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An Analysis of Intermodal Competition and Multiproduct Incumbent's Strategies in the French Market: What Drive High-Speed Trains' Prices and Frequencies?*

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Abstract: This paper presents an empirical analysis that examines the factors influencing service prices and frequencies of conventional high-speed trains (HSTs) in France. The study utilizes original data spanning from September 2019 to March 2020, focusing on the level of intermodal competition and the diversification strategy employed by the primary rail operator. The primary findings of the econometric analysis reveal that the determinants of the price per kilometer for both first and second-class conventional HST services exhibit some shared factors, particularly in relation to the technical characteristics of the routes and alternative options available. However, certain factors are specific to each category, such as the competitive environment, economic conditions, and demographic factors. The frequency of HST services is primarily influenced by travel time. In cases where conventional HSTs do not offer satisfactory service quality in terms of frequency and/or price, there is an auxiliary alternative option available to compensate for the limited frequency of conventional HST services.

Keywords: High-speed trains, Intermodal competition, Multiproduct firms' strategies, Low-cost transportation, France.
JEL Classification: L61, L92, R41, R48

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1. Introduction

In recent decades, there has been a notable diversification of long-distance transportation services, particularly in Europe. This diversification has been driven by two key trends: the emergence of low-cost offerings, which have facilitated market segmentation, and the rise of digital platforms, enabling the development of new services such as carpooling. As a result, there is now a wide range of transportation options for journeys exceeding 100km, including conventional air travel, low-cost air travel, high-speed trains (HSTs), conventional trains, low-cost trains, long-distance coaches, and carpooling. Additionally, the growth of intramodal competition has further increased this diversity. While several studies have examined the impact of one mode on another, there is limited research on both intramodal and intermodal competition.

This paper aims to investigate the effects of intramodal and intermodal competition on the pricing and frequency of HST services in France. The primary objective of our research is to gain a deeper understanding of the determinants of HST prices, considering the influence of competitive positioning of the HST relative to other modes of transportation and the impact of intra-rail mode range diversification. France provides an interesting case study for several reasons. Firstly, it offers a wide variety of intermodal competition, with BlaBlaCar leading the carpooling market, well-established coach services, and even long-distance air travel. Secondly, the historical rail operator in France (SNCF Group) was the first in Europe to introduce a unique form of competition known as "in-house competition," where a low-cost HST service (*Ouigo*) was developed alongside the conventional HST (*Inoui*). Understanding the management of this new service is crucial, particularly in identifying potential substitution patterns between the two offers. Lastly, France encompasses origins and destinations with varying characteristics in terms of distance, further enhancing the diversity for analysis.

This paper contributes to the existing literature by offering a comprehensive analysis of long-distance transportation supply and the significant interactions among different modes. It also provides insights into the French transportation system prior to the liberalization of the rail sector, serving as a basis for future comparative studies. The diversification of supply since the 2010s raises several questions on both the demand and supply sides. In this study, the effects on demand will not be addressed. We are only interested in the supply side, and more specifically in the interactions between the offers in terms of price and frequency. This choice is mainly motivated by the data set available. Consequently, we retain two questions to be addressed. Taking the HST service as our starting point, (1) How has the introduction of an internal low-cost service impacted prices and frequencies? (2) What are the effects on prices and frequencies due to the presence of alternative modal options, including low-cost airlines, carpooling, and coach travel?

The study focuses on five specific routes (origin-destination pairs of relevant markets), four of which are within France (Paris-Lyon, Paris-Bordeaux, Paris-Toulouse, and Paris-Nice), and one international route (Paris-Brussels). Although the number of lines is limited, they present interesting characteristics from the perspective of their diversity, whether it be in terms of competitive positioning or technical features. This variety allows us to consider the determinants of price and frequency in general. Indeed, these routes include HST services and feature varying levels of competition from intermodal and intramodal alternatives. Coaches are more prevalent on the Paris-Brussels route, while air travel is more prominent on the longer Paris-Nice route. The data covers all transportation options on these routes, including prices, capacities, and frequencies, during the period from September 2019 to March 2020, before the Covid-19 pandemic and before the liberalization of the French rail sector. The data analysis employs an econometric approach utilizing seemingly unrelated regression equations (Zellner, 1962).

The main findings reveal that the determinants of the price per kilometer for conventional HST services (1st and 2nd class) are partially shared, particularly concerning variables related to route characteristics and alternative options, while others are specific to the competitive, economic, and demographic environments. Frequency primarily depends on travel time. Specifically, it is observed that on routes where conventional HST services fail to provide satisfactory frequency and/or pricing, complementary alternative options, including low-cost HSTs, coaches, and carpooling, compensate for the limited frequency of conventional HSTs. On routes where round trips within a day are not feasible by HST, substitute alternatives, primarily low-cost flights, emerge.

Section 2 provides a summary of the relevant economic literature and outlines the French context in terms of transport supply and price regulation. Section 3 presents the data sources and the methodology employed. Section 4 describes the empirical strategy and variables used. Section 5 presents and discusses the econometric results. Finally, Section 6 concludes the paper.

2. Related Literature

This section presents the study's background and the lessons learned from the literature. Section 2.1 provides an overview of the diversification strategy of long-distance transport services in France. Section 2.2 presents the main results of the literature and their limitations. Finally, Section 2.3 focuses on the specific case of price regulation of HST in France and sets out the main hypotheses to be tested.

2.1. Diversification strategy of long-distance transport services

In recent decades, the long-distance transportation market in Europe, and particularly in France, has witnessed a notable diversification of services. This transformation has been propelled by the emergence of low-cost alternatives and the rapid growth of digital platforms. These developments have had a profound impact on the entire transportation landscape, with each mode experiencing unique manifestations of change.

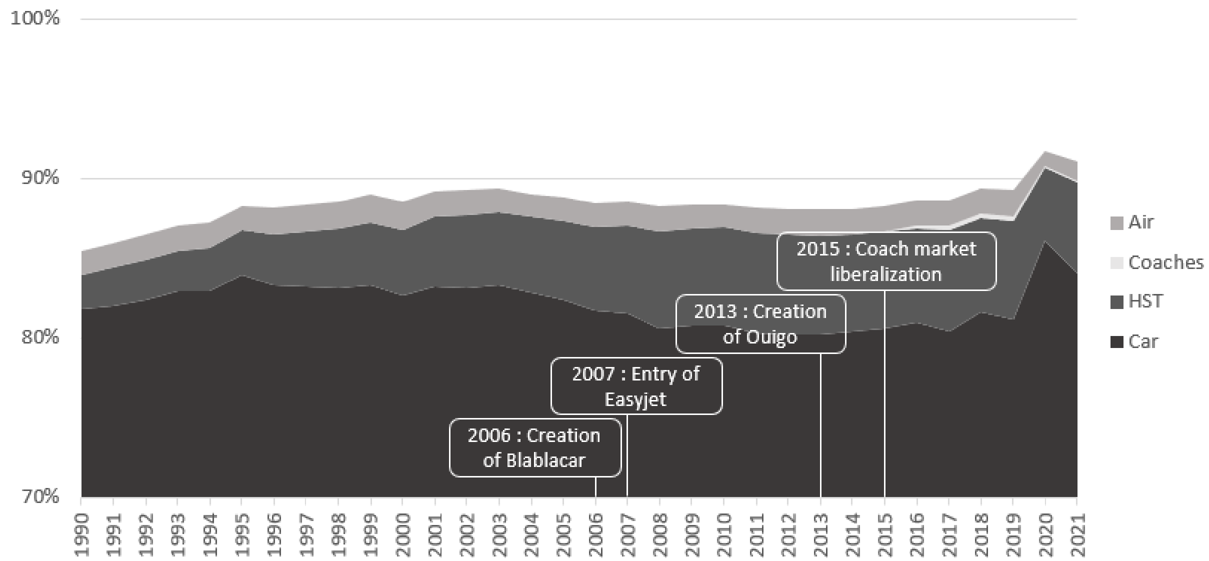

Fig. 1. Modal distribution of the main long-distance transport modes in France between 1990 and 2018 (excluding carpooling)
Source: *Les Comptes des transports* (2023)

Fig. 1 shows the modal distribution of long-distance transport in France between 1990 and 2018. The triptych is composed of the private car, which remains unchallenged, HST, which is increasing its share as the network expands, and air,[1] which has grown over the last few decades under the influence of low-cost air transport, although it is not very visible in Fig. 1 (+40%).[2]

The late 2000s witnessed a significant transformation in the landscape of long-distance transportation services. Notably, the advent of digital platforms fostering trust and connections facilitated the expansion of ride-sharing options for individual car owners. Among these platforms, BlaBlaCar, holding a virtual monopoly in Europe as of 2022, emerged as the leading player. Although the impact on the modal split remains relatively limited, several studies have indicated that this service can complement the prevailing public transportation provision, particularly rail services (Givoni and Dobruszkes, 2013; Beria et al., 2018; Bergantino and Madio, 2020; Laroche and Lamatkhanova, 2022).

The rail sector has also undergone a transformation by applying part of the low-cost airline strategy to its services to create in 2013 the low-cost high-speed operator Ouigo, an SNCF subsidiary. It complements, or even replaces on certain routes, the more conventional HST (Inoui). Chiambaretto and Fernandez (2014) show that the transfer of the low-cost model from air to rail has not been total due to the technical and regulatory specificities of the rail sector. It has considerably broadened the user base, with minimal price posted dropping from about €25 in the old system to €10 for the low-cost offer.

The road sector saw a last evolution starting in 2015 with the authorization to operate and the liberalization of the coach market in France. This marks the return of collective road transport services in France with competition that was very strong in the first years before a consolidation of the sector around two main players in 2022, Flixbus and BlaBlaBus (subsidiary of BlaBlaCar). Blayac & Bougette (2023) have shown that the reduction in the number of competitors may have had a negative effect on prices and capacities. Nevertheless, these services seem to have found their place alongside carpooling and low-cost HST.

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[1] The remaining 10-15% can primarily be attributed to long-distance mobility using conventional Intercités trains. Besides, the share of long-distance carpooling in France during the period covered by Figure 1 is marginal and estimated at around 1.6% (Source: General Commission for Sustainable Development, "Long-distance Carpooling: Current State and Growth Potential," no. 146, Studies and Documents, May 2016, p. 5). Given the relatively minor proportion, it is reasonable that carpooling is not visually discernible in Figure 1.

