Market Structure and Partnership Levels in Air-Rail Cooperation

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Abstract:

In this paper, we build a theoretical model to study the underlying factors behind the various partnership levels in different cooperation schemes between airline and high-speed rail (HSR). We study two different intermodal relationships: a parallel one where the networks of the airline and the rail operator overlap partially and a vertical one where they do not overlap at all. We examine the situations when the cooperation levels are either exogenous or endogenous. For any given cooperation level, we show that the incremental profit of a vertical partnership is higher than that of a parallel partnership. However, when the two types of partnerships are both possible, the parallel partnership might be dominated by the vertical partnership only when the air-rail connecting service is sufficiently inferior to the connecting flight. The social welfare level of a parallel partnership is higher than that of a vertical partnership when the air-rail connecting service is sufficiently superior to the connecting flight. When the cooperation level is also a decision variable, a parallel partnership will have higher cooperation level than a vertical partnership when the travel time of HSR is sufficiently short compared with that of air.

Keywords: Airline, High-speed rail, Cooperation, Parallel partnership, Vertical partnership

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1. Introduction

In recent years, we have seen a reawakening of passion towards the rail sector around the globe, mainly ignited by the growing popularity of high-speed rail (HSR). For instance, as the second largest economy in the world, China has not only built the world's longest HSR network in less than 5 years (with over 16,000 km of track in service as of December 2014), but also become the earnest advocate and exporter of its HSR technology. So far, HSR has mainly been recognized as a competitor and substitute of the air transport, especially for routes with distances less than 1,000 km (e.g., Janic, 1993; Rothengatter, 2011). Examples abound where these two modes fiercely compete with each other. On short-haul routes, airlines usually lose ground to HSR, being either forced out of market totally or into big cutbacks. The impact of HSR introduction on air travel demand has been dramatic in some cases. Recent cases of air route cancellations due to HSR competition include a number of Chinese domestic markets such as Nanjing-Shanghai, Zhengzhou-Xi’an, Changsha-Guangzhou and Wuhan-Nanjing (Fu et al., 2012; 2014). On the Paris-Nantes route, the introduction of the TGV network has decreased the traffic by 30% (Dobruszkes, 2011). The same situation is observed in other routes like Paris-Rennes or Paris-Brest (Chi, 2004). Similarly, in Spain, before the HSR link was established between Madrid and Seville at early 1990s, the mix of air/rail passengers was 67% and 33% respectively. After the introduction of HSR, the mix changed to 16% and 84%. The numbers are forecasted to become 13% and 87% by 2020, according to Barròn et al. (2009). The introduction of the HSR link between Taipei and Kaohsiung in Taiwan has reportedly cut domestic air traffic by 50% by 2012. The opening of South Korea's first HSR line had significantly reduced airline demand in Korea's domestic market (Park and Ha, 2006).

However, air transport is still unchallengeable for its ability to provide long-distance travel and its extensive network. In fact, HSR can also complement air service by offering connections between airports and nearby cities, and the potential for airline-HSR cooperation exists due to the hub-and-spoke network adopted by most major airlines. Under hub-and-spoke operation, two flights (“legs”) are offered to passengers as one journey from their origin airport to the destination airport through a hub airport. With HSR, however, both these two legs need not be air flights: on legs where HSR service is
comparable with flights in terms of (total) journey time and cost, HSR service may also be used in combination with a flight as one journey, with one booking for the entire two-legs trip. Such airline-HSR cooperation may be viewed simply as a special type of “code sharing” – i.e. two airlines cooperate to offer a hub-and-spoke operation with each offering one leg of a flight (and a non-operating carrier is allowed to put its code on the operating airline’s flight number) – which has been a common practice in the airline industry (e.g. Oum et al., 1996; Brueckner, 2001; Ito and Lee, 2007; Gayle, 2008). Air-rail intermodal cooperation is also promoted by policy makers because it is generally believed that substituting air traffic with rail traffic can alleviate the ever-growing airport congestion (Janic, 2011). The different comparative advantages of these two transport modes have inspired some researchers and practitioners to shift their focuses from the modal substitutability to modal complementarity. Again, these are mainly empirical papers (Cokasova, 2006; Givoni and Banister, 2006), while few works have addressed this issue analytically (Jiang and Zhang, 2014; Socorro and Vievens, 2013).

A closer look at the phenomenon reveals some interesting aspects that have never been noticed by literature. To start with, substantial differences exist between different air-rail cooperation cases. On the one hand, the airlines that work with the rail operator in an intermodal cooperation might be of different types. Some cooperation cases are between domestic airlines and rail operators, such as in China, Portugal, Switzerland and USA; while other cases involve only foreign airlines, such as in Italy and Spain. Furthermore, in countries like France, Germany, UK as well as Canada, both situations exist simultaneously. On the other hand, the levels of cooperation in different cases can be diverse. Some cooperation is basic and nothing more than an emergency back-up strategy for extreme cases. For example, there is a re-protection agreement between Air Canada and VIA Rail, which will only be triggered under major delay or cancellation disruptions from the air sector. Some cooperation is very advanced with features like integrated ticketing, dedicated carriage, coordinated scheduling and baggage push. Under such partnership, the service is comparable to, if not better than, any connecting flight. The

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1 In fact, the air-rail cooperation is not confined with high-speed rail. There are also cases of such intermodal partnerships in countries without real HSR, such as US and Canada.

2 Please find the appendix for a summary of the existing cases of air-rail cooperation.
Most renowned example of such high cooperation level is the AIRail service provided by Lufthansa and Deutsche Bahn at Frankfurt Airport. More partnerships have a cooperation level that is in between these two extremes. In particular, for these services, tickets are usually integrated but baggage push and dedicated train compartments are seldom available. Such cases abound across Europe and Asia (in Taiwan as well as Mainland China). More interestingly, some anecdotes seem to imply a relationship between these two aspects and, in most cases, evidence shows that domestic airlines obtain higher cooperation levels with HSR compared to foreign airlines.

