence, we also derive the market equilibrium, if this strategy is used. The cost function of the network system equals the sum of the cost functions of airlines and airports reduced by the revenues which the airports realize from their business relationship with the airline. The systems' revenues are gained in the market between passengers and the system. In our model setting we obtain:

$$K_{System,i} = K_{Airline,i} + K_{Airport,i} - q_i x_i \;\; \forall \;\; i \in \{1;2\}$$
$$\Rightarrow \Pi_{System,i} = p_i x_i - K_{System,i}.$$

We derive the condition for profit maximization of a system i and find the best response of a system i to the pricing of a system j:

$$\max_{p_i} \Pi_{System,i} \;\; \forall \;\; i \in \{1;2\}$$
$$\Leftrightarrow p_i = \frac{a + dp_j + bc + be}{2b} \;\; \forall \;\; i \in \{1;2\}, i \neq j$$

System optimisation can either be done in both systems or in one system.

3.3.3.1 System Optimization of both systems

By substituting the best response functions we obtain the Nash equilibrium in this market:

$$p_i = p_i^{Ref} = \frac{be + bc + a}{2b - d} \;\; \forall \;\; i \in \{1;2\}$$

As a consequence the level of passenger demand in the system is found at

$$x_i = \frac{b(a - be - bc + de + dc)}{2b - d} \;\; \forall \;\; i \in \{1;2\}.$$

Joint profit maximization of hub airports and their network carrier replicates the market results of perfect competition on the upstream market. Thus, this strategy is welfare enhancing. If there is an incentive for airlines and airports to use this strategy, there is no need for regulation of the business relationship between hub airlines and hub airports – at least there is no need for regulation to achieve efficient market results that maximize social welfare.

Furthermore, we calculate joint profits of the systems in this market equilibrium:

$$\Pi_{System,i}^{Joint} = \frac{b\big((-e-c)b+(e+c)d+a\big)^2}{(2b-d)^2} \;\; \forall \;\; i \in \{1;2\}.$$

In this approach we only calculate the system profit as profits of airlines and airports cannot be calculated without discussing the overall game of profit distribution between airlines and airports. This is due to the fact that minimal profits of airlines and airports have to be determined first, in order to decide whether profit sharing is possible that ensures cooperation between airlines and airports. This will be determined in *section 4* of this paper.

3.3.3.2 System Optimization in one system

We also consider whether there is an incentive for one network system to use joint profit maximization while the other system does not. If this is not the case, system optimization might be a good strategy in a one-shot game, but it does not evolve dynamically from vertical separation between airlines and airports, which we find in most countries. Thus, we also have to find the market equilibrium in this case. We assume that system 1 conducts joint profit maximization whereas airports and airlines in system 2 optimize profits separately. Therefore, system 1 optimizes profits assuming that there is a given ticket price of system 2. We have already derived the reaction function for system 1:

$$p_1 = \frac{a+dp_2+bc+be}{2b}.$$

Separate profit maximization of hub airports and network carriers in system 2 leads to the following reaction function of airline 2 as derived in *section 3.3.2*:

$$p_2 = \frac{a+dp_1+bc+bq_2}{2b}$$

Substitution of reaction functions yields the market equilibrium:

$$p_1 = \frac{2ab+da+dbc+dbq_2+2b^2c+2eb^2}{4b^2-d^2};$$

$$p_2 = \frac{2ab+da+dbc+ebd+2b^2c+2b^2q_2}{4b^2-d^2}.$$

Thus, we obtain the demand function for airport 2:

$$x_2 = \frac{b(2ab+da+dbc+edb-2b^2c-2b^2q_2+d^2c+d^2q_2}{4b^2-d^2}.$$

Profit maximization of airport 2 yields:

$$\max_{q_2} \Pi_{Airport,2}$$
$$\Leftrightarrow q_2 = \frac{(-2c+2e)b^2+\big((e+c)d+2a\big)b+d((c-e)d+a)}{4b^2-2d^2}.$$

