Fewer seats, resilient frequencies: Impacts of large-scale High-Speed Rail liberalisation on air transport supply.

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Abstract

This paper examines the liberalisation of high-speed rail (HSR) as a driver of intermodal competition in long-distance passenger transport. While previous research has primarily focused on the effects of HSR infrastructure deployment on aviation, less is known about how opening HSR markets to new entrants reshapes this competition. Drawing on the Spanish HSR liberalisation in 2021, we are the first to evaluate the causal effects of a large-scale liberalisation on competing air transport supply. Using a regression discontinuity design, we find significant long-term reductions in airline seat supply (10-16%), but limited impact on frequencies. We then uncover two mechanisms underlying these results. First, airlines' primary response was to down-gauge aircraft. Second, a market share emerged from the need of legacy carriers to preserve frequencies to feed their hub. Our results underscore the broad and significant implications of liberalisation for intermodal substitution.

JEL Classification: L43; L51; L92; L93; R41; R42

Keywords: Airlines, High-speed rail, Liberalisation, Intermodal competition. Transportation.

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Introduction

High-speed rail (HSR hereafter) has emerged in recent decades as a modern mode of transportation, garnering increasing interest and presence worldwide, and contributing to the global transportation landscape as an efficient alternative for medium- to long-distance travel. Due to its operating speeds exceeding 250 km/h, HSR transforms the dynamics of transport markets, offering a competitive alternative to traditional modes such as aviation, conventional rail, and road transport.[1]

Despite its high capital costs, supportive policies for HSR have been implemented in Europe, as many national governments and the European Commission have promoted HSR as a more sustainable mode of transportation, contrasting with road and air transportation. On the latter, authorities are concerned about the large growth rates experienced (66% between 2005 and 2019 in air traffic – excluding the UK-)(European Commission, 2023) and the projected traffic (global air transport over the long term is expected to grow by around 5% annually until 2030). As a low-carbon transportation option, once built, it is expected to reduce greenhouse gas (GHG) emissions compared to these modes (See Prussi and Lonza, 2018; Tang et al., 2023; among others).[2] Nonetheless, some scholars have warned that the net balance could be negative if this results in greater mobility demand, rather than just a modal diversion (D'Alfonso et al., 2015; Chen et al., 2021; Jiang et al., 2021).

The EU promotes HSR on several fronts. First, it committed to an ambitious action plan in 2021 intended to double high-speed rail traffic by 2030 and triple it by 2050.[3] Second, it contributes to financing investments in the Trans-European Transport Network (TEN-T) initiative, which aims to increase the HSR network in Europe from 11,000 km to 32,000 km by 2050 under the Green Deal Agenda. Third, it promotes competition by supporting the opening of the rail market and encouraging private-sector participation to increase service quality and reduce costs. This latter EU strategy aimed to boost rail

[1] Throughout the manuscript we refer by HSR to the rail infrastructure and rail services able to accommodate and travel at speeds for 250 km/h or higher.

[2] Environmental advantages of new HSR are heavily dependent on the energy and emissions made during the construction phase. A life-cyle analysis often questions this contribution and demands high efficiency and environmental advantage during the operational phase to offset previous emissions. See Chester and Horvat (2010) and Chang and Kendall (2011), among others on the life-cycle of HSR emissions.

[3] The EU Sustainable and Smart Mobility Strategy (COM(2020) 789 final) set these ambitious milestones to HSR developments due to the pivotal role of HSR in achieving Sustainable and efficient transport.

passenger transport by completing the liberalisation process, as outlined in the Fourth Railway Package in December 2016.[4] Its approval marked the final step in the liberalisation of rail services across Europe. However, outcomes of this market pillar were still disappointing by 2020, with only 6.6% of passengers-km of commercial services under new entrants' operations (CNMC, 2024a)

Indeed, very few markets have been liberalised and opened to both competition and private participation in the case of classic HSR (≥ 250 Km/h). We only find large-scale liberalisations in Italy (2012) and Spain (2021), and at a much lower scale in France (late 2021, on the Paris-Lyon line).[5] Outside Europe, HSR liberalisation is rare, with only Japan (1990s) and South Korea (2016) offering relevant experiences that hardly resemble the European model.[6]

This paper examines whether pro-competitive liberalisation processes can serve as a new catalyst for additional intermodal impacts favouring high-speed rail, driven by downward price pressure, increased frequencies, and better alignment of rail services with passenger demand.

We empirically evaluate the causal impact of the recent liberalisation of Spanish HSR on domestic air transport supply using the quasi-experimental regression discontinuity method. Therefore, our contributions are threefold. First, we evaluate the impacts of large-scale HSR liberalisation (≥ 250 km/h) on intermodal competition with air transportation by focusing on how new entrants shifted the equilibrium on treated routes. So far, the literature has examined only HSR openings, new connectivity/accessibility (routes), rail liberalisations for services and rail infrastructure standards for lower speeds (<250 km/h). Second, we are also the first to provide causal estimates on the intermodal impact of a large-scale HSR liberalisation on airline supply,

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[4] The EU has historically led the liberalization process of rail transport since 2001 with a gradual opening to competition to increase railways' modal share and increasing integration of national markets towards a single EU railway market.

[5] France allowed for the the entry of a private operator in the Paris-Lyon route at the end of 2021, as part of the Paris-Milan route.

[6] Japan fragmented the State-owned operator Japanese National Railways (JNR) into regional and functional monopolies in the late 1980s that were privatized in the 90s. South Korea separated Super Rapid Train (SR corporation) in 2016, which competes with Korail, both publicly owned companies.

using a quasi-experimental method. Previous literature had mainly focused on pre-post comparisons and other non-causal methods (see the review by Givoni and Dobruszkes, 2013). To our knowledge, only Wang et al. (2020) employed a quasi-experimental differences-in-differences strategy. Still, they evaluate the case of a single entry in a single route by the low-cost commercial unit of the State-owned incumbent in a non-liberalised French market. Our analysis differs in evaluating several entries, including companies unrelated to the incumbent, across various corridors of a larger-scale liberalised market. Third, by considering the effects of different entries over time, we are the first to examine the heterogeneous effects of HSR market structure changes from monopoly to duopoly and triopoly).

Finally, we utilise data for the Spanish domestic air transport and HSR markets for the following reasons. First, it is the market with the largest number of competitors among the countries that liberalised HSR, comprising three companies and four commercial brands, making it a suitable case for obtaining insights into the potential of liberalisation. Second, it has one of the largest domestic air transport markets in Europe, only behind France and the United Kingdom. Third, Spain has the most extensive HSR network in Europe, and route distances between the most relevant cities are in a suitable range for HSR-air direct competition.[7] Moreover, the radial structure of the HSR network linking Madrid (core) with the dense coastal urban agglomerations overlaps several dense air routes.

The remainder of this manuscript is structured as follows. Section 2 summarises the related literature. Section 3 describes the liberalisation of high-speed rail services in Spain. Section 4 presents our empirical strategy, describing the methods, variables, and data. Section 5 presents our main results, discussed in Section 6. The manuscript briefly concludes in Section 7.

2. Related literature on the effects of HSR liberalisation

[7] Route distance is the most distinctive and decisive feature of HSR relative (dis)advantage against aviation and road transport (Albalate and Bel, 2012).

Intense intermodal competition is an expected result of successful liberalisations due to a decrease in prices and additional supply (seats and frequencies), because (1) cross-elasticities between rail and aviation are known to be high (Starkie, 2002; Park and Ha, 2006) and (2) increased HSR frequencies offer better fit for personalised trips playing a role in the decline of air travel passengers and flights (See Yang and Zhang, 2012; Li et al, 2019).

The literature on rail services liberalisation is clear on its effects on prices. Opening the market to competition has decreased prices across Europe, including Sweden (Vigren, 2017; 13%), the Czech Republic (Tomes et al., 2016; 46%), and Austria (Tomes and Jankova, 2018; 20-25%), among others. Yet, few articles address classic HSR liberalisation (≥250 Km/h).

The Italian case, the first and the most studied, shows significant price reductions (between 10-40%) (See the review by Beria et al., 2023), frequency increases, and service innovations (see Cascetta and Coppola, 2015; Bergantino et al., 2015; Beria et al., 2016; Beria et al., 2019; and Beria et al., 2022). Similar results on prices were recently confirmed by Brenna (2024) through a quasi-experiment on two liberalised routes in Spain. The outcomes on the prices charged by the incumbent operator (RENFE-AVE) on the routes Madrid-Alicante and Madrid-Sevilla/Málaga decreased by an average of 28-30%.

Despite the lack of analysis comparing intermodal competition with air transportation in Italy and Spain, the literature provides sound evidence on its key elements. It suggests the relative improvement of HSR over air transportation, implying modal substitution and strategic airline responses (such as capacity, frequencies, aircraft, schedules, prices, etc.). The effects of competition are not solely reflected in prices.

Instead, higher frequencies and better quality explain the increased demand across Europe (Beria et al. 2025).