Naturally questions arise from such observations: what causes such a wide-ranging differences of air-rail cooperation? Are these two features, type of the airline involved in a partnership and the cooperation level, somehow linked to each other? Although some papers have qualitatively analyzed the nature and the implications of air-rail intermodal agreements (Chiambaretto and Decker, 2012; European Commission, 2006), our paper is the first attempt to answer these questions analytically. We build a theoretical model to analyze the underlying factors behind the various air-rail partnership cases. Two different intermodal relationships are identified: a parallel one where the networks of the airline and the rail operator overlap partially and a vertical one where they do not overlap at all.

We examine the situations when the cooperation levels are either exogenous or endogenous. For any given cooperation level, we show that the incremental profit of a vertical partnership is higher than that of a parallel partnership. However, when the two types of partnerships are both possible, the parallel partnership might be dominated by the vertical partnership only when the air-rail connecting service is sufficiently inferior to the connecting flight. The social welfare level of a parallel partnership is higher than that of a vertical partnership when the air-rail connecting service is sufficiently superior to the connecting flight. When the cooperation level is endogenous, a parallel partnership will have higher cooperation level than a vertical partnership when the travel time of HSR is sufficiently short compared with that of air.

The existing literature on the interactions between air and HSR has mainly focused on the (short-term) market equilibrium of airline-HSR competition (i.e., traffic and price levels), with empirical approaches (Behrens and Pels, 2012; Dobruszkes, 2011; González-Savignat, 2004; Park and Ha, 2006), game theory setting (Adler et al., 2010) or analytical
perspective (Yang and Zhang, 2012). Some recent contributions have investigated the long-term impacts of high-speed rail competition on air transport studying how the market coverage and the network choice of an airline would respond to HSR competition on origin-destination trunk routes (Jiang and Zhang, 2015), as well as the effects of air-rail competition on environment and social welfare (D’Alfonso et al., 2015a; 2015b).

The contribution of this paper is mainly two-fold. On the one hand, it is the first theoretical paper to discuss the driving forces behind the various cooperation levels in different air-rail partnerships. With the growing popularity of this intermodal arrangement around the world, due to reasons such as airport capacity constraint and environmental concerns, it would be of great benefits to the academia as well as the transport industry to better understand its mechanism. On the other hand, this paper also provides a thorough welfare analysis for the two types of air-rail partnerships. Given that potential anti-trust issues may become more relevant in the air-rail cooperation (Jiang and Zhang, 2014), our conclusions should have some indications for the policy makers as well.

The paper is organized as follows. Section 2 sets up the basic model. Section 3 analyzes the two intermodal partnerships regarding the corresponding profits, social welfare as well as cooperation levels under different conditions. Section 4 and Section 5 compare the two partnership cases considering the cooperation level as exogenous and endogenous, respectively. Section 6 contains concluding remarks.

2. Model

In this paper we only consider a connecting market involving a domestic leg and an international leg. There are three companies in the picture: a domestic legacy airline, a domestic high-speed rail operator and a foreign airline. We assume that the domestic airline can serve both legs with its own operation, while the HSR operator can only serve

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3 This is different from papers like Jiang and Zhang (2014) that also study the two direct markets in a simple three-nodes network. Admittedly if we take into account factors like economies of traffic density which link the direct markets with the connecting market, the results we obtain will be different under the two settings. However, with this paper we do not attempt to address all intricate issues. Instead, we aim to use the simplest possible model to serve as the first step analysis of this interesting topic.
the domestic leg and the foreign airline can only serve the international leg. It is possible for both airlines to form intermodal partnership agreement with the HSR operator. In particular, while the foreign airline needs to work with the HSR to enter the domestic market, the local airline may serve the connecting market. The network structure is represented in Figure 1.

==Insert Figure 1==

This setting is representative. On the one hand, node 2 represents a domestic hub city that is used by the local airline as gateway to the outside world, while node 1 represents a peripheral city within the country. On the other hand, node 3 is an important international hub, or a collection of such international hubs, with the presence of both the domestic airline and the foreign airline. An example of this setting is as follows. The domestic airline is Air France while the foreign airline is Air China. Node 2 is Paris Charles de Gaulle while node 3 is Beijing Capital. Node 1 represents a French peripheral city, e.g., Nantes. Both Air France and Air China may offer the connection between Paris Charles de Gaulle and Beijing Capital. However, Air China may not offer the flight connection between Paris Charles De Gaulle and Aéroport Nantes Atlantique, while Air France can. Finally, HSR may serve the high-speed rail connection between Paris and Nantes.

In this setting, three potential scenarios may happen. First, when no intermodal partnership is established, the domestic airline will be a monopoly in the connecting market that has nothing to do with the other two players. Second, the foreign airline cooperates with the domestic HSR operator to provide air-rail connecting service as a competing product to the connecting flight service offered by the domestic airline. Third, the domestic airline forms a partnership with the HSR operator and the two companies work together to provide air-rail connecting service to replace the connecting flight service. It should be noted that we assume away the horizontal differentiation between air and rail service but keep vertical (quality) differentiation in the model. We dub the second scenario as vertical partnership while the third scenario as parallel partnership.
following the transportation literature (Park, 1997). Equivalently, according to Chiambaretto and Decker (2012) and European Commission DG Competition (2007), the vertical partnerships can also be referred to as a “behind and beyond” agreement. In particular, according to Chiambaretto and Decker (2012), the majority of intermodal agreements between air transport and HSR are of the ‘behind and beyond’ route category, in which an airline sells (or puts its code on) a non-offered route, operated by the rail operator to provide connections with its own scheduled services. However, some intermodal agreements cover parallel operations, where an airline and a rail operator compete on a given route, but also enter into a code-share agreement that allows the airline to sell rail tickets (with its own flight number).

