THE EFFECTS OF AIRLINE AND HIGH SPEED TRAIN INTEGRATION

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Abstract

High speed trains (HSTs) and airlines have been usually considered as alternative modes of transport in competition with each other. Although competition is generally welfare enhancing, the integration of airlines and HSTs may be profitable from the social point of view. In this paper we analyze the environmental and social effects of airline and HST integration in two different scenarios. On the one hand, we consider airports with capacity restrictions. On the other hand, we consider airports with low competition between airlines. In both cases, we show that airline and HST integration is always privately profitable, while it may be also profitable from the environmental and/or social perspective.

Keywords: integration, airline, high speed train (HST)
JEL classification: L11, L22, L93

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1. Introduction

High speed trains (HSTs) and airlines have been traditionally considered as alternative modes of transport in competition with each other. Indeed, due to both the possibility of moving passengers from city centre to city centre and the shorter travel time, the high-speed rail transportation has become particularly competitive on routes under 600 km in length or one hour flight (Givoni, 2005). Although several authors set different thresholds on the distance for which the HST loses its advantage over aircraft (Pavaux, 1994; Buchanan and Partners, 1995; Janic, 2003; De Rus and Nombela, 2007; Vickerman, 2009), most authors agree that the HST is no longer competitive for distances above 800 km in length (Commission for Integrated Transport, 2004; Givoni and Banister, 2007).

Despite the undoubted advantages that competition generally has on social welfare, sometimes airline and HST integration may be profitable. Indeed, since 2001 the European Union has recognized the positive effects of airline and HST integration, stating in its White Paper that *"network planning should therefore seek to take advantage of the ability of HST to replace air transport and encourage rail companies, airlines and airport managers not just to compete, but also to cooperate"* (Commission of the European Communities, 2001, p.53; Givoni and Banister, 2006).

One of the main arguments in favour of the integration of airline and HST refers to the release of slots at some major airports with capacity constraints. A clear example is the case of the Frankfurt airport that operates at its maximum capacity most of the time. In this context, the AirRail Service is created, a joint venture between Lufthansa, Deutsche Bahn and Fraport, which connects Frankfurt airport with Stuttgart from March 2001 and with Cologne from May 2003. With this agreement, passengers purchase a single ticket for the entire trip by plane and HST, and they pick up their luggage at the final destination. Due to this agreement, Lufthansa was able to replace the route Frankfurt-Cologne at Frankfurt airport by other more profitable routes. AirRail Service is probably the example of the most complete intermodal integration in Europe, but it is not the only one. Thus, there are agreements between the airline Finnair and the railway company SBB, whereby Finnair has expanded its offering to four new destinations (Bern, Basel, Lausanne and Luzern) by integrating its flights from Helsinki to Zurich with rail services to these four cities at the airport of Zurich. Other examples are the agreements between Air France and the national railway company SNCF to create TGV Air, or those between KLM and Thalys to cover the route between Antwerp and Amsterdam Schiphol airport.

A second argument in favour of airline and HST integration refers to the reduction of the environmental pollution. In general, the plane is considered a mean of transport more harmful to the environment than HST, especially in regard to its impact on climate change. Givoni (2007) examines empirically the level of air pollution and climate change impact of air and HST travel between the cities of Paris and London. He concludes that replacing a seat on a plane by a seat on a HST is always beneficial from the environmental point of view. Other studies such as Eurocontrol (2004) and Schreyer et al. (2004) confirm these findings.

Taking into account the effects of airline and HST integration on airport congestion and the environment, Givoni and Banister (2006) estimate the benefits of airline and railways integration at Heathrow airport. These authors conclude that for routes with less than 600 km in length, where the HST route is not more than 20% longer than the aircraft route, and the average HST speed along the route is at least 250 km per hour, the operation of airline and railway integration is beneficial for the airlines, passengers and the environment.

This article develops a theoretical model which aims to analyze under what circumstances it may be beneficial the integration between HST and airlines. In particular, this paper examines, on the one hand, the effects of airline and HST integration on the environment and social welfare at airports with capacity constraints. On the other hand, we analyze the effects of airline and HST integration on the environment and social welfare at airports with low competition between airlines. In both cases, it is argued that airline and HST integration has important gains from the private point of view, while it may also have significant gains from the social and /or environmental perspective. In particular, we show that at capacity-constrained airports airline and HST integration never conveys damages for the environment, though the effects on social welfare are not unambiguously positive. The reason is that, on the one hand, the integration reduces intermodal competition, which reduces consumer surplus. On the other hand, the integration allows the airline to serve new markets which increases the surplus of the consumers in these other markets. For airports with low competition, we show that airline and HST integration results in greater competition, lower prices, more variety for consumers and, therefore, higher social welfare. However, given that lower prices imply a higher demand for travel, if the increase in the number of passengers by air in a certain route exceeds the corresponding decrease in the other route in which HST operates, the effect of airline and HST integration on the environment could be negative.

The rest of the paper is organized as follows. Section 2 analyzes airline and HST integration in two different scenarios. First, in subsection 2.1 we study the effects of airline and HST integration in airports with capacity restrictions. Then, in subsection 2.2 we analyze the effects of airline and HST integration on airlines competition. Finally, Section 3 presents some general conclusions.

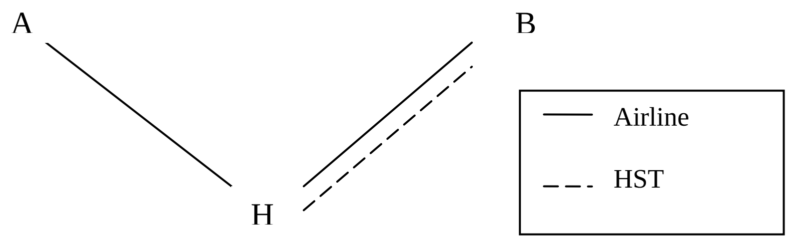
2. The effects of airline and high speed train integration

2.1. Airports with capacity restrictions

2.1.1. The model

Suppose a network structure with two routes: a domestic route and a transoceanic route. The transoceanic route is operated just by an airline, while the domestic route is operated by the airline and a high speed train (HST). Figure 1 represents such a network structure.