The entry of low-cost rail services (sometimes with brands owned by incumbent operators) has also been assessed recently. Brenna (2024) found no statistically significant price reductions on AVE in the Madrid-Alicante route with the entrance of AVLO (owned by RENFE). Nonetheless, a 21% short-term average decrease in second-class AVE prices was causally associated with the entry of OUIGO. This suggests that only independent new entrants exert real price pressure in HSR.

Yet, low-cost brands do offer lower-priced services, making HSR more competitive and potentially affecting intermodal competition in the low-willingness-to-pay market segment. Wang et al. (2020) employ a differences-in-differences model to assess the introduction of low-cost rail units, still owned by SNCF, on the high-speed route between Paris and Marseille, finding a substantial 39% decrease in air traffic. This confirms that both new operators and low-cost services may alter intermodal competition.

3. High-speed rail liberalisation in Spain as a source of intermodal competition

3.1 Policy framework and the liberalisation process

Since the year 2000, high-speed rail gained momentum in Spain, becoming the main protagonist of interurban transport infrastructure policy, receiving high budgetary priority and definitively marking the narrative of territorial and transport policy of successive governments (see Albalate and Bel, 2011; Albalate and Bel, 2012; Beria et al., 2018). As a result, the Spanish HSR network became the second longest in the world in 2010, just behind China's, and the largest in Europe. In 2023, the Spanish HSR network with standard speeds of ≥250 km/h was 3,189 km long.

Despite this investment effort, the low-intensity use of such large and expensive infrastructure led to overcapacity in Spanish high-speed rail, which drew criticism due to negative socioeconomic returns (see Betancor and Llobet, 2016; Beria et al., 2018; European Court of Auditors, 2018; Airef, 2020). Low demand and the financial burden of both the publicly owned infrastructure developer ADIF and operator RENFE[8] encouraged actions to limit the costs of new investments in low-density corridors. They boosted efforts to increase occupancy factors and infrastructure utilisation, both of which are essential to improving the socioeconomic return (UIC Brochure, 2018). One of the most influential policies was the recent liberalisation of HSR services in the densest corridors, which took place in 2021.

In 2018, Spain transposed the EU Directive 2016/2370 on the opening of the domestic passenger transport services market and established December 2020 as the date of liberalisation.[9,10] The model chosen optimised the existing capacity with an integrated cadenced timetable (see Montero and Ramos (2022) for details). As a result, the previous capacity was increased by 60%. 70% of the new capacity was available for new undertakings, and the remaining was left for annual assignments. Six interested companies applied for the technical and operating capacities in 2019 for the three asymmetric framework agreements at stake. They included joint capacities across the three corridors to avoid the expected cherry-peaking effect on the single densest Madrid-

[8] According to the statistics of the Bank of Spain, among the public Spanish companies dependent on the central Administration, Adif stands out, with a debt of 18.750 million by April 2023 as the mot indepted company. Likewise, Renfe registered a debt of 6,136 million, being the third most indepted publicly owned company only behind ADIF and AENA (Airports' manager company).

[9] Directive (EU) 2016/2370 of the European Parliament and the Council of 14 December 2016 amending Directive 2012/34/EU as regards the opening of the market for domèstic passenger transport servicies by rail and the governance of the railway infrastructure.

[10] Note EU Directive 2012/34 already imposed the liberalisation of railway services in Europe by December 2020.

Barcelona route.[11,12] Due to the excess of bidders, a tender was organised and agreements were signed between the infrastructure manager and three capacity-awarded operators (RENFE, SNCF and ILSA-Trenitalia) in May 2020 (Stojadinovic et al., 2019).[13] The Competition Authority, *Comisión Nacional de los Mercados y la Competencia* (CNMC), monitored the process and oversees the market.

Framework capacity was allocated for ten years to the three corridors: Madrid-Barcelona, Madrid-Levante (branch lines to Valencia and Alicante), and Madrid-South (branches to Sevilla and Málaga). Liberalisation was feasible in this short period due to the existing excess capacity and modern infrastructure, which enabled interoperability (CNMC, 2024).[14]

The company OUIGO, a subsidiary of the French state-owned *Société Nationale des Chemins de Fers* (SNCF), obtained the smallest package (10%) but became the first new operator to enter the Madrid-Barcelona route in May 2021. Soon after, it started operations on the Madrid-Valencia line and connected Madrid to Alicante in 2023. Finally, it also served the corridor Madrid-Sevilla/Malaga in January 2025. Outside the initial agreed-upon corridors framework, OUIGO also initiated train services linking Valladolid with Madrid, Alicante, and Valencia in 2024.

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[11] According to Directive 2012/34/EU, a framework agreement is "a legally binding general agreement […] setting out the rights and obligations of an applicant and the infrastructure manager in relation to the infrastructure capacity to be allocated and the charges to be levied over a period longer than one working timetable period" (Article 3(23)).

[12] According to Montero and Ramos (2022) with the capacity tender an element of 'competition for the market' was introduced in the 'open access' 'competition in the market' model designed by the European Union for the construction of the Single European Railway Area.

[13] RENFE is the incumbent's Spanish railway operator, SNCF is the incumbent rail operator in France and ILSA is a joint venture mainly participated by Trenitalia and Globalia.

[14] Capacity was only limited and constrained by the bottlenecks in stations, where conventional and high-speed rail converge.

IRYO, a second entrant owned by a mix of Italian and Spanish private corporations, among which Trenitalia is the main shareholder, was awarded the second package (30%) and initiated operations on the Madrid-Barcelona and the Madrid-Valencia links in late 2022. They finally offered the first train services on the Madrid-Seville/Málaga lines in 2023. Finally, IRYO connected Madrid to Alicante with their services the same year.

RENFE, the publicly owned and incumbent operator, which received the most extensive package (70%), responded to this competition by launching its low-cost brand, AVLO, which was set to operate in the Madrid-French border corridor in 2021, just one month after OUIGO's entry. Later, AVLO was extended to several lines (Madrid-Valencia, Madrid-Alicante, Madrid-Sevilla/Málaga, and Valladolid-Alicante). Also, RENFE added the AVLO commercial service on routes not subject to competition in 2024. In all, RENFE increased its capacity by 20% (Brenna, 2024).

According to the European Commission (2024), Renfe AVE and IRYO are regular HSR operators due to their service characteristics.[15] On the contrary, OUIGO and AVLO belong to the group of pure low-cost operators. Thus, the resulting market for liberalised railways can be split into competition based on quality (AVE and IRYO) and on price (OUIGO and AVLO).

Figure 1 displays the chronology of the increasing number of commercial operators by main Origin-Destination. Table 1 presents information on company entry dates for the main liberalised routes competing with air transportation. Figure 2 displays

[15] These services include two classes, modifiability of tickets, luggage included, first-class lounge, and subscriptions or discounts for specific groups, among others.

the 2025 HSR network map in Spain by commercial operators, and Figure 3 the split of HSR passengers and seats available by route.

Figure 1. Chronology of the market structure by commercial brands of the main liberalised HSR lines in Spain.

