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Alessandro Avenali
Tiziana D’Alfonso
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Technical Report n. 9, 2019
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Alessandro Avenali¹, Tiziana D’Alfonso¹*, Alberto Nastasi², Pierfrancesco Reverberi²

¹Department of Computer, Control, and Management Engineering Antonio Ruberti, Sapienza University of Rome, Via Ariosto 25, 00185, Rome, Italy

This version: March 2019

*Corresponding author
Tel: +39 06 77274 105
Fax: +39 06 77274 074
E-mail address: dalfonso@dis.uniroma1.it (Tiziana D’Alfonso)

Abstract

Air transport and HSR are not simple competitors. Indeed, air and HSR services can be complements on long-haul routes served by connecting flights through a hub airport. This complementarity creates room for cooperation between airlines and HSR operators, particularly relating to international connecting passengers. Airport managers are also interested in such agreements since they affect, among others, air traffic volumes and the demand for slots on the part of the airlines. In this framework, we develop a theoretical model to study transport operators’ incentives to cooperate, and the strategic role of airports in facilitating or dampening airline-HSR cooperation via the airport per passenger fee. In our model, transport operators cooperate to offer a bundle of domestic HSR and international air services via a multimodal hub airport. We show that the scope for cooperation depends on two main factors, that is, the related sunk costs and mode substitution between air and HSR services.

Keywords: Airline; high speed rail; cooperation; competition; airport per passenger fee; sunk costs

1. Introduction

European Union (EU) leaders have endorsed the objective of developing a EU-wide multimodal TEN-T (Trans European Network-Transport) by 2030, which will connect major airport hubs to the high-speed rail (HSR) network by 2050, when the majority of medium-distance passenger transport should go by rail (EC, 2011, pp. 9, 19). This is because of the projected increase in demand for flights,
which makes capacity at hub airports scarce and the impact of aviation on the environment a growing concern (ICAO, 2014).

In this framework, air transport and HSR are not simple competitors. Indeed, air and HSR services can be complements on long-haul routes served by connecting flights through a hub airport. If HSR is an effective substitute for either of these flights, then connecting passengers may combine air and HSR services. This complementarity creates room for cooperation between airlines and HSR operators, which indeed have signed many intermodal agreements worldwide, particularly relating to international connecting passengers (see Section 2). Airport managers are also interested in such agreements since they affect, among others, air traffic volumes and the demand for slots on the part of the airlines.

In this paper, we develop a theoretical model to study transport operators’ incentives to cooperate, and the strategic role of airports in facilitating or dampening airline-HSR cooperation. In our model, transport operators cooperate to offer a bundle of domestic HSR and international air services via a multimodal hub airport. We show that the scope for cooperation depends on two main factors, that is, the related sunk costs and mode substitution between air and HSR services.

On the one hand, huge investments (discussed in Section 2) are often required to make cooperation effective, which can be a major barrier to intermodal agreements. Indeed, transport operators have to jointly incur considerable sunk costs to ensure that passengers perceive the multimodal trip as a real alternative to the connecting flight. Clearly, an intermodal agreement is incentive-compatible as long as all the involved players achieve benefits in excess of the (relevant share of the) sunk costs of cooperation. Thus, complementarity between transportation modes derives from compatibility, and compatibility is a strategic decision.

On the other hand, mode substitution affects traffic volumes and the mode share both in connecting markets, where air and HSR services mainly act as complements, and in short-haul markets, where they are competing for passengers. Therefore, the impact of the intermodal agreement on transport
operators’ profits depends on the degree of substitutability between air and HSR services, which also has an impact on the airport company that collects revenues from the landing fee charged to airlines. We find that transport operators’ incentives to cooperate may not be aligned with the airport company’s attitude towards intermodal agreements. Compared to the benchmark case of competition, under cooperation transport operators’ total profits increase whereas the airport company’s profit decreases with the degree of substitutability between air and HSR services. As to transport operators this is because, as products are stronger substitutes, the profit of the multiproduct monopoly arising after cooperation is increasingly higher than the total profit in a competitive duopoly. As to the airport company, if mode substitution is stronger then the landing fee has to be significantly reduced to avoid a massive shift of passengers from air to HSR services, particularly after an intermodal agreement.

Thus, when the sunk costs are as high as transport operators would not cooperate, the airport company may find it profitable to facilitate airline-HSR cooperation, provided that mode substitution is weak. In such a case, airport managers may decide to participate in the infrastructure investments needed to make cooperation effective. For instance, Lufthansa, Deutsche Bahn, and Fraport (the company managing Frankfurt airport) have agreed to share the costs related to deploying the luggage system for the intermodal product. On the other hand, when mode substitution is strong, the airport company may prefer to dampen airline-HSR cooperation, for instance, by influencing strategically the ease of transfer between the rail station at the airport and air terminals.

This paper contributes to the growing body of literature that investigates airline-HSR cooperation.¹ In this framework, the great majority of papers does not consider the strategic role of airports that follows from the vertical relationship with airlines.

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¹ A burgeoning literature has investigated airline-HSR competition, both theoretically (see e.g. Yang and Zhang, 2012; D’Alfonso et al., 2015, 2016; Jiang and Zhang, 2016) and empirically (see e.g. Fu et al., 2014; Wan et al., 2016).
Jiang and Zhang (2014) find that airline-HSR integration improves social welfare when mode substitution in overlapping markets is sufficiently low (so that the adverse effect on competition is small), or the hub airport capacity is tight (so that integration may alleviate congestion). Xia and Zhang (2016) assume that air and HSR services are vertically differentiated. They find that after integration, when the hub capacity is tight, the airline withdraws from the market where it has less competitive advantage over HSR. They also find that airline-HSR integration is likely to improve welfare when the hub airport is capacity constrained. However, both papers do not model transport operators’ incentives to cooperate since they assume that there are no sunk costs related to airline-HSR integration.