Figure 1. Network structure in airports with capacity restrictions



The network structure depicted in Figure 1 implies two routes- AH (the transoceanic route) and HB (the domestic route)- but three possible markets: passengers willing to travel from city A to city H, passengers willing to travel from city H to city B, and passengers willing to travel from city A to city B.

The trip from city A to city H can only be made by air. Thus, the airline is a monopolist in this market. For the sake of simplicity we assume a linear demand in the market AH:

$$q_A^{AH} = \alpha - p_A^{AH}, \tag{1}$$

where α is a positive parameter representing the market size.

The trip from city H to city B can be made either by air or by HST. Let us suppose that passengers in the market HB consider the airline and the HST as differentiated products. Following Dixit (1979) and Singh and Vives (1984), we assume that consumers maximize a quadratic and strictly concave utility function. With such utility function, both the airline and the HST face linear demand functions as follows:

$$\begin{aligned} q_A^{HB} &= \beta - p_A^{HB} + dp_T^{HB} \\ q_T^{HB} &= \beta - p_T^{HB} + dp_A^{HB}, \end{aligned} \tag{2}$$

where β is a positive parameter denoting the market size. Parameter d measures the degree of product differentiation between the airline and the HST and belongs to the interval (0,1). It takes values close to zero when the airline and the HST are considered by passengers as independent products, and values close to one when the airline and the HST are considered as perfect substitutes.

There is not a direct route for travelling from city A to city B. Thus, passengers willing to travel from/to these two cities have to, first, make the route AH by air and, second, decide in city H whether they continue the trip by air or they prefer to switch and make the route HB by HST. However, we assume that, in absence of cooperation between the airline and HST, it is too costly for passengers to switch from one mode of transport to the other in terms of connection time, timetable incompatibilities, baggage transportation, etc. Therefore, in absence of cooperation between the airline and the HST, it is not worth for any passenger in route AB to make the route AH by air and the route HB by HST. In other words, in absence of cooperation between the airline and the HST, the airline acts as a monopolist in the market AB and faces the following demand:

$$q_A{}^{AB} = \gamma - p_A{}^{AB}, \tag{3}$$

where γ is a positive parameter and $p_A{}^{AB}$ denotes the ticket price for the whole trip, which satisfies the following non-arbitrage condition: $p_A{}^{AB} \leq p_A{}^{AH} + p_A{}^{HB}$. The non-arbitrage condition implies that purchasing the trip AB should not be more costly than buying two trips, one from city A to city H and the other from city H to city B. Otherwise, nobody would purchase the trip AB and airline's pricing policy would be no valid.

We assume that the airport in the city H has some capacity restrictions. Let us denote by $\overline{Q}$ the maximum quantity of passengers that can travel through airport H.

Finally, we assume that the marginal operating cost for the airline is constant and identical in all routes and it is denoted by C. However, notice that the marginal operating cost of carrying passengers from city A to city B for the airline is $2C$, since no direct flights are available. We also assume that the marginal operating cost for the HST in route HB is constant and equal to c, with

c = λC, where λ < 1.[1] Finally, in order to have the model well defined we assume that $\alpha, \beta, \gamma > C$. Moreover, in order to guarantee interior solutions we assume that: $\lambda > \frac{1}{Cd}\left(C\left(2-d^2\right)-\beta\left(d+2\right)\right)$.

2.1.2. The integration effects

In order to analyze the effects of airline and HST integration in an airport with capacity restrictions, let us start analyzing the optimal quantities and prices to be offered by each mode of transport in absence of cooperation.

Case 1: No cooperation between the airline and the HST

Before analyzing the optimal prices and quantities in a capacity-constrained airport in absence of cooperation between the airline and HST, let us examine the optimal solutions in the case of no capacity constraints.

If there is no capacity constraint in airport H and no cooperation between the airline and the HST, the airline acts as a monopolist in both markets, the AH and the AB, though it competes with differentiated products with the HST in the market HB. Formally, the airline chooses the ticket prices for each market and solves the following maximization problem:

$$\underset{p_A^{AH}, p_A^{HB}, p_A^{AB}}{Max} (\alpha - p_A^{AH})(p_A^{AH} - C) + (\beta - p_A^{HB} + dp_T^{HB})(p_A^{HB} - C) + (\gamma - p_A^{AB})(p_A^{AB} - 2C). \tag{4}$$

First order conditions for the airline are given by the following:

$$\alpha - 2p_A^{AH} + C = 0. \tag{5}$$

$$\beta - 2p_A^{HB} + dp_T^{HB} + C = 0. \tag{6}$$

$$\gamma - 2p_A^{AB} + 2C = 0. \tag{7}$$

Expressions (5) and (7) provide the monopoly prices charged by the airline in markets AH and AB, respectively. Expression (6) defines the reaction function

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[1] In short haul air routes where HST services can replace aircraft services, it is reasonable to assume that the marginal operating cost for the airline is higher than the marginal operating cost for the HST, since airlines must pay a high fixed cost of fuel consumption during the take-off (see, for example, the report of Steer Davies Gleave, 2006). Besides, airlines pay for operating in airports, while high-speed train operators do not usually pay at all for infrastructure costs. Moreover, the latter usually receive subsidies to afford variable costs.

of the airline in market HB due to changes in the ticket price charged by the HST in that market.