Thus, we calculate equilibrium ticket prices:

$$p_1 = \frac{4(c+e)b^3 + \big((-e-c)d + 4a\big)b^2 + d\big((-e-c)d + a\big)b - 2d^2a}{2(2b-d)(2b^2-d^2)};$$

$$p_2 = \frac{b^3(e+c) + \big((c+e)d + 3a\big)b^2 - d^2(c+e)b - ad^2}{(2b-d)(2b^2-d^2)}.$$

Comparing both prices, we find that $p_1 < p_2$ if $\big(a - b(e+c) + d(e+c)\big) > 0$, $b.d > 0$ and $\sqrt{2}b > d$ which is true for $b > d,\ b,d > 0$. Thus, system optimization leads to lower prices compared to the antagonist system which conducts separate optimization by airlines and airports. As a consequence, there is considerable higher demand for system 1.

We calculate the following profits for this combination of strategic options:

$$\Pi^{Dev}_{System,1} = \frac{(-be-bc+a+de+dc)^2 b(4b^2-2d^2+db)^2}{4(2b-d)^2(2b^2-d^2)^2} - (A+F);$$

$$\Pi^{Dev}_{System,2} = \frac{(3b^2-d^2)(-be-bc+a+de+dc)^2 b}{2(2b-d)^2(2b^2-d^2\,)} - (A+F).$$

Lower ticket prices in system 1 lead to additional passengers on the network, which, in turn, lead to higher profits for system 1 in comparison to system 2, if, in addition to the above mentioned conditions, $2b^3 + 5db^2 - 2d^3 > 0$. For $b > d,\ b,d > 0$ this condition is true. In addition to these results, we also obtain profits of airlines and airports in system 2:

$$\Pi^{Dev}_{Airport,2} = \frac{b(2b+d)(-be-bc+a+de+dc)^2}{4(2b^2-d^2)(2b-d)} - F;$$
$$\Pi^{Dev}_{Airline,2} = \frac{b(-be-bc+a+de+dc)^2}{4(2b-d)^2} - A.$$

4 DOMINANT STRATEGIES, PROFIT DISTRIBUTION AND IMPLICATIONS FOR ECONOMIC REGULATION

In *section 3* we have derived the market results for different combinations of strategic options for airlines and airports. We have found that hub airports might not have an incentive to exploit market power, if network airlines and their hub carriers conduct joint profit maximization of their aviation system. However, we have not analyzed, so far, whether joint profit maximization is a dominant strategy for the aviation systems. If it is dominant, it will evolve as the equilibrium strategy in the market. In this case, there is no need for economic regulation of the hub airline-hub airport relationship in order to ensure allocative efficiency as the market result is welfare-enhancing with regard to the upstream market.

The structure of the game between the network systems is shown in *figure 2*:

Network 1 \ Network 2	**Separate optimization**	**Joint optimization**
Separate Optimization	$\Pi^{Sep}_{System,1}, \Pi^{Sep}_{System,2}$	$\Pi^{Dev*}_{System,1}, \Pi^{Dev*}_{System,2}$
Joint Optimization	$\Pi^{Dev}_{System,1}, \Pi^{Dev}_{System,2}$	$\Pi^{Joint}_{System,1}, \Pi^{Joint}_{System,2}$

Figure 2 – Game Structure of Airline-Airport Networks

Because the model is symmetric, we know that $\Pi^{Dev}_{System,1} = \Pi^{Dev*}_{System,2}$ and $\Pi^{Dev}_{System,2} = \Pi^{Dev*}_{System,1}$. The ratios of the profits in different cases are as follows:

1. $\Pi^{Sep}_{System,1} < \Pi^{Joint}_{System,1}$. This condition holds as $b, d > 0$ and $b > d$. Furthermore, we have to assume that b is considerably higher than d. This assumption is necessary, as it ensures that there is enough additional traffic attracted by lower prices of both systems in order to offset the profit decreasing effect of lower ticket prices. There is empirical evidence that there is relevant growth of overall aviation markets as ticket prices decrease,[13] which implies that b is indeed considerably higher than d. Furthermore, if ticket prices for the hub and spoke system decrease, some passengers might also shift from O/D-connections to the hub and spoke network. This would increase the difference between b and d even more.