We assume that travelers maximize a (strictly concave) quadratic utility function as proposed by Singh and Vives (1984). This approach has been used in transport literature (Flores-Fillol and Moner-Colonques, 2007; Oum and Fu, 2007; Socorro and Viecens, 2013; D’Alfonso et al., 2015). Let $Q$ be the total number of connecting passengers. The utility function is:

$$U = \alpha Q - \frac{1}{2} Q^2 \quad (1)$$

A simple linear inverse demand function can be derived from equation (1), which is given by:

$$P = \alpha - Q \quad (2)$$

Here $P$ is the “full price” of the passengers, which includes the ticket price and the nonmonetary travel cost. The travel cost is determined by two factors: travel time and travel convenience. On route travel time is more or less fixed. We use $T_A^d$, $T_R^d$ and $T_A^i$ to denote the monetized travel time of air service on the domestic leg, rail service on the domestic leg and air service on the international leg, respectively, with $T_A^d$, $T_R^d$ and $T_A^i$ being all positive values. We normalize the monetized connecting time and travel convenience (measured by the ease of check-in, security check, luggage push, etc.) of connecting flight to be 0. For the air-rail service, this value is a decreasing function of the
air-rail cooperation level $\delta$, with $\delta \geq 0$. For simplicity, we assume this function adopts a simple linear form and equal to $-\delta$. The ticket price of a connecting flight is:

$$p_{AA} = P - T^d_A - T^i_A$$

And the ticket price of an air-rail connecting service is a function of $\delta$:

$$p_{AR}(\delta) = P - T^d_R - T^i_A + \delta$$

On the cost side, we assume that the operating costs are $c^d_A$, $c^d_R$ and $c^i_A$ for air service on the domestic leg, rail service on the domestic leg and air service on the international leg, respectively. There is also a fixed cost involved in any intermodal partnership, and it is an increasing function of the cooperation level $\delta$. For instance, as also noted in the Introduction, less integrated forms of agreement are similar to traditional interlining agreements, in which an airline is authorized to sell rail tickets, without any further integration of the products. In contrast, more integrated intermodal agreements can involve a form of code-share arrangement. Here the airline and the rail operator decide to ‘share’ the same train trip, and each operator allocates its own flight/train number to the train trip. In this case, there is usually some integration of IT systems which becomes more costly. Deeper forms of integration can take the form of coordination of through-baggage handling and other dedicated services such as separate first and business class dining facilities on trains, and the cost of the logistics involved in implementing these integrations dramatically increases (Chiambaretto and Decker, 2012). In particular, we denote the fixed cost involved in any intermodal partnership as $C(\delta)$, with $C(\delta) > 0$, $C'(\delta) > 0$ as well as $C''(\delta) > 0$. For simplicity, we assume that $C(\delta) = \mu \delta^2$, with $\mu \geq 0$.

In the first scenario where only the domestic airline offers connecting flight, its objective function is

$$\pi^M = (p_{AA} - c^d_A - c^i_A)q^M$$

$^4$These assumptions are in place to maintain the concavity of the objective function with respect to $\delta$. The function can be more general like $C(\delta) = \mu(\delta + \delta^2)$.
where the superscript $M$ stands for monopoly. The social welfare function in this scenario is:

\[ W = \alpha q^M - \frac{1}{2} q^{M^2} - (T_A^d + T_A^i + c_A^d + c_A^i)q^M \]  

(6)

In the second scenario where vertical partnership between the foreign airline and the HSR operator is in place, the objective functions of the domestic airline and the air-rail partnership are:

\[ \pi^D = (p_{AA} - c_A^d - c_A^i)q^D \]  

(7)

\[ \pi^V = (p_{AR} - c_R^d - c_A^i)q^V - \mu \delta^2 \]  

(8)

where the superscript $D$ stands for domestic airline, while the superscript $V$ stands for vertical partnership. The social welfare function is:

\[ W = \alpha(q^D + q^V) - \frac{1}{2}(q^D + q^V)^2 - (T_A^d + T_A^i + c_A^d + c_A^i)q^D - (T_R^d + T_A^i + c_R^d + c_A^i)q^V - (T_R^d + T_A^i + c_R^d + c_A^i)q^D - (T_R^d + T_A^i + c_R^d + c_A^i)q^V - \mu \delta^2 \]  

(9)

In the third scenario where parallel partnership between the domestic airline and the HSR operator is in place, the objective functions of the air-rail partnership is:

\[ \pi^P = (p_{AR} - c_R^d - c_A^i)q^P - \mu \delta^2 \]  

(10)

where the superscript $P$ stands for parallel partnership. And the social welfare function is given by:

\[ W = \alpha q^P - \frac{1}{2} q^{P^2} - (T_R^d + T_A^i + c_R^d + c_A^i)q^P - \mu \delta^2 \]  

(11)

For analytical simplicity, we normalize $T_R^d + T_A^i + c_R^d + c_A^i = 0$ and $T_A^d - T_R^d + c_A^d - c_R^d = t$, with $t$ being either a positive or a negative value. When, $\delta = 0$, serving the domestic leg through air, rather than rail, is more costly when $t \geq 0$. In this case, we will say that the air-rail partnership is superior to the connecting flight in terms of the sum of
operating costs borne by the transport operator and the monetized travel time borne by travelers. Otherwise, when, \( t \leq 0 \), serving the domestic leg through rail is more costly.\(^5\)

3. Scenario Analysis

In this section, we analyze the equilibrium traffic and cooperation level (if any) in the three scenarios one by one. We focus on the equilibrium profits of the companies so as to study their incentives to form each partnership, as well as the social welfare levels in order to forge relevant policy implications.