[2] There was a 40% rise in passenger volume, from 11.4 billion passenger-kilometers in 1990 to 15.9 billion passenger-kilometers in 2018. These figures are derived from official government transportation statistics, which can be accessed at the following URL: https://www.statistiques.developpement-durable.gouv.fr.

Lastly, this study does not deal with the opening of the French rail network to competition from 2021. The scope of our analysis is situated before the arrival of this new intramodal competition, which limits the analysis of the effect of low-cost rail services on the conventional HST offer (*Inoui*) to a more or less substitutable multi-product service offer.

2.2. Diversification challenges in the academic literature

The diversification of supply since the 2010s raises several questions on both the demand and supply sides. In this study, the effects on demand will not be addressed. We are only interested in the supply side, and more specifically in the interactions between the offers in terms of price and frequency. This choice is mainly motivated by the data set available. Consequently, we retain two questions to be addressed. Taking the HST service as our starting point, (1) how has the introduction of an internal low-cost service impacted prices and frequencies? (2) what are the effects on prices and frequencies due to the presence of alternative modal options, including low-cost airlines, carpooling, and coach travel?

Question (1) has been relatively little addressed compared to question (2). From a theoretical point of view, Ivaldi and Vibes (2008) showed that the introduction of an LC rail offer could have a significant impact on the fares charged by the incumbent operator (-30%) but little impact on air travel. Nevertheless, they did not consider that competition could be home-grown as happened in 2013 with the creation of Ouigo. The company can more easily distinguish its offer to segment demand as much as possible and maximize its profits by minimizing the risk of cannibalization (Chiambaretto and Fernandez, 2014).

However, Beria et al. (2018) show that even in a single operator system, supply segmentation can influence prices. They observe lower prices in Italy where the incumbent competes with its public service obligation (PSO) services compared to other lines. They also suggest that there may be an indirect effect of carpooling or coaching on HST fares. This observation refers to the question (2) which has been more widely discussed in the literature, especially on the competitive or non-competitive relationship between HST and air.

In broad terms, the authors agree that there is a relationship between the evolution of HST and air travel. Ivaldi and Pouyet (2018) suggest that rail is a highly constrained mode compared to other modes and is therefore relatively insensitive to intermodal competition. However, its intensity is highly debated. Givoni and Dobruszkes (2013) show a stronger substitution between HST and modes such as car, HSTs, or air than with carpooling or coaches. Cascetta and Coppola (2014) state that competition between HST and car is stronger than with air, the latter being less substitutable because of its time savings. Bergantino and Madio (2020) explain these observations by a greater proximity of customers between HST, air and car, sensitive to time savings and less to price, unlike alternative modes such as carpooling or coaches. Their users generally have a high price elasticity and are more likely to choose longer and less expensive modes.

Concerning air travel, many studies have been produced, notably in Spain and China, to evaluate the effect of the deployment of the high-speed network on air services. Overall, they confirm the effect of HST on air services for distances less than 900km or 3h travel time (Gonzales-Savignat, 2004; Rothengatter, 2011; Yang and Zhang, 2012; Gundelfinger-Casar and Coto-Millan, 2017; Xia and Zhang, 2016; Zhang et al., 2018; Chen et al., 2019; Wang et al., 2021).

On short-haul routes, Zhang et al. (2019) estimate a price reduction for air of 34% and 60% for frequency. In the Spanish case, Jimenez and Betancor (2012) observe a 17% reduction in air frequency and an increase in overall demand. Conversely, for connections longer than 3 hours by HST, several authors point to a marked effect on the number of seats but relatively weak on frequency (Albalate et al., 2014; Dobruszkes, 2011; Dobruszkes et al., 2014). Gundelfinger-Casar and Coto-Millan (2017) show that pro travelers accustomed to these routes have low price elasticity favoring schedule and travel time for their modal choice.

This result questions the often taken-for-granted substitutability of the two modes. Castillo-Manzano et al. (2015) showed that in the Spanish case, only 14% of air demand shifted to HST between 1999 and 2012, demonstrating a lower-than-expected substitutability between the two modes and the ability of HST to create its own demand. Finally, Mizutani and Sakai (2021) investigate the comparative effect of HST on a conventional air offer versus a new low-cost air offer. They find that the effect of HST is greater than that of the low-cost airline, especially because of its effect on volumes.

Nevertheless, most of the studies cited focus on the effects of HST on air travel and not the other way around. Only a few studies explore the effects of a new air service on HST. For example, Friebel and Niffka (2009) analyze the effect of a new low-cost airline (Germanwings) in Germany on the incumbent airline (Lufthansa) and the incumbent rail operator (Deutsche Bahn, DB). They show a very strong reaction on the part of Lufthansa, particularly on fares, unlike DB, which has reacted little to the new entrant. They suggest that DB may be less flexible than Lufthansa, particularly because of the technical constraints inherent in rail travel and a more rigid fare policy. For the other modes (carpooling, coaches), there is less work. One reason is the risk of substitution between modes, which seems less obvious insofar as the speed and price differentials are high. However, several authors show that the markets are not completely independent (Fageda and Sansano, 2018; Gremm, 2018; Laroche and Lamatkhanova, 2022). Gremm (2018) shows that rail prices are lower on routes exposed to intermodal competition (mainly coaches) than those where rail is a monopoly. Laroche and Lamatkhanova (2022) find that the probability of finding a carpool or coaches route increases with the price of rail tickets.

Finally, analyzing the coach market, Fageda and Sansano (2018) find that intramodal competition is primarily expressed through frequencies while intermodal competition is expressed through prices. Again, however, the literature is primarily concerned with the effect of rail on other modes, not the effect of other modes on it.

This literature review suggests several avenues of exploration for our study considering our primary objective of our research is to gain a deeper understanding of the determinants of HST prices, considering the influence of competitive positioning of the HST relative to other modes of transportation and the impact of intra-rail mode range diversification.

First, the scope of analysis should be extended to all modes. Most studies are limited to one or two modes in competition with rail and do not cover the whole market and its interactions. Second, the effects of intermodal competition and of the segmentation of rail services on HST prices have yet to be analyzed. Most studies focus on the effect of HST on alternative modes and not the other way around, assuming that HST would be a price maker and insensitive to the evolution of alternative services. In a context where the long-distance market is evolving very rapidly with new services, this assumption deserves to be reconsidered. Finally, the effect of a highly segmented multi-product offer for a single producer on a single route remains to be tested empirically. Our study proposes a textbook case by considering the Inoui offer in relation to Ouigo.

2.3. Pricing policy of the high-speed train in the French experience

This last point focuses on the pricing structure for HST in France. Several key elements are to be considered in setting prices, including public regulation, the internal strategy of maximizing revenues through joint price-capacity management (yield management), and the effect of infrastructure costs (access charges).

Train fares in France are set according to a simple formula that considers the number of kilometers multiplied by a degressive fare to which is added a constant that reflects the fixed costs inherent in rail travel. The price of tickets increases with distance but less than proportionally so as not to penalize long distance travel.

The maximum price of HST ticket prices is thus capped by the government, and the national operator SNCF is free to adjust its fares within this range. Under this constraint, the solution found in the 1990s to maximize revenues and increase the attractiveness of the HST was to implement yield management techniques to the HST product (Finez, 2014). The objective is to maximize the company's revenues by varying the sales price of a single seat according to various criteria (age, reason, reservation date, etc.) on the model of the airline industry.

Perennes (2014) demonstrates that this approach is particularly suitable for economic activities characterized by regulatory price caps, high fixed costs, and the production of non-storable goods. Consequently, SNCF utilizes a range of mechanisms to establish its pricing, leveraging sales data, train occupancy rates, and computer algorithms that analyze real-time reservation dynamics. The aim is to capture user surplus while minimizing social welfare losses through the ability to offer competitive prices.

However, Perennes (2014) point out that users rarely actually pay the capped price because of the discounts offered, except on the busiest routes such as Paris-Lyon. This structuring of fares should be considered to understand the fare differences observed in the rest of the study between the different routes. Fares should vary according to distance, but also according to the level of wealth of the territories (ability to pay) and demography (age structure). These determinants will be controlled for by socio-demographic controls.

Finally, the analysis of prices and frequencies cannot avoid the debate on the cost of access to infrastructure. The railway industry is highly vertically integrated, with the need for railroads in good condition to run trains (Bougette et al., 2021). Following the EEC/440/91 directive, the infrastructure manager was separated from the railway operators. In France, *SNCF Réseau* is the infrastructure manager in charge of the network while *SNCF Voyageurs* is in charge of the operation of rail services.

The use of the network by a train is conditional on the payment of a right of way charged per kilometer for any type of track. There is a debate among economists about the effect of these access charges on price and frequency. France stands out from the rest of Europe for having adopted pricing that tends toward full cost (Sanchez-Borras and Lopez-Pita, 2011; Nash, 2018). In this case, the user is considered to bear all the costs incurred by the infrastructure, unlike most other European networks that price their access at marginal cost, with the taxpayer taking all or part of the fixed costs of the network (Sanchez-Borras and Lopez-Pita, 2011).

The effect of a high access cost is debated. It may reduce traffic (Sanchez-Borras et al., 2010), and its effect seems to be stronger on frequencies than on prices (Börjesson et al., 2021). Operators have an incentive to use infrastructure more efficiently by reducing the number of trains and increasing their capacity. Crozet and Chassagne (2013) show that despite the high level of access charges in France, they do not constitute a barrier to entry or a handicap for the rail system because of the fine modulation implemented by the infrastructure manager to capture the operator's surplus and send the right price signals regarding the availability of the infrastructure (time modulation).

The effect of access charges should therefore be marginal in our study, but nevertheless perceptible in the evolution of prices or capacities according to time periods. For this reason, it will be necessary to distinguish between several time periods. Prices are expected to be higher during peak hours, while trains are expected to have more capacity.

3. Data Collection

This section specifies the scope of the study, the data collection method, the sources used, and the nature of the data collected.