Jiang et al. (2017) investigate different air-rail cooperation schemes between a rail operator and either a domestic or a foreign airline in a single transportation market. Partners incur a fixed cost to make the partnership effective and such a cost is an increasing function of the cooperation level, which is endogenous in the model. The authors find that the cooperation level is lower when both partnerships coexist than when only one partnership exists.

Avenali et al. (2018) study the strategic formation of airline-HSR partnerships, depending on the sunk costs necessary to make cooperation effective and on transport operators’ bargaining power in negotiating agreements. The authors investigate the conditions under which either a capacity purchase or a joint venture agreement improves consumer surplus and social welfare, depending on the level of congestion at hub airports and on mode substitution between air and HSR services.

Recent contributions consider a multiple-airport system (MAS) where independent airports are linked by the HSR. Takebayashi (2015) proposes a numerically calibrated model to investigate the impact of the HSR linkage on competition between two airports in the case where airlines and the HSR also compete. He finds that the degree of airport-HSR connectivity affects the market shares of the two airports. Then, Takebayashi (2016) discusses the possibility of cooperation between airports and the HSR. He shows that cooperation between the HSR and the smaller-demand airport can reduce
congestion at the larger-demand airport. Finally, Takebayashi (2018) studies the efficiency of a MAS with the HSR connecting the airports. The numerical analysis shows that reducing airport charges at uncongested airports is effective for improving social welfare. However, all of these papers do not consider transport operators’ incentives to cooperate.

Xia et al. (2018) develop a revenue-sharing mechanism between the airline and the HSR in a MAS. The authors find that social welfare increases with the HSR linkage, and that airline-HSR cooperation serves effectively as a way to divert passengers from capacity-constrained to unconstrained airports. The authors do not model the vertical relation between airports and airlines, and thereby they ignore the role of airports in facilitating (or dampening) airline-HSR cooperation.

This paper is organized as follows. Section 2 discusses the incentives to airline-HSR cooperation. Section 3 introduces the model. Sections 4 and 5 deal, respectively, with the benchmark case of competition and with airline-HSR cooperation. Section 6 discusses the strategic role of airports in influencing cooperation. Section 7 contains concluding remarks and directions for future work.

2. Incentives to intermodal cooperation

There are a number of key drivers and barriers to intermodal agreements, some of which are specific to the major players involved, that is, airlines, HSR operators, and airport companies, while others are common to such players. These drivers and barriers have been widely discussed in the literature (Eurocontrol, 2005; Givoni and Banister, 2006; Vespermann and Wald, 2011; Chiambaretto and Decker, 2012). We summarize the main arguments in Table 1, while in Figure 1 we report some examples of intermodal products with varying degrees of seamlessness and intensity of cooperation. In what follows, we briefly discuss the most important points, and we highlight some issues that may deserve further attention.

== Insert Table 1 and Figure 1 about here ==
One of the main reasons for intermodal cooperation on the part of airlines is that they can provide wider access (i.e., from a larger number of cities in a country) to their services from the hub airport to international destinations. For instance, Qatar Airways or Etihad Airways have increased their market share in France with the ‘tgvair’ combined product, by which they sell rail trips to 19 cities in France from Paris-CDG airport (see Figure 1).

After an intermodal agreement, airlines can also divert part of the short-haul traffic to HSR, thereby making the relevant airport slots available for routes that are more profitable. This is particularly important in hub-and-spoke networks with congested hubs, where slots are scarce and expensive.2 In such a case, the downside of intermodal agreements is that airlines may lose control of feeder routes, to the benefit of either HSR operators or competing airlines. This often leads airlines to maintain short-haul feeder flights on routes where intermodal agreements are in place. For instance, after Lufthansa and Deutsche Bahn have agreed to offer the ‘AIRail Service’ combined product (see Figure 1), multimodal passengers can take either flights or HSR trains from Frankfurt to Stuttgart, while flights from Frankfurt to Cologne are no longer available.

As to HSR operators, they benefit from cooperation in that it increases their load factor and market share on short-haul routes, with no significant increase in marginal costs once the rail infrastructure is deployed. On the other hand, rail infrastructure is a possible barrier to intermodal agreements as long as platform capacity and HSR slots are not sufficient to feed airlines’ hubs.

Airport companies are interested in airline-HSR agreements since they can be a means to redistribute the use of slots from short-haul flights to more profitable long-haul flights (that are subject to higher landing fees), to expand their catchment areas and effectively compete with adjacent airports, to promote some commercial activities in airport terminals, and to address environmental targets. The other side of intermodal cooperation for airports are revenue losses from a partial (instead of a

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2 EU policy-makers promote a revision of airport slot regulation to efficiently manage capacity at congested hubs (see Avenali et al., 2015, for a theoretical study).
complete) reuse of freed slots, particularly at uncongested airports, and from stronger airport competition due to overlapping catchment areas.

A major barrier to intermodal agreements that is of interest to all players is the huge investments required to make cooperation effective, which result in considerable sunk costs. As a baseline, transport operators should enable passengers to purchase a single ticket for the entire multimodal trip (i.e., to buy a bundle of domestic HSR and international air services). This requires operators to integrate their information technology and computer reservation systems. Moreover, it requires operators to coordinate schedules between air and HSR services, thereby taking the risk of possible delays on one segment of the journey, and providing passengers with proper warranties. Operators may also offer coordinated baggage handling (so that passengers should not care about baggage transfer at the intermediate stop), and/or supplementary services on HSR trains similar to those offered on short-haul flights (e.g., dining).