On the other hand, the HST chooses the ticket price for the domestic route HB that solves the following problem:

$$\underset{p_T^{HB}}{Max}\,(\beta - p_T^{HB} + dp_A^{HB})(p_T^{HB} - c). \tag{8}$$

Thus, the first order condition for the HST is given by:

$$\beta - 2p_T^{HB} + dp_A^{HB} + c = 0, \tag{9}$$

which defines the reaction function of the HST due to changes in the ticket price charged by the airline in market HB.

From the airline and HST maximization programs in absence of cooperation and capacity constraints, we obtain the following optimal prices and quantities for each market and mode of transport:[2]

$$\begin{aligned}
p*_A^{AH} &= \frac{\alpha + C}{2}, & q*_A^{AH} &= \frac{\alpha - C}{2} \\
p*_A^{HB} &= \frac{2C + 2\beta + d\beta + cd}{(2+d)(2-d)}, & q*_A^{HB} &= \frac{2\beta - 2C + d\beta + Cd^2 + cd}{(2+d)(2-d)} \\
p*_A^{AB} &= \frac{\gamma + 2C}{2}, & q*_A^{AB} &= \frac{\gamma - 2C}{2} \\
p*_T^{HB} &= \frac{2c + 2\beta + d\beta + Cd}{(2+d)(2-d)}, & q*_T^{HB} &= \frac{2\beta - 2c + d\beta + cd^2 + Cd}{(2+d)(2-d)}.
\end{aligned} \tag{10}$$

If airport H is capacity-constrained, the airline may be unable to satisfy all markets.[3] Note that markets are independent, and because of the linearity in demand functions and costs, we can determine the markets that the airline will optimally satisfy first just comparing the profits that the company obtains in each individual market. Hence, we have the following situations that will be simply determined by the value of parameters:

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[2] We assume that β and d satisfy that $dp^*{}_T^{HB} \le \beta$ and $dp^*{}_A^{HB} \le \beta$, that is, in equilibrium one firm can capture at most all the market of the competing firm.

[3] We assume that expanding airport capacity is not possible.

i) *If* $\Pi^{*AH}_{A} > \Pi^{*HB}_{A} > \Pi^{*AB}_{A}$ *the airline satisfies first the demand in market AH, second the demand in market HB, and finally the demand in market AB.*

ii) *If* $\Pi^{*AH}_{A} > \Pi^{*AB}_{A} > \Pi^{*HB}_{A}$ *the airline satisfies first the demand in market AH, second the demand in market AB, and finally the demand in market HB*

iii) *If* $\Pi^{*AB}_{A} > \Pi^{*AH}_{A} > \Pi^{*HB}_{A}$ *the airline satisfies first the demand in market AB, second the demand in market AH, and finally the demand in market HB.*

iv) *If* $\Pi^{*AB}_{A} > \Pi^{*HB}_{A} > \Pi^{*AH}_{A}$ *the airline satisfies first the demand in market AB, second the demand in market HB, and finally the demand in market AH.*

v) *If* $\Pi^{*HB}_{A} > \Pi^{*AH}_{A} > \Pi^{*AB}_{A}$ *the airline satisfies first the demand in market HB, second the demand in market AH, and finally the demand in market AB.*

vi) *If* $\Pi^{*HB}_{A} > \Pi^{*AB}_{A} > \Pi^{*AH}_{A}$ *the airline satisfies first the demand in market HB, second the demand in market AB, and finally the demand in market AH.*

For the purposes of this paper, the interesting cases are those where the optimal solution implies that the amount offered by the airline in the market HB, given the capacity constraints at the airport H, is strictly positive, i.e. $q_A^{HB} > 0.$ Otherwise, if the optimal solution implies that the amount offered by the airline in the market HB, given the capacity constraints at the airport H, is zero, integration would have no effect.

For this reason and to continue with the analysis we concentrate on the situation *(v)*. Consequently, if airport H is capacity-constrained and there is no cooperation between the airline and HST, we consider the situation under which the airline decides to satisfy first the demand in market HB, second the demand in market AH, and finally the demand in market AB. Note that each situation can be analysed without loss of generality as we will do below with situation *(v)* and main results do not change qualitatively. For instance, if we consider situation *(i),* where the airline satisfies first the demand in market AH, second the demand in market HB, and finally the demand in market AB, results differ only in the level of private and social profitability of the integration. If the capacity restrictions in airport H are sufficiently important and the airline can only satisfy the demand in market AH, the airline and HST integration would have no effects on private and social benefits. However, if the capacity restrictions in airport H are not sufficiently important, and the airline can satisfy the demand in market AH and at least part of the demand in market HB, main results are basically the same to those obtained when considering situation *(v)*.

Thus, taking into account the results in expression (10) and depending on how strict is the capacity constraint in airport H ($\overline{Q}$), we can distinguish the following equilibrium outcomes:

a) If $\overline{Q} \leq q*_A^{HB}$, the optimal quantities to be offered by the airline and the HST are given by:

$$q_A^{HB} = \overline{Q};\ q_A^{AH} = 0;\ q_A^{AB} = 0; q_T^{HB} \geq q*_T^{HB}, \tag{11}$$

where q_T^{HB} is obtained by substituting the corresponding prices in the reaction function of the HST given by expression (9).

b) If $\overline{Q} \leq q*_A^{HB} + q*_A^{AH}$, the optimal quantities to be offered by the airline and the HST are given by:

$$q_A^{HB} = q*_A^{HB};\ q_A^{AH} = \overline{Q} - q*_A^{HB};\ q_A^{AB} = 0; q_T^{HB} = q*_T^{HB}. \tag{12}$$