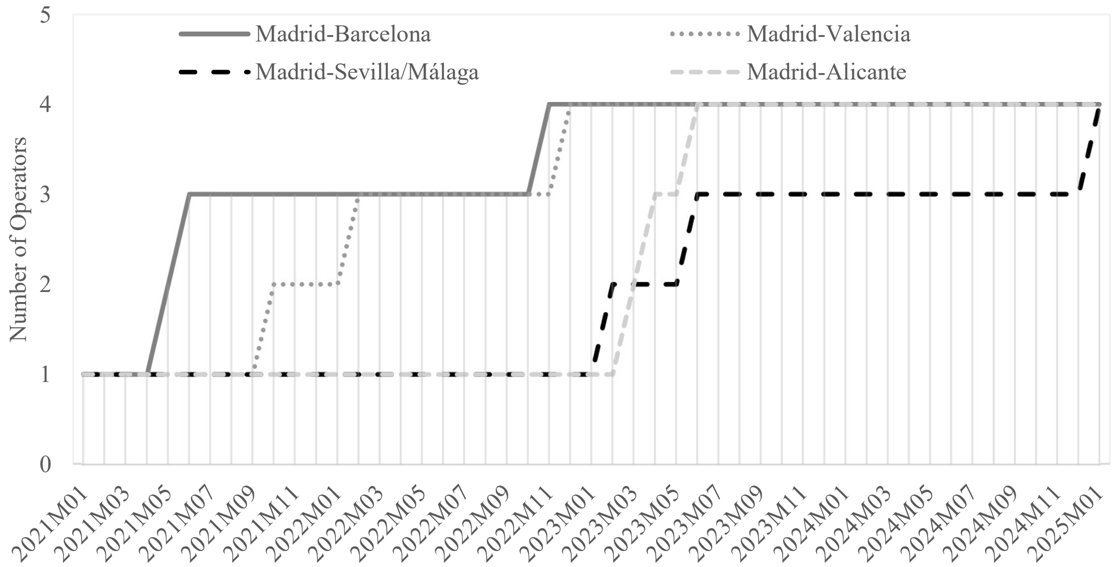
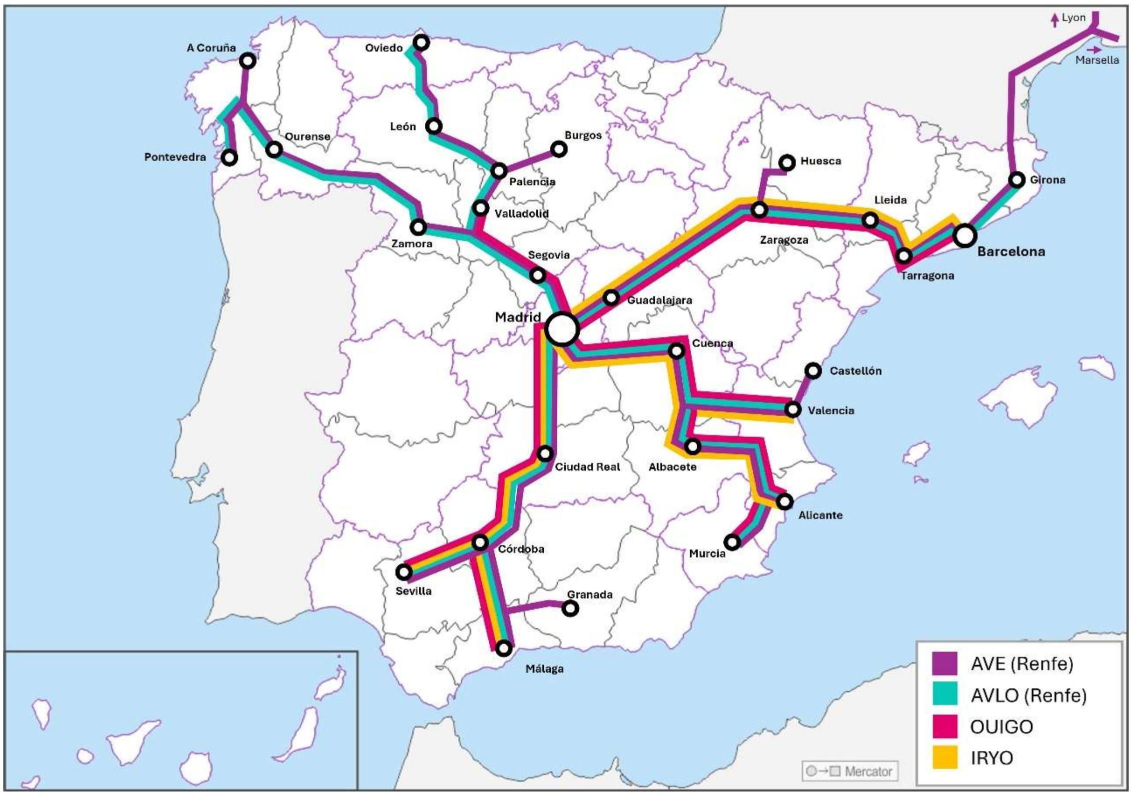


Table 1. HSR liberalisation chronology by main OD routes.

Route	Company	Brand	Entry
Madrid-Barcelona	Ouigo	Ouigo	10/05/2021
	Renfe	Avlo	23/06/2021
	Iryo	Iryo	25/11/2022
Madrid-Valencia	Ouigo	Ouigo	08/10/2022
	Iryo	Iryo	26/12/2022
	Renfe	Avlo	21/02/2022
Madrid-Sevilla/Málaga	Iryo	Iryo	30/03/2023
	Renfe	Avlo	01/06/2023
	Ouigo	Ouigo	16/01/2025
Madrid-Alicante	Renfe	Avlo	27/03/2023
	Ouigo	Ouigo	23/04/2023
	Iryo	Iryo	02/06/2023
Valladolid-Alicante	Renfe	Avlo	08/04/2024
	Ouigo	Ouigo	19/04/2024
Madrid-Murcia	Renfe	Avlo	10/12/2023
	Ouigo	Ouigo	03/09/2024

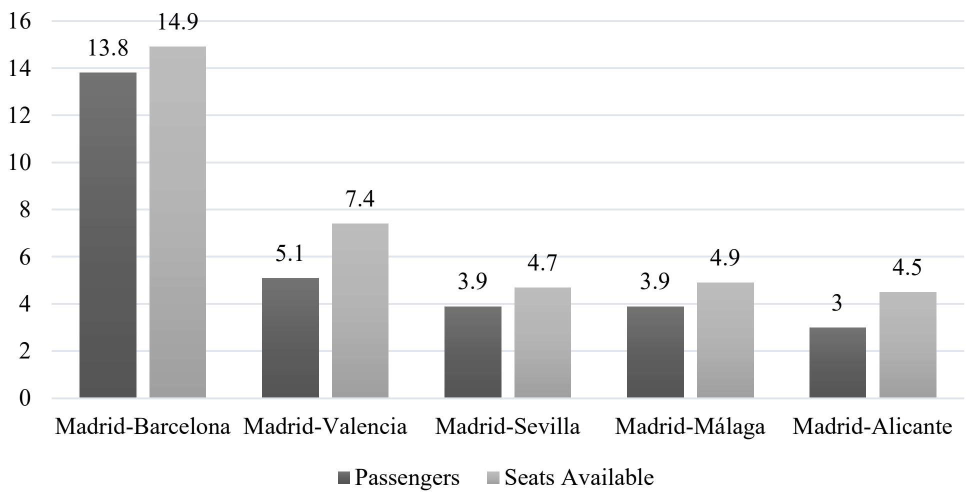
Source: Own elaboration.

Figure 2. Map of the HSR liberalised network and operators.



Source: Own elaboration.

Figure 3. HSR Passengers and seats available (in millions) by main liberalised routes in 2023.



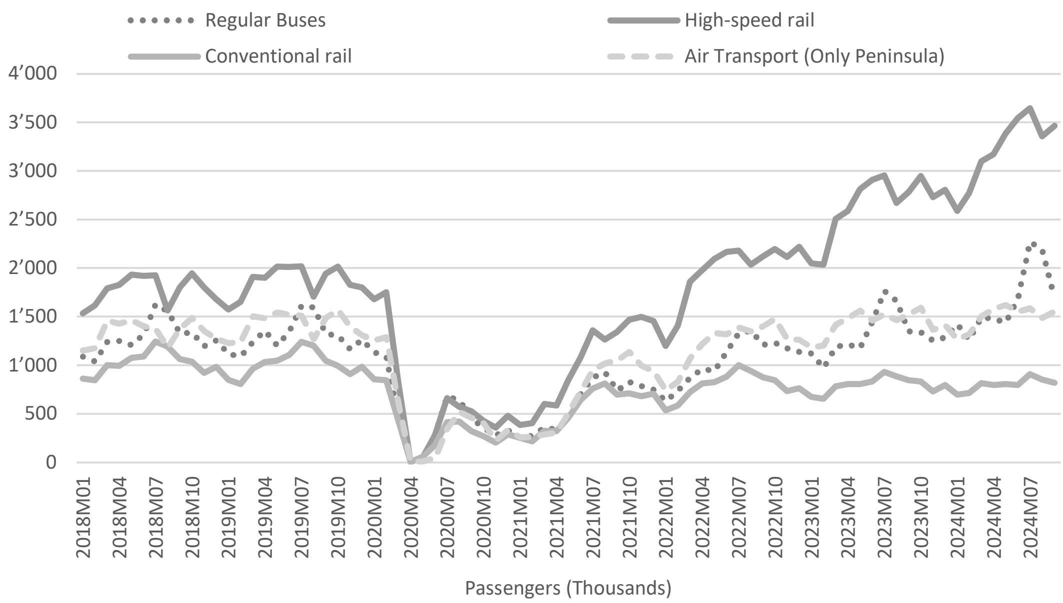
Source: CNMC

Two major challenges accompanied the start of liberalisation in 2021. First, long-distance mobility was still recovering from COVID-19 restrictions, with passenger levels not yet reaching pre-pandemic levels until spring 2022. Yet rail rebounded faster than competing modes, especially in early liberalised corridors such as Madrid–Barcelona (+29% vs. 2019) and Madrid–Valencia (+10%). Second, energy prices surged in 2021 and remained high, diverging from the cost expectations operators used when applying for capacity.