The most important obstacle to cooperation is perhaps the absence of the HSR station at the hub airport to enable passenger intermodality. Indeed, the cost of deploying the HSR link to the hub airport may be significantly (and sometimes prohibitively) high. Since the benefits of cooperation accrue to all the involved players, then the infrastructure cost should ideally be split among beneficiaries. This means that the private (usually the airlines, and possibly airport companies) and the public (usually rail operators, and possibly airport companies) sectors are called to jointly take on the responsibility to make cooperation effective. As long as intermodal agreements are beneficial to society as a whole, policy makers are also called to play an active role and pave the way for such agreements to become feasible, by providing the involved players with suitable (e.g., fiscal) incentives and/or direct funding (subject to budget constraints) to support infrastructure investments.

An additional factor (somewhat overlooked in the above mentioned literature) that may help explain the attitude of the involved players towards intermodal agreements is the degree of substitutability between air and HSR services. Indeed, mode substitution affects the impact of the agreement on
traffic volumes and on the mode share. On the one hand, substitutability is essential to determine whether long-distance passengers may consider the airline-HSR combined product as an effective alternative to the connecting flight. On the other hand, substitutability measures the strength of competition for passengers in short-haul markets served by both the airline and the HSR operator.

It is worth noting that assessing these effects is relevant not only to airlines and to HSR operators, but also to airport companies, whose revenue depends primarily on air traffic. Thus, in order to calibrate landing fees, airport managers should anticipate how mode substitution affects the impact of intermodal agreements on traffic volumes and mode shares.

In this framework, it may happen that transport operators and airport companies have conflicting interests on intermodal agreements. For instance, transport operators might be more inclined to sign an agreement in response to a high degree of substitutability because, among other factors, they can expect to achieve high traffic volumes for the airline-HSR combined product. Instead, if mode substitution is high then airport managers might have a less favorable attitude towards the agreement. This is because under cooperation, when mode substitution is stronger, transport operators have the incentive to induce passengers to travel by train instead of flying, thereby reducing the costs related to paying the landing fee. Therefore, the airport company has to significantly reduce such a fee to preserve air traffic volumes, which are the only source of revenues for the company.

In the next section, we discuss these issues more formally by means of a theoretical model.

3. The model

We consider three players, an airline $a$, a HSR transport operator $r$, and an airport company $h$, which run a transportation network of three nodes (i.e., cities) illustrated in Figure 2. The airline operates the short-haul (e.g., domestic) route between city O and city H. In the same market (also called overlapping market), the HSR transport operator offers a direct ride. The airline also serves two long-
haul (e.g., international) routes, that is, market HD with a direct connection and market OD (also called connecting market) with a one-stop trip via city H.³

=== Insert Figure 2 about here ===

City H can serve as a multimodal hub, since there is a HSR station at the airport. Travelers from city O to city D could, in principle, transfer from O to H by HSR and then fly from H to D. Given that market OD is covered by a single-carrier service, we assume that multimodal trips do not occur unless the airline and the HSR cooperate to offer a bundle of domestic HSR and international air services.⁴

Let $M = \{OH, HD, OD\}$ be the set of markets $m$, and $T = \{A, R, AA, AR\}$ the set of transportation products $t$, where $t = A$ ($t = R$) stands for a direct flight (HSR ride), $t = AA$ stands for a connecting flight via hub H, and $t = AR$ stands for the multimodal trip via hub H. Let $T_m$ be the subset of transportation products available in market $m$. Given the network in Figure 2, we have that $T_{OH} = \{A, R\}$, $T_{HD} = \{A\}$, and $T_{OD} = \{AA\}$ when the airline and the HSR do not cooperate, or $T_{OD} = \{AA, AR\}$ when they cooperate. Thus, there are at most five travel choices for passengers.

We consider the following inverse demand curves in relevant markets:⁵

$$p_{OH}^A = \alpha - q_{OH}^A - \gamma q_{OH}^R$$
$$p_{OH}^R = \alpha - q_{OH}^R - \gamma q_{OH}^A$$
$$p_{HD}^A = \alpha - q_{HD}^A$$
$$p_{OD}^{AA} = \alpha - q_{OD}^{AA} - \gamma q_{OD}^{AR}$$
$$p_{OD}^{AR} = \alpha - q_{OD}^{AR} - \gamma q_{OD}^{AA}$$

where $p_m^t$ and $q_m^t$ respectively are prices and traffic volumes for transportation products $t \in T_m$ in market $m \in M$ (note that product $AR$ is supplied only in the case of airline-HSR cooperation, and

³ We borrow from Jiang and Zhang (2014) the topology and market structure of the network.
⁴ This assumption is made for simplicity, but is not essential for the results (see the discussion in Avenali et al., 2018).
⁵ These demand curves can be obtained by assuming that the representative passenger in each market has a strictly concave quadratic utility function à la Singh and Vives (1984).
\( q_{OD}^{AR} = 0 \) in the absence of cooperation. Parameter \( \alpha \) \((\alpha > 0)\) measures the maximum willingness to pay (hereafter, wtp) for product \( t \in T_m \), while \( \gamma \) \((0 < \gamma < 1)\) measures the degree of substitutability between transportation products, where the lower \( \gamma \), the lower the substitutability. For simplicity, we assume that \( \alpha \) and \( \gamma \) are the same in all markets.

We now turn to the supply side. As to transport operators, for simplicity we assume that: (i) the size of vehicles is the same for each transportation mode in each market and (ii) the relation among passengers, seats, and flights/HSR rides is of the fixed proportions type (see e.g., Basso, 2008), such that the product between the size of vehicles and the load factor is constant for all services in all markets (we normalize such product to unity). Thus, prices per flight/HSR ride, per seat, and per traveler are equivalent. We assume that the operating cost per flight/HSR ride, per seat, or per traveler is constant and, for simplicity, normalized to zero. However, the airline has to pay the airport company a price per flight (or landing fee) \( w \). If transport operators decide to cooperate, then they should jointly incur sunk costs \( F \) \((F > 0)\) for cooperation to become effective (see the discussion in Section 2).