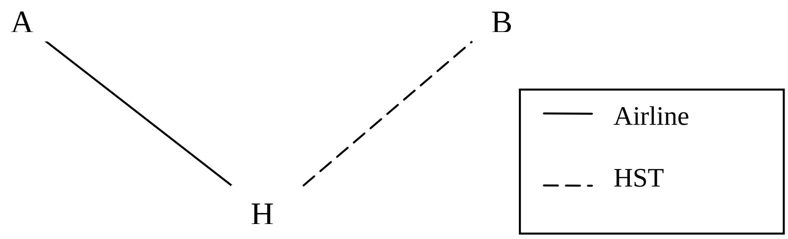
c) If $\overline{Q} \leq q*_A^{HB} + q*_A^{AH} + q*_A^{AB}$, the optimal quantities to be offered by the airline and the HST are given by:

$$q_A^{HB} = q*_A^{HB};\ q_A^{AH} = q*_A^{AH};\ q_A^{AB} = \overline{Q} - q*_A^{HB} - q*_A^{AH}; q_T^{HB} = q*_T^{HB}. \tag{13}$$

Case 2: Airline and HST integration

In this case, we assume that the airline and the HST decide to integrate. Thus, the airline stops operating the route HB, which is now operated by the HST as a monopolist. Due to this agreement, the airline is able to release slots in airport H to satisfy other markets. Notice that the airline and the HST share the joint profits that they get in markets AH, HB, and AB. The network structure is now represented in Figure 2.

Figure 2. The network structure in airports with capacity restrictions and airline and HST integration



When the airline and the HST decide to integrate passengers willing to travel from city A to city H can only do it by plane. Similarly, passengers willing to travel from city H to city B can only do it by train. In this latter case, the HST operates as a monopolist and captures all the demand in this market:

$$q_T^{HB} = 2\beta - p_T^{HB}. \tag{14}$$

Passengers willing to travel from city A to city B must travel the route AH by plane and the route HB by train. In general, switching from one mode of transport to the other may imply an additional cost for AB passengers in terms of additional connecting time, timetable incompatibilities, baggage transportation, etc. However, if the airline and HST integration is complete this switching cost may be considerably reduced. For the sake of simplicity, we assume that the airline and HST integration is complete and the switching cost for AB passengers is negligible. Moreover, we assume that AB passengers are charged a single ticket for the whole trip both in plane and HST denoted by p_{A+T}^{AB}. Thus, the demand for the market AB is given by:

$$q_{A+T}^{AB} = \gamma - p_{A+T}^{AB}. \tag{15}$$

Similarly to what we did in Case 1, we start analyzing the airline and the HST maximization programs when they decide to integrate and there is no capacity constraint in airport H. In this case, the airline and the HST jointly solve the following maximization problem:

$$\underset{p_A^{AH},\, p_T^{HB},\, p_{A+T}^{AB}}{Max} (\alpha - p_A^{AH})(p_A^{AH} - C) + (2\beta - p_T^{HB})(p_T^{HB} - c) + (\gamma - p_{A+T}^{AB})(p_{A+T}^{AB} - C - c). \quad (16)$$

From the first order conditions of the above maximization program we can obtain the optimal prices and quantities if the airline and the HST decide to integrate and there is no capacity constraint in airport H, which are given by:

$$\begin{aligned} p{**}_A^{AH} &= \frac{\alpha + C}{2} = p{*}_A^{AH}, & q{**}_A^{AH} &= \frac{\alpha - C}{2} = q{*}_A^{AH} \\ p{**}_T^{HB} &= \frac{2\beta + c}{2}, & q{**}_T^{HB} &= \frac{2\beta - c}{2} \\ p{**}_{A+T}^{AB} &= \frac{\gamma + C + c}{2}, & q{**}_{A+T}^{AB} &= \frac{\gamma - C - c}{2}. \end{aligned} \quad (17)$$

Even in the case that the airline and the HST decide to integrate, if airport H is capacity-constrained the airline may be unable to satisfy the demand in all markets. To be consistent with the situation *(v)* considered in Case 1 (when integration is absent) we now consider the situation under which the inequality $\Pi^{**}{}_A^{AH} > \Pi^{**}{}_A^{AB}$ holds and where, if airport H is capacity-constrained, the airline satisfies first the demand in market AH, and then the demand in market AB.

Thus, taking into account the results in expression (17) and depending on how strict is the capacity constraint in airport H ($\overline{Q}$), we can distinguish the following equilibrium outcomes:

a) If $\overline{Q} \le q{*}_A^{AH}$, the optimal quantities to be offered by the airline and the HST are given by:

$$q_A^{AH} = \overline{Q};\ q_A^{AB} = 0;\ q_T^{HB} = q{**}_T^{HB}. \quad (18)$$

b) If $\overline{Q} \le q{*}_A^{AH} + q{**}_{A+T}^{AB}$, the optimal quantities to be offered by the airline and the HST are given by:

$$q_A^{AH} = q{*}_A^{AH};\ q_A^{AB} = \overline{Q} - q{*}_A^{AH};\ q_T^{HB} = q{**}_T^{HB}. \quad (19)$$

Let us now compare the optimal results for the case in which the airline and the HST are integrated and those where they are not integrated in a capacity-constrained airport.

Proposition 1: *If airport H is capacity-constrained, the airline and HST integration is always privately profitable, that is, the airline and the HST obtain higher or equal joint profits.*

