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Master Thesis [programme Economics of Markets and Organisations]

Competition in rail passenger transport in Spain: Entry on the Madrid-Barcelona High-Speed Line and Ticket Prices

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The Spanish high speed rail market has been open for competition since 2020. Incumbent Renfe runs high speed trains on this route since 2008. Entrant Ouigo started its operations on the Madrid-Barcelona route in May 2021. Entrant Iryo started its operations on the Madrid-Barcelona route in November 2022. This paper studies the impact of entry from railway undertaking Iryo on the Madrid-Barcelona high speed line on average rail ticket prices on this route. The results show that average rail ticket prices decreased with 30.7 percent.

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1. Introduction

Spain has the world-second largest high speed rail network after China (see Figure 1). Madrid-Barcelona is the most important high speed line in terms of passenger ridership. However, number of daily train departures and passengers numbers were relatively low in the entire country, also compared to other modes of transport such as air transport. In order to increase ridership and to comply with EU legislation regarding open access competition and PSO, the Spanish Ministry of Transport opened up the high speed rail market for competition between the biggest cities in Spain.

As discussed by Montero and Melero (2020), congestion in the Madrid and Barcelona train stations has given the Spanish infrastructure manager *Adif* the opportunity to plan an orderly entry of competitors. The infrastructure manager created a schedule for train services throughout the day in the three most important high speed corridors in the country (i.e. Madrid-Barcelona, Madrid-Valencia/Alicante and Madrid-Sevilla/Malaga). In addition, the infrastructure manager chose to only create three packages while putting 70 percent of the overall capacity in these packages. The packages included three asymmetric bundles. 60 percent of the capacity would be designated for package A, 30 percent for package B, and 10 percent for package C. The packages would cover all three of the major high-speed routes. There were six bids and only three packages available. Hence, some applications had to be excluded (i.e. not being granted capacity), therefore railway undertakings had the incentive for strategic overbidding. Package A was won by Renfe, package B by Iryo and package C by Ouigo. There also remains capacity for another railway undertaking in the annual allocation process (i.e. 30 percent of total capacity), but it is questionable whether another competitor would be able to operate profitable given that the remaining time slots or train paths may only be during the less popular travel times. The winning railway undertakings are required to adhere to strict conditions set during the tender procedure about the routes they operate, their frequencies, timetables and stops for the next ten years.

Incumbent Renfe is operating on the Madrid-Barcelona high speed line since the opening of the line in 2009. In May 2021, entrant Ouigo started its operation on the Madrid-Barcelona high speed line. In June 2021, incumbent Renfe reacted to the entry of Ouigo by introducing its budget high speed train *Avlo*. Next, in November 2022, Iryo started its operation on the Madrid-Barcelona high speed line.

Approximately half of the train services connect Madrid and Barcelona non-stop in 2:30h, a true competitor in terms of travel time to the air route between Madrid and Barcelona which was the busiest air route in the world until the opening of het Madrid-Barcelona high speed line. Other services have different stopping patterns serving cities such as Zaragoza and Tarragona which are on the route between Madrid in Barcelona, depending on the stopping pattern increasing travel time to 2:45h and 3:12h.

The aim of this paper is to assess the impact of entry from railway undertaking Iryo on the Madrid-Barcelona high speed line on average rail ticket prices on this route. The main research question is:

> *What is the impact of entry from railway undertaking Iryo on the Madrid-Barcelona high speed line on average rail ticket prices?*