As to the airport company, for simplicity we assume that the operating cost per flight is constant and normalized to zero. Furthermore, we focus on the case where the hub is not capacity constrained.

The timing of the game is as follows. At stage one, transport operators decide whether to cooperate (thereby incurring sunk costs to make their services compatible) or not. At stage two, the airport company sets the landing fee. Finally, at stage three the airline and the HSR operator set quantities in relevant markets (either cooperatively or not).\(^6\) We solve the game backwards. In doing so, we restrict attention to parameter values for which equilibrium quantities are strictly positive.\(^7\)

4. **Benchmark case: No agreement**

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\(^6\) This assumption reflects that both airport and the HSR platform capacities cannot be easily increased. Indeed, capacity adjustments are slower and more costly to implement than price adjustments, since the former require lumpy and irreversible investment. In this sense, we are taking a short-run rather than a long-run perspective. We thus follow a number of relevant papers, such as Jiang and Zhang (2014), D’Alfonso et al. (2015, 2016), and Xia and Zhang (2016).

\(^7\) This means that \( \gamma < \frac{1}{2} (\sqrt{41} - 5) \) holds. Under this assumption, equilibrium prices and profits are also strictly positive.
Consider first the benchmark case where transport operators do not cooperate. Thus, the airline is a monopoly in markets OD and HD, while the HSR operator and the airline compete à la Cournot in market OH. At stage three, the HSR operator and the airline respectively solve:

\[
\max_{q_{OH}^R} \pi_r = p_{OH}^R q_{OH}^R
\]

\[
\max_{q_{OH}^A,q_{HD}^A,q_{OD}^{AA}} \pi_a = p_{OH}^A q_{OH}^A + p_{HD}^A q_{HD}^A + p_{OD}^{AA} q_{OD}^{AA} - w(q_{OH}^A + q_{HD}^A + 2q_{OD}^{AA})
\]

where \( p_m^t (t \in T_m, m \in M) \) are as in (1). By the first-order conditions for both profits, we find the vector of quantities \( q^N(w) = (q_{OH}^{AN}(w), q_{OH}^{RN}(w), q_{HD}^{AN}(w), q_{OD}^{AA}(w)) \) that solves problem (2)-(3), where \( N \) stands for no agreement.

At stage two, the airport company chooses \( w \) in order to maximize profit:

\[
\max_w \pi_h = w(q_{OH}^{AN}(w) + q_{HD}^{AN}(w) + 2q_{OD}^{AA}(w))
\]

By the first-order condition for (4), we obtain:

\[
w^N = \frac{\alpha(3\gamma^2 + 2\gamma - 16)}{10\gamma^2 - 48}
\]

By plugging \( w^N \) in \( q^N(w) \), we find the equilibrium vector \( q^N \), that is:

\[
q^N = (q_{OH}^{AN}, q_{OH}^{RN}, q_{HD}^{AN}, q_{OD}^{AA}) = \begin{pmatrix}
\frac{\alpha(5\gamma^2 + 3\gamma - 16)}{(\gamma + 2)(5\gamma^2 - 24)}, \\
\frac{\alpha(7\gamma^2 - 8\gamma - 48)}{2(\gamma + 2)(5\gamma^2 - 24)}, \\
\frac{\alpha(7\gamma^2 - 2\gamma - 32) + 96}{20\gamma^2 - 96}, \\
\frac{\alpha(\gamma^2 - \gamma - 4)}{5\gamma^2 - 24}
\end{pmatrix}
\]

Then, by plugging \( q^N \) in (1), we find the equilibrium vector of prices \( p^N = (p_{OH}^{AN}, p_{OH}^{RN}, p_{HD}^{AN}, p_{OD}^{AA}) \) for transportation products. Finally, by plugging \( q^N, p^N \) and \( w^N \) in their respective profit functions, we find the equilibrium profits for transport operators, \( \pi^N_a \) and \( \pi^N_r \), and for the airport company, \( \pi^N_h \) (see Appendix).

5. Air-rail cooperation
In this section, we consider the case of full-scale cooperation between the airline and the HSR operator to provide the combined service in the connecting market. In such a case, the two firms set quantities in relevant markets to maximize their joint profit.

5.1 Traffic volumes

Assume that transport operators have decided to cooperate at stage one. Therefore, at stage three, they act as a merged firm that solves:

\[
\max_{q_{OH}^A, q_{OH}^R, q_{HD}^A, q_{OD}^A, q_{OD}^R} \pi_{ar}
\]

\[
= p_{OH}^A q_{OH}^A + p_{OH}^R q_{OH}^R + p_{HD}^A q_{HD}^A + p_{OD}^A q_{OD}^A + p_{OD}^R q_{OD}^R
\]

\[-w(q_{OH}^A + q_{HD}^A + 2q_{OD}^A + q_{OD}^R)\]

By the first-order conditions for (8), we find the vector \( q^I(w) \), that is:

\[
q^I(w) = (q_{OH}^{A_I}(w), q_{OH}^{R_I}(w), q_{HD}^{A_I}(w), q_{OD}^{A_I}(w), q_{OD}^{R_I}(w)) = \left( \frac{\alpha - \alpha y - w}{2(1 - y^2)}, \frac{\alpha - \alpha y + wy}{2(1 - y^2)}, \frac{\alpha - \omega}{2}, \frac{\alpha - \alpha y + wy - 2w}{2(1 - y^2)}, \frac{\alpha - \alpha y + 2wy - w}{2(1 - y^2)} \right)
\]

where \( I \) stands for integration. Based on (8), we can study the impact of \( w \) on traffic volumes. Remark 1 summarizes the comparative statics of \( q^I(w) \) with respect to the landing fee.\(^8\)

