

COMPETITION AND COOPERATION BETWEEN HSR AND AIR TRANSPORTATION IN EUROPE

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Abstract

New high-speed rail (HSR) lines may have an enormous influence on the provision of air services. The attention has been devoted to competition between both transportation modes but in some cases HSR services may also have an intermodal complementary role with air transportation. By taking a supply oriented empirical analysis, we study the impact of HSR on air service frequencies and seats offered by airlines in large European countries. We emphasize the distinction between routes with and without a hub airport as an endpoint and we also examine the influence of the location of the HSR station. We generally find direct competition between HSR and airlines, but we also provide some evidence that HSR can provide feeding services to long haul air services in hub airports, particularly in hub airports with HRS stations.

Keywords: High-Speed Rail, Airlines, Competition, Cooperation.

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1. INTRODUCTION

Extension of High Speed Rail has provoked important changes in the supply of interurban transportation in those countries that have extended HSR networks and services. Among the most important effects, we can remark the replacement of demand in other modes, and notably in air transportation, the main competitor of HSR because of the characteristics of these services and their generalized cost. Indeed, an extensive literature on the intermodal interaction between HSR and air services has developed, mostly focusing on competition between both modes. Instead, literature that analyzes complementarities between HSR and air is much scarcer. Our paper intends to contribute to the literature, first, by providing new and relevant evidence of the effects of competition HSR-air; second, contributing to the understanding on potential complementarities between both services.

Demographic and mobility characteristics – also including urban structure and economic and commercial patterns- and supply features like travel time, access to city centers, cost and frequencies, are all major determinants of the competitiveness of HSR against other modes of transportation (See González-Sauvignat, 2004; Dobruszkes, 2011; Albalade and Bel, 2012).

The literature has consistently shown that the competitiveness of High Speed Rail highly depends on the route distance, given that it appears to be more efficient for medium distance routes than in case of short and long haul routes (Janic, 1993; Capon et al. 2003; IATA Air Transport Consultancy Services, 2003; GAO, 2009). However, note that given the heterogeneous speeds of High-Speed services, route distance appears to be just an imperfect proxy of travel time, the definitely determinant of competitive advantage.

As the evidence shows, HSR harms air transportation above all alternative modes due to its ability to capture a relative large market share with passengers mainly coming from airlines in medium distances (See Román, et al. 2007; Martín and Nombela, 2008). Already in Japan, the pioneer country introducing High Speed Rail technology in the world in 1964, it was easily detected a rapid decrease of airline transportation after the

extension of the High Speed Rail network. According to Taniguchi (1992), HSR was more competitive in less than 438 miles distance because of higher frequency of services, the cheaper fare, the proximity to city centers and service reliability and safety. In fact, the market share of the *Shinkansen* is always greater than that of airlines for routes of less than 600 miles in Japan (Albalade and Bel, 2012). The distance between main cities, the city structure and the ability to exploit scale and density economies that can be translated into lower generalized cost of transportation seem to explain this overwhelming superiority of Japanese High Speed Rail.

Also in Europe, the European Commission (1996) early provided data on changes in modal shares following the introduction of HSR on some European routes as well, showing how air traffic experienced the most pronounced impact. On the Paris-Lyon route, for instance, the share of air traffic fell from 31% to 7% between 1981 and 1984.¹ Klein (1997) evaluated the TGV-Atlantique's impact on modal competition finding that air travel experienced a sharp reduction in journeys between 90 and 180 minutes of duration, while its competitiveness is recovered for distances beyond this time interval.

In the case of the Madrid-Seville route, the share of air traffic fell from 40% to 13% between 1991 and 1994 (European Commission, 1996; Park and Ha, 2006). More recently, the Spanish AVE enjoyed the 85% of the market share of the Madrid-Seville line, more than 70% of the Madrid-Málaga line, and around 50% of the Madrid-Barcelona line in 2009, in detriment, above all, to the airplane (Albalade and Bel, 2012). This superiority decreases in route distance given that its share becomes modest for routes beyond 400 miles. Indeed, the AVE only enjoys a 30% of market share of seats on the Barcelona-Seville route. Notice that most of these seats are not used from origin-end trip (BCN-Seville), but to intermediate destinations between both cities.). This is explained by the longer duration of HSR trip, twice the duration of air services, by its more expensive ticket and by the limited number of frequencies. The continuous extension of the HSR network in Spain has allowed new studies on airline reactions to the opening of new HST services. Among others, Jiménez and Betancor (2012) find HSR openings have reduced the number of air transport operations by 17% in Spain.