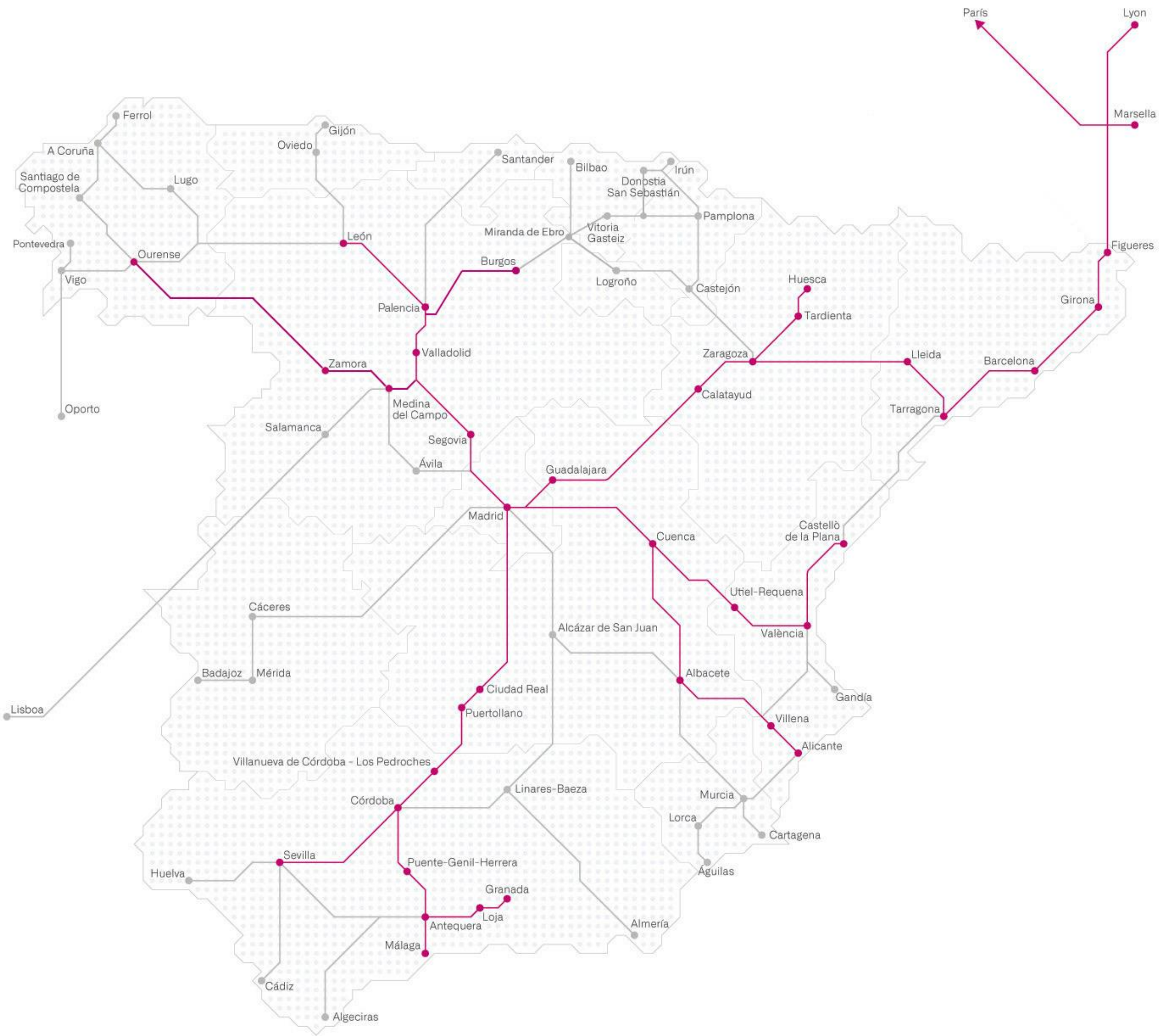
This question is answered by the following sub-questions and hypotheses:

> *What is the impact of entry from railway undertaking Iryo on the Madrid-Barcelona high speed line on average rail ticket prices for railway undertaking Renfe?*
> Hypothesis: Average rail ticket prices for Renfe decreased after entry from Iryo.
>
> *What is the impact of entry from railway undertaking Iryo on the Madrid-Barcelona high speed line on average rail ticket prices for railway undertaking Ouigo?*
> Hypothesis: Average rail ticket prices for Ouigo decreased after entry from Iryo.
>
> *What is the impact of entry from railway undertaking Iryo on the Madrid-Barcelona high speed line on average rail ticket prices for all railway undertakings?*
> Hypothesis: Average rail ticket prices for all railway undertakings decreased after entry from Iryo.
>
> *How do average rail ticket prices evolve over time for several numbers of days ahead of departure?*
> Hypothesis: Average rail ticket prices increase with a convex function when the departure date in approaching.
>
> *How do average rail ticket prices change over time before and after the point that Iryo entered the Madrid-Barcelona high speed line?*
> Hypothesis: Average rail ticket prices decrease over time, both in the period before entry of Iryo (i.e. anticipation to entry) and in the period after entry of Iryo (i.e. indication for price war).