3.1. Scope of study

Fig. 2 shows the five routes on which the study is based. They are oriented in the Paris direction, with four solely national routes (Bordeaux-Paris, Toulouse-Paris, Lyon-Paris, Nice-Paris) and one international (Brussels-Paris). Their purpose is to connect major urban centers in France and Europe with varying characteristics in terms of distance, population, type of transport infrastructure, and diversity of supply. More specifically, the Brussels-Paris link is a special case in that it is international. It is mainly subject to technical and organizational constraints for rail (rolling stock, staff qualifications), which contributes to its higher operating cost (Laroche and Guihéry, 2013). It is also the shortest of the panel.

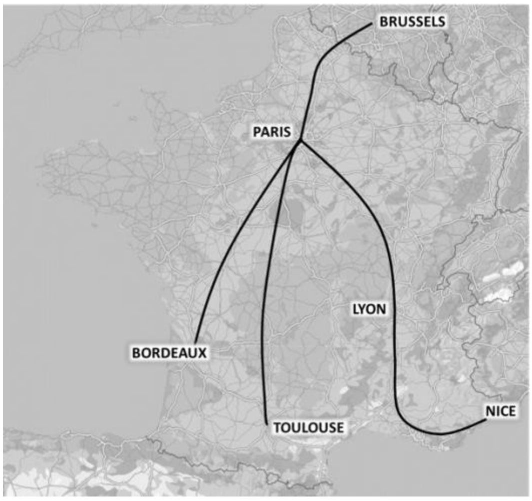

Fig. 2. The five routes under study

The Lyon-Paris and Bordeaux-Paris links differ from the rest of the panel in that they are of similar distance, with Lyon's advantage (466 km versus 585 km for Bordeaux). Lyon has more inhabitants than Bordeaux (1.3 million and 749,595 respectively), but both cities are very attractive, and both are linked to Paris by a high-speed line and an efficient highway network. Finally, Toulouse-Paris and especially Nice-Paris are characterized by a greater distance from Paris (677km and 933km respectively) and the absence of a high-speed line to serve them. This variety in line profiles directly impacts the diversity of transportation services, which reinforces the interest of the data panel.

Table 1 illustrates the multimodal diversity of the sample by considering the modal share of the different modes available. The modal share is defined in terms of the seating capacity of each mode, as demand data were not available for the study. In addition, the private car is excluded from the evaluation, again because of lack of data. The shortest routes (Brussels, Bordeaux, and Lyon) are dominated by rail, while the longest routes (Nice and Toulouse) are more evenly balanced between air and rail. In all cases, road solutions (coaches and carpooling) are marginal, although they are more prevalent on short routes than on long routes.

Table 1. Distribution of modal shares (by estimated number of seats) by route.

To Paris	Train	Air	Coaches	Carpooling
Lyon	95%	2%	3%	0.1%
Brussels	90%	1%	8%	0.1%
Bordeaux	89%	8%	2%	0.1%
Toulouse	45%	51%	3%	0.3%
Nice	48%	52%	0%	0.1%

3.2. Data collection method and sources

Data collection was conducted from September 24, 2019, to March 10, 2020, which marked the beginning of lockdown in France following the COVID-19 pandemic. In total, 13 days were analyzed. They are all positioned on Tuesdays as a reference day with a collection at D-7. Each day was a working day, with public holidays, school vacations and strikes excluded from the analysis.

The data was gathered using web scraping techniques and originates from the commercial websites of various operators identified in the market. To identify the available offers, we utilized the www.omio.fr comparator. Subsequently, we visited the operators' individual websites to acquire the most comprehensive and reliable information available.

For railway data, due to the monopoly situation of the national operator, we referred to its reference site, www.sncf-connect.com. However, to ensure thoroughness, we also consulted their site dedicated to low-cost services (https://www.ouigo.com).

Regarding coach travel, the data required visiting two websites associated with the two operators that dominated the French market in 2019 – Flixbus (www.flixbus.com) and BlaBlaBus (https://www.blablacar.fr/bus). BlaBlaBus is also utilized for carpooling, as it holds a virtual monopoly in this domain within France. No other website for carpooling was included in our data collection.

Finally, data concerning air travel was collected from the Google flight database, which provides a comprehensive listing of different flights.

3.3. Descriptive data

The collected data is diverse and relies heavily on the level of information available on the operators' websites. The data used for the study is common to all operators and includes departure/arrival times, departure/arrival locations, and prices. This information enables us to reconstruct schedules, travel times, distances, frequencies, and estimate the capacity offered in terms of available seats.

Table 2 presents the raw data acquired for each of the identified transport services, with a primary focus on the rail mode, which is the main subject of our study.[3] The rail mode data is

[3] For detailed data organized by specific routes, refer to Appendix Tables A0 to A4.

further divided into conventional HSTs (Inoui and Thalys), low-cost high-speed trains (Ouigo), and non-high-speed rail services (Intercity, night Intercity, Izy, and regional trains). Data for other modes are aggregated.

In total, our raw sample consists of 3,907 observations, covering all routes and the entire period under study. It should be noted, however, that the frequency and number of seats data are provided on a daily basis.[4]

[4] A more detailed description of the raw data collection and transformation process is provided in the appendix (see A5).

Table 2. Raw descriptive statistics

		Obs.	Mean	Min.	Max.
Rail (conventional HST: Inoui, Thalys)	2nd class price	946	83.3	23	132
	1st class price	946	115.5	37	189
	Frequency (per day)	946	14.5	3	23
	Number of seats (per day)	946	12,950	1,530	23,460
	Distance	946	492.7	322	940
	Travel time	946	2:32:41	1:22:00	6:15:00
Rail (low-cost HST: Ouigo)	2nd class price	220	23.9	10	79
	Frequency (per day)	220	4.5	1	11
	Number of seats (per day)	220	4,671.5	634	13,948
	Travel Time	220	2:34:07	1:43:00	5:57:00
Rail (HST excluded: Intercity, Night Intercity, regional train)	2nd class price	110	43.9	15	86
	1st class price	77	67.2	23	130
	Frequency (per day)	110	2.9	1	5
	Number of seats (per day)	110	1,556.9	393	3,600
	Distance	110	543	322	683
	Travel time	110	5:47:35	2:23:00	8:13:00
Bus (all operators)	Price	960	16.5	5	79
	Frequency (per day)	960	15.5	1	39
	Number of seats (per day)	960	786	50	1950
	Distance	960	457	322	940
	Travel time	960	6:21:20	3:45:00	13:50:00
Air (all operators)	Price	1,152	244.6	40	769
	Frequency (per day)	1,152	17.7	1	38
	Number of seats (per day)	1,152	2,697	150	5,700
	Distance	1,152	718.6	240	940
	Travel time	1,152	1:23:36	00:55:00	1:45:00
Carpooling	Price	519	40.7	13	88.5
	Frequency (per day)	519	9	1	38
	Number of seats (per day)	519	25.1	3	114
	Distance	519	523.8	265	933
	Travel time	519	5:26:53	1:51:00	11:10:00

The comparison between transportation modes ranks air travel as the fastest and most frequent option, averaging 17.7 services across all routes. Air travel is highly concentrated on the longest distances, but has less capacity compared to rail. On the other hand, rail services are abundant and have a high capacity for all distances, although the average speed is lower than that of air travel.

Coaches are also very frequent, especially on the shortest routes. However, they seem to be penalized by a relatively low average speed when compared to other modes, resulting in longer travel times on average.

Surprisingly, carpooling is faster and positioned on an average distance closer to rail travel than to coaches. This might be due to the higher average speed of cars compared to coaches, which allows carpooling to cover longer distances in equivalent travel times.

When it comes to pricing (i.e., basic pricing for 1st and 2nd class without any options), it is evident that air travel ranks as the most expensive mode. Conversely, low-cost HST and coaches represent the most economical options. Carpooling, despite its benefits, is comparatively less attractive due to a higher average price.

In general, transport offers seem to be relatively stable with little variation in terms of frequency, except for carpooling, where the offer in normal periods can vary by up to 2.5 times.

4. Empirical Strategy

The empirical strategy relies on employing econometric modeling, specifically the Seemingly Unrelated Regression Equations Models (SURE models). In this approach, we process the raw data collected to achieve two main objectives: (i) we consider the context of intermodal and intramodal competition, with a specific focus on intra-firm competition in our case; (ii) we identify the determinants of prices for both 1st and 2nd class, as well as the frequencies of HST services.

4.1. Consideration of the competitive environment

In this study, we have analyzed thirteen days and categorized the observations related to the supply of transport services for different routes (Brussels-Paris, Bordeaux-Paris, Toulouse-Paris, Nice-Paris, and Lyon-Paris) into three main daily periods: Morning, for rail services departing before 9:00 a.m.; Afternoon, for those departing between 9:00 a.m. and 5:00 p.m.; and Evening, for those departing after 5:00 p.m. This segmentation draws from the Network Statement provided by the national network (SNCF Réseau, 2024), outlining the daily distribution of peak and off-peak times. By considering these distinct periods, we are able to differentiate between customer types, typically associating professionals with peak periods and leisure travelers with off-peak periods. It also allows us to examine the variations in intramodal and intermodal competition that correspond with these time segments.

To measure the intensity of competition, we constructed indicators based on the data collected (see Section 3.3). The *HHI_PASS* variable measures the intensity of intermodal competition for the specific time of day and route under consideration. To calculate this index, we employed the standard Herfindhal-Hirschman index (HHI) approach,[5] using the market shares of each mode of transport (train, air, coaches, and carpool) in terms of passengers carried (based on the number of available seats times the average load factor or the route considered). The HHI_PASS is computed as follows:

$$HHI\_PASS = \sum_{m=1}^{4} s_m^2$$

where *m* denotes the mode of transport, and s_m is the market share of the mode for the respective period, route, and date.

Additionally, we assessed the degree of intramodal diversification for the rail mode, focusing on frequency and different rail products (Inoui, Ouigo, Intercity, Regional train). The Herfindhal-Hirschman index was used once again to measure this diversification, considering the market share of each rail product *g* for the given period, route, and date. The formula for *HHI_TRAIN* is as follows:

$$HHI\_TRAIN = \sum_{g=1}^{4} s_g^2$$

Here, *g* represents the rail product, and s_g is the frequency market share of the rail product *g* for the corresponding period, route, and date. Both the *HHI_PASS* and *HHI_TRAIN* indices yield values between 0 and 10,000, reflecting low/high concentration for *HHI_PASS* and high/low diversification for *HHI_TRAIN*, respectively. A monopoly is defined when HHI equals 10,000, and in the railway sector a market is considered highly concentrated, indicative of an oligopoly, when HHI exceeds 1,800 (Laroche et al., 2019). A low concentration level is identified when HHI is below 1,000.