¹ Bonnafous (1987) found that the change between 1980 and 1985 was even more pronounced, from 48% to 17% between Paris and Lyon.

In the case of Germany, Ellwanger and Wilckens (1993) early identified an increase of rail market share of 11% with the introduction of High Speed Rail between Frankfurt and Cologne, being air transportation the main victim of passenger losses. On the contrary, Dobruszkes (2011) finds that the flag carrier airline Lufthansa increased services after the entry into service of the Cologne-Frankfurt line by complementing its services. However, it was later forced to reduce its frequencies with the entry into service of the HSR line between Cologne and Munich, even being a service with several stops and not travelling the whole route at highest speed.

Also in Korea, the two airlines providing significant services between Seoul and the rest of main cities anticipated the arrival of HSR and drastically reduced the frequency of flights in 2004. Between Seoul-Daegu the number of monthly air departures fell from 517 to 293 prior to the entry of HSR and to 183 two months after the entry (Suh, Yang and Kim, 2005), being these figures consistent with those of Park and Ha (2006). Similarly, in Taiwan, the air services between Taipei and Kaohsiung, lost market share from 24% to 13% with the introduction of HSR services (See Yung-Hsiang Cheng, 2010).

Indeed, intermodal competition not only has effects on the market share, but also disciplines their pricing. The report by Steer Davies Gleave (2006) for the European Commission identifies sharp reductions of air service fares because of competing High Speed train services, being so large that they might drop below rail prices. Yang and Zhang (2012) also find that airfares are decreasing in rail speed when the marginal cost of High Speed rail is not very large.

In spite of this competitive pressure exerted by High-Speed rail, the transformation of the airline market towards a greater presence of low cost carriers provides a better defensive framework for air transportation. Indeed, Antes et al. (2004) find that the competitive pressure of low cost carriers obligates both air and rail transport to reconsider their pricing strategy. In Japan, for instance, the airline industry has only been able to effectively grow due to the appearance of low cost carriers following the air transport liberalization (Albalade and Bel, 2012). Steer Davies Gleave (2006) acknowledges that competition between HSR and air transportation is less straightforward where air transportation is operated by low-cost carriers. In the same vein, Beherens and Pels (2012) show that although High speed rail is a competitor for

both conventional and low cost carriers, some conventional airlines were pulled out of the market between London-Paris.

Competition pressure and its consequences seems to mitigate in the long run once the market is already adjusted after the entrance of High Speed Rail. Vickerman (1997) followed the modal change provided by High speed rail in France and found that the increase of train passengers took place almost entirely during the first years of HSR operation and then became much more moderate. Similarly, Beherens and Pels (2012) consider that the evidence on the large market share gained by the Eurostar in the London-Paris route and the withdrawal of aviation alternatives indicate that competition will certainly decline in the long run. This may award market power to HSR given that, as reported by Steer Davies and Glaeave (2006), rail operators may increase prices to maximize profits in these circumstances without losing a significant market share.

In some instances, HSR introduction not only reduces the market share of air transportation or affect their prices, it might even produce air routes cancellations given the superiority of HSR respect to air services. It was early seen in the opening of HSR services in Japan, when the air route between Tokyo and Nagoya was cancelled.² In China, for example, some 50% of flights less than 310 miles in length and about 20% of flights between 500 and 620 miles become unprofitable as a result of HSR competition according to declarations of the managing director of the General Administration of Civil Aviation of China (CAAC) in 2009.³ As illustration, two of the cancelled routes were Nanjing-Wuhan and Zhengzhou-Xi'an, which were later resumed when decisions were taken to slow the speed of HSR services. Similarly, airlines reacted cancelling air services in Taiwan, such as the Taipei-Taichung route by Mandarin Airlines – and reaching agreements of cooperation with the rest of airlines to permit any passenger with a reservation to be able to use any of the airlines to cooperatively compete against HSR (See Albalade and Bel, 2012 for a review of these circumstances).