**Remark 1.** Assume that the airline and the HSR operator cooperate. In equilibrium, as the landing fee increases air passengers decrease in all markets (i.e., \( \frac{\partial q_{OH}^{A_I}(w)}{\partial w} < 0, \frac{\partial q_{HD}^{A_I}(w)}{\partial w} < 0, \frac{\partial q_{OD}^{A_I}(w)}{\partial w} < 0 \)), and we also have that:

\(^8\) We can prove that the same qualitative results hold in the benchmark scenario, namely, we find that \( \frac{\partial q_{OH}^{A_N}(w)}{\partial w} < 0, \frac{\partial q_{HD}^{A_N}(w)}{\partial w} < 0, \frac{\partial q_{OD}^{R_N}(w)}{\partial w} > 0 \) and \( \frac{\partial q_{OH}^{A_N}(w) + q_{OH}^{R_N}(w)}{\partial w} < 0 \). For brevity, all proofs are omitted and are available upon request from the authors.
(i) in market OH, HSR passengers increase (i.e., \( \partial q_{OH}^{RJ} / \partial w > 0 \)) and total traffic decreases (i.e., \( \partial (q_{OH}^{A} + q_{OH}^{RJ}) / \partial w < 0 \));

(ii) in market OD, passengers on the airline-HSR service decrease if and only if transportation products are weak substitutes (i.e., \( \partial q_{OD}^{AR} / \partial w < 0 \) iff \( \gamma < 0.5 \)), and total traffic decreases (i.e., \( \partial (q_{OD}^{A} + q_{OD}^{AR}) / \partial w < 0 \)).

Intuitively, since the landing fee is a cost to the airline, then as \( w \) increases the merged firm finds it profitable to reduce the number of air passengers in all markets, while increasing the number of HSR passengers in market OH (where total traffic decreases). An increase in \( w \) also reduces total traffic volumes in market OD. Since the cost of a connecting flight (2\( w \)) is twice the cost of the air-rail combined service (\( w \)), then the merged firm tends to substitute air-rail services for connecting flights. This particularly occurs if transportation products are strong substitutes (\( \gamma > 0.5 \)), in which case passengers on the airline-HSR service increase in response to an increase in \( w \).

5.2 Landing fee

At stage two, the airport company chooses \( w \) in order to maximize profit:

\[
\max_w \pi_h = w \left( q_{OH}^{A} + q_{HD}^{A} + 2q_{OD}^{AA} + q_{OD}^{AR} \right) \quad (9)
\]

By the first-order condition for (9), we obtain:

\[
w^* = \frac{\alpha(\gamma^2 + 4\gamma - 5)}{2(\gamma^2 + 4\gamma - 7)} \quad (10)
\]

Remark 2 summarizes the impact of mode substitution on \( w^* \).

**Remark 2.** Assume that the airline and the HSR operator cooperate. In equilibrium, as the degree of substitutability between products increases the landing fee decreases (i.e., \( \partial w^* / \partial \gamma < 0 \)).

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\(^9\) Qualitatively, the same result holds in the benchmark scenario, namely, we can prove that \( \partial w^N / \partial \gamma < 0 \).
Clearly, when mode substitution is stronger passengers are ready to travel by train instead of flying. Therefore, the airport company has the incentive to reduce the landing fee in order to preserve air traffic volumes, which are the only source of revenues for the company.

By plugging $w^i$ in $q'(w)$, we find the equilibrium vector $q^i$, that is:

$$q^i = \left( q_{OH}^{A,H}, q_{OH}^{R,H}, q_{HD}^{A,H}, q_{OD}^{A,H}, q_{OD}^{R,H} \right) = \left( \begin{array}{c}
\frac{\alpha(9 - 9\gamma - 2\gamma^2)}{4(7 - \gamma^2 - 4\gamma)(1 + \gamma)} \\
\frac{\alpha(14 - 3\gamma - \gamma^2)}{4(7 - \gamma^2 - 4\gamma)(1 + \gamma)} \\
\frac{\alpha(9 - 4\gamma - \gamma^2)}{4(7 - \gamma^2 - 4\gamma)} \\
\frac{\alpha(4 - 5\gamma - \gamma^2)}{4(7 - \gamma^2 - 4\gamma)(1 + \gamma)} \\
\frac{\alpha(9 + \gamma)}{4(7 - \gamma^2 - 4\gamma)(1 + \gamma)} 
\end{array} \right)$$

Based on (11), we can study the impact of mode substitution on traffic volumes. Remark 3 summarizes the results.\(^{10}\)

**Remark 3.** Assume that the airline and the HSR operator cooperate. In equilibrium, as the degree of substitutability between products increases, we have that:

(i) in market HD, air passengers increase (i.e., $\frac{\partial q_{HD}^{A}}{\partial \gamma} > 0$);

(ii) in market OH, air passengers decrease (i.e., $\frac{\partial q_{OH}^{A}}{\partial \gamma} < 0$) whereas HSR passengers decrease if and only if transportation products are weak substitutes (i.e., $\frac{\partial q_{OH}^{R}}{\partial \gamma} < 0$ if $\gamma < \tilde{\gamma}$, where $\tilde{\gamma} \cong 0.461$).