3.2 Outcomes of the liberalisation on the HSR market

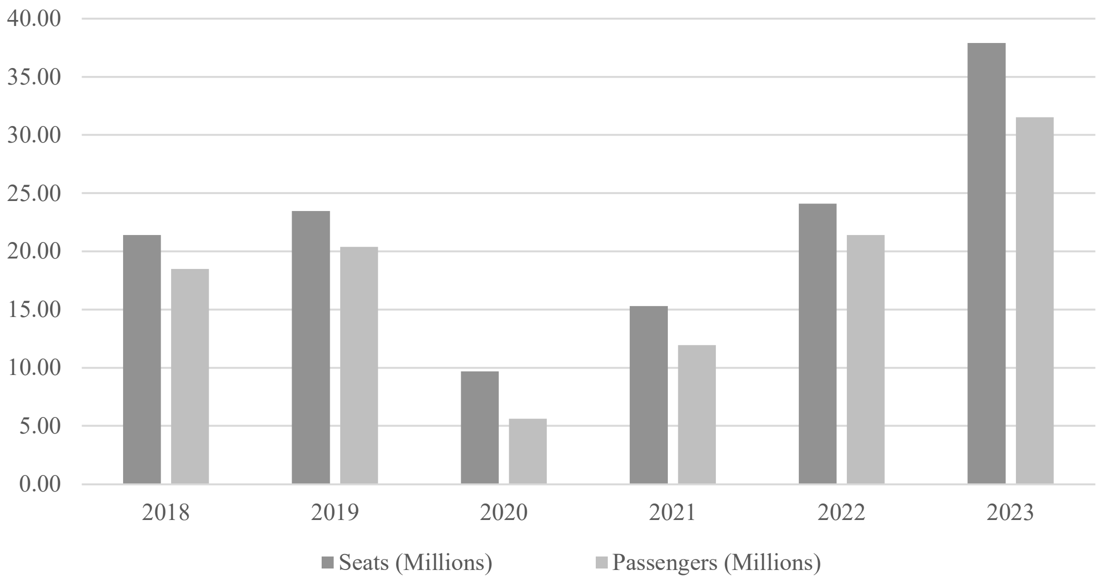
A preliminary evaluation of the liberalisation process appears positive from both demand and supply performance perspectives. Indeed, liberalisation contributed to both passenger (demand) and capacity growth (supply). Figure 4 shows the monthly change in long-distance passengers by mode over time, indicating that HSR is the mode performing best, with high growth rates and traveller volumes exceeding pre-COVID-19 levels. Figure 5 illustrates the growth in demand and supply for the specific liberalised corridors.

Figure 4. Monthly passengers by long-distance mode in Spain, January 2018- July 2024.



Source: Spanish National Statistics Institute (INE), Passenger transport statistics.

Figure 5. Annual high-speed rail passengers and seats available in Spain (2018-2023).



Source: CNMC.

According to CNMC (2024a), liberalisation increased supply by increasing frequencies and seats available. Daily average frequencies in the three main corridors rose from 78 to 115 per direction, and seats increased by more than 60% compared to 2019. It also favoured a new range of commercial offers, such as differentiated tariffs by seat/class, greater flexibility, and personalised services, among others. There was a 47% increase in seats offered just between 2022 and 2023 (CNMC 2024b).

The liberalisation boosted high-speed rail demand. The regulator estimates a consumer surplus of 343 MEUR due to lower prices and induced new demand (CNMC 2024a). Overall, rail transport accounted for most of the growth in long-distance demand since 2019, increasing by 5 percentage points and reaching a 56% market share (among interurban buses and air travel). The regulator (CNMC 2024a) attributes the increase in railway passenger numbers to the liberalisation process, reaching 10 million by the end of 2023, up from 2019. Demand figures were about 45% higher than in 2019, with an annual growth rate of 36.6% between 2022 and 2023 (CNMC 2024b).

Furthermore, the regulator highlighted that on routes where competition was introduced earlier and where there are more commercial operators, demand nearly doubled due to competitive pressure (CNMC 2024a).

The liberalisation was reflected almost immediately in cheaper tickets. The European Commission (2024) reports fare cuts ranging from 20% to 50%, with Madrid–Barcelona and Madrid–Alicante seeing the steepest declines. On the Barcelona route, RENFE even moved ahead of OUIGO's entry by lowering AVE fares months before the new competitor arrived (García-Samaniego and Campos, 2024). Brenna (2024) confirms this overall picture, estimating average reductions of around 28–30% on the Madrid–Alicante and the Madrid–Sevilla/Málaga corridors. The pattern, however, was not uniform. OUIGO's aggressive low-cost strategy drove sharp, immediate price drops (over 20% in second class), whereas IRYO mainly pushed down first-class fares, with more moderate cuts of about 16%. By contrast, RENFE's own low-cost brand, AVLO, barely altered the incumbent's pricing behaviour. As a result, the incumbent monopolist lost a significant market share to new entrants just three years after liberalisation. While RENFE maintains its dominant position on all routes, there are significant differences across corridors, with market shares of over 70% in corridors where competition began later and fewer competitors operate. In these routes, RENFE's low-cost brand holds a residual position, while the opposite holds in more competitive routes.

3.3 Intermodal competition and airlines' reactions

These changes in the rail market are relevant in themselves, but their broader significance lies in how they reshape competition with other long-distance modes, particularly aviation. HSR demand growth, driven by lower prices, increased frequencies, and a more varied commercial offer, is the source of its growing market share against the two modes most directly impacted: air transportation and conventional rail. Figure 4 confirms a redistribution effect across modes due to the increased relative attractiveness in favour of HSR. Recent empirical evidence suggests that road transport has experienced only a limited impact from the introduction of HSR services in Spain and no effect from its liberalisation (Albalate and León-Gómez, 2024).[16] Thus, we focus on the impact of HSR liberalisation on air transport supply and airlines' strategic behaviour.

Low-cost carriers dominate the domestic air transport market in Spain, with few full-service airlines remaining, primarily as feeder services for long-distance flights from Madrid or Barcelona. Although some authors argue that low-cost airlines are better positioned to compete with HSR, the empirical literature shows that HSR is a fierce competitor for both conventional and low-cost airlines (see Behrens and Pels (2012), Xia et al. (2018), Li et al. (2019), among others). Indeed, the evidence by Su et al. (2020) suggests that HSR can bring significantly more competition than low-cost carriers, especially on short-distance routes of less than 1,000 km.

The competitive landscape of the air routes under analysis is fundamental to understanding the subsequent impact of HSR liberalisation. Indeed, by 2023, HSR market shares on main rail routes competing with air travel indicate the strong competitive nature and advantage of HSR in dense Spanish corridors, particularly due to the medium distance between nodes (see Table 2). HSR market share exceeded 75% on all liberalised routes: Madrid-Valencia (92%), Madrid-Sevilla (87%), Madrid-Alicante (87%), Madrid-

[16] Similar results were found by Borsati and Albalate (2020) for Italian highways.

Barcelona (82%) and Madrid-Málaga (78%). Indeed, the CNMC (2024a) highlighted that the higher number of passengers on routes with rail competition increased rail transport's modal share relative to air to 85%. The largest increase was observed on the Madrid-Barcelona line, with a 20 percentage-point increase. Market shares are distributed across different types of company ownership, and according to the numerical assessment of intermodal competition on the Rome-Milan route by Wang et al. (2023), this is also relevant in the magnitude of the expected modal shift. The largest intermodal effects and consumer surplus gains are observed when the new entrant is a privately owned, unrelated operator to the incumbent. Instead, HSR incumbent-owned entrants yield higher overall revenues, support railway financing, and cause less damage to aviation.

Table 2: Distance and Travel times by O-D routes by HSR and Air Transport, 2023.

Route	***Distance by HSR (Km)***	***Travel time by HSR[1]***	***Travel time by Air[1]***	***Market share HSR***
Madrid-Barcelona	621	2h:30min	1h:15min	82%
Madrid-Valencia	391	1h:50min	1h:00min	92%
Madrid-Alicante	422	2h:15min	1h:00min	87%
Madrid-Sevilla	471	2h:30min	1h:05min	87%
Madrid-Málaga	513	2h:30min	1h:10min	78%
Madrid-Murcia	473	2h:45min	1h:05min	n.a.[2]

Note: 1. Travel times from HSR station to HSR station or from main airport to main airport.
2. Data on the modal share on the Madrid-Murcia is not available yet.

Table 3: Air transport supply in the main liberalised routes, 2023.