Recent works providing with evidences of fierce intermodal competition between air and high speed rail transportation is, as shown, an emerging bunch of literature. However, scarce attention has been devoted to the intermodal complementarities

² Other routes abandoned after the introduction of High-Speed Rail in Japan were those that connected Tokyo with Sendai, Niigata, Aichi and Iwate. All of them with distances below 350 miles.

³ Li Jiaxiang declarations can be found in the magazine for airline company executives, *Airline Leader* (2011).

between both modes of transportation. Among the exceptions we find Givoni and Banister (2006), who highlight the potential integration of both modes. As illustration, they claim that airlines may use railway services as additional spokes in their network of services from a hub airport to complement and substitute existing aircraft services. Similarly, Clewlow et al. (2012), suggest an efficient role of HSR as complementary mode to relieve congestion at airports by providing short-haul services in support of longer-haul airline services. They conclude that HSR lines appear to serve as successful feeders for international air traffic at Frankfurt Airport and at Paris-CDG. Grimme (2006) also illustrates cooperation by exploring AIRail, an integrated ticketing and baggage handling service offered by Deutsche Bahn (rail operator), Lufthansa (Air carrier) and Fraport (Airport). Albaladejo, Bel and Zhong (2013) analyze intramodal and intermodal connectivity in the planning of the new stations envisaged in the California HSR network. All considered, the scope of cooperation is still an area of scarce knowledge.

Indeed, intermodal complementarities between HSR and air transportation have also been considered as primary transportation policy goals in France, where it is a key component of transportation policy since 1995 and has been recently reinforced by the National program for the environment “Granelle 2” that pursues – among other objectives- the improvement of HSR access and commuting to major airports since 2010. This policy framework facilitates the emergence of new cooperative experiences of code share, single ticketing and one stop baggage check agreements between airlines and SNFC (French Rail operator).

By taking a supply oriented empirical analysis, we study the impact of HSR on air service frequencies and seats offered by airlines in large European countries. More specifically, we focus on the study of HSR impact on national air routes in the four European countries with the longest HSR networks. Beyond analyzing the competitive role of HSR, this paper also tries to identify the potential of intermodal cooperation suggested in those works mentioned above. In the next section, we present our empirical methodology and the main data we use in our analysis. Next we present the empirical results. Finally, we discuss our main findings and policy implications.

As illustration, we include Figure 1 in order to show the potential for connectivity between HSR and Airports in the cities with the busiest Airports of Europe.

Insert figure 1 about here

2. EMPIRICAL ANALYSIS: METHODOLOGY AND DATA

Our empirical analysis is based on data of domestic routes for four countries in the European Union; France, Germany, Italy and Spain. The analysis focuses on these four countries because the size of their domestic air transport markets is large and these are the European countries with a sufficient number of air routes with and without competition of high-speed train services.

We have data available for a high proportion of domestic routes in each of the considered countries. Given that our main interest is the analysis of competition and complementarities between air and high-speed train services, we exclude from the sample those air routes that have an island as an endpoint. Routes that do not have air services in most of the years of the considered period are also excluded from the sample. The period of analysis is determined by data availability and it goes from 2002 to 2010 when we consider frequencies and it goes from 2002 to 2009 when we consider seats.

The equations to estimate at the route level are the following⁴:

$$Seats = \alpha + \beta_1 Population + \beta_2 GDP + \beta_3 Distance + \beta_4 D^{hub} + \beta_5 D^{high_speed_train} + \epsilon$$

(1)

$$Frequencies = \alpha + \beta_1 Population + \beta_2 GDP + \beta_3 Distance + \beta_4 D^{hub} + \beta_5 D^{high_speed_train} + \epsilon$$

(2)

where the dependent variables are the total number of seats (*Seats*) and the total number of annual frequencies (*Frequencies*) offered by airlines in the route. We consider the following exogenous explanatory variables in both equations:

Population: Weighted average of population at the origin and destination regions of the route.

GDP: Weighted average of Gross Domestic Product per capita at the origin and destination regions of the route (weights are based on population).

⁴ Note that we do not treat airline services in different directions on a given route as separate observations as this would overlook the fact that airline supply must be identical, or nearly identical, in both directions of the route. Thus, we consider the link with the origin in the largest airport. For example, on the route Madrid-Barcelona-Madrid, we consider the link Madrid-Barcelona but not the link Barcelona-Madrid.