4.2. Econometric modeling

The primary objective of our research is to gain a deeper understanding of the determinants of HST prices, considering the influence of competitive positioning of the HST relative to other

[5] We use the HHI as market concentration measure. The index was developed independently by the two economists Hirschman (1945) and Herfindahl (1950). HHI is widely used to evaluate market concentration in the airline industry, as evidenced by studies such as Oliveira and Oliveira (2018) or Groshe et al. (2020). The index emphasizes the square of the market shares, thereby disproportionately enlarging the influence of larger firms within the HHI. This approach is based on the premise that the largest firms in a market possess disproportionately greater market power.

modes of transportation and the impact of intra-rail mode range diversification. Specifically, we focus on the HST Inoui services offered by SNCF, which utilize railcars with two distinct comfort classes. Managing the available capacity for each comfort class becomes crucial from the operator's perspective. Our analysis aims to identify the various factors that potentially affect the prices of HST services in both the 1st and 2nd classes (refer to section 2.3). Additionally, we acknowledge that the two comfort classes are not entirely isolated from each other.

From an econometric standpoint, accurately estimating the determinants of the prices of 1st and 2nd class HST services requires us to account for some degree of dependence between the error terms of the two equations defining them. To address this issue, we draw inspiration from the approach used by Fageda and Sansano (2018) in their study of the long-distance coach service market, where they employed a Seemingly Unrelated Regression Equations (SURE) model. By utilizing a SURE model, we can effectively capture the interrelated nature of the two dependent variables while considering potential cross-equation correlations.

In addition to investigating the determinants of HST prices, we also aim to analyze the factors influencing HST frequencies. To achieve this, we introduce the dependent variables used in our analysis (Section 4.2.1) as well as the explanatory variables considered (Section 4.2.2). Subsequently, we provide a brief overview of the SURE model we employ to carry out our econometric analysis (Section 4.2.3).

4.2.1. Dependent variables

The study focuses on three primary variables: the prices of HST services in first and second class, and the frequencies of the incumbent operator's flagship product (Inoui in the case of SNCF). In the context of the French case (see 2.3), the pricing of HST services considers not gross prices, but prices per kilometer, also referred to as kilometer prices, for each of the routes analyzed in this article.[6] Descriptive statistics for these variables are presented in Table 3, while Fig. 3 illustrates the Price per kilometer for 1st class, Fig. 4 for 2nd class, and Fig. 5 shows the Frequency data.

[6] We explored the possibility of working with gross prices instead of per-kilometer prices and of introducing a price dispersion indicator, following the approach initiated by Borenstein and Rose (1994). Ultimately, we chose to use per-kilometer pricing, and to model the logarithm of this variable.

Table 3. Descriptive statistics

Variable	N	Mean	Standard deviation	Minimum	Maximum
Frequency	929	6.85	2.22	1.00	10.00
PK_HST_1	894	0.26	0.10	0.05	0.45
PK_HST_2	905	0.19	0.08	0.02	0.32

The analysis reveals significant disparities in the price per kilometer among different routes, particularly in 1st class. The average price per kilometer is 0.26€/km, ranging from a minimum of 0.05€/km to a maximum of 0.45€/km, highlighting a substantial factor of 9. Fig. 4 provides a visual representation of these phenomena.

Out of the 5 routes studied, 3 routes demonstrate a comparative advantage in favor of HST – namely, Brussels, Bordeaux, and Lyon. However, when considering pricing strategies (*PK_HST*, 1st class), the relationships differ across these cities. Both Brussels and Lyon show little fare variability, primarily due to their reliance on business customers. Conversely, Bordeaux exhibits much more variability in pricing.

For the Nice and Toulouse routes, where the HST rail mode lacks a competitive edge in terms of price, time, and frequency, the situation is more nuanced. The pricing variability remains low for Nice, while Toulouse experiences more significant fluctuations, often in connection with access via Bordeaux or Montpellier.

The observations are consistent in relation to the 2nd class. The average price per kilometer is €0.19/km, with a minimum of €0.02/km and a maximum of €0.32/km, revealing a significant factor of 16. This considerable variability in prices is likely attributed to various factors, including the time period under consideration, the implementation of Yield Management to optimize train loadings, variations in competitive positioning among different routes, and regulatory influences. Notably, among the regulatory factors, the adoption of an article within the framework of the Climate and Resilience Law (August 22, 2021) from the Citizens' Climate Convention stands out. This article pertains to the prohibition of domestic flights when a rail alternative of less than 2.5 hours is available. Only the Nice-Paris and Toulouse-Paris routes in our sample could potentially justify the use of domestic flights. Interestingly, Fig. 3 and 4 illustrate that the price per kilometer for these routes is lower compared to others where HSTs have a distinct competitive advantage. As a result, we consider the prices per kilometer as dependent variables while introducing the distance as a control variable.[7] In the econometric

[7] Caution is advised if the reader intends to compare Tables 3 and 4 with Table 2, which contains raw data

estimation phase, we expect the estimated coefficient of the distance variable to be negative for both 1st and 2nd class.

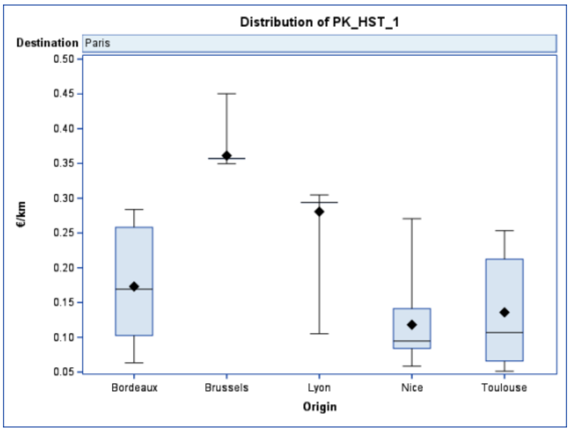

Fig. 3. Price per kilometer of HST - 1st class by route

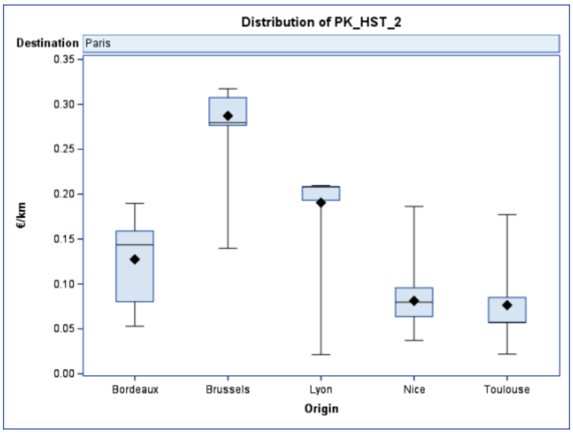

Fig. 4. Price per kilometer of HST – 2nd class by route

aggregated or detailed by route (see Appendix A0 to A4). There are two main sources of discrepancies. The first is related to the number of observations (refer to Appendix A5 for details). The second source of discrepancy concerns the units of measurement employed. For instance, in Table 2, the price is listed as a gross price, whereas in subsequent tables, such as Table 3, the variable modeled is the price per kilometer. Likewise, the average number of frequencies is reported per day in Table 2, but relates to specific periods (morning, afternoon, and evening) in the result tables.

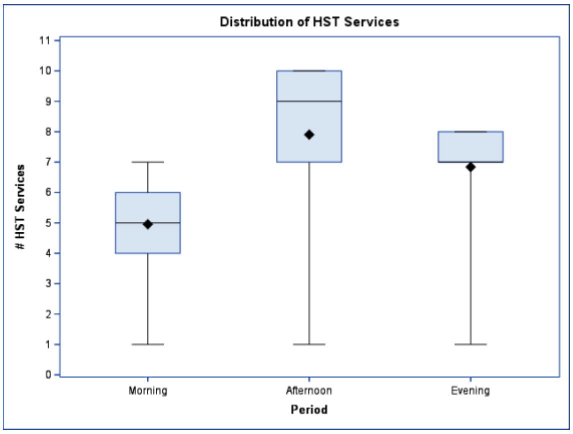

Fig. 5. Frequency of HST services by time of day

The frequency of HST services varies from 1 to 10, depending on the period considered (Morning, Afternoon, and Evening) and the specific route, with an overall average of 6.85 for all periods combined. Fig. 5 illustrates the dispersion of HST frequencies by time of day for all routes analyzed in this study.

4.2.2. Explanatory variables

The explanatory variables used in the various regressions can be categorized into three main groups. Firstly, they encompass the technical characteristics of the routes and the transportation options available. Table 4 provides a brief presentation of these variables along with their descriptive statistics. The variables in this category include:

- *Distance (in kilometers)*: The distance between the origin and destination cities, exhibiting significant variation depending on the route and time of day. On average, the distance between cities is 490 km (ranging from 312 to 940 km).
- *Travel Time (in minutes)*: The time taken to travel between the origin and destination cities. The average travel time is 2 hours and 14 minutes (ranging from 1 hour and 22 minutes to 7 hours and 48 minutes).
- *Capacities and Frequencies of other train types (Low-cost, Intercity, Regional Train (Regio))*: Considering the diverse situations, these variables naturally account for differences in observable scenarios.
- *Capacities and Frequencies of other transportation modes (Coaches, Low-Cost Flight, Carpooling)*: These factors also contribute to the overall transportation offer and vary depending on the specific route and time of travel.

The aforementioned variables reveal highly contrasting conditions, reflecting the complexity of the transportation system under study.