Route	*Airlines serving the route*	*FSA / LCC*	*Connecting flights (Y/N)*
Madrid-Barcelona	Iberia	FSA	Y
	Air Europa	FSA	Y
	Vueling Airlines	LCC	Y
Madrid-Valencia	Air Europa	FSA	Y
	Iberia	FSA	Y
Madrid-Alicante	Iberia	FSA	Y
	Air Europa	FSA	Y
Madrid-Sevilla	Iberia	FSA	Y
Madrid-Málaga	Air Europa	FSA	Y
	Iberia	FSA	Y
Madrid-Murcia	Volotea	LCC	N

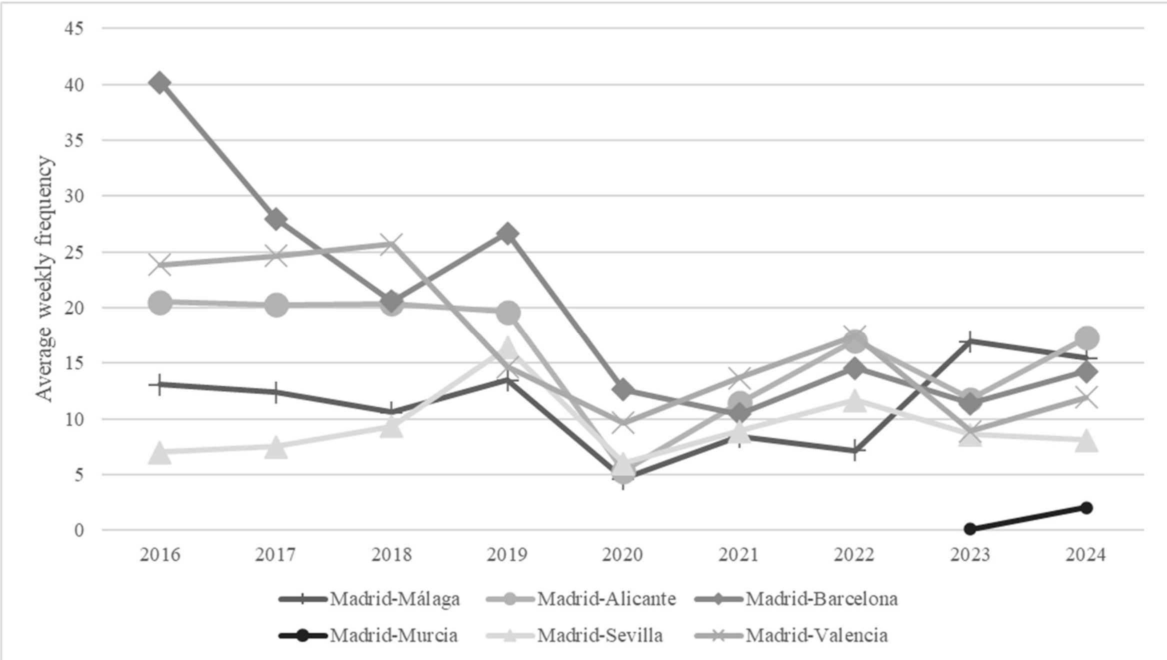
Note: FSA – Full Service Airline, LCC: Low-cost carrier

In the analysed corridors, the airline market structure was dominated by two airline groups: IAG (through Iberia and Vueling) and Air Europa. A key feature of these corridors is that, except for Volotea on the Madrid-Murcia route, all serving airlines offered connection options at Madrid-Barajas Airport. This highlights the strategic importance of these routes for feeding hub-and-spoke networks. The flights that remained after the entry of HSR were predominantly those with a significant share of connecting passengers, which compete less directly with HSR's point-to-point service.

Vueling, despite offering connections, functioned primarily as a low-cost carrier (LCC) focused on high-density, point-to-point traffic with its Airbus A319/320/321 fleet. This strategic divide suggests that these airlines will react differently to the competitive shock from HSR, a point we revisit in Section 6. In a separate development reflecting the dynamism of the LCC segment, other carriers have explored new opportunities on thinner routes, as exemplified by Volotea's operation on the Madrid-Murcia corridor. However, this service was supported by a local marketing contract (La Verdad, 2023).

However, a strategic focus on connecting traffic comes with consequences for airlines. As noted by D'Alfonso et al. (2015), this often forces airlines to accept lower overall passenger numbers and potentially to offer fewer frequencies than would be sustained alongside a higher proportion of point-to-point demand. This trade-off is visible in the evolution of average weekly flight frequencies, but only in the Madrid-Barcelona corridor, as illustrated in Figure 6.

Figure 6. Evolution of the average weekly flight frequency in the studied corridors, 2016-2024.



Source: OAG Schedules.

4. Empirical Strategy

In this section, we describe the empirical strategy we follow to assess the causal impact of High-Speed Rail (HSR) liberalization on short-haul domestic flights in Spain.

To construct our panel dataset of air transport supply, we use data from the OAG (Official Airline Guide) Schedules Analyser. OAG's schedule database is a widely used standard source in academic air transport research. Our database contains detailed information on all planned flights, including origin and destination airports, operating carrier, aircraft type, departure and arrival times, seat availability, and flight frequency. Our dataset covers the daily supply of flights from 2016 to 2024 for each corridor in our sample.

We use different outcome variables to define air travel supply for each HSR equivalent corridor at the daily level. We use the daily total number of seats, the daily flight frequency and the sum of the average number of seats per flight for each corridor.[17] Given that airlines can adapt supply through different behavioural strategies, we use each outcome variable to explore these strategies. The total number of seats offered at the corridor level provides a rough measure of the total capacity deployed by airlines, yet changes in this variable can be achieved either through changes in flight frequency or by changing aircraft (with different capacities). Models for the impact of HSR liberalisation on total corridor frequency and the sum of average seats per flight are estimated to explore how airlines achieve supply adaptations. Descriptive statistics for the outcome variables are reported in Table 4. For example, total daily seats evolution during the period of analysis is shown in Figure 7.

[17] The sum of the average number of seats per flight is obtained by adding upt the ratio between the total number of seats offered by each company and their frequency of flights, and then adding up this figure for all companies operating within each corridor. This gives us more variability than simply averaging out across companies and obtaining an average aircraft capacity at corridor level.

Figure 7. Evolution the of daily total number of seats supplied in HSR-affected corridors

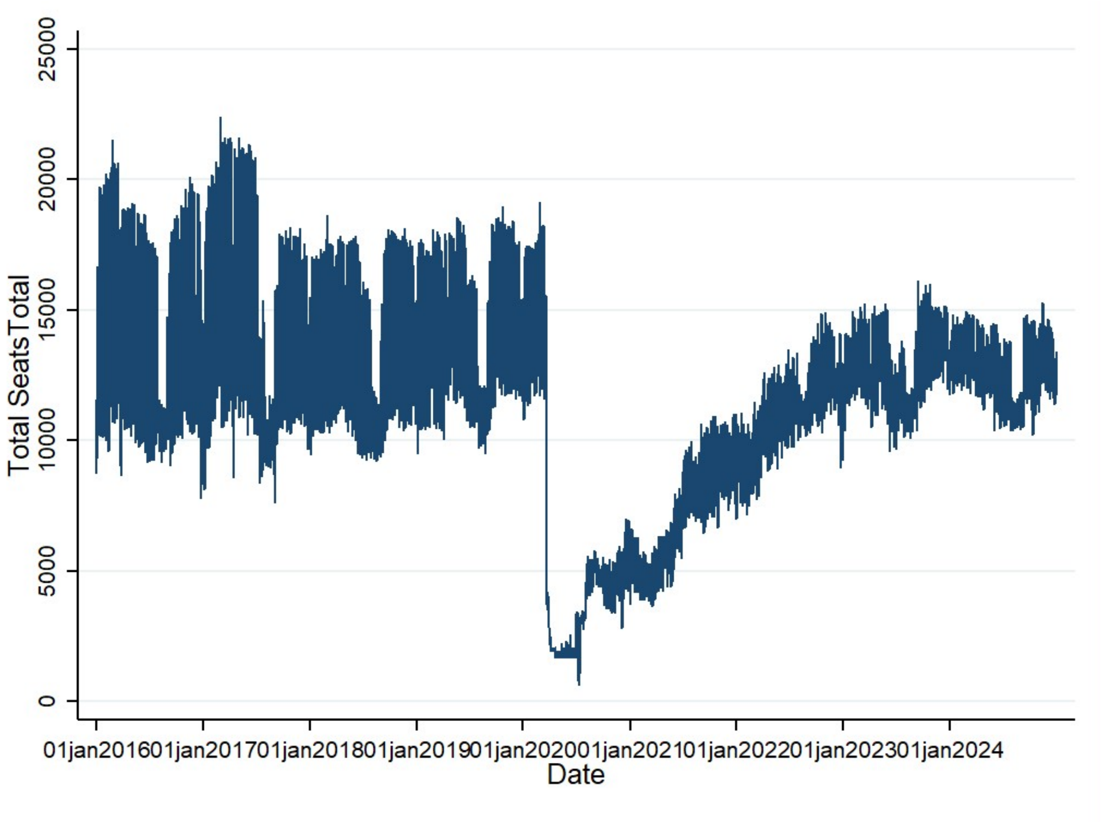


Table 4: Descriptive statistics (outcome variables)

Variable	Mean	Std. Dev.	Min	Max
Seats (total)	2,521.35	3,104.11	72	17,749
Frequency	15,97	14,96	1	93
Sum Seats per flight	1,092.95	928.35	72	5,594

A simple pre/post analysis provides a useful baseline for estimating the conditional correlation between HSR liberalisation and air travel outcomes, as depicted in (1). Each outcome variable is introduced in the model as the daily figure at the corridor level in logs (Y_{it}), so we use a semilogarithmic specification. We define a treatment variable dummy (T_t) that equals 1 for all air travel routes from the date HSR liberalisation is implemented in that specific corridor (and onwards) and 0 before that. This means that δ, the impact measure, should be interpreted as the percentage change in each specific air-travel outcome variable attributable to the liberalisation of HSR services.

$$Y_{it} = \beta_0 + \delta \cdot T_t + \beta_1 \cdot X_{it} + \alpha_i + \varepsilon_{it} \tag{1}$$

In (1), we control for potential confounding factors through (X_{it}) by including time-specific effects, allowing for differences in air travel outcomes based on the day of the week, week of the year, season and year fixed effects. This is aimed at controlling for seasonality in travel patterns, changes in air traffic taxes, and fuel price fluctuations that could have affected airlines' supply. Additionally, we also include the interaction between year- and week-specific effects to control for COVID-related lockdowns that limited travel in Spain during part of the period included in our sample, as well as other potential shifts in business and leisure travel patterns after the Pandemic or HSR liberalisation. We also include corridor-level fixed effects to account for potential unobserved heterogeneity across HSR-equivalent corridors, as their flight demand levels may differ systematically by connectivity, size, and presence of competing transportation modes. The fixed-effects model (FE) described in (1) utilises within-corridor variation over time to obtain δ as an average treatment effect (ATE) estimate.