Distance: Number of kilometers flown to link the endpoints of the route. Given that we may expect a non-linear relationship between distance and the supply of flights, this variable is measured in logs.

D^{hub} : Dummy variable that takes the value of one for those routes where at least one of the endpoints is a hub airport of a network airline.

$D^{\text{high_speed_train}}$: Dummy variable that takes the value of one for those routes where high-speed train services are competing with airline flights. We only account for direct services with no connections/transfers and where lines are for HSR, excluding routes with sections of conventional rail tracks.

Note that we include country and year dummies in both equations, being 2002 the excluded year and Germany the excluded country.

Airline frequencies data have been obtained from RDC aviation (capstats statistics). Data for population and GDP per capita at the NUTS 3 level (Statistical unit used by Eurostat) have been provided by Cambridge Econometrics (European Regional Database publication). Data for distance have been obtained from Official Airlines Guide (OAG) and the website of webflyer (<http://www.webflyer.com>).

The hub airports in the considered countries of our analysis are Paris (Charles de Gaulle and Paris-Orly), Frankfurt, Munich, Madrid, Rome-Fiumicino and Milan-Malpensa until 2007. Hub airports are those airports where a network airline integrated in an international alliance exploits the connecting traffic. Two basic characteristics of hub airports are their large size and that a network airline has a high share of all flights through such airports (usually above half of total flights). Large airports in the considered countries like Barcelona, Dusseldorf or Milan-Malpensa are not currently hub airports because most of their traffic is channeled by airlines operating point-to-point routes.

The High Speed variable denotes those routes connected by High speed train services of at least 250 Km/h without any transfer/connections. We only consider direct routes where the whole trip is carried out on High Speed railways, not considering routes with part of the railway being of conventional characteristics. We obtained information on the lines by checking the High Speed rail maps offered by the International Union of Railways (UIC) and information on direct services across Europe has been collected from the search engines provided by SNFC-Voyages, commercial online ticket distributor of SNCF, the French railway company. This variable is constructed as a

binary variable taking value 1 for High Speed Rail connections and 0 for routes not satisfying our requirements.

The variables of population and GDP are demand shifters at the route level. Indeed, demand should be higher in those routes that connect richer and more populated endpoints. The number of annual seats and frequencies should be higher in thicker routes. Thus, we expect a positive sign of the coefficients associated to population and GDP.

The variable for hub airports is also a demand shifter at the route level. Demand at hub airports is higher than that generated by local population due to the exploitation of connecting traffic by the hubbing airline. Thus, we expect a positive sign of the coefficient associated to this variable.

Concerning the variable of distance, demand of air services should be higher in longer routes because competition coming from cars and trains should be softer. Otherwise, airlines may be required to offer high-frequency services in shorter routes to be able to compete with other transportation modes. Note also that airlines may prefer to use smaller planes at higher frequencies in short-haul routes. Thus, we may expect a positive relationship between distance and seats but less clear it is the relationship between distance and frequencies.

The main variable of interest in our analysis is the dummy variable for high-speed train services. Competition of high-speed train services may have a substantial influence on the amount of seats and frequencies offered by airlines in the routes.

Demand of air services should be lower in those routes where airlines are competing with high-speed train services because travelers have another fast option to make the trip. In the case of hub airports, the decrease in the demand of air services may come from point-to-point traffic but also from the feeder traffic. This is particularly the case when the hub airport has a high-speed train station as it is the case of Paris-Charles de Gaulle or Frankfurt.

However, airlines may still be required to keep high-frequency services to be competitive against high-speed train services. Indeed, frequencies are typically considered as the main quality attribute of air services because higher frequencies reduce the expected schedule delay cost which is the difference between the desired and actual time of departure.

Overall, we expect a negative sign of the coefficient associated to the dummy variable for high-speed train services in the seats equation, while less clear is the expected sign in the frequency equation.