3.1 Benchmark case

In the first scenario, the domestic airline is a monopoly with connecting flight service. The monopolist maximizes its profits \( \pi^M \) with respect to the traffic quantity, and the equilibrium traffic and the equilibrium profit of the airline are straightforward:

\[
q^M_1 = \frac{\alpha}{2} \tag{12}
\]

\[
\pi^M_1 = \frac{\alpha^2}{4} \tag{13}
\]

where the subscript 1 denotes the scenario of no intermodal cooperation.

3.2 Vertical partnership

In the second scenario, there are two products in the market, the connecting flight offered by the domestic airline and the air-rail connecting service offered by the foreign airline-HSR operator partnership. We first consider the case when the cooperation level \( \delta \) is

\(^5\) A hidden assumption here is that when the domestic airline cooperates with the rail operator, it will provide air-rail connecting service to the market only. In reality, it is possible for the domestic airline to retain its connecting flights even after a partnership with the rail operator is formed (Jiang and Zhang, 2014). For analytical simplicity, this possibility is assumed away on the ground that it is in fact quite unusual.

\(^6\) Quantity competition may be the more appropriate choice in case of limited capacities, even if firms are price setters. Quinet and Vickerman (2004) remark that this is the case found, for example, in rail. The main reason why high-speed rail capacity (i.e., tracks, train stations) is difficult to change (relative to the ease and rapidity of price adjustments) is that investments are lumpy, time-consuming and irreversible. Brander and Zhang (1990), Brander and Zhang (1993) and Oum et al., (1993) find some empirical evidence that rivalry between airlines is consistent with Cournot behavior. Cournot behavior has been assumed, among others, in Jiang and Zhang (2014), Pels et al. (2004) and Zhang and Zhang (2006).
exogenously given. In this case, the competition is modeled as a one-stage game in which the domestic airline and the foreign airline-HSR operator partnership compete à la Cournot. Equilibrium traffics are:

\[
q_2^D(\delta) = \frac{\alpha - t - \delta}{3}
\]

(14)

\[
q_2^V(\delta) = \frac{\alpha + 2(t + \delta)}{3}
\]

(15)

where the subscript 2 denotes the scenario of vertical partnership. To ensure non-negativity of the equilibrium traffic, we need to impose conditions \(-\alpha/2 + \delta \leq t \leq \alpha - \delta\).

The equilibrium profits of the domestic airline and the air-rail partnership are:

\[
\pi_2^D(\delta) = \frac{(\alpha - t - \delta)^2}{9}
\]

(16)

\[
\pi_2^V(\delta) = \frac{(\alpha + 2t + 2\delta)^2}{9} - \mu^2
\]

(17)

And the social welfare level given \(\delta\) is:

\[
W_2(\delta) = \frac{8\alpha^2 + 8\alpha(t + \delta) + 11(t + \delta)^2}{18} - \mu^2
\]

(18)

If we treat \(\delta\) as a decision variable, the competition is modeled as a two-stage game. In the first stage, the foreign airline-HSR operator partnership maximizes its profit deciding on the level of cooperation. In the second stage, taking the first-stage choice as given, the domestic airline and the foreign airline-HSR operator partnership compete à la Cournot. As noted, cooperation may involve decision on logistics and informative systems which imply a sunk cost in the short run. Consequently, the decision on the level of cooperation can be seen as a long run decision, since it cannot be easily adjusted in the short run once that the partnership has been established.
Thus, by backward induction, we first derive the equilibrium traffic - which correspond to (16) and (17) - and, then, the equilibrium level of cooperation between the foreign airline and the HSR operator, which is:

\[
\delta_2 = \frac{2(\alpha + 2t)}{9\mu - 4}
\]  

(19)

It should be noted that second-order condition requires \(\mu > 4/9\).

Plugging \(\delta_2\) into equations (16) - (18), we can obtain:

\[
\pi_2^D = \frac{[\alpha(3\mu - 2) - 3\mu t]^2}{(9\mu - 4)^2}
\]  

(20)

\[
\pi_2^V = \frac{\mu(\alpha + 2t)^2}{9\mu - 4}
\]  

(21)

\[
W_2 = \frac{4\alpha^2(3 - 14\mu + 18\mu^2) + 4\alpha t(18\mu^2 - 5\mu) + t^2(99\mu^2 - 32\mu)}{2(9\mu - 4)^2}
\]  

(22)

### 3.3 Parallel partnership

In the third scenario, there is again only one product in the market, which is the air-rail connecting service offered by the domestic airline and HSR operator. Again, we first consider the case when the cooperation level \(\delta\) is exogenously given. The partnership maximizes its profits with respect to the traffic quantity. Equilibrium traffics are:

\[
q_3^P(\delta) = \frac{\alpha + t + \delta}{2}
\]  

(23)

where the subscript 3 denotes the scenario of parallel partnership. Again, to ensure non-negativity of the equilibrium traffic, we need to impose condition \(t \geq -(\alpha + \delta)\). Since \(\alpha > 0\), this condition is less stringent than the previous non-negativity conditions, so we still have \(-(\alpha/2 + \delta) \leq t \leq \alpha - \delta\).

The equilibrium profit of the partnership is:
The social welfare level given $\delta$ is:

$$W_3(\delta) = \frac{3(\alpha + t + \delta)^2}{8} - \mu \delta^2$$  \hspace{1cm} (25)

Again, if we treat $\delta$ as a decision variable, in the first stage, the domestic airline-HSR operator partnership maximizes its profit deciding on the level of cooperation. In the second stage, taking the first-stage choice as given, the partnership maximizes its profits with respect to the traffic quantity. The equilibrium traffic is described in (23), while, in the first stage, we find the equilibrium level of $\delta$:

$$\delta_3 = \frac{\alpha + t}{4\mu - 1}$$  \hspace{1cm} (26)

It should be noted that second-order condition requires $\mu > 1/4$. Combining with the constraint from Section 3.2, we have $\mu > 4/9$.