A potential limitation with the model described in (1) is that unobserved factors changing over time could simultaneously drive short-haul flight supply up or down, leading to a correlation between the error term and time, biasing the estimation of the parameter of interest (δ). Some of these factors include changing traveller preferences, reduced business travel due to the rise of teleconferencing, or any underlying trends affecting air travel demand and supply independently of HSR liberalisation, beyond what we can control with the interaction between year- and week-specific effects.

To address these endogeneity concerns, we estimate the policy impact around the HSR liberalisation date in each corridor while flexibly controlling for nonlinearities in air travel demand through the inclusion of a global polynomial time trend $f(x_t)$.[18] This allows us to isolate changes in air travel supply driven solely by HSR liberalisation by estimating a global polynomial regression discontinuity in time model (RDiT-global), as described in (2), where δ represents a local estimate of the average treatment effect (ATE) around the liberalisation date.

$$Y_{it} = \beta_0 + \delta \cdot T_t + f(\tilde{x}_t) + \beta_1 \cdot X_{it} + \alpha_i \cdot \varepsilon_{it} \qquad (2)$$

The identification strategy in (2) relies on the key assumption of local randomisation around the liberalisation date, meaning that in the absence of the policy, short-haul flight travel outcome variables would not have changed discontinuously on the implementation date. This assumption ensures that HSR liberalisation is exogenous to flight supply and that no manipulation of the running variable (time) biases our estimates.

Relying on *RDiT-global* comes with challenges, as it inherently departs from the local randomisation assumption by including observations far from the liberalisation date. Additionally, the true functional form of the underlying trend is unknown, and misspecification can lead to biased estimates. When dealing with noisy data, low-order polynomials may oversmooth the trend, prompting statistical tests to recommend high-order polynomials, as suggested by Lee and Lemieux (2010). However, high-order polynomials have been criticised by Gelman and Imbens (2019) for assigning disproportionate weight to observations distant from the cutoff, making estimates highly sensitive to the chosen polynomial order.

To further strengthen our identification strategy, we follow the approach suggested by Gragera et al. (2024), which estimates a semi-parametric version of the previous RDiT-global model. This approach introduces K-2 bins (to avoid collinearity) into the model specified in equation (2), termed *RDiT-global+bins*. These bins divide the running variable (time) into K

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[18] For this polynomial we assume continuity (no slope changes or structural break) in the relation between the outcome and the running variable across the date of liberalisation. Discontinuity can be accounted for by simply including interaction terms between the treatment and the running variable terms.

equal-sized intervals on each side of the cutoff, with widths optimally selected using the data-driven approach proposed by Calonico et al. (2015). This strategy accounts for deviations from the underlying trend that fall outside the cutoff for each outcome variable, ensuring the effect is primarily captured within bins contiguous to the liberalisation date and reducing sensitivity to polynomial order selection. The estimate from RDiT-global + bins gives a somewhat more local estimation of the Average Treatment Effect (ATE).

Additionally, we estimate a local regression on the residualised outcome variable (RDiT-local), restricting the analysis solely to the vicinity of the liberalisation date. In this case, we obtain the residualised outcome variable by subtracting the predicted values based on equation (1) from the flight demand figures. This local regression is also commonly described in the regression discontinuity literature as a non-parametric approach. By applying it to the residualised outcome variable, we effectively control for seasonality patterns and other time-varying confounders while still focusing exclusively on the immediate (short-run) impact of HSR liberalisation on short-haul flights. It is essential to note that focusing solely on the immediate vicinity of the implementation date can reduce estimation bias, albeit at the expense of lower precision due to a significantly reduced sample size.

All previous models give estimates that implicitly assume δ is a constant treatment effect. However, each of their estimates gives somewhat more weight to observations within different ranges around the discontinuity, meaning they provide estimates that are closer or farther from the long- and short-run effects. On the one hand, FE and RDiT global models give approximations to the long-run treatment effect under the assumption that it is constant over time. For instance, the FE model provides an estimate of the impact as the mean difference between the pre- and post-intervention periods. RDiT global provides an estimate based on the difference around the discontinuity, calculated using the adjusted polynomial relation between the outcome and the running variable, incorporating all observations in the sample, which may be affected by data noise. RDiT global + bins smooths out such noise and provides a similar estimate, correcting for the bias due to the polynomial trend and assigning arbitrary weights to observations far from the discontinuity. RDiT local also assumes a constant treatment effect, but estimates it only in the immediate vicinity of the liberalisation date, thereby capturing the short-run treatment effect.

As a further robustness check to verify whether models align with the short-run estimate, we also estimate a dynamic FE model that includes the lagged outcome variable on the right-hand side of (1). This will yield the model described in (3), from which we can retrieve the estimates for both the short-run (δ) and long-run ($\frac{\delta}{1-\gamma}$) treatment effects.

$$Y_{it} = \beta_0 + \gamma \cdot Y_{it-1} + \delta \cdot T_t + \beta_1 \cdot X_{it} + \alpha_i + \varepsilon_{it} \tag{3}$$

Short-run estimates from the FE dynamic model should be equivalent to the RDiT local ones; however, long-run estimates from it will be equivalent to the FE static model and may differ from RDiT global ones due to bias introduced by unobserved factors that change over time. As pointed out in Hausman & Rapson (2018), RDiT tends to yield treatment effect coefficients that approach the long-run treatment effect, which is the relevant policy figure rather than short-run adaptations.

6. Results

Table 5 reports the results for the impact of liberalisation on the total number of seats supplied by airlines in the five corridors affected by it, for the alternative specifications described in section 4. Panel A reports FE models where we successively incorporate different sets of covariates. The first column, which includes only corridor fixed effects, shows a large positive impact, but it does not adequately control for confounders, such as the ridership plunge caused by COVID-related lockdowns. On the contrary, the most comprehensive models indicate a negative impact of liberalisation, with a 29.8% reduction in the number of aircraft seats supplied, failing to account for potential underlying trends driven by other factors that vary over time during the period of analysis. Panel A also reports the FE dynamic results, suggesting that the short-run impact of liberalisation on the total number of aircraft seats supplied is a reduction of around 6.8%.

Panel B, in an attempt to correct this, reports the RDiT global estimates for a range of polynomial-order specifications for such a trend, as described in (2). Noisy data suggest that even high-order specifications fit the data better under the AIC criterion, with substantial variation in the estimates across them. This occurs because the polynomial order introduces an arbitrarily high weight to observations far from the date of liberalisation. This introduces sensitivity in the estimates, with the total number of aircraft seat reductions fluctuating between 2.5% and 29.8%.

Panel C addresses the noise in the data and reports estimates for RDiT global + bins, showing more stable estimates across polynomial specifications, with a total reduction in aircraft seats of 10.6-15.1%. This gives us an estimate of the long-run effect (within the time frame we analyse) of HSR liberalisation on airline supply. Panel D reports RDiT local results, which confirm that the short-run effect of liberalisation on the total number of seats supplied is a reduction of around 6% to 9%, similar in magnitude to the FE dynamic model. However, these estimates are not statistically significant due to the reduced sample size.