Table 1 provides some descriptive statistics of the variables used in the empirical analysis. First of all, the country with the lowest number of observations is France in spite of being the second biggest country in our sample. Spain is the country with the thicker routes, while Italy is the one with thinner routes. The mean route distance is around 500-600 kilometers for all countries except for Germany which is lower than 400 kilometers. The proportion of routes with a hub airport as an endpoint is about 50% in all countries except in France where the proportion of routes with hub airports is 65%. Finally, France is the country with a higher proportion of routes subject to competition from high-speed train services. 40% of air routes in France are subject to intermodal competition while these percentages are lower than 10% in the other countries.

Insert table 1 about here

Table 2 shows some additional information for the largest airports in the considered countries. The interest of this table lies on data for Paris-Charles de Gaulle and Frankfurt airports which both have a high-speed train station in their sites. Paris-Charles de Gaulle is the largest hub airport of Air France-KLM with a very extensive network of international destinations with non-stop flights. In comparison to Paris-Orly, the number of domestic destinations with non-stop flights is surprisingly low in Paris-Charles de Gaulle. A similar situation is taking place in Germany where the main hub airport of Lufthansa, Frankfurt, has less national destinations than Munich. In Spain, both Madrid and Barcelona have a similar number of national destinations while Madrid has a denser network of international destinations. In Italy, Rome-Fiumicino has higher levels of connectivity than Milan-Malpensa whichever the indicator of performance we use.

Our analysis relies fundamentally on routes with air traffic so that we are not able to test whether the feeder traffic of Frankfurt and specially Paris-Charles de Gaulle is being channeled by train but table 2 shows some exploratory evidence in this direction.

Insert table 2 about here

Table 3 shows the results of the regressions using the random (route) effects estimator. An important advantage of the random effects models is that accounts for route heterogeneity that is not captured by the explanatory variables of our equations. Standard errors are robust to heterocedasticity.

3. RESULTS

The main results shown in table 3 are as follows. Airlines subject to competition from high-speed train services reduce the number of seats offered in the route in comparison to airlines operating in routes that share similar features but that are not subject to competition. Indeed, the coefficient associated to the dummy variable for high-speed train services is negative and statistically significant at the 10% level when the dependent variable is the number of seats in the route. However, the coefficient associated to this variable is negative but not statistically significant when the dependent variable is the number of frequencies in the route. Thus, airlines may be required to keep high frequencies when competing with high-speed train services even though the demand of air services has been reduced.

Insert table 3 about here

Regarding the other explanatory variables, we find the expected positive effect for the variables of population and the dummy for hub airports. However, the coefficient associated to the variable of GDP is negative albeit not statistically significant.

The coefficient associated to the variable of distance is positive and statistically significant both in the seats and frequency regressions. As expected, the amount of seats offered by airlines in longer routes is higher due to the higher competitiveness of planes in relation to surface transportation modes. The positive effect of the distance variable in the frequency equation suggests that the increase of demand of air services in longer routes have a stronger effect than the softer frequency competition from trains and cars and the higher efficiency of larger planes that we can expect in longer routes.

Taking these results into account, we make additional regressions of the seats and frequency equations. In this regard, we make regressions for sub-samples that consider each country separately and within each country we also make the distinction between routes with hubs and no hubs as endpoints. In order to simplify the exposition of results, table 4 only shows the results of our main variable of interest: The dummy variable for high-speed train services.

Insert Table 4 about here

Concerning the regressions with all routes of each country, we find that airlines reduce both seats and frequencies in Spain and they reduce seats but not frequencies in Germany when competing with high-speed train services. In contrast, we do not find a statistical significant effect of high-speed train services on the supply of air services in Italy and France.

When we focus on the distinction between routes with and without a hub airport as an endpoint, we find that high-speed train services have a more negative effect in routes with hub airports in Spain, France and Italy. Indeed, the coefficient associated to the dummy for high-speed train services is negative and statistically significant in Spanish routes with both hubs and no hubs as endpoints but the magnitude of the coefficient is much higher when we consider routes with hubs. In France and Italy, the coefficient of this variable takes a negative sign in the regressions for routes with hubs and even a positive sign in the regressions with no hubs as endpoints. In general, this variable does not show statistical significant effects in the regressions for France and Italy. However, it is remarkable that the coefficient of this variable has a negative sign and is statistically significant in the regression of the seats equation that uses the sub-sample of routes that have Paris-Charles de Gaulle as an endpoint. Indeed, the HSR station at CDG may therefore substitute feeding services by air transportation, what offer the possibility to airlines of reducing or even cancelling unprofitable feeding flights. Moreover, HSR brings passengers to Paris as endpoint that were not going to the airport even when they used to travel by plane.