Proof:

a) *If* $\overline{Q} \leq q{*}_{A}^{HB}$, *the optimal quantities to be offered by the airline and the HST in absence of cooperation are given by expression (11). In this latter case, the airline can only partially satisfy market HB. Joint profits for the airline and the HST are lower when they compete than when they integrate and act as a monopolist in market HB. In addition, if the airline and the HST decide to integrate, the airline could release slots in airport H, take care of other markets and obtain additional benefits.*

b) *If* $\overline{Q} \leq q{*}_{A}^{HB} + q{*}_{A}^{AH}$, *the optimal quantities to be offered by the airline and the HST in absence of cooperation are given by expression (12). In this case, the airline and the HST compete in market HB and the airline could only partially take care of market AH. However, if the airline and the HST decide to integrate, on the one hand, the joint benefits with a monopoly in market HB will be greater than those of competition. On the other hand, the airline could satisfy more demand in market AH and/or market AB, obtaining greater profits than in the case in which cooperation does not exist.*

c) *If* $\overline{Q} \leq q{*}_{A}^{HB} + q{*}_{A}^{AH} + q{*}_{A}^{AB}$, *the optimal quantities to be offered by the airline and the HST in absence of cooperation are given by expression (13). In this case, the airline and the HST compete in market HB and the airline would satisfy in monopoly regime the demand in market AH and part of the demand in market AB. However, if the airline and the HST decide to integrate, first, the joint benefits with a monopoly in market HB will be greater than those of competition. Second, the benefits in market AH would* *be identical irrespective of whether the airline and the HST integrate or not. Finally, the benefits in market AB will be greater if they integrate since, on the one hand, the demand is better satisfied and, on the other hand,* $c \leq C$. ■

From the proof of Proposition 1 we can conclude that the lower the capacity in airport H, the more privately profitable is the airline and HST integration. Thus, if airport H has important restrictions of capacity, the airline, when competing with the HST in the domestic market HB, will be unable to satisfy the demand in the other markets. Nevertheless, if the competition between the airline and the HST disappears the airline will be able to release slots in airport H to satisfy markets AH and AB. If airport H does not have important restrictions of capacity, the airline will not need to release so many slots to satisfy the other markets and the airline and HST integration will be less profitable. This result is summarized in Corollary 1.

Corollary 1: *The lower the capacity in airport H, the more privately profitable is the airline and HST integration.*

Once we have considered the private benefits of the airline and HST integration, let us analyze the consumer surplus in each market. On the one hand, we have a negative effect since when the airline and the HST integrate the competition in market HB disappears. On the other hand, there is a positive effect since the airline and HST integration will allow the airline to release slots in airport H and to satisfy the demand in more markets.

Proposition 2: *If airport H is capacity-constrained, the airline and HST integration always reduces the consumer surplus in market HB. However, the airline and HST integration never reduces the consumer surplus in markets AH and AB. In particular, if airport H has sufficiently important capacity restrictions, the airline and HST integration increases the consumer surplus in at least one of these latter markets.*

Proof:

a) *If* $\overline{Q} \leq q*_A^{HB}$, *the optimal quantities to be offered by the airline and the HST in absence of cooperation are given by expression (11). In this case, the airline can only satisfy the demand in market HB. The prices of the airline and the HST are lower in competition than when the airline and the HST integrate and act as a monopolist. Therefore, the consumer surplus in market HB is always lower when the airline and the HST decide to integrate. On the other hand, when the airline and the HST decide to integrate, the airline may be able to satisfy the demand in other markets, Thus, the consumer surplus in the other markets may be higher.*

b) *If* $\overline{Q} \leq q*_A^{HB} + q*_A^{AH}$, *the optimal quantities to be offered by the airline and the HST in absence of cooperation are given by expression (12). In this case, the airline and HST compete in market HB and the airline can only partially satisfy the demand in market AH. On the one hand, if the airline and the HST decide to integrate the monopoly price in market HB is higher than the prices under competition, and thus, the consumer surplus is lower. On the other hand, if the airline and the HST decide to integrate the airline can satisfy more demand in markets AH and/or AB, and thus the consumer surplus will be higher in those markets.*

c) *If* $\overline{Q} \leq q*_A^{HB} + q*_A^{AH} + q*_A^{AB}$, *the optimal quantities to be offered by the airline and the HST in absence of cooperation are given by expression (13). In this case, the airline and the HST compete in market HB and the airline would satisfy in monopoly regime the demand in market AH and part of the demand in market AB. First, if the airline and the HST decide to integrate the monopoly price in market HB is higher than the prices under competition, and thus, the consumer surplus is lower. Second, the price and consumer surplus in market AH is identical irrespective of whether the airline and the HST decide to integrate or not. Finally, if the airline and the HST decide to integrate, the consumer surplus in market AB is higher since, on the one hand, the airline can satisfy more demand in this market and, on the other hand,* $c \leq C$. ■

Let us now analyze the welfare effects of the airline and HST integration. On the one hand, we know that, if airport H is capacity-constrained the airline and HST integration is always privately profitable. On the other hand, the airline and HST integration reduces the competition in market HB, and thus the consumer surplus. Finally, the airline and HST integration allows the airline to release slots in airport H and to satisfy demands that were unsatisfied. For that reason, if the demand in market HB is not high enough, the airline and HST integration is welfare enhancing. This result is summarized in Corollary 2.

Corollary 2: *If airport H is capacity-constrained and the demand in market HB is not high enough, the airline and HST integration is socially profitable.*

One of the main arguments used to justify airlines and HST integration is the reduction of noise and air pollution. In general, aircrafts are considered more detrimental for environment than the HST (see, for example Schreyer et al., 2004; or Givoni, 2007). For that reason, let us assume that for each passenger aircrafts emit a level of pollution denoted by e_A, while the HST emits a level of pollution denoted by e_T, with e_T significantly lower than e_A. Moreover, for the sake of simplicity, let us assume that e_T is sufficiently close to zero, i.e. $e_T \approx 0$. Now we analyze the environmental effects of the airline and HST integration if airport H is capacity-constrained.