Plug $\delta_3$ into equations (24) and (25), we can also obtain:

$$\pi_3^p = \frac{\mu(\alpha + t)^2}{4\mu - 1}$$  \hspace{1cm} (27)

$$W_3 = \frac{\mu(6\mu - 1)(\alpha + t)^2}{(4\mu - 1)^2}$$  \hspace{1cm} (28)

4. **Exogenous Cooperation Level**

We’ll first look at the case when $\delta$ is exogenously given. This case, although may not the most realistic one, is policy relevant, because it helps the policy makers to evaluate the cost and benefit of an investment that can potentially induce an air-rail cooperative
scheme at a certain partnership level.\(^7\) In the following section we’ll discuss how finding out the company profits and the social welfare under different air-rail cooperation levels and different cooperative paradigms can have implications for policy makings.

### 4.1 Independent partnership scenarios

Let’s first focus on the case when only one type of partnership (either parallel or vertical) is possible, due to given conditions.\(^8\) In this case, it would be important to see which partnership generates more extra profits for the firms that are engaged, so the policy makers would have an idea about which partnership is less costly to facilitate in situations when government intervention is needed. In particular, the extra profit of a vertical partnership is simply \(\pi^V_2(\delta)\), since neither the foreign airline nor the HSR operator can get access to the connecting market in the benchmark case (first scenario). On the other hand, the extra profit generated by a parallel partnership is equal to \(\pi^P_2(\delta) - \pi^M_1\), with the domestic airline involved both with and without the partnership. A comparison of these two extra profits gives rise to Proposition 1.

**Proposition 1:** For any given cooperation level, the incremental profit of a vertical partnership is higher than that of a parallel partnership.

**Proof:**

We have \([\pi^P_2(\delta) - \pi^M_1] - \pi^V_2(\delta) = -[3\alpha^2 + 6(t + \delta)^2 + (\alpha - t - \delta)^2]/36 < 0\), which means that the extra profit from vertical partnership is higher than that from parallel partnership. So we can conclude that for a given \(\delta\), it is more likely for a vertical partnership other than a parallel partnership to be formed.

Q.E.D

The intuition behind Proposition 1 is straightforward. The two companies involved in a vertical partnership, the rail operator and the foreign airline, are both originally excluded

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\(^7\) For example, one important factor that will influence air-rail partnership is the location of the rail station (Givoni and Banister, 2006). The closer the distance between a rail station and an airport, the more likely air-rail cooperation will exist. At current stage, the rail station is largely a decision of the governments.

\(^8\) For instance, protectionist countries may be more cautious about vertical partnerships due to the involvement of a foreign airline. On the contrary, countries with stringent anti-trust policies may not be in favor of the parallel partnerships given the largely competitive relationship between the domestic air sector and the rail sector. See Chiambaretto and Decker (2012) for the analysis of competition law issues associated with intermodal agreements.
from the connecting market. Therefore, it is relatively easy for them to gain positive profit by entering the market. The parallel partnership, on the other hand, involves the domestic airline that is already in the market enjoying monopoly status in the first place, so it is hard to obtain extra profit from this type of intermodal cooperation.

Proposition 1 is particularly policy relevant. Consider two situations with similar market conditions except that one can only develop parallel partnership while the other can only develop vertical partnership. Proposition 1 tells that it is always easier to induce a vertical partnership than a parallel partnership, due to the higher incremental profits the two partnering companies can earn. Given that in many cases the governments also need to incur costs (infrastructure building, etc.) in fostering such intermodal cooperation, this conclusion has a very important role in the cost-benefit analysis of public investment decision.

4.2 Interdependent partnership scenarios

However, when both partnerships are possible, we need to do more than simple scenario comparisons to find out which type is more likely to exist. For example, when both partnerships are possible (without political barrier), the benchmark scenario for the domestic airline in deciding whether to form partnership with the rail operator is no longer scenario 1 when neither of the partnerships is formed. Instead, it becomes scenario 2 where vertical partnership between the foreign airline and the rail operator is formed, as long as this vertical partnership can bring positive profit. Meanwhile, the reservation price of the rail operator to get into a parallel partnership is not nil any more, since it would be able to obtain a positive profit in a vertical partnership. Analytically, the following relations hold. When a parallel partnership is formed, $\pi_x^p(\delta)$ is the equilibrium profit obtained by the alliance, with $\gamma \pi_x^p(\delta)$ being the portion of profits retained by the HSR operator, $0 \leq \gamma \leq 1$, and, consequently, $(1 - \gamma)\pi_x^p(\delta)$ being the portion of profits retained by the domestic airline. Similarly, when a vertical partnership is formed, $\pi_x^v(\delta)$ is the equilibrium profit obtained by the alliance, with $\phi \pi_x^v(\delta)$ being the portion of profits retained by the HSR operator, $0 \leq \phi \leq 1$, and, consequently, $(1 - \phi)\pi_x^v(\delta)$ being the portion of profits retained by the foreign airline. In this occurrence, $\pi_x^v(\delta)$ is the profit retained by the domestic airline. Thus, to make sure the equilibrium parallel
partnership type, the following condition must hold: (i) $\gamma \pi_3^D(\delta) \geq \varphi \pi_2^Y(\delta)$, which assures that the HSR’s participation constraint to the parallel partnership is not violated; (ii) $(1 - \gamma)\pi_3^D(\delta) \geq \pi_2^D(\delta)$, which assures that the domestic airline’s participation constraint to the parallel partnership is not violated. Summing up relations (i) and (ii) we obtain: $(1 - \gamma)\pi_3^D(\delta) + \gamma \pi_3^Y(\delta) \geq \varphi \pi_2^Y(\delta) + \pi_2^D(\delta)$, that is we need to compare $\pi_3^D(\delta) - \varphi \pi_2^Y(\delta)$ and $\pi_2^D(\delta)$. Some simple analysis reveals a strong conclusion, which is summarized as Proposition 2 as follows.