In the case of Germany, the coefficient associated to the high-speed train services is negative and statistically significant in the regressions for routes with no hubs as endpoints both when we consider seats and frequencies as dependent variable. Such coefficient is negative but not statistically significant in the regressions focusing on hub airports. Note that we do not have enough observations to make the distinction between hub airports with and without a high-speed train station as we can do in the case of France.

Overall, airlines operating in Paris-CDG and Madrid are clearly affected by high-speed train services. Losses of point-to-point traffic may be added to the lower profitability of connecting routes. It could be that those hub airports are losing frequencies in their connecting traffic due to competition from high-speed train services. As we mention above, we are not able to provide direct evidence that a substantial amount of feeder traffic to Paris-Charles de Gaulle is being served by surface and not by air. However, our results seem to suggest that domestic routes to such airport have fewer frequencies when competing with high-train services while the network of non-stop destinations at Charles de Gaulle is less dense than expected by its size.

High-speed train services do not seem to harm the competitiveness of air short-haul routes in routes with no hubs in Italy and France. In these countries, the connectivity of

cities not served by hub airports could have been improved because travelers have two fast options with high-frequency services to make the trip. In Spain, all air routes are negative affected by high-speed train services but it is the hub of Iberia in Madrid which appears to be more damaged by intermodal competition.

In contrast, cities not served by hub airports could have been more negatively affected in Germany by high-speed train services while the hubs of Lufthansa are not clearly affected by intermodal competition. A possible explanation of this result is that the design of the high-speed train network on Germany has been more focused on improving the connectivity of cities of different size and this may have harmed air services that connect those cities. In France, the high-speed train network focuses on connecting Paris with the rest of cities in the country so that the effect of high-speed train services is mainly based on routes to the airport of Paris with high-speed train station. In Italy, the design of the network is focused on connecting the south and north and maybe Rome-Fiumicino has been more damaged due to the lower attractiveness of the connecting traffic but such negative effect on air services is modest.

4. DISCUSSION

Our research has focused on the effects of HSR services on air traffic at the route level. The empirical analysis confirms that airlines subject to competition from HSR do decrease the number of seats offered in the route. However, frequencies of air services in the route do not have a significant decrease (with the exception of Spain). Thus, airlines seem to follow the strategy of keeping high frequencies when they compete with HSR services even if the demand of air services has been reduced, so that air competitiveness is not further reduced.

Reduction of air service in hub airports is generally higher than in no-hub airports. This result might be explained from the fact that while HSR competition affects all point-to-point air routes serviced by HSR, complementarities between HSR and air services further affects hub airports, as HSR might be acting as feeder of long haul services in those airports, further reducing air services supply. Germany is an exception to that result, as we find that hub airports do not show a net decrease of air services supply. We interpret these results taking into account that Frankfurt and Munich do not serve as final destination for domestic traffic as much as Paris does. Furthermore, the high speed network in France is denser than HSR network in

Germany. Therefore, HSR competition for point to point services and HSR replacement of air services to feed long haul flights in hub airports has lower effects in Germany.

Our analysis provide indirect evidence that HSR can provide feeding services to long haul air services in hub airports, and this could be particularly significant in hub airports with HRS stations such as Charles de Gaulle. In this regard, airlines providing long haul services could benefit from these complementarities as this allows them reducing the supply of connecting flights that might be not profitable on themselves. Indeed, airlines that provide long haul flights can improve the cost function by reducing frequencies or even cancelling unprofitable routes where services were offered only to provide connecting flights that could feed long distance flights. This provides a rationale for network airlines' demand to have HSR stations built and operated in the hub airports where they are based.