Proposition 3: *If airport H is capacity-constrained, the airline and HST integration is never detrimental from the environmental point of view. In particular, if the restrictions of capacity in airport H are not sufficiently important the airline and HST integration will reduce the environmental pollution.*

Proof: *The airline and HST integration is detrimental (beneficial) for the environment if and only if it increases (diminishes) the amount of passengers carried by plane. With important restrictions of capacity in airport H, airline and HST integration does not affect the amount of passengers carried by plane since the slots that are released in airport H are immediately used to satisfy other markets. Therefore, in this case the airline and HST integration has no* *effect on the environment. However, if the restrictions of capacity in airport H are not sufficiently important, the airline and HST integration reduces the number of passengers carried by plane and, therefore, the environmental contamination.*■

The airline and HST integration is never detrimental in environmental terms because it never increases the number of passengers carried by plane. With important restrictions of capacity in airport H, the airline and HST integration does not have any effect on the environment since the slots that are released in airport H are immediately used to satisfy the demand in other markets. Nevertheless, if the restrictions of capacity in airport H are not sufficiently important, the airline and HST integration will allow the airline to reduce the number of passengers carried by plane and, therefore, to reduce the environmental contamination.

2.1.3. Conclusions

Although airlines and HSTs are usually considered as alternative modes of transport, sometimes their cooperation may be welfare enhancing.

In this subsection we considered an airport with capacity restrictions and we analyzed the welfare and environmental effects of airlines and HST integration. In particular, we showed that airlines and HST integration is always privately profitable while, only under certain conditions, it is also socially profitable. In addition, we showed that airlines and HST integration is never detrimental for the environment. On the contrary, sometimes it reduces the environmental contamination.

These results would justify airline and railway integration in airports that are highly congested. This is, for instance, the case of the Frankfurt airport, where the airline company Lufthansa has reached an agreement with the railway company Deutsche Bahn to cover the Frankfurt-Stuttgart and Frankfurt-Cologne routes.

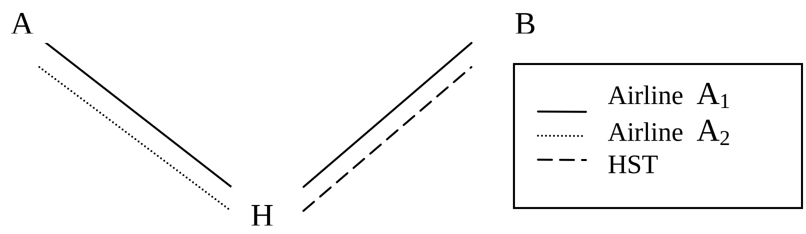
2.2. Airports with low airline competition

2.2.1. The model

As in the previous subsection we assume two routes, a transoceanic route, AH, and a domestic route, HB. In this setting, we consider three types of markets: passengers willing to travel from city A to city H, passengers willing to travel from city H to city B and passengers willing to travel from city A to city B. There is no direct route satisfying the market AB and the network structure is very similar to the one assumed in the preceding subsection. The only difference is that the transoceanic route AH is now operated by two airlines that compete in prices with differentiated products.[4]

Airline A_1 operates both routes, while airline A_2 operates only the route AH. The passengers of the market AB could, under certain circumstances, make the trip combining airline A_2 for the route AH with the high-speed train (HST) for the route HB. Figure 3 shows the new network structure.

Figure 3. The network structure with airline competition



The demand functions in the market AH are given by:[5]

$$q_{A1}^{AH} = \alpha - p_{A1}^{AH} + d_1 p_{A2}^{AH}$$
$$q_{A2}^{AH} = \alpha - p_{A2}^{AH} + d_1 p_{A1}^{AH}, \tag{20}$$

[4] Consumers may perceive different airlines as different products due to multiple reasons such as brand loyalty to a particular airline, the existence of frequent flier programs etc, (see, for instance, Brueckner and Whalen, 2000, Flores-Colonques Fillol and Moner, 2007; or Socorro and Betancor, 2010).

[5] As we did in the previous subsection, and following Dixit (1979) and Singh and Vives (1984), we assume that consumers maximize a quadratic and strictly concave utility function.

where d_1 measures the degree of product differentiation between the airlines and α is a positive parameter that indicates the market size. Parameter d_1 belongs to the interval (0,1), taking values close to zero when the airlines are considered by passengers as independent products, and values close to one when the airlines are considered as perfect substitutes.

Similarly, in the market HB airline A_1 and the HST also compete in prices with differentiated products and demands:

$$\begin{aligned} q_{A1}{}^{HB} &= \beta - p_{A1}{}^{HB} + d_2 p_T{}^{HB} \\ q_T{}^{HB} &= \beta - p_T{}^{HB} + d_2 p_{A1}{}^{HB}, \end{aligned} \tag{21}$$

where d_2 measures the degree of product differentiation between airline A_1 and the HST, and β measures the market size. Parameter d_2 can be interpreted as parameter d_1.

Finally, demand functions for market AB are given by:

$$\begin{aligned} q_{A1}{}^{AB} &= \gamma - p_{A1}{}^{AB} + d_3 \left(p_{A2+T}{}^{AB} + x \right) \\ q_{A2+T}{}^{AB} &= \gamma - \left(p_{A2+T}{}^{AB} + x \right) + d_3 p_{A1}{}^{AB}, \end{aligned} \tag{22}$$

where γ is a positive parameter that measures the size of the markets. Parameter d_3 measures the degree of product differentiation for the consumer of making the whole trip with airline A_1 or doing so by combining airline A_2 with the HST. Parameter d_3 can also be interpreted as parameter d_1. The parameter x represents the switching cost, that is, the additional cost that a traveller must pay (in terms of additional connection time, timetable incompatibilities, baggage transportation, etc.) if he decides to travel with the combination of flight and train. In particular, if this additional cost is high enough, airline A_1 enjoys a monopoly on the market AB. On the contrary, as long as there is a complete integration between airline A_2 and the HST, the value of x tends to zero.