Moreover, total traffic in market OH decreases (i.e., $\frac{\partial (q_{OH}^{A} + q_{OH}^{R})}{\partial \gamma} < 0$):

\(^{10}\) Qualitatively, the same results hold in the benchmark scenario, namely, we can prove that $\frac{\partial q_{HD}^{A}}{\partial \gamma} > 0$, $\frac{\partial q_{OH}^{A}}{\partial \gamma} < 0$, $\frac{\partial q_{OH}^{R}}{\partial \gamma} < 0$ if $\gamma < 0.851$, and $\frac{\partial (q_{OH}^{A} + q_{OH}^{R})}{\partial \gamma} < 0$, with the only exception of passengers on the connecting flight, for which we find that $\frac{\partial q_{OH}^{A}}{\partial \gamma} > 0$. Since $\gamma < \frac{1}{2} (\sqrt{41} - 5)$ (see Footnote 7), $\frac{\partial q_{OH}^{R}}{\partial \gamma} < 0$ always holds in the feasible parameter region.
(iii) in market OD, passengers on the connecting flight decrease \( \frac{\partial q^{AAJ}_{OD}}{\partial \gamma} < 0 \) whereas passengers on the airline-HSR service decrease if and only if transportation products are very weak substitutes \( \frac{\partial q^{ARJ}_{OD}}{\partial \gamma} < 0 \) iff \( \gamma < \gamma^\ast \), where \( \gamma^\ast = 0.207 \). Moreover, total traffic in market OD increases if and only if products are strong substitutes \( \frac{\partial (q^{AAJ}_{OD} + q^{ARJ}_{OD})}{\partial \gamma} > 0 \) iff \( \gamma > \gamma^\ast \), where \( \gamma^\ast = 0.548 \).

The rationale for Remark 3 is as follows. From Remark 2, if mode substitution is stronger then the airport company has the incentive to reduce \( w \). Then, consistent with Remark 1, \( q^{AAJ}_{HD} \) increases since the supply of flights is less costly. In market OH (respectively, OD), when \( \gamma \) increases flights (respectively, connecting flights) and HSR rides (respectively, air-rail services) become stronger substitutes. Therefore, the merged firm has the incentive to substitute HSR rides (air-rail services) for flights (connecting flights), since the former are less expensive than the latter. If \( \gamma \) is sufficiently high, then the supply of HSR rides (air-rail services) increases with \( \gamma \). Note that the same result holds for total traffic in market OD.

By plugging \( q^I \) in (1), we find the equilibrium vector of prices \( p^I = (p^{AAJ}_{OH}, p^{RJ}_{OH}, p^{AAJ}_{HD}, p^{ARJ}_{OD}, p^{ARJ}_{OD}) \) for transportation products. Finally, by plugging \( q^I, p^I \) and \( w^I \) in their respective profit functions, we find the equilibrium profits for the merged firm, \( \pi^I_{ar} \), and for the airport company, \( \pi^I_{h} \) (see Appendix).

We find that the airport company’s profit decreases as long as the degree of substitutability between products increases. Generally, this is because (from Remark 2 and Footnote 9), the landing fee decreases with the degree of substitutability.\(^{11}\)

**Remark 4.** Assume that the airline and the HSR operator cooperate. In equilibrium, as the degree of substitutability between products increases, the airport company’s profit decreases (i.e., \( \frac{\partial \pi^I_{h}}{\partial \gamma} < 0 \)).

5.3 Cooperation or competition?

\(^{11}\) We can prove that the same qualitative result holds in the benchmark scenario, namely, we find that \( \frac{\partial \pi^N_{h}}{\partial \gamma} < 0 \).
At stage one, transport operators decide whether to cooperate (thereby incurring the sunk costs $F$) or not, by anticipating the landing fee at stage two, and passenger traffic volumes at stage three. Proposition 1 illustrates transport operators’ decision.

**Proposition 1.** If the sunk costs are sufficiently low, that is, if $F$ is such that $0 < F \leq F_1$ holds, where $F_1 = \pi_{ar}^I - (\pi_a^N + \pi_r^N)$, then the airline and the HSR operator find it profitable to cooperate.

Proposition 1 simply follows from the fact that, under cooperation, the merged firm realizes a profit that is higher than the sum of the profits accrued to transport operators in the benchmark case of competition. Thus, as long as the sunk costs of cooperation are sufficiently low (more precisely, lower than the difference in industry profits between the cooperative and the competitive scenarios), transport operators can manage to incur such costs and provide the combined service in market OD. Note that the value of $F_1$ can be taken as a measure of the scope for cooperation. Thus, the higher $F_1$ the greater the number of cases where transport operators find it profitable to incur the sunk costs of cooperation. Remark 4 shows that cooperation is generally easier as long as mode substitution is stronger (except for some extreme cases where the degree of substitutability between products is very low). Indeed, if products are stronger substitutes, then industry profits increase more in the presence of a multiproduct monopolist (that is, the integrated firm) than of two independent firms.

**Remark 4.** Let $F_1 = \pi_{ar}^I - (\pi_a^N + \pi_r^N)$. Then, $F_1$ increases with the degree of substitutability between products, unless $\gamma$ is very low (i.e., $\frac{\partial F_1}{\partial \gamma} > 0$ iff $\gamma > \tilde{\gamma}$, where $\tilde{\gamma} \simeq 0.047$).

Table 2 compares equilibrium quantities before and after cooperation.

Thus, total traffic in market OH declines after cooperation due to reduced competition between transport operators. Instead, total traffic in market OD increases after cooperation due to the supply of the new transportation product, that is, the air-rail combined service.

6. **The role of airports**
Let us now focus on the role of the airport company. For this purpose, we compare the scenario where transport operators cooperate with the benchmark case of competition, first in terms of the level of the landing fee (Proposition 2), and then in terms of the airport company’s profit (Remark 5). We show that, in both circumstances, the results obtained depend on mode substitution.