**Proposition 2:** When the two types of partnerships are both possible, the parallel partnership might be dominated by the vertical partnership only when the air-rail connecting service is sufficiently inferior to the connecting flight, i.e., when $t + \delta < -\alpha/11$.

Proof:

Given that $\varphi \in [0,1]$ and $\pi_2^Y(\delta) \geq 0$, $[\pi_3^D(\delta) - \varphi \pi_2^Y(\delta)] - \pi_2^D(\delta)$ is decreasing in $\varphi$.

When $\varphi = 1$, we have $[\pi_3^D(\delta) - \varphi \pi_2^Y(\delta)] - \pi_2^D(\delta) = [\alpha + 11(t + \delta)][\alpha - (t + \delta)]/36$. We have $\alpha - (t + \delta) > 0$ from the non-negativity conditions. However, $\alpha + 11(t + \delta)$ can be either positive or negative. In particular, when $t + \delta > -\alpha/11$, $[\pi_3^D(\delta) - \pi_2^Y(\delta)] - \pi_2^D(\delta) > 0$. Therefore, when $t + \delta > -\alpha/11$, $[\pi_3^D(\delta) - \varphi \pi_2^Y(\delta)] - \pi_2^D(\delta) > 0$ is always true. In other words, only when $t + \delta < -\alpha/11$ will $[\pi_3^D(\delta) - \varphi \pi_2^Y(\delta)] - \pi_2^D(\delta) < 0$ be possible.

Q.E.D

Intuitively, when the air-rail connecting service is inferior to the connecting flight, the domestic airline is facing a trade-off. If it forms a partnership with the rail operator, it degrades its service to lower quality; however, at the same time, it can deter the formation of the partnership between the foreign airline and the rail operator, hence retaining the monopoly status in the connecting market. Apparently, only when quality of the air-rail connecting service is sufficiently lower than that of the connecting flight, the domestic airline will find it beneficial to accommodate a new competitor instead of to reduce the quality of its own service.
Proposition 2 is very interesting, particularly when in comparison with Proposition 1. Proposition 1 tells that it is harder for a parallel partnership than for a vertical partnership to gain positive benefit for the companies involved, while Proposition 2 points out that even the domestic airline will not be able to gain anything from a parallel partnership, it might eventually be set in place because the domestic carrier will be hurt even more by the formation of a vertical partnership. Together these two propositions may somehow explain why in reality we see parallel partnerships in some cases and vertical partnerships in others.

4.3 Social welfare comparison

For the policy makers, company profits are less of a concern compared with total social welfare level. Therefore, it is important to make sure which type of air-rail partnership can generate a higher level of social welfare. Mathematically it is very straightforward with a simple comparison between $W_2(\delta)$ and $W_3(\delta)$. A clear conclusion can be easily obtained as Proposition 3.

**Proposition 3:** The social welfare level of a parallel partnership is higher than that of a vertical partnership when the air-rail connecting service is sufficiently superior to the connecting flight, i.e., when $t + \delta > 5\alpha/17$.

Proof:

We have $W_2(\delta) - W_3(\delta) = [5\alpha - 17(t + \delta)][\alpha - (t + \delta)]/72$.

Since $\alpha - (t + \delta) > 0$, we have $W_2(\delta) - W_3(\delta) < 0$ when $t + \delta > 5\alpha/17$, and $W_2(\delta) - W_3(\delta) > 0$ otherwise.

*Q.E.D*

Two components have played a role in the social welfare comparison between the two types of air-rail partnership. One is market structure. In a parallel partnership scenario, the connecting market is a monopoly with no competition; while in the vertical partnership scenario, competition does exist between the partnership and the incumbent airline. Therefore, the market structure effect favors the vertical partnership scenario regarding social welfare comparison. However, there is also a quality premium effect, which depends on how many passengers can enjoy a high quality product. When the
cooperation level of the intermodal partnership is sufficiently high, the quality of the air-rail connecting service will be higher than that of the connecting flight. Under a parallel partnership, all passengers take the high-quality air-rail connecting service; while under a vertical partnership, only a proportion of passengers take the air-rail connecting service, with the rest taking the lower-quality connecting flight. Therefore, compared with the vertical partnership scenario, the parallel partnership scenario has a quality premium, which is a benefit towards the social welfare, counteracting the welfare loss due to lower competition. The higher the cooperation level, the higher this quality premium, and thus the more likely that a parallel partnership will induce a higher social welfare level.

Proposition 3 has important policy implication because it suggests that not a single type of air-rail cooperation can dominate the other under all circumstances, and the differentiator is the cooperation level. This conclusion might be connected with the observation that vertical partnerships usually come with lower cooperation level while parallel partnerships usually are associated with higher cooperation level.

Combining Propositions 2 and 3, we can see that when the two types of partnerships are both possible, for any given level of the cost of partnership, $\delta$, there exists a range, i.e., $t + \delta < -\alpha/11$, under which vertical partnership is the socially optimal outcome and will naturally happen. In those constellations, the policy makers have no need to worry, even though it might seem that the other type of partnership introduces competition into the market and thus is favorable. However, if $t + \delta$ falls out of this range, policy intervention may be worth of consideration for social welfare improvement.