As in the previous subsection, we assume that the marginal operating cost for the airlines is constant, identical on all routes and equal to C. Moreover, the marginal operating cost of carrying passengers from city A to city B for the airlines is $2C$, since there are no direct flights. For the HST we assume that the marginal operating cost in the route HB is constant and equal to *c* = λC, where λ < 1. To have a well-defined model we need to assume that $\alpha, \beta, \gamma > C$. Furthermore, in order to ensure interior solutions, we assume that:

$$\lambda > \max\left\{\frac{1}{Cd_2}\left(C\left(2-d_2^{\,2}\right)-\beta\left(d_2+2\right)\right), \frac{1}{Cd_3}\left(C\left(4-d_3\left(2d_3+1\right)\right)-\gamma\left(d_3+2\right)\right)\right\}.$$

2.2.2. The integration effects

For the sake of simplicity, we consider only two extreme cases for the switching cost x. On the one hand, and without loss of generality, we normalize the switching cost to zero for the case in which airline A_2 and the HST decide to integrate. On the other hand, we consider the extreme case in which the switching cost is so high that it is no worth for any passenger to travel first with airline A_2 and then change to the HST.

Case 1: No cooperation between airline A_2 and the HST

If there is no cooperation between airline A_2 and the HST, the switching cost x will be excessively high and no passenger on the market AB will choose to travel with the combination of airline and HST. In this case, airline A_1 has a monopoly on the market AB and the demand in this market is given by:

$$q_{A1}^{\;AB} = 2\gamma - p_{A1}^{\;AB}, \tag{23}$$

where the non-arbitrage condition $p_{A1}^{\;AB} \le p_{A1}^{\;AH} + p_{A1}^{\;HB}$ is assumed to be satisfied in equilibrium.

Thus, airline A_1 chooses the ticket prices for the routes AH, HB and AB and solves the following maximization problem:

$$\underset{p_{A1}^{\;AH},\, p_{A1}^{\;HB},\, p_{A1}^{\;AB}}{Max} (p_{A1}^{\;AH} - C)q_{A1}^{\;AH} + (p_{A1}^{\;HB} - C)q_{A1}^{\;HB} + (p_{A1}^{\;AB} - 2C)q_{A1}^{\;AB}. \tag{24}$$

Airline A_2 operates just the route AH and therefore chooses the ticket price that solves the following:

$$\underset{p_{A2}{}^{AH}}{Max}\,(p_{A2}{}^{AH}-C)q_{A2}{}^{AH}. \tag{25}$$

Finally, the HST chooses the ticket price for the route HB that solves the following maximization program:

$$\underset{p_T{}^{HB}}{Max}\,(p_T{}^{HB}-c)q_T{}^{HB}. \tag{26}$$

Optimal prices that arise from solving the maximization problems of airline A_1, airline A_2 and the HST are given by:[6]

$$\begin{aligned}
&p*_{A1}{}^{AH}=p*_{A2}{}^{AH}=\frac{\alpha+C}{2-d_1},\\
&p*_{A1}{}^{HB}=\frac{1}{4-d_2{}^2}\left(2\left(C+\beta\right)+\left(c+\beta\right)d_2\right),\\
&p*_T{}^{HB}=\frac{1}{4-d_2{}^2}\left(2\left(c+\beta\right)+\left(C+\beta\right)d_2\right),\\
&p*_{A1}{}^{AB}=\gamma+C.
\end{aligned} \tag{27}$$

Notice that in the market AH operate two symmetric firms, and because of this in equilibrium they set identical prices. However, the cost difference between the HST and airline A_2 in route HB allows the HST to set a lower price.[7]

<u>Case 2: Integration between the airline and the high-speed train</u>

Now suppose that the airline A_2 and HST integration is complete. In particular, assume that the switching cost x is negligible, that is, *x=0*. The main consequence for the markets is that the market AB is no longer a monopoly since AB passengers have also the option to do this trip with the combination of

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[6] We assume that β, d_1 and d_2 satisfy the conditions such that in equilibrium one firm can capture at most all the market of competing firms.

[7] In other words, if λ were equal to 1, both firms would set the same price. That is:

$$p*_{A1}{}^{HB}\left(\lambda=1\right)=p*_T{}^{HB}\left(\lambda=1\right)=\frac{\beta+C}{2-d_2}.$$

HST and airline A_2. We assume that airline A_2 and the HST jointly set the price for the whole trip from city A and city B and thus they share the corresponding joint profits.

The expressions of the maximization problems that solve the companies for markets AH and HB are the same as presented in the previous subsection. Now in addition, airline A_2 and the HST solve the following:

$$\underset{p_{A2+T}{}^{AB}}{Max}\ (p_{A2+T}{}^{AB} - C - c)q_{A2+T}{}^{AB}. \tag{28}$$

Since markets are independent, and therefore there are no network effects on other markets, the only effect of the integration is over the market AB. Now, equilibrium prices in this market are given by:[8]

$$\begin{aligned} p^{**}{}_{A2+T}{}^{AB} &= \frac{1}{4-d_3{}^2}\left(2\left(C+c+\gamma\right)+\left(2C+\gamma\right)d_3\right), \\ p^{**}{}_{A1}{}^{AB} &= \frac{1}{4-d_3{}^2}\left(2\left(2C+\gamma\right)+\left(C+c+\gamma\right)d_3\right). \end{aligned} \tag{29}$$

The combination of HST and plane also has a competitive advantage of lower costs, therefore we have that $p^{**}{}_{A2+T}{}^{AB} < p^{**}{}_{A1}{}^{AB}$.

Now we discuss the welfare gains or losses arising from the complete integration between airline A_2 and the HST.[9]

As we have already indicated, since the markets are independent, the only effect of the integration is on market AB, so we can concentrate on analyzing the changes that occur therein.

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[8] We assume that β and d_3 satisfy that in equilibrium at most one firm may capture the entire market of the competing firm.

[9] This can be understood as an analysis of the "winners" and / or "losers" that would involve measures to reduce the value of the switching cost x. This could be due to improvements in the infrastructure that allows connection between different modes of transport as well as measures taken by the companies themselves to facilitate the interconnection (coordination of arrival and departure schedules, baggage check to final destination, etc.).