Publicly available data on rail ticket prices is very scarce or non-existent. This makes it difficult or impossible to evaluate governmental policies on railway markets and make recommendation on what model suits best under which conditions. For this paper the author collected a unique dataset on rail ticket prices on the Madrid-Barcelona high speed line. This paper shows that average rail ticket prices for all railway undertakings on the Madrid-Barcelona high speed line decreased as a result of tightened competition by the entry of Iryo on this route. This paper does not study the entry of Ouigo in May 2021.

This paper as organized as follows: section 2 contains a literature review, section 3 describes the data, section 4 discusses the methodology, section 5 presents the results and sections 6 includes the discussion and conclusions.

Figure 1. The long-distance railway network in Spain. The pink lines are high speed lines. Source: renfe.com



2. Literature review

The European economy benefits greatly from the railway industry. Numerous societal goals are also achieved by rail, including connectivity and serving as an alternative to air and land transportation. This substantial contribution makes the rail market a subject of public interest. In the majority of nations, railways were managed by public control that was upheld by the legislation (Feuerstein et al., 2018). As a result, the railways are still publicly owned and governed in many nations. Due to their assumed economies of scale, vertically integrated railway businesses were perceived as a monopoly (Beria et al., 2012). However, this perception has changed, and today the only thing still viewed as a monopoly is the rail infrastructure. Since the management and ownership of the network infrastructure are separated from the provision of services, competition is now a possible (Alexandersson, 2009).

In Europe, there has historically been little competition in the rail industry. Efficiency brought on by competition ought to result in reduced prices and improved connectivity. However, market characteristics that favour a monopoly, such as the availability of train paths, market potential, low profitability, infrastructure costs, and access to rolling stock, frequently disregard theories of competition. Only recently has there been more widespread open competition. In order to expand rail markets for services, the EU introduced four legislative packages between 2001 and 2016. Governments and networks will need to comply with additional requirements starting in 2023 before direct PSOs can be granted. The packages also involve the liberalization of the domestic and international passenger markets to new competitors. Businesses would have the option of providing competing services or participating in competitive tendering for PSOs. This law has already been partially or fully adopted in numerous nations. At the time of writing, almost half of European nations permit open access competition, albeit this is only the case in a small number of them (Casullo, 2016). Contrarily, PSO contracts through competitive tendering are somewhat more typical in regional travel and seldom ever occur in long distance transit.

Two types of competition exist in high speed rail services: open access competition and competitive tenders for PSO contracts. Operators compete in tender-based competition by bidding for the sole monopoly rights to run every service on a certain market (i.e., competition for the market). Open access competition is market competition in which operators compete simultaneously for the same customers on the same tracks and along the same routes. PSO contracts are less common in Europe in long-distance traffic compared to open access competition.

In Europe, there are two different types of open access competition. The first is niche market competition, which is evident in Germany and the UK. According to research, open access competition in the UK was severely controlled and inefficient in order to protect the PSO contracts' financial stability (Jones, 2000). Potential competitors must demonstrate that they are supplying a new market and will not compete with already established franchisees for customers. As a result, there is no actual direct competition in the open access environment. According to Tomes et al. (2016), Germany segmented its domestic rail market into regional submarkets and the long distance market. Regional markets frequently receive grants and subsidies through competitive tendering under PSO contracts. Under open access competition, the long distance market is completely liberalized and is not subsidized. However, the market leader Deutsche Bahn currently holds a 99% market share (Deville & Verduyn, 2012). There were eleven new operator entries starting in 1994 (Séguret, 2009). Due to expensive infrastructure costs, the covert integration of long distance and regional transport, and DB's prejudice against new competitors, the majority of them failed and only two carriers are currently functioning and operating on a small number of routes.