TABLE 5 – Estimation results for the total number of seats supplied

	Panel A - FE (static and dynamic)				
Treatment	0.247***	-0.298***	-0.298***	-0.298**	-0.068***
	(0.008)	(0.011)	(0.011)	(0.106)	(0.013)
Log(# of seats) t-1					0.774***
					(0.044)
R^2	0.062	0.646	0.646	0.646	0.852
Corridor FE	Yes	Yes	Yes	Yes	Yes
Time-specific FE	No	Yes	Yes	Yes	Yes
Interactions	No	No	Yes	Yes	Yes
Clustered S.E.	No	No	No	Yes	Yes
Lagged dep. Variable	No	No	No	No	Yes
	Panel B - RDiT global (variable slope)				
	p = 1	p = 2	p = 3	p = 4	p = 5
Treatment	-0.298***	-0.0645***	-0.0732***	-0.0255**	-0.0277**
	(0.0107)	(0.00978)	(0.0101)	(0.0118)	(0.0120)

R^2	0.646	0.737	0.737	0.738	0.738
	Panel C - RDiT + bins (variable slope)				
	p = 1	p = 2	p = 3	p = 4	p = 5
Treatment	-0.151***	-0.111***	-0.112***	-0.106***	-0.107***
	(0.0211)	(0.0222)	(0.0225)	(0.0234)	(0.0234)
R^2	0.749	0.749	0.749	0.749	0.749
	Panel D - RDiT local				
	p = 0	p = 1		p = 0	p = 1
Treatment	-0.0636	-0.0901		-0.0622	-0.0998
	(0.0611)	(0.0811)		(0.0595)	(0.0859)
Kernel Type	Triangular	Triangular		Uniform	Uniform
BW Loc. Poly. (h)	145.4	244.8		113.6	178
BW Bias (b)	343	390		313.5	328.2
Non-treated obs.	725	1220		565	890
Treated obs.	730	1225		570	895

Note: The units of observation for all specifications are the 5 corridors connecting Madrid to Alicante, Barcelona, Málaga, Sevilla and Valencia, during the period January 2016 to December 2024 (16,044 observations). The dependent variable is daily total number of seats in logs offered by airlines in each corridor. Panel A reports estimates from FE regressions fitting Equation 1, sequentially including different sets of covariates. Panel B reports estimates from RDiT global depicted in Equation 2 for the linear (p = 1) to quintic (p = 5) polynomial time trend, with AIC suggesting even higher order polynomials as better fits with wild variations in the estimates. Panel C reports estimates from RDiT global depicted in Equation 2, including time-specific bins common to all corridors, for specifications linear (p = 1) to quintic (p = 5) polynomial time trend. All specifications include 26 bin dummies pre-intervention and 16 bins post-intervention (98 and 78 days, respectively), following the data-driven procedure of Calonico et al., (2015). Panel D reports estimates from a non-parametric RDiT local regression for a combination of zero and linear degree polynomials with triangular and homogeneous kernel weights. Estimates in panel D are computed using the data-driven MSE optimal bandwidth choice and the robust bias-corrected statistics proposed in Calonico et al. (2018, 2022). Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

To gain insight into the mechanism by which airlines reduce supply when facing competition by HSR, we replicate the same analysis for the daily frequency of flights and the average number of seats per flight offered each day across affected corridors, as total seat capacity could be reduced either by decreasing the frequency of flights, down-gauging (using smaller aircrafts) or some combination of both.

Table 6 shows the results for the impact of HSR liberalisation on the daily flight frequency. Panels A (FE models) and B (RDiT global) show results very similar to those for the total number of daily seats supplied, with variations due to data noise. Panel C (RDiT global + bins) addresses previous issues and suggests that flight frequency has experienced a small reduction due to HSR liberalisation. Only the linear model shows a statistically significant reduction of about 4.5%, yet the point estimates across polynomial specifications agree on the direction and the general magnitude of the change (ranging from -4.5% to -1.6%), even though lower orders should be preferred. Panel D (RDiT local) confirms this small impact with non-statistically significant estimates ranging from -3.1% to -1.1% in the daily frequency of flights, due to larger standard errors in a heavily reduced sample.

TABLE 6 – Estimation results for the daily frequency of flights

	Panel A - FE (static and dynamic)				
Treatment	-0.037***	-0.243***	-0.243***	-0.243**	-0.068**
	(0.007)	(0.009)	(0.009)	(0.054)	(0.016)
Log(Total # of seats supplied) t-1					0.721***
					(0.040)
R2	0.002	0.700	0.700	0.700	0.850
Corridor FE	Yes	Yes	Yes	Yes	Yes
Time-specific FE	No	Yes	Yes	Yes	Yes
Interactions	No	No	Yes	Yes	Yes
Clustered S.E.	No	No	No	Yes	Yes
Lagged dep. Variable	No	No	No	No	Yes
	Panel B - RDiT global (variable slope)				
	p = 1	p = 2	p = 3	p = 4	p = 5
Treatment	-0.243***	-0.0909***	-0.0512***	-0.00706	-0.0152
	(0.00904)	(0.00879)	(0.00901)	(0.0105)	(0.0107)
R2	0.700	0.747	0.751	0.752	0.753
	Panel C - RDiT + bins (variable slope)				
	p = 1	p = 2	p = 3	p = 4	p = 5
Treatment	-0.0452**	-0.0266	-0.0182	-0.0183	-0.0166
	(0.0188)	(0.0191)	(0.0194)	(0.0201)	(0.0201)
R2	0.760	0.760	0.760	0.760	0.760
	Panel D - RDiT local				
	p = 0	p = 1		p = 0	p = 1
Treatment	-0.0133	-0.0223		-0.0162	-0.0311
	(0.0403)	(0.0581)		(0.0445)	(0.0606)
Kernel Type	Triangular	Triangular		Uniform	Uniform
BW Loc. Poly. (h)	176.6	245.6		100.2	184.6
BW Bias (b)	370.2	381.3		257.9	329.7
Non-treated obs.	880	1225		500	920
Treated obs.	885	1230		505	925

Note: The units of observation for all specifications are 5 corridors during the period January 2016 to December 2024 (16,044 observations) covering the relations Madrid, Alicante, Madrid-Barcelona, Madrid-Málaga, Madrid-Sevilla and Madrid-Valencia. The dependent variable is the daily flight frequency in logs offered by airlines in each corridor. Panel A reports estimates from FE regressions fitting Equation 1, sequentially including different sets of covariates. Panel B reports estimates from RDiT global, depicted in Equation 2, for the linear (p = 1) to quintic (p = 5) polynomial time trend, with AIC suggesting that higher-order polynomials provide a better fit. Panel C reports estimates from RDiT global, depicted in Equation 2, including time-specific bins common to all corridors, for polynomial time trends from linear (p = 1) to quintic (p = 5). All specifications include 28 bin dummies pre-intervention and 14 bins post-intervention (91 and 88 days, respectively), following the data-driven procedure of Calonico et al., (2015). Panel D reports estimates from a non-parametric RDiT local regression for a combination of zero and linear degree polynomials with triangular and homogeneous kernel weights. Estimates in panel D are computed using the data-driven MSE optimal bandwidth choice and the robust bias-corrected statistics proposed in Calonico et al. (2018, 2022). Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 7 shows the results for the impact of HSR liberalisation on the daily number of seats per flight. Panel A (FE models) suggests a reduction in the number of seats per flight (-33.4%) of the same magnitude as for the total number of seats, with a 13.9% decrease in the short run when using a dynamic model. Panel B (RDiT global) confirms this, showing reductions ranging from 33% to 16% due to the sensitivity of polynomial specifications to noisy data. Panel C (RDiT global + bins) counters this and suggests long-run reductions slightly above the ones detected for the total number of seats (Table 5), ranging from -18% to -11%. Panel D (RDiT local) point estimates confirm that the short-run effect of liberalisation on the total number of seats supplied is a reduction of around 6% to 9%, equivalent to the one found for the total number of seats (even estimates are not statistically significant due to the reduced sample size).

These results show that HSR liberalisation has impacted the airline industry in the corridors affected by reducing total supply. This reduction seems to be achieved by shifting to smaller aircraft rather than by reducing frequencies.

TABLE 7 – Estimation results for the daily number of seats per flight

	Panel A - FE (static and dynamic)				
Treatment	0.364***	-0.334***	-0.334***	-0.334**	-0.139**
	(0.006)	(0.011)	(0.011)	(0.101)	(0.050)
Log(Total # of seats supplied) t-1					0.580***
					(0.043)
R2	0.166	0.521	0.521	0.521	0.679
Corridor FE	Yes	Yes	Yes	Yes	Yes
Time-specific FE	No	Yes	Yes	Yes	Yes
Interactions	No	No	Yes	Yes	Yes
Clustered S.E.	No	No	No	Yes	Yes
Lagged dep. Variable	No	No	No	No	Yes
	Panel B - RDiT global (variable slope)				
	p = 1	p = 2	p = 3	p = 4	p = 5
Treatment	-0.334***	-0.161***	-0.172***	-0.186***	-0.204***
	(0.0113)	(0.0111)	(0.0115)	(0.0134)	(0.0136)
R2	0.521	0.583	0.584	0.584	0.585
	Panel C - RDiT + bins (variable slope)				
	p = 1	p = 2	p = 3	p = 4	p = 5
Treatment	-0.185***	-0.139***	-0.138***	-0.111***	-0.124***
	(0.0232)	(0.0247)	(0.0247)	(0.0259)	(0.0263)
R2	0.605	0.606	0.606	0.606	0.606
	Panel D - RDiT local				
	p = 0	p = 1		p = 0	p = 1
Treatment	-0.0603	-0.0928		-0.0628	-0.0969
	(0.0482)	(0.0675)		(0.0518)	(0.0674)
Kernel Type	Triangular	Triangular		Uniform	Uniform
BW Loc. Poly. (h)	219.6	318.9		135	262.4
BW Bias (b)	498.2	504.8		380.9	463.5
Non-treated obs.	1095	1590		675	1310
Treated obs.	1100	1595		680	1315