Table 4: Descriptive Statistics - Explanatory Variables

Variable	N	Mean	Standard deviation	Minimum	Maximum
DISTANCE	929	490.33	157.84	312.00	940.00
TT_HST (min)	929	134.50	72.11	82.00	448.00
CAPA_LC_TRAIN	929	1,956.04	2,290.97	0.00	6,340.00
CAPA_INTERCITES	929	30.65	156.63	0.00	1,203.00
CAPA_LC_COACH	929	332.02	199.57	0.00	900.00
FREQ_LC_TRAIN	929	1.66	1.75	0.00	5.00
FREQ_REGIO	929	0.48	1.02	0.00	3.00
FREQ_LC_COACH	929	6.64	3.99	0.00	18.00
FREQ_LC_AIR	929	0.28	0.80	0.00	4.00
FREQ_CARPOOL	929	10.89	12.94	0.00	81.82
SPEED_HST	929	3.88	0.58	1.36	4.88
HHI_PASS_CTRD	929	0.00	1,143.07	-3,802.08	1,368.68
HHI_TRAIN_CTRD	929	0.00	2,028.24	-3,820.66	3,565.11
YOUNG_MEAN	929	24.28	2.90	20.54	27.50
SENIOR_MEAN	929	12.26	1.31	10.63	15.77
POP_MEAN	929	829,948.87	185,197.59	624,528.00	1,062,234.83
UNEMP _MEAN	929	12.39	0.54	11.89	13.56

The second major category of variables groups together factors that characterize the competitive environment of routes. This category is based on three variables developed for this purpose:

- The *HHI_PASS_CTRD* variable is derived from the HHI_PASS variable, which captures the degree or intensity of intermodal competition, using the standard definition of the HHI index (ranging from 0 to 10,000). For the *HHI_PASS_CTRD* variable, we have applied centering with respect to the average *HHI_PASS* for the specific period of the day under consideration. Consequently, a positive (or negative) value of this variable for an observation in our database indicates a higher (or lower) degree of concentration compared to all other observations in the same period.
- The *HHI_TRAIN_CTRD* variable aims to capture the degree or intensity of intramodal competition. When there are no intramodal competitors, this variable serves as an indicator of the range diversification implemented by the incumbent operator (e.g., SNCF and the OUIGO, OUIGO Train classique, Regional train, Intercités offers, etc.). The *HHI_TRAIN_CTRD* variable is derived from the *HHI_TRAIN* variable, which is calculated based on the frequencies offered rather than the number of passengers carried.

The centering process for *HHI_TRAIN_CTRD* is the same as for *HHI_PASS_CTRD*. In this context, any positive (or negative) value of the *HHI_TRAIN_CTRD* variable in our database reflects less (or more) range diversification.

- The variable *SPEED_HST* can be considered an indicator of the quality of the HST service. In France, HST services have often been criticized for making frequent stops or utilizing a large portion of conventional (non-HST) infrastructure (cf. Cour des Comptes, 2014). The variable *SPEED_HST* is defined as the ratio of distance to travel time by HST, expressed in minutes per kilometer (km/min). The minimum and maximum values of *SPEED_HST* are 1.36 and 4.88, respectively, with an average of 3.88. These values correspond to "commercial speeds" of 82 km/h, 293 km/h, and 233 km/h, respectively.

The third and final category of explanatory variables used comprises economic and demographic factors related to the relationships under consideration. These factors include the proportion of young people aged 15-29, the share of people aged 60-74, the unemployment rate of 15–64-year-olds, and the population of the origin and destination cities (Source: INSEE for French data in the year 2018, and IBSA for Belgian data in the year 2017).

To calculate these variables for each route, we use the geometric mean of the values for the origin and destination cities. This approach enables us to simultaneously consider the emission factors and/or attraction factors of the origin and destination cities, similar to a gravity model. Additionally, it allows us to retain the original unit of measurement.

On average, the proportion of 15–29-year-olds for the routes in our sample is 24.3%, the share of 60–74-year-olds is 12.3%, and the unemployment rate is 12.4%.

The explanatory variables provided above are utilized to elucidate the factors influencing the pricing of both HST 1st and 2nd class services, as well as the frequency of HST services. The subsequent section outlines the econometric modeling approach employed for this analysis.

4.2.3. The SURE model

The SURE model is of great interest due to its ability to estimate various equations that collectively define the functioning of a system. These models leverage the information provided by the covariance matrix of the error terms associated with each equation. However, it is essential to ensure that the variables dependent on certain equations do not act as explanatory variables for the other equations within the system.

The baseline equation of the system for the routes k considered for each period of the day (Morning, Afternoon, and Evening) is the following:

$$Y_k = \alpha_0 + \alpha_1 DISTANCE_k + \alpha_2 TT\_HST_k + \alpha_3 CAPA\_LC\_Train_k + \alpha_4 CAPA\_Intercities_k + \alpha_5 CAPA\_LC\_Coach_k + \alpha_6 FREQ\_LC\_Train_k + \alpha_7 FREQ\_Regio_k + \alpha_8 FREQ\_Coach_k + \alpha_9 Freq\_LC\_Air_k + \alpha_{10} Freq\_Carpool_k + \alpha_{11} SPEED\_HST_k + \alpha_{12} HHI\_PASS\_CTRD_k + \alpha_{13} HHI\_TRAIN\_CTRD_k + \alpha_{14} YOUNG\_Mean_k + \alpha_{15} SENIOR\_Mean_k + \alpha_{16} POP\_Mean_k + \alpha_{17} UNEMP\_Mean_k + \varepsilon_k \quad (1)$$

where Y_k is, respectively, *log(PK1)*$_k$, *log(PK2)*$_k$ and *log(FREQ)*$_k$. The explanatory variables are those described in paragraph 4.2.2 and belonging to one of the three categories: the technical characteristics of the routes and the transportation options available, the competitive environment of routes, and the economic and demographic factors associated with the origin and destination cities. ε_k is an error term.

To estimate the model, we employ the Feasible Generalized Least Square (FGLS) method, which operates in two stages. First, each equation is estimated separately via the OLS (*Ordinary Least Squares*), and the obtained error terms enable us to determine the covariance matrix of these errors. Subsequently, this covariance matrix is utilized to estimate the entire system (1) via Generalized Least Squares (GLS).

The estimators obtained through the SURE models are equivalent to those achieved by an equation-by-equation OLS estimation when the covariance matrix is diagonal or when the explanatory variables are identical for each equation.

In this particular case, we have chosen a semi-log model for our analysis.[8]

5. Results

5.1. Econometric estimation

The model described by the system of equations (1) is estimated using the procedure outlined in section 4.2.3. After the initial step of OLS estimations, the covariance matrix of the error terms is computed. Interestingly, this estimation reveals significant correlations, particularly

[8] The logarithmic transformation of dependent variables allows, in a way, to smooth the variable over time and to avoid phenomena that are too significant in variance or trend.

among the error terms of the equations that explain the price per kilometer of HST 1st and 2nd class services (refer to Table 5).

Table 5: Seemingly Unrelated Regression Estimation

Cross Model Covariance			
	LPK1	LPK2	LFREQ
LPK1	0.089296	0.064942	0.001250
LPK2	0.064942	0.071913	0.000647
LFREQ	0.001250	0.000647	0.020999

Cross Model Correlation			
	LPK1	LPK2	LFREQ
LPK1	1.00000	0.81041	0.02887
LPK2	0.81041	1.00000	0.01664
LFREQ	0.02887	0.01664	1.00000

System Weighted MSE	0.9959
Degrees of freedom	2650
System Weighted R-Square	0.8029

In a second step, GLS are applied. The results obtained are presented in Table 6.

Table 6: The SURE model – Estimation results

	Log(PK1)	*Log(PK2)*	*Log(FREQ)*
Variables	**Coef. *(SE)***	**Coef. *(SE)***	**Coef. *(SE)***
Intercept	-0.00768 *(0.1094)*	5.4314 *(0.4761)****	0.19195 *(0.1143)**
DISTANCE	-0.0018 *(0.0001)****	-0.00133 *(0.0001)****	
TT_HST (min)			-0.00263 *(0.0004)****
CAPA_LC_TRAIN	-0.00005 *(7.2E-6)****	-0.00004 *(5.0E-6)****	
CAPA_INTERCITES		-0.00022 *(4.5E-5)****	
CAPA_LC_COACH	-0.00025 *(0.0001)****	-0.00017 *(8.0E-5)***	
FREQ_LC_TRAIN			0.14047 *(0.0064)****
FREQ_REGIO			0.11031 *(0.0117)****
FREQ_LC_COACH			0.02626 *(0.0024)****
FREQ_LC_AIR			-0.11049 *(0.0121)****
FREQ_CARPOOL			0.00191 *(0.0006)****
SPEED_HST	0.135492 *(0.0304)****		0.08363 *(0.0362)***
HHI_PASS_CTRD	0.000104 *(1.7E-5)****		
HHI_TRAIN_CTRD			0.00012 *(5.6E-6)****
YOUNG_MEAN	-0.08206 *(0.0076)****		-0.01842 *(0.0053)****
SENIOR_MEAN			0.17625 *(0.0141)****
POP_MEAN	1.296E-6 *(1.3E-7)****		-5.83E-7 *(9.9E-8)****
UNEMP _MEAN		-0.51827 *(0.04)****	
# of Observations[9]	892	892	892
*** Statistical significance at 1% level, ** Statistical significance at 5% level, * Statistical significance at 10% level.			

[9] The estimation of the system (1) must be performed on the same number of observations to adequately estimate the covariance matrix of the error terms. This explains the number of observations used can differ in Tables 2, 3, and 5. The estimation is performed on 892 observations for each dependent variable.

From a statistical standpoint, the presented results strongly support the choice of estimating a SURE model. This is because the covariance matrix is not diagonal, and the explanatory variables used to explain the mileage prices in 1st and 2nd class, as well as the frequencies of HST services, are not identical.

The model's explanatory power, represented by the system of equations, is highly satisfactory, with a weighted R^2 of 0.8029. Additionally, the analyses of the residuals from the SURE model do not reveal any significant elements (see Appendices).

5.2. Economic analysis and discussion

5.2.1. Determinants of the price per kilometer of HST 1st class services

In the first category, which comprises technical characteristics of the routes and transport offers (cf. 4.2.2), three variables show significant negative coefficients. These variables are *DISTANCE*, *CAPA_LC_TRAIN*, and *CAPA_LC_COACH*. Consequently, all other factors being constant, the price per kilometer in 1st class decreases with distance, indicating reduced competitiveness of this mode as distance increases. This result is consistent with predictions of the gravity model, which suggests that individuals are less inclined to travel extensive distances.