**Proposition 2.** Assume that the airline and the HSR operator cooperate. In equilibrium, the airport company sets a higher landing fee compared to the benchmark case of competition if and only if transportation products are weak substitutes. Formally, \( w^I > w^N \) iff \( \gamma < \bar{\gamma} \), where \( \bar{\gamma} \cong 0.334 \).

From Remark 2 and Footnote 9, we have that \( \frac{\partial w^I}{\partial \gamma} < 0 \) and \( \frac{\partial w^N}{\partial \gamma} < 0 \). We can also prove that \( \left| \frac{\partial w^N}{\partial \gamma} \right| < \left| \frac{\partial w^I}{\partial \gamma} \right| \). As transportation products become stronger substitutes, the airport company loses more revenues from setting a high landing fee under cooperation than under competition. Indeed, in the former case revenues from air traffic would be lower not only in market OH, where passengers move to HSR, but also in market OD, where passengers move from connecting flights to the airline-HSR combined service. Therefore, the airport company sets a higher charge under cooperation than under competition if and only if the degree of substitutability between products is sufficiently low.

As to the airport company’s profit, we find that it is higher under cooperation than under competition if and only if the degree of substitutability between transportation products is sufficiently low (Remark 5). Indeed, from Proposition 2, in such a case the airport company can maintain a higher landing fee in the cooperative scenario. However, in some circumstances where the landing fee is lower under cooperation, the airport company can still benefit from the supply of the air-rail combined service on the part of transport operators.

**Remark 5.** Assume that the airline and the HSR operator cooperate. In equilibrium, the profit of the airport company is higher than in the benchmark case of competition if and only if transportation products are weak substitutes. Formally, \( \pi^I_h > \pi^N_h \) iff \( \gamma < \bar{\gamma} \), where \( \bar{\gamma} \cong 0.377 \).

Figure 3 outlines the behavior of transport operators as well as of the airport company, and the consequent outcomes of the model.
Depending on $F$ and $\gamma$, we can draw a number of different scenarios. Let us first consider the case where $F \geq F_1 = \pi^{I}_{ar} - (\pi^{N}_{a} + \pi^{N}_{r})$. In this case, the airline and the HSR operator would not find it profitable to integrate. However, when $\gamma < 0.377$, the airport company would benefit from integration between transport operators. It follows that, as long as $0 < F - F_1 < \pi^{I}_{h} - \pi^{N}_{h}$, the airport company is willing to share the sunk costs, and thereby in equilibrium transport operators can manage to integrate and provide the combined service in market OD. Conversely, if $F - F_1 > \pi^{I}_{h} - \pi^{N}_{h} > 0$, the outcome of the three stage game is the competing scenario.

Let us now consider the case where $F < F_1 = \pi^{I}_{ar} - (\pi^{N}_{a} + \pi^{N}_{r})$. In this case, the airline and the HSR transport operator integrate to provide the air-rail combined service. When $\gamma < 0.377$, we have that $\pi^{I}_{h} > \pi^{N}_{h}$, that is, the airport company also benefits from integration between transport operators. Instead, when $\gamma \geq 0.377$, firms’ incentives are not aligned, since the airport company would prefer transport operators to compete rather than cooperate. Therefore, the airport company might adopt a ‘sabotage’ strategy to delay and/or deter a cooperation agreement between transport operators. For instance, the airport company may influence strategically the ease of transfer between the rail station at the airport and air terminals. Indeed, the literature discusses different factors affecting users’ perception of air-rail product quality relating to physical and logical ease of transfer at the airport (IATA, 2003; EC, 2006; ITS, 2009; Riley and Kumpoštová, 2010; Janic, 2011). Physical barriers include the walking distance of the connection between the airport rail station and air terminals, the number of level gaps in the walking transfer (stairs, ramps, escalators, lifts), the design adaptation for disabled passengers making the transfer, as well as other comfort issues in the transfer path (weather protection, lighting, cleanliness, corridor design, supply of shops and facilities). On the other hand, logical barriers include the availability of real time information at the airport, personalized information services (e.g., by mobile phone) or information desks about the connection between the
airport rail station and air terminals, as well as the general perception of security along the transfer path at the airport.

7. Concluding remarks

Air transport and HSR have begun to act not only as simple competitors, but also as complementary modes. In recent years, several airline-HSR agreements have been signed worldwide. Policy makers, especially in Europe, encourage cooperation as a means to abate transaction costs and promote intermodality in passenger transport.

In this paper, we have assumed that the airline and the HSR operator cooperate to offer a bundle of domestic HSR and international air services via a multimodal hub airport. We have developed a theoretical model to study how transport operators’ incentives to cooperate and the airport company’s attitude towards cooperation depend on the sunk costs necessary to make cooperation effective and on mode substitution between air and HSR services.

As long as the sunk costs of cooperation are sufficiently low (more precisely, lower than the difference in industry profits between the cooperative and the competitive scenarios), transport operators can manage to incur such costs and provide the combined service in the connecting market. This occurs more easily as transportation products become stronger substitutes because, in such a case, industry profits increase more under cooperation than in a competitive duopoly.

However, if mode substitution is stronger then the airport company loses a large amount of revenues from setting a high landing fee under cooperation than under competition. Indeed, in the former case air traffic revenues would be lower not only in the short haul market where passengers would shift from flights to HSR rides, but also in the connecting market where passengers would prefer the airline-HSR combined service to the connecting flight. Therefore, the airport company sets a higher landing fee under cooperation than under competition if and only if the degree of substitutability between air and HSR is sufficiently low. Generally, this reflects in a higher profit for the airport company under cooperation than under competition when mode substitution is weak.
It follows from the foregoing statements that firms’ incentives may not be aligned. First, this happens when the sunk cost of cooperation is low (such that transport operators find it profitable to cooperate) and mode substitution is strong (such that the airport company would prefer transport operators to compete rather than cooperate). In such a case, the airport company may adopt a ‘sabotage’ strategy to delay and/or deter a cooperation agreement between the airline and the HSR operator.