However, it is not clear that hub airports would benefit from this strategy. On one side, congested airports would be relieved of problems derived from insufficient capacity. On the other, hub airports with excess capacity could be damaged by the reduction of air services supply, which could further damage their profitability. Recall that connecting flights can be cancelled when HSR provides feeding services, and HSR may transport also passengers whose final destination was the city, not the airport itself (connections). Hence, those passengers will travel now to the city by different modes other than air, thus reducing the aggregate volume of airport passengers. Therefore, the structure of air services supplied from the airport, and the state of the airport capacity (congested versus excess capacity) must be taken into account by transport planners and policy makers when deciding on the installation of HSR stations in airports. In the same direction, we believe that future research should devote efforts to analyze the potential impact on HSR traffic of connectivity between airports and HSR services.

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TABLES

Table 1. Descriptive statistics of variables (mean values at the route level)

	Spain	France	Italy	Germany
Number of observations	369	290	369	585
Seats	296303.6	254368.3	237192.5	238351.6
Frequencies	2287.69	1923.76	1688.50	1943.22
Population	4375.42	8085.34	2944.14	1068.27
GDP	117.69	156.58	126.12	192.74
Distance	501.10	527.27	598.72	368.10
D^{hub}	0.46	0.65	0.48	0.42
D^{high_speed_train}	0.065	0.38	0.087	0.080

Table 2. Descriptive statistics of largest airports in each country (data for 2010)

	Hub airport	National Destinations with non-stop services	International destinations with non-stop services	Total frequencies (national + international)
Madrid	YES	21	164	211859
Barcelona	NO	22	133	130394
Paris-CDG	YES	15	229	228256
Paris-ORY	YES	31	104	111520
Rome-FCO	YES	19	165	159602
Milan-MXP	YES/NO*	6	133	85470
Frankfurt	YES	14	244	218664
Munich	YES	19	181	185159

Note: Data about the share of the dominant airline is for the first quarter of 2011

.* : Milán MPX cannot be considered a hub airport after Alitalia ceased offering connections and long distance flights in 2007

Table 3. Results of equation estimates (GLS-Random effects model): Direct competition between air and high-speed trains

	Dependent variable: Seats	Dependent Variable: Frequencies
Population	44.03*** (12.90)	0.26 (0.08)***
GDP	-583.78 (632.36)	-1.26 (3.95)
Distance	177575.9 (54723.07)***	931.51 (347.42)***
D^{hub}	171961.9 (57283.35)***	840.48 (342.31)***
D^{high_speed_train}	-66922.34 (38671.47)*	-335.52 (257.74)
Intercept	-842283 (319113.7)***	-4160.03 (2062.61)**
Country fixed effects	YES	YES
Time fixed effects	YES	YES
N	1428	1607
R²	0.15	0.14
χ^2 (Test Joint Significance)	90.00***	88.29***

Notes: Standard errors in parenthesis (Robust to heterocedasticity). Significance at 1% (***), 5% (**), 10% (*)

Table 4. Results of equation estimates for the variable D^{high_speed_train} (GLS-Random effects model)

	Samples of routes¹:	Dependent variable: Seats	Dependent Variable: Frequencies
	All routes	-336769.7 (158248.7)**	-1889.25 (944.05)**
Spain	Hub airports	-472718.8 (205255.4)**	-3365.48 (1019.19)***
	No hub airports	-124523.4 (22208.15)***	-474.08 (110.31)***
	All routes	19336.49 (93036.35)	135.09 (571.68)
France	Hub airports with high-speed train station	-134558.6 (77111.8)*	-624.93 (479.67)
	Hub airports with no high-speed train station	-154017.3 (321551.6)	-1205.39 (1822.55)
	No hub airports	47786.96 (16652.14)***	238.11 (155.89)
	All routes	-20439.17 (30543.9)	-257.58 (369.91)
Italy	Hub airports	-38909.64 (40726.24)	-508.46 (522.74)
	No hub airports	2929.90 (10590.28)	115.83 (129.75)
	All routes	-129263.3 (31731.67)***	-269.27 (290.44)
Germany	Hub airports	-52826.08 (143405.3)	-165.18 (322.39)
	No hub airports	-127725.3 (37255.5)***	-995.25 (261.07)***

Note 1: 1. All routes. 2. Routes with hub airports as endpoints. 3. Routes without hub airports as endpoints

Note 2: Standard errors in parenthesis (Robust to heterocedasticity) and clustered by route. Significance at 1% (***), 5% (**), 10% (*)

FIGURES

Figure 1. Biggest airports in Europe and their connectivity to HSR (>250 Km/h).