The same trend applies to the variables *CAPA_LC_TRAIN* and *CAPA_LC_COACH*, which reflect the impact of alternative modes of transportation (LC coaches and LC trains) on the price per kilometer. A well-established supply of these alternative modes is likely to moderate the price per kilometer of HST services in 1st class. However, it is important to note that this moderation effect will probably be more prominent during non-peak periods of the day (AFTERNOON). Additionally, this result may also indicate the effective use of SNCF's yield management system to ensure optimal utilization of HST capacity. In this context, SNCF must consider the presence of a viable low-cost offer (coaches and trains).

Moving on to the variables in the **second category**, which pertain to the competitive environment of the routes (see 4.2.2), the positive coefficients associated with the variables *SPEED_HST* and *HHI_PASS_CTRD* were expected.

The variable *SPEED_HST* serves as a proxy for the extent of HST infrastructure utilization along a given route, and it has a significant positive impact on the price per kilometer of 1st class HST services. This relationship is graphically illustrated in Fig. 1 and A1, where routes like Brussels-Paris and Lyon-Paris exhibit the highest average price per kilometer (0.36 €/km and 0.28 €/km, respectively) and also have correspondingly high values of the *SPEED_HST* variable (averaging 3.88 and 3.89). These routes exemplify the ideal characteristics of a HST service, emphasizing the use of dedicated infrastructure with minimal stops.

In contrast, routes like Nice-Paris and Toulouse-Paris display contrasting characteristics, offering HST services with a lower price per kilometer (0.12 €/km and 0.14 €/km, respectively) and lower average values of the *SPEED_HST* variable (averaging 2.50 and 2.58). These routes demonstrate a combination of affordability and relatively lower use of dedicated infrastructure.

The Bordeaux-Paris route stands out from the others, as it exhibits the highest average value of the *SPEED_HST* variable (4.48) in our sample, while maintaining an intermediate average price per kilometer (0.17 €/km). This finding suggests the influence of multiple factors affecting the price per kilometer of HST services, including elements from both the supply side (e.g., infrastructure tolls) and the demand side (e.g., catchment area and type of customer).

Moving on, the variable *HHI_PASS_CTRD* also has a positive and significant effect on the price per kilometer of HST services, which was as anticipated. When this variable takes a positive value for an observation, it indicates a higher concentration of service demand during the considered period of the day compared to other observations. In situations where strong organized competition is absent, the incumbent rail operator can fully exploit its competitive advantage over other modes of transportation. Conversely, when there is less competitive advantage and/or when the incumbent rail operator faces more competition (especially intermodal competition), the variable *HHI_PASS_CTRD* takes on a negative value, contributing to a downward pressure on the price per kilometer of the HST - 1st class services in question.[10]

Two variables from the **third category** (economic and demographic environment, see 4.2.2) have shown significance. These variables are *YOUNG_MEAN* (with a negative sign) and *POP_MEAN* (with a positive sign). Consequently, the higher proportion of people aged 15 to 29 years in the connected cities (geometric mean) contributes, ceteris paribus, to a decrease in the price per kilometer of 1st class HST services. While the relationship is not immediately evident, it could be interpreted as indicative of a more competitive dynamic, particularly regarding intermodal competition. On the other hand, the size of the potential market, represented by the geometric mean of the population of the connected cities (*POP_MEAN*), has

[10] A graphical representation of the HHI_PASS_CTRD variable for the different routes and time periods is provided in the Appendix (see Fig. A2).

a positive effect on the price per kilometer of 1st class HST services. This effect was as expected and consistent with the findings of the gravity modeling of spatial interactions.

The mileage prices of 1st class HST services are influenced by various factors. Some of these factors are related to technical characteristics or alternative offers, such as distance, capacity of the locomotive train (CAPA_LC_TRAIN), and capacity of coaches (CAPA_LC_BUS). Others are connected to competitive positioning, like quality of HST service (SPEED_HST) and HHI_PASS_CTRD (a measure of concentration in the passenger market). Additionally, economic and demographic factors of the connected cities, such as YOUNG_MEAN and POP_MEAN, also play a role in determining the prices.

The determinants of mileage prices for 1st class HST services align with much of the existing research in this area (Bergantino and Madio, 2020; Borjesson et al., 2021). However, it is worth considering whether these same determinants apply to explaining the mileage prices of second-class HST services.

5.2.2. Determinants of the price per kilometer of HST 2nd class services

The presence of two distinct comfort classes (1st and 2nd class) in conventional HSTs introduces additional complexities. The rail operator must implement more sophisticated capacity management and pricing strategies to strike the right balance between maximizing revenue and minimizing waste risk (Finez, 2014; Perennes, 2014).

The results (refer to Table 6) confirm certain factors that have an impact on the pricing of mileage for 1st class HST services. These factors belong to the 1st category (route technical characteristics and transport offer, see 4.2.2) and include distance (*DISTANCE*) as well as capacities offered by alternative modes (*CAPA_LC_COACH*) and/or other rail “products” or “ranges” (*CAPA_LC_TRAIN* and *CAPA_INTERCITES*). The negative and statistically significant coefficients for these variables indicate their influence in moderating the price per kilometer of HST services for long trips (where the comparative advantage of HST is less pronounced) and/or in situations where a more developed financially viable alternative is available. Notably, none of the variables in the second category (competitive environment of HST, see 4.2.2) play a significant role in explaining the mileage prices of second-class HST services.

Finally, among the variables in the 3rd category (economic and demographic environment, cf. 4.2.2), only the geometric mean of the unemployment rates of the origin and destination cities appears to influence the price per kilometer of 2nd class HST services. The associated negative coefficient indicates that, ceteris paribus, routes with higher average unemployment rates experience a reduction in the price per kilometer.

The factors influencing the price per kilometer of HST services (1st and 2nd class) can be categorized into two parts: common determinants, which notably include variables explaining the technical characteristics of the route and the alternative transportation options, and specific determinants, such as the competitive environment, economic conditions, and demographic factors. These factors collectively highlight the intricacy involved in devising a fare strategy for the existing rail operator. The primary objective is to efficiently manage the available capacity in both 1st and 2nd class while effectively catering to the mobility needs of individuals.

5.2.3. Determinants of HST service frequency

The results of the econometric estimation (Table 6) highlight several explanatory factors for the frequency of HST services. Among these factors, we find those belonging to the first category of variables (technical characteristics of the routes and transport offer, see 4.2.2). These factors include travel time (*TT_HST_MIN*) and the frequency offered by alternative modes of transport (*FREQ_LC_TRAIN, FREQ_REGIO, FREQ_LC_COACH, FREQ_CARPOOL, and FREQ_LC_AIR*).

Logically, travel time (*TT_HST_MIN*) negatively affects the frequency of HST services on a given route. This observation reflects the competitive advantage of HST for relatively short trips (less than 2-3 hours) compared to other modes of transport. Beyond this travel time threshold, the frequency of conventional HST services decreases, and alternative options start to develop. These alternatives may involve intra-modal diversification or intermodal competition. In our study, intra-modal diversification is represented by low-cost HSTs (*FREQ_LC_TRAIN*) and regional trains (*FREQ_REGIO*), while intermodal competition includes freely organized coach services (*FREQ_LC_COACH*), low-cost flights (*FREQ_LC_AIR*), and carpooling (*FREQ_CARPOOL*). The coefficients associated with the frequencies of the different modes in the estimation phase are mostly positive, except for the low-cost air mode, which negatively affects HST frequency. This finding suggests that on routes where conventional HST services are less frequent or less affordable, complementary alternatives such as low-cost HSTs, regional express trains, coaches, and carpooling play a compensatory role.

Additionally, the frequency of HST services is positively related to two variables belonging to the second category (competitive environment of routes, see 4.2.2). These variables are

SPEED_HST and *HHI_TRAIN_CTRD*. Regarding the *SPEED_HST* variable, it aligns with the main complaints and recommendations made in the Court of Auditors report (2014): a HST service should operate on a dedicated infrastructure with minimal stops. The positive sign associated with the variable *HHI_TRAIN_CTRD* indicates that on routes with a more diversified range of rail products than others, the frequency of conventional HST services will be lower, all else being equal. This relates to the concept of alternative substitutable offers in the intramodal case.

Lastly, explanatory factors for the frequency of HST services in the third category (economic and demographic environment, cf. 4.2) include the size of the origin and destination cities (*POP_MEAN*), the share of young people aged 15 to 29 years old (*YOUNG_MEAN*), and the share of people aged 60 to 74 years old (*SENIOR_MEAN*). The results align with expectations. The negative sign associated with the variables *YOUNG_MEAN* and *POP_MEAN* does not suggest reduced mobility needs but rather a preference for alternative, more flexible, and affordable modes of transport. On the other hand, the positive coefficient associated with the *SENIOR_MEAN* variable reflects the attachment of this population category to conventional HST services. Finally, the observed negative correlation might reflect the incumbent's Malthusian approach of managing capacity to exert upward pressure on demand and maximize profits, as suggested by Crozet (2022).

These results should not obscure the limitations inherent in our study, which predominantly stem from two distinct categories: data collection from booking sites and a more refined analysis by time of day and by route. For the former, we gather posted prices from various websites, not the actual prices paid by customers, for bookings made seven days prior to the departure of HST on a typical non-holiday Tuesday. We are aware that price variability can result from data collections on different days or times, or from data collected on the departure day. The data is consistently gathered using the same methodology, safeguarding against erratic variations, yet likely masking numerous phenomena. Regarding the latter limitation, the number of lines and observations does not allow for more detailed econometric analyses by time of day or by route. Nonetheless, we have endeavoured to provide descriptive insights that may illuminate the observed differences.

The analysis of the determinants affecting the pricing of both first and second-class conventional high-speed train (HST) services, as well as their frequencies, yields significant insights into the key influencing factors. This study underscores the critical roles of three main categories of variables: the technical characteristics of the routes, the competitive environment, and socio-economic and demographic factors. It further highlights the importance of intermodal competition and the effects of the existing rail operator's range diversification strategies.