5. Endogenous Cooperation Level

As we have discussed above, we can obtain clear policy implications from the cases of exogenous cooperation level. However, it is also important to realize that in many cases the cooperation level is in fact a decision variable of the companies involved in an intermodal partnership. When we take this aspect into account, the analysis becomes less straightforward but yields some interesting insights. In the following text, we’ll compare the equilibrium cooperation levels under different partnership scenarios, as well as the
profit and social welfare implications of these scenarios when cooperation level is endogenous.

5.1 Cooperation level decisions

By comparing $\delta_2$ and $\delta_3$, we can reach Propositions 4 and 5.

**Proposition 4:** Parallel partnership will have a higher cooperation level than vertical partnership when the travel time of HSR is sufficiently short compared with that of air, i.e., $t > (\mu - 2)\alpha/7\mu$.

Proof:

We have $\delta_2 - \delta_3 = [(2 - \mu)\alpha + 7\mu t]/(4 - 25\mu + 36\mu^2)$.

Since $\mu > 4/9$, we have $4 - 25\mu + 36\mu^2 > 0$ for all feasible $\mu$. In other words, $\delta_2 - \delta_3$ increases in $t$. Given the other parameters, it is easy to show that as long as $t > (\mu - 2)\alpha/7\mu$, we can conclude that $\delta_2 - \delta_3 > 0$.

Q.E.D

It should be noted that the difference between the optimal cooperation levels under a parallel partnership and a vertical partnership is monotone in $t$ but not in $\alpha$. The increase of $t$ will only benefit the intermodal partnership. Therefore, $t$ is not related to the cost of partnership increase. On the other hand, the increase of $\alpha$ benefits not only the intermodal partnership but also the standalone domestic airline in the case of vertical partnership. In other words, when $\alpha$ is larger, the domestic airline will earn higher profits no matter whether it is partnering with the rail operator or not. In this case, $\mu$ will play a role in deciding whether the increase of $\alpha$ will enhance or deter the increase of the parallel partnership level.

5.2 Profit and social welfare comparisons

Next we should discuss the profit and social welfare comparisons between the two cooperation scenarios when $\delta$ is endogenous. We will focus on the case in which a unique interior solution exists as well as equilibrium traffic quantities are non-negative. We first present Proposition 5, which compares the company profits under the two types of intermodal partnerships.
**Proposition 5:** The parallel partnership will dominate the vertical partnership if the travel time of HSR is sufficiently short compared with that of air, i.e., when \( t \geq -\alpha/11 \). Otherwise, there exists \( t^*(\mu, \alpha) \) such that the vertical partnership will dominate the parallel partnership if \( t \leq t^*(\mu, \alpha) \).

Proof: Let’s consider the feasible set, \( S = \{ (\alpha, \mu, t): \alpha \geq 0, \mu \geq 4/9, 2\alpha - 3\alpha \mu + 3\mu t \leq 0, 3\mu(\alpha + 2t) \geq 0, 2\mu(\alpha + t) \geq 0 \} \), in which a unique interior solution exists as well as equilibrium traffic quantities are non-negative in each scenario. It results \( \Delta \pi = (\pi^p_3 - \pi^p_2) - \pi^D_2 \geq 0 \) for each \( (\alpha, \mu, t) \in S \) if \( t \geq -\alpha/11 \). When \( t < -\alpha/11 \), \( \Delta \pi < 0 \) for each \( (\alpha, \mu, t) \in S \) if and only if \( t \leq t^*(\mu, \alpha) \), with

\[
t^*(\mu, \alpha) = \frac{14\alpha - 55\alpha \mu + 45\alpha \mu^2}{\mu(-37 + 99\mu)} - \sqrt{3} \frac{16\alpha^2 - 184\alpha^2 \mu + 777\alpha^2 \mu^2 - 1431\alpha^2 \mu^3 + 972\alpha^2 \mu^4}{\mu^2(-37 + 99\mu)^2}
\]

Q.E.D.

Figure 2 illustrates results in Proposition 5 for \( \alpha = 100 \) and \( t \leq -100/11 \). In particular, the black area delimits the unfeasible set of parameters, the grey area denotes the set of feasible \( (\mu, t) \) such that the vertical will dominate the parallel partnership, while the white area the set of feasible \( (\mu, t) \) such that the parallel will dominate the vertical partnership.

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Proposition 5 is very similar to Proposition 2, as they both tell that when \( t \) is sufficiently large, the parallel partnership will dominate the vertical partnership, no matter whether the cooperation level is exogenous or endogenous. The only difference is that when cooperation level is endogenous, the marginal cost of increasing this level will also play a role. In particular, if \( \mu \) is large, it is less likely for the parallel partnership to dominate the vertical partnership. This is because if a partnership is too expensive to form, the
domestic airline, which can earn positive profit regardless, will have a lower incentive to get involved in a partnership than the other two players, which needs a partnership in order to obtain positive profit.

Proposition 6 illustrates, instead, the impact of partnership’s formation on social welfare.

**Proposition 6:** The vertical partnership will generate higher social welfare level than the parallel partnership if the marginal cost of partnership is not sufficiently large, i.e., \( \mu < (9 + \sqrt{17})/12 \). Otherwise, there exist \( t^{**}(\mu, \alpha) \) and \( t^{***}(\mu, \alpha) \) with \( t^{**}(\mu, \alpha) \leq t^{***}(\mu, \alpha) \) such that the vertical partnership will generate higher social welfare level than the parallel partnership if and only if \( t \leq t^{**}(\mu, \alpha) \) or \( t > t^{***}(\mu, \alpha) \).