The admission of a competitor onto a major rail line with significant demand and passenger numbers is the second type of open access competition. In this case, providers do compete simultaneously for the same clients on the same route. Examples are to be found on several countries in Europe. For example, open access is permitted across the whole network in Sweden. However, open access only runs on a few routes because of the low profitability. Since 2010, two railway undertaking entered the Stockholm-Göteborg railway line and the Stockholm-Malmö railway line. Train intermodal market share climbed and prices dropped, however the newcomer ceased operations in Sweden after two years (Fröid and Byström, 2013). On the Stockholm-Göteborg route, MTR entered the Swedish market in 2015 and is now successfully competing with incumbent SJ (Vigren, 2017). On the high speed lines in Italy, open access competition started in 2013. Due to this, rates were reduced by almost 30%, the frequency of the service was increased, the quality of the service improved, and the number of passengers increased significantly (Cascetta & Coppola, 2014). Open access is also used on the main line connecting Vienna and Salzburg in Austria. Due to competition, this line's frequency rose and the new competitor provided lower fares. In addition, this study notes that. On the other hand, businesses that operate under open access are sometimes unprofitable since competition frequently leads to price wars that are unwinnable and a loss of scale advantages that forces one of the competitors out of business. For instance, RegioJet left the market in Slovakia in 2017 as a result of the lack of sustained profitability (Kvizda, 2019). In line with this, despite new competitors' lower unit costs than market leaders, on-track competition has not resulted in substantial efficiency gains. This increases the pressure on operators who compete in an open access market to maintain their viability.

3. Data

Available data on ticket prices in long distance rail passenger transport is very limited. This also holds for Spain. The Ministry of Transport publishes quarterly reports on passenger numbers and ticket prices (e.g. CNMC, 2023). The reports summarize the developments in the Spanish railway market and evaluate the policy of the introduction of competition on the Madrid-Barcelona high speed line on a very general level. However, the data behind the reports is not publicly available and, hence, the reports are not suitable for extensive research into the effects of competition on rail ticket prices. For example, the reports do not provide insight in daily or even weekly ticket prices, individual trains and prices on different days to departure. In order to thoroughly evaluate the Spanish policy regarding introducing competition on the Madrid-Barcelona high speed line more extensive data is needed.

For the analyses in this paper, a unique dataset has been created by the author. In Spain, it is common to book train tickets online at the websites from the railway undertakings. Tickets for Renfe, Ouigo and Iryo can be bought at renfe.com, ouigo.com/es and iryo.eu, respectively. Previous research in other countries such as Italy, Sweden and CZ used web crawlers to obtain ticket price data from online booking sites from railway undertakings. This means that for every departure during a particular period the lowest available price was collected by requesting a corresponding booking enquiry. However, a trial for using a web crawler on renfe.com was unsuccessful and lead to an error message in Spanish that could be freely translated to 'the website is currently not available'. On another device at the same time, it was indeed possible to book train tickets at renfe.com without the web crawler. This suggests that Renfe blocks unusual booking enquiries.

Thus, without the option of using a web crawler, the price data had to be collected manually by making reservation requests on the websites of the railway undertakings Renfe, Ouigo and Iryo, but quitting the booking process before selecting a journey and continuing to the payment page. With the booking requests, for each train departure the lowest available ticket price was collected, based a one-way ticket for an adult without reduction, direct high speed trains only, ticket valid on one specific departure only, non-exchangeable and non-refundable[1]. In general, the price that is collected is for the lowest fare or travel class. But if the lowest fare or travel class on a particular departure was sold out, the ticket price for the next available fare or travel class on that specific departure was collected. If a particular train was fully booked, this was collected in the dataset instead of a ticket price. Ticket prices were collected in both directions, hence, from Madrid to Barcelona and from Barcelona to Madrid. Intermediate stops such as Zaragoza and Tarragona were ignored, as well as *Media Distancia*

[1] Depending on the ticket conditions of the railway undertakings. In general, the lowest fare or travel class are non-refundable and non-exchangeable. In general, higher fares or travel classes are refundable and exchangeable for a fee.