Note: The units of observation for all specifications are 5 corridors during the period January 2016 to December 2024 (16,044 observations), covering the relations Madrid-Alicante, Madrid-Barcelona, Madrid-Málaga, Madrid-Sevilla, and Madrid-Valencia. The dependent variable is the daily number of seats per flight, logged, offered by airlines in each corridor. Panel A reports estimates from FE regressions fitting Equation 1, sequentially including different sets of covariates. Panel B reports estimates from RDiT global depicted in Equation 2 for the linear (p = 1) to quintic (p = 5) polynomial time trend, with AIC suggesting a better fit for higher polynomial orders. Panel C reports estimates from RDiT global, depicted in Equation 2, including time-specific bins common to all corridors, for polynomial time trends from linear (p = 1) to quintic (p = 5). All specifications include 19 bin dummies pre-intervention and 18 bins post-intervention (132 and 70 days each, respectively), following the data-driven procedure of Calonico et al., (2015). Panel D reports estimates from a non-parametric RDiT local regression for a combination of zero and linear degree polynomials with triangular and homogeneous kernel weights. Estimates in panel D are computed using the data-driven MSE optimal bandwidth choice and the robust bias-corrected statistics proposed in Calonico et al. (2018, 2022). Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

6. Discussion

Our empirical analysis reveals a nuanced airline response to HSR liberalisation. While the treatment effect is consistently negative and statistically significant for the number of seats per flight across all specifications (Table 5), the impact on flight frequencies is smaller or nonexistent (Table 6) and most (if not all) of the change in supply is achieved through aircraft down-gauging (Table 7). Note that in Figure 6, we observe a significant reduction in the frequency in the Madrid-Barcelona corridor. This suggests that airlines' primary capacity adjustment was not through a drastic reduction in the number of flights, but rather through two distinct strategic responses (i.e., a change in aircraft gauge and a market share shift mechanism) driven by different competitive pressures.

Firstly, intense point-to-point competition drove the LCA response based on a down-gauging mechanism. Vueling was highly exposed to HSR, which is a direct substitute for its core point-to-point traffic. As a defensive move, Vueling engaged in down-gauging (i.e., swapping larger aircraft for smaller ones) to maintain service levels while reducing capacity. This is evident in Table 8, which shows the evolution of the frequency share by aircraft type in the largest corridor (i.e., Barcelona-Madrid). It is apparent that Vueling employed aircraft downgauging within the constraints of a rigid fleet, as is typical for low-cost carriers. They reduced the number of A320s (180 seats) and increased the number of A319s (144 seats) frequencies. The Vueling down-gauging to adjust capacity was driven by falling point-to-point demand; however, the limitations of such a strategy, given its rigid fleet, meant that a frequency reduction was also necessary. Crucially, this strategy proved unsustainable, leading to their eventual exit from the route on March 30, 2025. This finding refines the conclusions of Albalate et al. (2015), who found that airlines might not reduce frequencies as much to compete with

HSR. The main difference is that Albalate et al. (2015) focused on a previous period, 2002 to 2009, when the number of HSR operators was limited; we looked at a more recent period, dominated by various HSR operators, in other words, with higher competitive pressure from HSR operators toward airline operators.

Secondly, the strategic need to protect hub connectivity drove the network carrier response. In contrast to low-cost carriers, network carriers use these routes to feed their hubs. Their demand comes from connecting passengers who are less likely to switch to HSR. These airlines have a strong strategic incentive to maintain frequencies to protect their hub's connectivity and schedule integrity. As HSR enters, the proportion of point-to-point passengers in the cabin will decrease, while the share of hub-feeding passengers will remain unchanged. Consequently, the network carrier has an incentive to reduce the average number of seats per flight on the route through down-gauging. Indeed, Iberia reduced the number of A321 flights, which have 200 seats, and significantly increased the A320 (between 180 and 186 seats) and, to a lesser extent, the A319 (141 seats). The goal isn't just capacity reduction, but frequency preservation, as it is essential for maintaining the schedule integrity and network connectivity. The value of a flight frequency lies not just in the point-to-point revenue it generates, but also in the downstream revenue it generates for connecting passengers and feeds into the rest of the network. The simultaneous exit of point-to-point-focused LCAs and the resilience of hub-fed network traffic constitute a significant market-share shift on these routes, favouring the network carriers. This outcome aligns with Dobruszkes's (2011) findings, which also showed a reduction in airline seat supply but a stable evolution in frequencies in response to HSR entry.

Understanding these two distinct strategic responses is critical because it demonstrates that an aggregate analysis of route-level supply can mask fundamentally different airline strategies. Our findings move beyond a simple view of intermodal competition, revealing a market that reconfigures itself around two service models: a resilient, hub-feeding network service and a more vulnerable P2P service. The substitution of flights dominated by P2P traffic appears inevitable, particularly when the HSR network's star-like pattern replicates the airline network configuration without intermodal integration (Levinson, 2012). This provides a more granular understanding for policymakers, suggesting that while overall seat capacity may fall, the essential connectivity provided by network carrier hubs is likely to remain resilient.

TAULA 8 – Evolution of the share of frequencies by aircraft type of the two leading airline operators in the Barcelona-Madrid corridor. Source: Based on OAG Schedules.

	2016	2017	2018	2019	2020	2021	2022	2023	2024
Iberia									
Airbus A319	1%	1%	7%	9%	12%	3%	5%	7%	4%
Airbus A320	27%	21%	43%	46%	49%	62%	60%	77%	73%
Airbus A321	71%	78%	50%	45%	40%	36%	34%	16%	23%
Other	1%	0%	0%	0%	0%	0%	0%	0%	0%
Vueling									
Airbus A319	1%	0%	0%	0%	2%	9%	2%	7%	14%
Airbus A320	99%	99%	100%	100%	97%	90%	98%	90%	83%
Airbus A321	0%	1%	0%	0%	1%	1%	0%	3%	3%

7. Conclusions

High-speed rail is increasingly seen as an efficient alternative to air transport in long-distance travel. Many governments and international institutions, especially in Europe, are actively committed to expanding HSR infrastructure and favour policies and regulations that promote its development and utilisation, particularly amid growing concerns about climate change and the goal of consolidating a more sustainable mobility transportation network. Among them, the liberalisation of the rail market, particularly for high-speed rail, is considered a potential catalyst for mode substitution, thereby improving the relative attractiveness of HSR compared with environmentally inefficient domestic air transportation. Yet, few countries experimented with HSR liberalisation, and the scientific literature on intermodal impacts is still in its infancy. Only scarce and methodologically limited studies are available today. Previous research on intermodal competition had mainly focused on new HSR deployments or on pre-post comparisons.

This paper contributes to the literature by using a quasi-experimental approach to evaluate a large-scale HSR liberalisation involving several new entrants. Spain provides the ideal setting for this analysis because its large HSR and air transport markets compete directly over distances well suited to mode substitution, with significant overlap between their networks.

Our causal results confirm that HSR liberalisations can produce significant long-term impacts on air transport in competing routes – a reduction of between 10% and 16% in airline seats supplied - not only in new HSR deployments. We show that liberalisation may act as a second catalyst for mode substitution and as a strategy to increase the utilisation – and therefore the socioeconomic return – of the expensive HSR infrastructure. The supply of airlines in the evaluated treated corridors decreased in response to the increased competition in the HSR market. More interestingly, we provide insights into the strategic mechanisms employed by the airline industry, uncovering two strategic responses. The first is a defensive capacity reduction by LCCs, who react to intense point-to-point competition with frequency cuts and aircraft downgauging (within the limits of their rigid fleet). The second is a resilient hub-protection strategy by network carriers, who preserve frequencies for connecting traffic by also down-gauging, resulting in a market-share shift in their favour. The latter should be understood in the context of Spain's distinctive centralised configuration of the radial HSR network, which could resemble other centralised networks with the same nodes sharing airport and HSR hubs, such as France.

Ultimately, our findings provide valuable insights not only for promoting sustainable transport but also for airline executives navigating these markets, highlighting the vulnerability of pure point-to-point models and the enduring strategic value of hub connectivity. Because these results and their generalisation are essential to understanding the common implications of liberalisation, they must be confirmed in other experiences and contexts. Future research could examine the second-order impacts on airfares and consumer welfare. An analysis of how these supply shifts affect the network structures of smaller, regional airports would also be a valuable contribution. Furthermore, investigating the potential for air-rail intermodal cooperation in liberalised markets rather than pure competition remains an important question.

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