Proof. Let’s consider the feasible set, \( S = \{ (\alpha, \mu, t): \alpha \geq 0, \mu \geq 4/9, 2\alpha - 3\alpha \mu + 3\mu t \leq 0, 3\mu(\alpha + 2t) \geq 0 \} \), in which a unique interior solution exists as well as equilibrium traffic quantities are non-negative in each scenario. It results \( W_2 - W_3 \geq 0 \) for each \( (\alpha, \mu, t) \in S \) if \( \mu < (9 + \sqrt{17})/12 \). When \( \mu \geq (9 + \sqrt{17})/12 \), \( W_2 - W_3 \geq 0 \) for each \( (\alpha, \mu, t) \in S \) if and only if \( t \leq t^{**}(\mu, \alpha) \) or \( t > t^{***}(\mu, \alpha) \), with

\[
t^{**}(\mu, \alpha) = \frac{2(-11\alpha + 110\alpha \mu - 289\alpha \mu^2 + 198\alpha \mu^3)}{\mu(19 - 278\mu + 612\mu^2)} - \sqrt{\frac{128\alpha^2 - 2032\alpha^2 \mu + 12992\alpha^2 \mu^2 - 42651\alpha^2 \mu^3 + 75402\alpha^2 \mu^4 - 67392\alpha^2 \mu^5 + 23328\alpha^2 \mu^6}{\mu^2(19 - 278\mu + 612\mu^2)^2}}
\]

and

\[
t^{***}(\mu, \alpha) = \frac{2(-11\alpha + 110\alpha \mu - 289\alpha \mu^2 + 198\alpha \mu^3)}{\mu(19 - 278\mu + 612\mu^2)} + \sqrt{\frac{128\alpha^2 - 2032\alpha^2 \mu + 12992\alpha^2 \mu^2 - 42651\alpha^2 \mu^3 + 75402\alpha^2 \mu^4 - 67392\alpha^2 \mu^5 + 23328\alpha^2 \mu^6}{\mu^2(19 - 278\mu + 612\mu^2)^2}}
\]

Q.E.D.

Figure 3 illustrates results in Proposition 6 for \( \alpha = 100 \) when \( \mu \geq (9 + \sqrt{17})/12 \). In particular, the black area delimits the infeasible set of parameters, the grey area denotes the set of feasible \((\mu, t)\) such that the vertical will dominate the parallel partnership, while
the white area the set of feasible \((\mu, t)\) such that the parallel will dominate the vertical partnership.

\[== \text{Insert Figure 3} ==\]

In particular, we can draw the following lessons. For each \(\mu\), whether the vertical dominates the parallel partnership depends on \(t\): the vertical will dominate the parallel partnership if and only if the air-rail connecting service is sufficiently inferior or sufficiently superior to the connecting flight. This is a very interesting observation, probably due to the fact that \(t\) not only affects the welfare comparison directly but also influences the optimal cooperation levels that in turn have an impact on the welfare comparison.

6. Concluding Remarks

We build a theoretical model to analyze the underlying factors behind the various air-rail partnership cases. Two different intermodal relationships are identified: a parallel one where the networks of the two transport modes overlap partially and a vertical one where they do not overlap at all. We examine the situations when the cooperation levels are either exogenous or endogenous. For any given cooperation level, we show that the incremental profit of a vertical partnership is higher than that of a parallel partnership. However, when the two types of partnerships are both possible, the parallel partnership might be dominated by the vertical partnership only when the air-rail connecting service is sufficiently inferior to the connecting flight. The social welfare level of a parallel partnership is higher than that of a vertical partnership when the air-rail connecting service is sufficiently superior to the connecting flight. With the cooperation level as a decision variable, a parallel partnership will have higher cooperation level than a vertical partnership when the travel time of HSR is sufficiently short compared with that of air.

Some limitations exist due to the simplifications of our model. First, network effect is largely ignored in this paper. Incorporating the air as well as rail networks into the
analysis would likely alter some of the conclusions. And these changes may have profound policy implications, since network is one of the defining features of transportation systems. Second, many factors are either lumped together, such as the operating costs for both modes, or still omitted from our analysis, such as the possibility of repeated games and the principle-agent problem. Although as the first attempt to study this issue, it is necessary to simplify, while the preliminary results obtained from this paper are inspirational to a certain sense, it would be interesting to enrich the model more in future research and study the impacts of factors abstracted away from this paper. Besides, since we have analytically obtained the equilibrium outcomes for the partnership formation, another direction of future study will be to test these predictions empirically.

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# Appendix: Existing Cases of Air-Rail Partnership

| Country         | Rail Company          | Airline                                      |
|-----------------|-----------------------|----------------------------------------------|
| Canada          | Via Rail              | Royal Jordanian (Jordan); Air Transat; Hainan Airlines (China) |
| Canada          | Via Rail              | Air Canada                                  |
| China           | Yuehai Railway        | Hainan Airlines                              |
| China           | CRH                   | China Eastern                               |
| UK              | Heatrow Express;      | British Airways, Singapore Airlines (Singapore) |
|                 | First West Trains     |                                              |
| UK              | Southwest Trains      | Flybe                                       |
| France          | SNCF                  | Multiple airlines                            |
| France          | SNCF                  | Air France                                  |
| Germany         | Deutsche Bahn         | Lufthansa                                   |
| Germany         | Deutsche Bahn         | Multiple airlines                            |
| Italy           | Trenitalia            | Aegean (Greek)                              |
| Netherlands/Belgium | Thalys           | KLM                                         |
| Netherlands/France/Belgium | Thalys       | Jet Airways (India)                         |
| Portugal        | Comboios de Portugal  | TAP Portugal                                 |
| Spain           | Renfe                 | Avianca (Colombia)                          |
| Switzerland     | SBB                   | Swiss                                       |
| Taiwan          | Taiwan High Speed Rail| China Airlines                              |
| USA             | Amtrak                | United Airlines                             |

Note: In some countries, we can see parallel as well as vertical partnerships. They are usually for different origin-destination markets, or under different contractual forms. In rare cases both parallel and vertical partnerships exist to serve the same market, but we abstract away this possibility in our analytical model.
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