Proposition 4: *In airports with low competition between airlines, the integration between airline A_2 and the HST is always privately profitable, though it reduces the profits of airline A_1.*

Proof:

a) With integration, the HST and airline A_2 have access to a new market (AB), thus their profits increase because of the gains from this new market.

b) In the absence of cooperation between airline A_2 and the HST, airline A_1 obtains monopoly profits. However, when airline A_2 and the HST decide to integrate, airline A_1 has to compete with the combination of rail and air, so airline A_1 has lower profits. ■

We find that the integrated firms have access to a new market and, consequently, the integration is a profitable strategy for them. In contrast, airline A_1 loses its monopoly position and hence its profits are lower. In the next proposition we show that, because of the emergence of competition in market AB, consumers are better-off with integration. Moreover, social welfare is also higher.

Proposition 5: *In airports with low competition between airlines, the integration between airline A_2 and the HST increases consumer surplus and social welfare.*

Proof: *The integration between airline A_2 and the HST implies a drop in prices. It happens since the market is no longer a monopoly and becomes a market in which two alternative modes of transport compete for passengers. They gain variety and access to lower prices. Likewise, the greater competition and consumer surplus lead to a greater social welfare.* ■

In this context we will now analyze the environmental effects that could result from the integration between airline A_2 and the HST. As in the previous subsection, we assume that for each passenger, the plane emits a level of pollution denoted by e_A, while the HST emits a level of pollution denoted by e_T. Regarding e_A and e_T we maintain the same assumptions that we introduced in subsection 2.1.

Proposition 6: *In airports with low competition between airlines, the integration between airline A_2 and the HST has an ambiguous environmental effect.*

Proof: *The integration between an airline and the HST is detrimental (beneficial) for the environment if and only if it increases (decreases) the number of passengers carried by plane. The integration between airline A_2 and the HST resulting in a fall in prices leads to an increase in travel demand on the route AB. On the one hand, the number of passengers transported by air in route AH increases, but at the same time it decreases for the route HB, where the HST carries some passengers of market AB.*

Let us denote by $q*_{A1}^{AB}$ the quantity of travellers in the route AB when airline A_1 is a monopoly, and by $q*_{A1}^{AH(AB)}$ ($q*_{A1}^{HB(AB)}$) the quantity of passengers in the route AH (HB) making the trip AB. Note that $q*_{A1}^{AB} = q*_{A1}^{AH(AB)} = q*_{A1}^{HB(AB)}$. Similarly, let us denote by $q{**}_{A1}^{AB} = q{**}_{A1}^{AH(AB)} = q{**}_{A1}^{HB(AB)}$ the amount of passengers carried by airline A_1 when airline A_2 and the HST decide to integrate, and $q{**}_{A2T}^{AB} = q{**}_{A2}^{AH(AB)} = q{**}_{T}^{HB(AB)}$ is the quantity operated by the combination of airline A_2 and the HST.

Due to the competition when airline A_2 and the HST decide to integrate, it holds that $q{**}_{A1}^{AH(AB)} + q{**}_{A2}^{AH(AB)} > q*_{A1}^{AH(AB)}$. Therefore, the environmental effect in this route is negative. In contrast, the effect in the route HB is positive since $q{**}_{A1}^{HB(AB)} < q*_{A1}^{HB(AB)}$. Consequently, the net effect will be given by $q{**}_{A1}^{AH(AB)} + q{**}_{A2}^{AH(AB)} - q*_{A1}^{AH(AB)} - \left(q*_{A1}^{HB(AB)} - q{**}_{A1}^{HB(AB)}\right)$ or what is the same, by $2q{**}_{A1}^{AB} + q{**}_{A2}^{AH(AB)} - 2q*_{A1}^{AB}$. The statement in the Proposition follows from the fact that, depending on the parameter values, this expression can be positive or negative. ■

2.2.3. Conclusions

In this subsection we have analyzed the effects of airline and HST integration in airports with low competition between airlines. The main effect of integration is to foster competition in the market where the airline and the HST integrate. Without integration, the market is a monopoly of the other airline. When an airline and the HST decide to integrate the combination of HST and airline emerges as an alternative way of travelling for passengers, thus removing the monopoly status of the other airline. Consequently, integration means more competition, lower prices, more variety for consumers and therefore higher social welfare.

However, in this case, we can not say conclusively whether the environmental effect of integration would be positive or negative. Increased competition in the market translates into increased demand for travel, and although a significant proportion will be covered by the train, airline passengers will also increase, which has a negative impact on the environment.

3. General conclusions

Traditionally, airlines and HST have been understood as alternative transport modes competing with each other. However, since the beginning of the 90s, intermodality in transport of passengers has been one of the priorities of the European Union. In particular, it is thought that it may help to promote social cohesion of member countries, economic competitiveness and environmental protection.

This article analyzes the effects of airline and HST integration in two different contexts. On the one hand, we study the effects of integration in airports with capacity constraints. On the other hand, we analyze the effects of integration in airports with low competition between airlines. In the first case we show that integration reduces competition, however, since integration opens the possibility to serve new markets the effect on social welfare is ambiguous. In the second case, the integration allows for increased competition and a clear increase in social welfare. Regarding the effects on the environment, in the first case, the effect of integration is never harmful to the environment, whereas in the latter case, the effect is ambiguous.

It should be noted that the benefits discussed here apply to the case in which the integration is complete, that is, the infrastructure is sufficiently well connected and transfers are sufficiently well organized in terms of connection times, luggage transport, etc, such that changing from one mode to the other does not involve any additional cost to the passenger (i.e., switching costs are negligible). Thus, the benefits obtained here can be considered as the maximum cost that, from the private, social and environmental point of view may be incurred to achieve a complete integration.

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