6. Conclusion

In this pre-COVID-19 pandemic study, which was conducted before the liberalization of the French rail market, we used an original database to analyze the factors influencing prices and frequencies of conventional HST services in France, covering both first and second-class categories. The results revealed a combination of common and specific determinants that affect the price per kilometer of conventional HST services.

Among the common influences were factors related to the technical characteristics of the route and alternative transportation options. On the other hand, the competitive environment, economic conditions, and demographic factors showed specific effects. Interestingly, the study found that travel time played a pivotal role as the primary determinant of service frequency.

Moreover, the study highlighted the presence of alternative complementary offerings that aimed to compensate for the insufficient service quality of conventional HSTs on certain routes. These alternatives primarily included low-cost HSTs, coaches, and carpooling. Additionally, when round trips within a day were not feasible via HST, a substitute option in the form of low-cost flights was emerging.

The results underscore the multi-product strategy adopted by the incumbent, which diversifies offerings more on routes with higher potential demand. However, there remains room for increased frequency. The incumbent's strategy appears aimed at discriminating demand to maximize profits and to fill all available slots to deter new competition. Clearly, there is room for new operators on these routes to offer HST services, thereby increasing overall frequency. Conversely, on routes with smaller market potential where a less diversified offer is observed, new entrants could find opportunities overlooked by the incumbent.

Finally, this research has several limitations that future studies could address. For instance, incorporating an analysis of the demand side would complement our supply-focused approach, allowing for an exploration into mode substitutability and price and frequency elasticities. Also, enlarging the dataset to encompass a broader spectrum of relationships would provide more insight into socio-economic variability. Furthermore, examining service patterns across multiple days would offer a clearer picture of operational strategies. Lastly, our analysis was confined to Origin-Destination flows without considering the effect of intermediate train stops and market subdivisions, which could also inform a more nuanced understanding of operator strategies.

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Appendices

Tab. A0: Raw descriptive statistics for the route Brussels – Paris

Brussels – Paris		**Obs.**	**Mean**	**Min.**	**Max.**
Rail (conventional HST: Thalys)	2nd class price	294	92.2	45	99
	1st class price	294	116.2	115	145
	Frequency (per day)	294	22.6	21	23
	Number of seats (per day)	294	17 911	16 632	18 216
	Distance	294	322	322	322
	Travel time	294	1:22:00	1:22:00	1:22:00
Rail (low-cost HST: Ouigo)	2nd class price	-	-	-	-
	1st class price	-	-	-	-
	Frequency (per day)	-	-	-	-
	Number of seats (per day)	-	-	-	-
	Travel Time	-	-	-	-
Rail (HST excluded: IZY)	2nd class price	12	20.6	19	39
	1st class price	-	-	-	-
	Frequency (per day)	12	1	1	1
	Number of seats (per day)	12	393	393	393
	Distance	12	322	322	322
	Travel time	12	2:48:51	2:23:00	3:09:00
Bus (all operators)	Price	392	13.1	9	40
	Frequency (per day)	392	30.1	26	39
	Number of seats (per day)	392	1 507.6	1 300	1 950
	Distance	392	322	322	322
	Travel time	392	4:28:26	3:45:00	6:50:00
Air (all operators)	Price	25	389.2	287	542
	Frequency (per day)	25	1.9	1	2
	Number of seats (per day)	25	288.4	150	300
	Distance	25	240	240	240
	Travel time	25	00:55:00	00:55:00	00:55:00
Carpooling	Price	60	25.4	13	38
	Frequency (per day)	60	5.45	2	9
	Number of seats (per day)	60	16.3	6	27
	Distance	60	307.8	265	322
	Travel time	60	3:30:41	1:51:00	5:40:00

Tab. A1: Raw descriptive statistics for the route Lyon – Paris

Lyon - Paris		**Obs.**	**Mean**	**Min.**	**Max.**
Rail (conventional HST: Inoui)	2nd class price	289	88.6	23	97
	1st class price	289	130.2	49	142
	Frequency (per day)	289	22.2	22	23
	Number of seats (per day)	289	22 675.3	22 440	23 460
	Distance	289	466	466	466
	Travel time	289	2:00:21	1:53:00	2:14:00
Rail (low-cost HST: Ouigo)	2nd class price	138	21.4	10	79
	1st class price	-	-	-	-
	Frequency (per day)	138	10.4	8	11
	Number of seats (per day)	138	13 265.2	10 144	13 948
	Distance	138	493.9	466	507
	Travel Time	138	1:51:57	1:43:00	2:03:00
Rail (HST excluded: regional train)	2nd class price	51	65	65	65
	1st class price	-	-	-	-
	Frequency (per day)	51	3.9	3	5
	Number of seats (per day)	51	2 824.6	2 160	3 600
	Distance	51	466	466	466
	Travel time	51	5:21:00	5:21:00	5:21:00
Bus (all operators)	Price	296	17.2	5	79
	Frequency (per day)	296	22.8	21	26
	Number of seats	296	1 142.3	1 050	1 300
	Distance	296	466	466	466
	Travel time	296	6:21:25	5:35:000	7:30:00
Air (all operators)	Price	95	174.3	114	398
	Frequency (per day)	95	7.3	5	8
	Number of seats (per day)	95	1 096.1	750	1 200
	Distance	95	466	466	466
	Travel time	95	1:09:22	1:05:00	1:10:00
Carpooling	Price	243	36.7	17.5	54.5
	Frequency (per day)	243	18.6	9	38
	Number of seats (per day)	243	56	27	114
	Distance	243	466.4	384	486
	Travel time	243	4:47:42	4:10:00	6:10:00

Tab. A2: Raw descriptive statistics for the route Toulouse – Paris

Toulouse – Paris		**Obs.**	**Mean**	**Min.**	**Max.**
Rail (conventional HST: Inoui)	2nd class price	57	54.7	34	121
	1st class price	57	95	45	173
	Frequency (per day)	57	4.3	3	5
	Number of seats (per day)	57	2,236.1	1,530	2,550
	Distance	57	818	818	818
	Travel time	57	4:24:06	4:10:00	4:28:00
Rail (low-cost HST: Ouigo)	2nd class price	11	25.2	19	45
	1st class price	-	-	-	-
	Frequency (per day)	11	1.2	1	2
	Number of seats (per day)	11	774.8	634	1,268
	Distance	11	818	818	818
	Travel Time	11	4:41:11	4:33:00	4:53:00
Rail (HST excluded: Intercity, Night Intercity)	2nd class price	47	26.8	15	86
	1st class price	47	48.4	23	130
	Frequency (per day)	47	3.6	3	4
	Number of seats (per day)	47	1,541.4	1,203	1,753
	Distance	47	683	683	683
	Travel time	47	7:11:47	6:42:00	8:13:00
Bus (all operators)	Price	91	20.2	10	45
	Frequency (per day)	91	7	7	7
	Number of seats	91	350	350	350
	Distance	91	683	683	683
	Travel time	91	9:19:00	9:00:00	9:50:00
Air (all operators)	Price	467	248.7	40	515
	Frequency (per day)	467	35.9	34	38
	Number of seats (per day)	467	5,388.4	5,100	5,700
	Distance	467	683	683	683
	Travel time	467	1:24:48	1:15:00	1:40:00
Carpooling	Price	86	51.3	36.5	78
	Frequency (per day)	86	6.8	3	15
	Number of seats (per day)	86	20.4	9	45
	Distance	86	676.11	598	708
	Travel time	86	6:57:16	6:10:00	8:50:00

Tab. A3: Raw descriptive statistics for the route Bordeaux – Paris

Bordeaux – Paris		Obs.	Mean	Min.	Max.
Rail (conventional HST: Inoui)	2nd class price	253	75.4	31	111
	1st class price	253	104.3	37	175
	Frequency (per day)	253	19.4	18	20
	Number of seats (per day)	253	19,850.7	18,360	20,400
	Distance	253	585	585	585
	Travel time	253	2:10:48	2:01:00	2:34:00
Rail (low-cost HST: Ouigo)	2nd class price	48	20.6	10	49
	1st class price	-	-	-	-
	Frequency (per day)	48	3.6	3	5
	Number of seats (per day)	48	4,681.8	3,804	6,340
	Distance	48	585	585	585
	Travel Time	48	2:31:49	2:05:00	2:46:00
Rail (HST excluded: Intercity, Night Intercity, regional train)	2nd class price	-	-	-	-
	1st class price	-	-	-	-
	Frequency (per day)	-	-	-	-
	Number of seats (per day)	-	-	-	-
	Distance	-	-	-	-
	Travel time	-	-	-	-
Bus (all operators)	Price	161	20	7	49
	Frequency (per day)	161	12.3	12	14
	Number of seats	161	619.2	500	700
	Distance	161	585	585	585
	Travel time	161	8:20:43	7:00:00	12:30:00
Air (all operators)	Price	204	261.3	144	769
	Frequency (per day)	204	15.6	15	16
	Number of seats (per day)	204	2,353.8	2,250	2,400
	Distance	204	585	585	585
	Travel time	204	1:17:45	1:10:00	1:25:00
Carpooling	Price	115	45	25.5	74.5
	Frequency (per day)	115	8.6	2	11
	Number of seats (per day)	115	26	6	33
	Distance	115	590.7	528	639
	Travel time	115	6:05:50	5:00:00	9:10:00

Tab. A4: Raw descriptive statistics for the route Nice – Paris

Nice – Paris		**Obs.**	**Mean**	**Min.**	**Max.**
Rail (conventional HST: Inoui)	2nd class price	53	72.1	35	132
	1st class price	53	104.2	55	189
	Frequency (per day)	53	4	4	5
	Number of seats (per day)	53	2,079.2	2,040	2,550
	Distance	53	940	940	940
	Travel time	53	6:02:51	5:44:00	6:15:00
Rail (low-cost HST: Ouigo)	2nd class price	23	44.3	19	79
	1st class price	-	-	-	-
	Frequency (per day)	23	1.7	1	2
	Number of seats (per day)	23	1 121.6	634	1 268
	Distance	23	940	940	940
	Travel Time	23	5:51:16	5:49:00	5:57:00
Rail (HST excluded: Intercity, Night Intercity, regional train)	2nd class price	-	-	-	-
	1st class price	-	-	-	-
	Frequency (per day)	-	-	-	-
	Number of seats (per day)	-	-	-	-
	Distance	-	-	-	-
	Travel time	-	-	-	-
Bus (all operators)	Price	20	29.6	19	39
	Frequency (per day)	20	2	1	3
	Number of seats	20	100	50	150
	Distance	20	940	940	940
	Travel time	20	9:27:00	9:27:00	9:27:00
Air (all operators)	Price	361	238.5	40	555
	Frequency (per day)	361	27.7	26	30
	Number of seats (per day)	361	4,165.3	3,900	4,500
	Distance	361	940	940	940
	Travel time	361	1:31:04	1:25:00	1:45:00
Carpooling	Price	15	71.7	60	88.5
	Frequency (per day)	15	1.8	1	4
	Number of seats (per day)	15	5.6	3	12
	Distance	15	932.4	925	933
	Travel time	15	9:50:40	8:30:00	11:10:00

Appendix A5. Detailed Methodology for Dataset Construction

The 3,907 observations represent the raw data as collected. In this context, an observation corresponds to a transport service for a specific origin-destination on a given date. The transport services considered include HST, low-cost HST, regional express trains, intercity trains, flights (including those operated by low-cost carriers), long-distance buses, and carpooling. As we aim to study the determinants of first-class and second-class pricing, as well as HST frequencies while accounting for intramodal (multiproduct) competition and intermodal competition, we reprocessed the raw data. We found it initially necessary to segment the day into three periods: morning for trains departing before 9am, afternoon for trains between 9am and 5pm, and evening for trains departing after 5pm.