2. $\Pi^{Joint}_{System,1} < \Pi^{Dev}_{System,1} \iff -\frac{b^2(-be-bc+a+de+dc)^2 d(bd+8b^2-4d^2)}{4\,(2b-d)^2(2b^2-d^2)^2} < 0$. This condition is true for $b, d > 0, b > d$ and $\left(a - b(e+c) + d(e+c)\right) > 0$, which implies that there is positive passenger demand if airlines and airports use marginal costs as prices. Thus, if one of the systems uses joint profit maximization and the other system does not, system profits in the jointly optimized system are higher compared to a situation in which both systems use joint profit maximization.

3. From condition 1 and 2 we conclude that $\Pi^{Dev}_{System,1} > \Pi^{Sep}_{System,1}$. As a consequence, every system has an incentive to conduct joint profit maximization if the other system does not.

4. $\Pi^{Joint}_{System,1} > \Pi^{Dev*}_{System,1} \iff -\frac{b(a-be-bc+de+dc)^2(b-d)(b+d)}{2(2b-d)^2(2b^2-d^2)} < 0$. This condition is true as long as $b > d$ and $b, d > 0$. In a situation, in which the antagonist system uses joint profit maximization, joint profit maximization is the best response to this strategy.

Based on these results, we determine the presence of dominant strategies. For network 1, the best response to a separate optimization strategy by network 2 is joint optimization as $\Pi^{Dev}_{System,1} > \Pi^{Sep}_{System,1}$. Furthermore, if network 2 conducts joint optimization, we also find that joint optimization is the best response by network 1 because $\Pi^{Joint}_{System,1} > \Pi^{Dev*}_{System,1}$. Hence, joint optimization is a dominant strategy or the best response to all strategies of system 2. As our model is symmetric, the dominant strategy by network 2 is joint optimization as well. Thus, network carriers and their hub airports have strong incentives to conduct joint profit

[13] See for instance *Intervistas* (2007), pp. 43ff.

optimization in order to ensure the competitiveness of the overall network. This implication arises although we account for lock-in effects of the network carrier at its hub airport.

The presence of a dominant strategy, in this case, implies that the joint profit maximization equilibrium evolves dynamically even from a market with vertical separation. In this situation, airlines and airports in one system face an incentive to use joint profit maximization (*condition 3*). The best response of the antagonist is joint maximization as well (*condition 4*). Best response to the other system is joint optimization again (*condition 4 and symmetry*). Furthermore, there are no regrets in this equilibrium (*condition 1*). Thus, the equilibrium of cooperation between network carriers and hub airlines in the market for transfer passengers is stable. As a consequence, there is no need for regulators to intervene in the business relationship between a network carrier and its hub airport in the market segment of transfer passengers as joint profit maximization of airlines and airports ensures efficient and social welfare optimal market results.

However, airlines and airports will only cooperate, if the strategy of joint profit maximization maximizes individual profits of airlines and airports alike. We have already found that system profits are higher if both systems use a joint profit maximization strategy.[14] However, it is necessary to find a suitable mechanism of profit sharing which ensures cooperation. In this distributional game we can assume that airlines and airports will not conduct joint profit maximization if the other partner in the network does not agree to use this strategy. Thus, we have to study the profits that airlines and airports generate, as they do not use joint profit maximization. We consider two situations:

- In case that the antagonist system 1 uses joint profit maximization, airline 2 and airport 2 have the following optimal profits if they optimize separately: $\Pi^{Dev}_{Airline,2} = \frac{b(-be-bc+a+de+dc)^2}{4(2b-d)^2} - A$, $\Pi^{Dev}_{Airport,2} = \frac{b(2b+d)(-be-bc+a+de+dc)^2}{4(2b^2-d^2)(2b-d)} - F$. As shown above $\Pi^{Dev}_{System,2} = \Pi^{Dev}_{Airline,2} + \Pi^{Dev}_{Airport,2} < \Pi^{Joint}_{System,2}$ (*condition 4*). Thus, a higher system profit can be distributed to system 2, if the network carrier and the hub airport conduct joint profit maximization. The minimum profit claim in order to enforce joint profit maximization is the profit of the separation strategy, because both players are able to threaten the antagonist with this situation. But as the system profit is higher, it is possible to solve this problem by sharing additional profits. However, as set out above, it is necessary that there is significant market growth of the hub and spoke network due to lower ticket prices in order to ensure that this profit sharing mechanism exists.