A misalignment of incentives can also take place when the sunk cost of cooperation is high (such that transport operators would not find it profitable to cooperate) and the degree of substitutability between air and HSR services is low (such that the airport company would benefit from cooperation). In such a case, the airport company may be willing to share the sunk cost, so that transport operators can manage to cooperate and provide the combined service in the connecting market.

In this framework, the impact of airline-HSR agreements on passengers’ well-being and on social welfare is not clear-cut. Actually, intermodal cooperation increases product variety, but raises competition concerns as long as it involves some coordinated pricing in the hub-and-spoke network. Even with limited or no price coordination between transport operators, one should consider the role of congestion at hub airports. If a hub airport is capacity constrained then traffic volumes, and thereby the consumer surplus, in each relevant market are affected by the airline’s decision on how to allocate scarce slots among markets. In turn, this decision primarily depends on the landing fee set by the airport company. Despite the relevance of airline-HSR agreements, competition authorities have so far devoted little attention to considering the interplay among airlines, HSR operators and airport companies, and to evaluating the welfare effects of these agreements both under capacity-constrained and unconstrained airports. We could investigate these issues in future work.

References


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Takebayashi, M., 2016. How could the collaboration between airport and high speed rail affect the market?. *Transportation Research Part A: Policy and Practice*, 92, 277-286.


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<th>HSR</th>
<th>Airline</th>
<th>From Airport</th>
<th>To City</th>
<th>Brand</th>
<th>Common online ticket distribution</th>
<th>Integrated Ticketing</th>
<th>Integrated Loyalty programs</th>
<th>End to end check-in</th>
<th>Schedule coordination</th>
<th>Delay/connection assistance</th>
<th>Baggage Handling</th>
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<td>Frankfurt Airport</td>
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Figure 1. Examples of air-rail agreements (Source: Personal elaboration on data provided by Eurocontrol, 2005 and operators’ websites)
**Figure 2.** Structure of the network.

\[
F > F_1 = \pi_{hr} - (\pi_a^N + \pi_r^N)
\]
\[
F \leq F_1 = \pi_{hr} - (\pi_a^N + \pi_r^N)
\]

**Competition**

\[
\pi_h > \pi_h^N
\]
\[
\pi_h \leq \pi_h^N
\]

**Integration**

\[
\pi_h^I > \pi_h^N
\]
\[
\pi_h^I \leq \pi_h^N
\]

**Fixed costs of integration**

\[
0 \leq \gamma < 0.37733
\]
\[
\gamma \geq 0.37733
\]

**Figure 3.** Players’ strategies and model outcomes.
List of tables

<table>
<thead>
<tr>
<th>Player</th>
<th>Driver</th>
<th>Barrier</th>
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<tr>
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<td>• Partial reallocation of freed slots</td>
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<td>• Expansion of catchment area</td>
<td>• Catchment area overlap with other airports</td>
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<td></td>
<td>• Meeting customer needs for both transport and commercial activities</td>
<td>• Car parking revenue loss</td>
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<td></td>
<td>• Addressing environmental and landside congestion issues/targets</td>
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<td>Airlines</td>
<td>• Substitution of feeder flights by trains to free slots for more profitable routes</td>
<td>• Loss of control of the feeder routes</td>
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<td>• Wider access to air services from the hub</td>
<td>• Benefits to competing airlines</td>
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<td></td>
<td>• Reduction of operating costs</td>
<td>• Sunk cost of the intermodal agreement</td>
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<tr>
<td></td>
<td></td>
<td>• Difficulties in selling the intermodal product</td>
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<tr>
<td>Rail operators</td>
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<td>• Capacity and financial issues</td>
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<td></td>
<td>• Improving rail market share</td>
<td>• Sunk cost of the intermodal agreement</td>
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<tr>
<td></td>
<td>• Improving the image of high-speed rail</td>
<td>• Benefits to competitors (air transport)</td>
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*Table 1.* Drivers and barriers to intermodal agreements (Source: Eurocontrol, 2005; Givoni and Banister, 2006; Vespermann and Wald, 2011; and Chiambaretto and Decker, 2012).

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<th>Market HD</th>
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*Table 2.* Comparison of traffic volumes before and after cooperation.
## Appendix

### Equilibrium Profits

<table>
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<th>Benchmark case: No agreement</th>
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</thead>
<tbody>
<tr>
<td><strong>Airline</strong></td>
<td>$\pi^N_a = \frac{\alpha^2(9216 + 4608\gamma - 2336\gamma^2 - 1728\gamma^3 - 136\gamma^4 + 200\gamma^5 + 65\gamma^6)}{16(\gamma + 2)^2(5\gamma^2 - 24)^2}$</td>
</tr>
<tr>
<td><strong>High Speed Rail</strong></td>
<td>$\pi^N_H = \frac{\alpha^2(48 + 8\gamma - 7\gamma^2)^2}{4(\gamma + 2)^2(5\gamma^2 - 24)^2}$</td>
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<tr>
<td><strong>Airport</strong></td>
<td>$\pi^N_h = \frac{\alpha^2(48 + 8\gamma - 7\gamma^2)^2}{8(\gamma + 2)(5\gamma^2 - 24)}$</td>
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<table>
<thead>
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<th>Air-rail cooperation</th>
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<td><strong>Merger</strong></td>
<td>$\pi^I_{ar} = \frac{\alpha^2(\gamma^3 + 9\gamma^2 + 7\gamma - 65)}{16(\gamma + 1)(\gamma^2 + 4\gamma - 7)}$</td>
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<tr>
<td><strong>Airport</strong></td>
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</tr>
</tbody>
</table>