If one or more HST services were offered for a given day and period, we supplemented the rail offering with elements regarding alternative rail service (intramodal) and alternative modal offers (intermodal). Thus, some elements from the initial database were incorporated as variables that could explain the prices and frequencies of HSTs. The modified database reduced from 3,907 observations to 929 as mentioned in Table 4. This is not a loss of information since certain lines from the initial database (N=3907) were included in the final database (N=929).

To illustrate in more detail, if we sum the observations for the different modes and for the 5 origin-destination pairs, we obtain a total of 3,825 observations. For example, for the Brussels-Paris OD, we have a total of 783 observations (294+12+392+25+60). The difference between 3,907 and 3,825, i.e., 82 observations, is explained by the fact that for some ODs and certain times of the day, no conventional HST service was offered, rendering the observations collected for alternative modes obsolete.

Regarding the dependent variables (Table 3), we indeed find a count of 929 for frequencies. For the prices of first-class HST, we have 894 observations. This is explained by the fact that seven days before the train's departure, the HST service in this comfort class was fully booked, and no price could be collected from the website. A similar explanation applies to the prices for second-class HST, for which we have only 905 observations.

Fig. A0: Graphical analysis of residuals (SURE model)

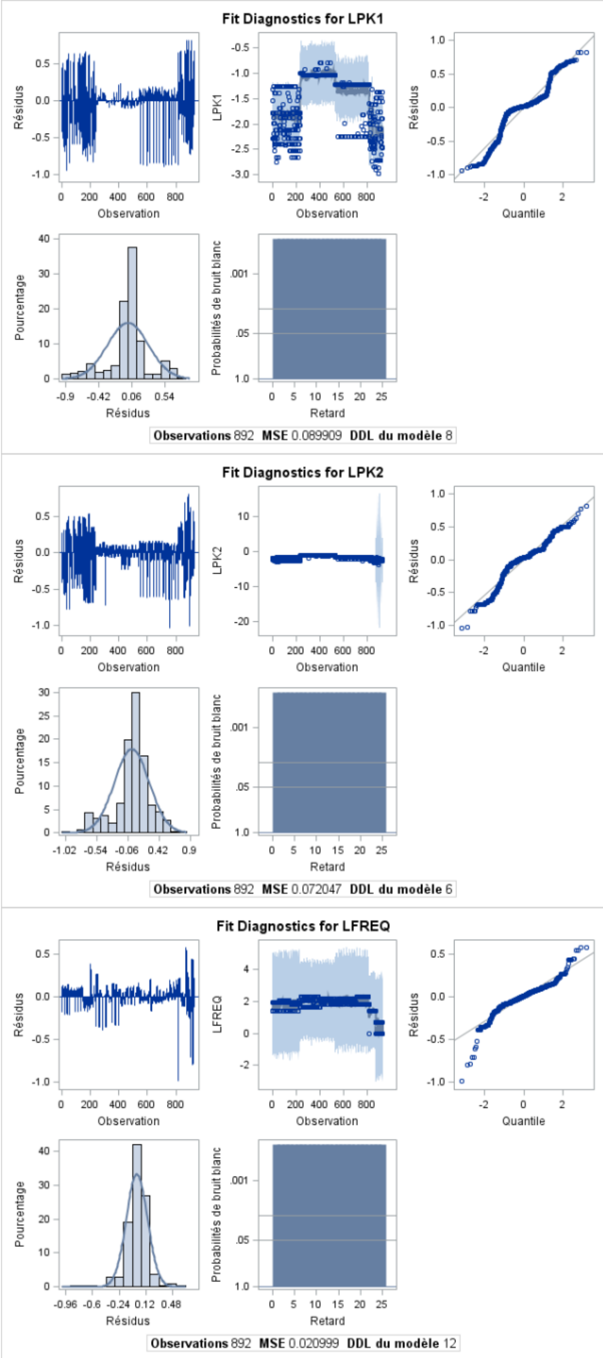


Fig. A1: Descriptive statistics - *SPEED_HST*

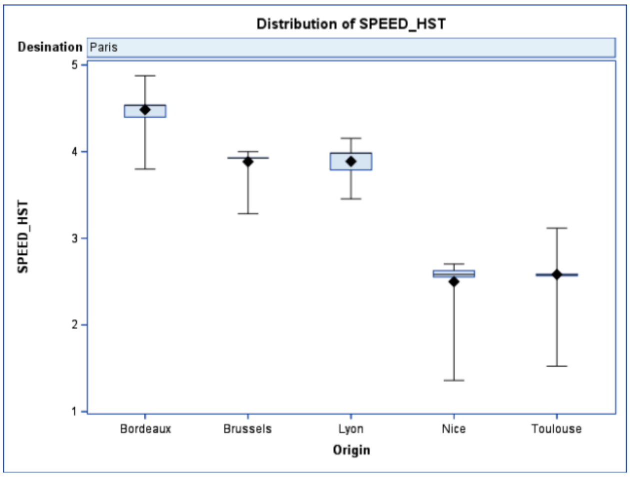


Fig. A2: Descriptive statistics - *HHI_PASS_CTRD*

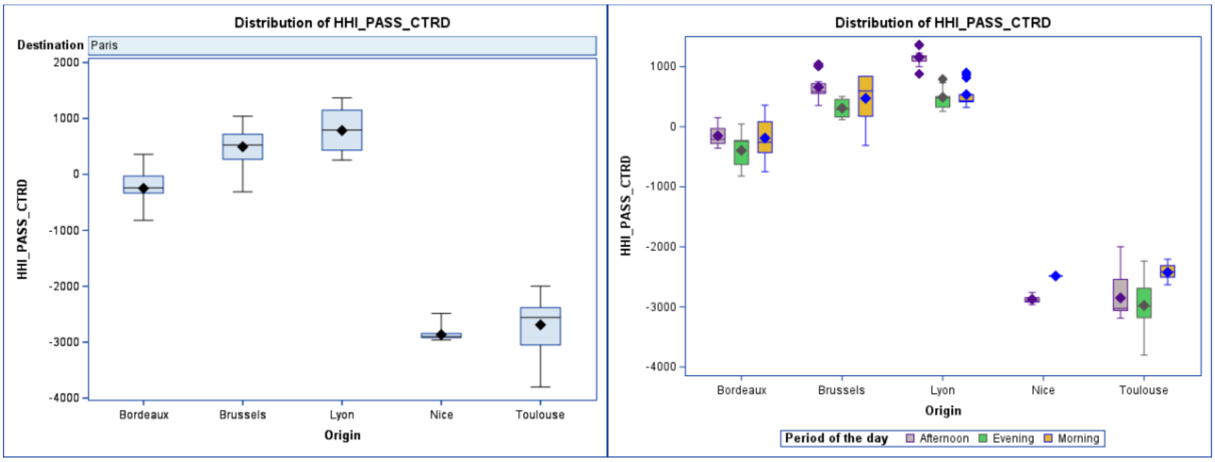
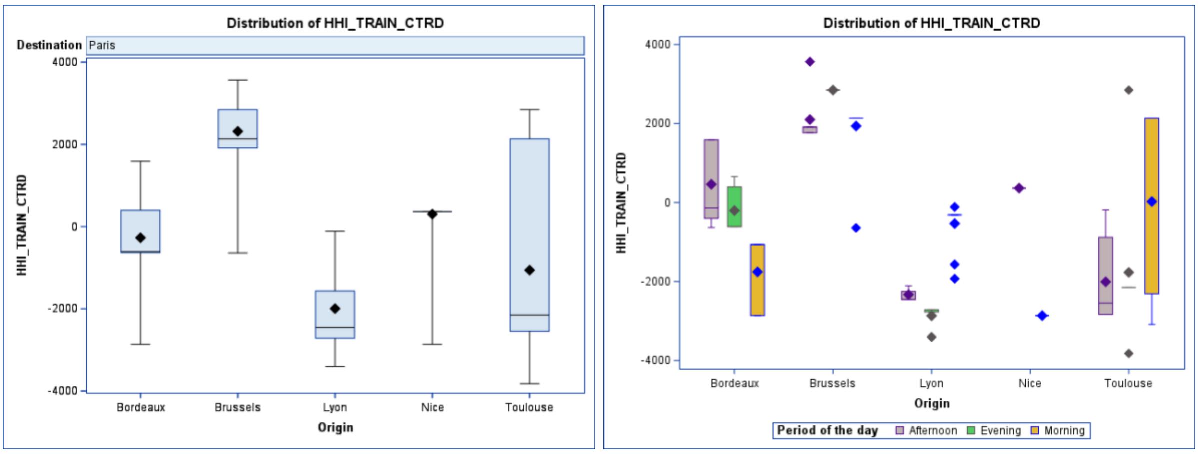


Fig. A3: Descriptive statistics - *HHI_TRAIN_CTRD*



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