- In case that antagonist system 1 does not use joint profit maximization, the minimum profit of airline 2 is $\Pi^{Sep}_{Airline,2} = \frac{(2b^2-d^2)^2(-be-bc+de+dc+a)^2 b}{(2b-d)^2(4b^2-db-2d^2)^2} - A$ and minimum profit of airport 2 is $\Pi^{Sep}_{Airport,2} = \frac{b(2b^2-d^2)(-be-bc+de+dc+a)^2(2b+d)}{(2b-d)(4b^2-db-2d^2)^2} - F$. As shown above, we find that $\Pi^{Sep}_{System,2} = \Pi^{Sep}_{Airline,2} + \Pi^{Sep}_{Airport,2} < \Pi^{Dev*}_{System,2}$ (*condition 3* and model symmetry). Thus, airlines and airports are able to find a suitable profit sharing contract again.

[14] The general conditions are shown above.

As a consequence, airlines and airports can find suitable profit sharing contracts which make joint optimization profit enhancing for both partners. The minimum profits of the partners are determined by the profits which they have in case of separate optimization which is the plausible strategy in case that the antagonist tries to exploit the relevant player.

Our theoretical analysis, therefore, shows that there is no need to regulate the business relationship between hub airports and hub airlines in the market for transfer passengers, as competition between aviation networks, which use different hubs, limits incentives for hub airports to exploit market power, which arises due to lock-in effects of the network carrier at its hub airport. Moreover, regulators should encourage hub airports and their hub airlines to negotiate long-term contracts of joint network optimization and profit sharing. One example of such a contractual agreement can be found between Fraport, the operating company of Frankfurt airport, and Lufthansa, who has bought a minority share (ca. 10 %) of Fraport. We also find other forms of vertical cooperation like joint ventures between hub airports and networks carriers (i.e. Terminal 2 at Munich Airport). These forms and other forms of contractual agreements are important to network carriers and hub airports alike to ensure the competitiveness of their common aviation network. These forms of cooperation do not threaten, but rather advance market results. Economic regulation of this business relationship is not necessary.

However, this policy implication is only valid for the market of transfer passengers as discussed in this paper. In the O/D-segment, a hub airport should be able to skim additional profits from the hub premium – even from the network carrier. Furthermore, access to the airport, quality standards and a fair level of charges for other airlines need to be ensured.[15] The latter is even more problematic in case of scarce capacity and the use of vertical cooperation between hub airports and the respective network carrier. In this respect, regulation is still necessary. Thus, there is strong evidence that asymmetric regulation is reasonable at hub airports.

5 CONCLUSION

Competition on the downstream market for transfer passengers between network airlines is an important element which affects the structure of the upstream market between hub airports and the respective network carrier. Due to the fact that airline demand for hub airport infrastructure is derived from the downstream passenger market, hub airports do not hold a classical monopoly position in the upstream market. Even lock-in effects of hub airlines do not change this notion. Based on a formal, theoretical model, we find evidence that network carriers and hub airports have strong incentives to cooperate and use means of joint profit maximization in the segment of transfer passengers. As the market results reflect results of hypothetical perfect competition on the upstream market, there is no need for regulation of the business relationship between network carriers and hub airports. Nevertheless, this does not imply that hub airports should not be regulated at all, as market power of hub airport with respect to O/D-traffic might exist and discriminatory behaviour of the airport is likely, if

[15] See *Serebrisky* (2003), p. 2.

vertical cooperation between the network carrier and the hub airport is used. Thus, there is a need for asymmetrical regulation of hub airports. On the one hand, regulators should support long-term profit sharing contracts of network carriers and hub airports or other contractual forms to ensure vertical cooperation. Thus, there are only weak incentives of market power abuse by the airport. On the other hand, there is a need to ensure that the hub airport does not discriminate against other airlines in the market segment of O/D passengers.

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