services that do not run via the high speed line but via the old line. Also observations for Renfe's budget high speed service *Avlo* were included in the sample. Price level is set to the booking date. Every day in the period from 26 September 2022 up to and including 26 January 2023 booking requests were made for all railway undertakings in operation. This is called the booking date. From 26 September 2022 up to and including 24 November 2022 only Renfe and Ouigo were operating trains on the Madrid-Barcelona high speed line. Iryo started operating revenue services on 25 November 2022, which means that from 25 November 2022 up to and including 26 January 2023 all three carriers Renfe, Ouigo and Iryo were in operation. In the dataset distinction is made between travel date and booking date. The travel date is the date of departure, while the booking date is the date on which a booking request was made. The difference between travel date and booking date is the number of days to departure. Ticket price data was collected for multiple booking horizons, i.e. 1 day to departure, 3 days to departure, 1 week to departure, 1 month to departure and 2 months to departure. This means that at every (booking) day from 26 September 2022 up to and including 26 January 2023 data was collected for these five periods to departure. As a result, the lowest available ticket price for every train departure in the period from 26 November 2022 up to and including 26 January 2023 is observed five times before the train departs, namely for 2 months ahead of departure, 1 month ahead of departure, 1 week ahead of departure, 3 days ahead of departure and 1 day ahead of departure. This also implies that for travel dates before 26 November 2022 and after 26 January 2023 not all different booking horizons (similar to days to departure, also used in this paper) have been observed (e.g. data collection started at 26 September 2022, so for trains on 30 September 2022 there is data 1 day to departure and 3 days to departure but there is no data 1 week to departure, 1 month to departure and 2 months to departure).

Hence, for Renfe, Ouigo and Iryo, in every booking request at a specific booking date the lowest available ticket price for a specific train departure at a specific travel date is collected, as well as the railway undertaking that is operating the train, the number of days to departure for which the ticket price is collected and the travel direction (Madrid-Barcelona or Barcelona-Madrid). The data has been processed with Excel and Stata.

In order to identify the effect on rail ticket prices of the entry of Iryo on the Madrid-Barcelona high speed line, price data on other routes than the Madrid-Barcelona line would have been valuable, for example, to control for time fixed effects to account for e.g. demand shocks and change in governmental transport policies. Comparable lines in terms of market and services to the Madrid-Barcelona high speed lines are the Madrid-Valencia, Madrid-Alicante, Madrid-Sevilla and Madrid-Malaga high speed lines. Unfortunately, this data has not been collected. The most important reasons are that (i) those high speed lines are included in the market packages that were tendered by the

Spanish Ministry of Transport and thus treated (i.e. entry of Ouigo and Iryo) as the Madrid-Barcelona high speed line, and (ii) collecting this data manually would have been impracticable. All other railway lines in Spain are under PSO with regulated ticket prices and hence not suitable to use as control data.

In Table 1a, 1b and 1c the descriptive statistics for the data that is collected on het Madrid-Barcelona high speed line are shown for railway undertakings Renfe, Ouigo and Iryo, respectively. Data from the entire booking day period from 26 September 2022 up to and including 26 January 2023 is included in the descriptive statistics, not separating the pre-entry and post-entry periods regarding the entry of Iryo on 25 November 2022. The prices and departures include both travel directions (Madrid-Barcelona and Barcelona-Madrid). This should be interpreted so that the displayed statistics aggregate both travel directions and the number of daily departures includes both directions. For example, the average of 41 daily departures for Renfe is the number of trains that runs daily from Madrid to Barcelona and from Barcelona to Madrid in total. Hence, the average number of trains that runs daily from Madrid to Barcelona and is operated by Renfe approximates 20.

The first column presents the number of days to departure for which a price is observed, with the full sample shown in the last row. The second column presents the average ticket price in euro. Average ticket prices for Renfe seem to be higher than average ticket prices for Ouigo and Iryo, for all number of days to departure. Average prices of Ouigo and Iryo seem to be approximately equal. The third column shows the median of the ticket price. As with the average price, prices for Renfe seem higher than prices for Ouigo and Iryo. The fourth column presents the standard deviation. The fifth column shows the minimum ticket price that corresponds to a particular number of days to departure. Minimum prices for Renfe seem to be lower than minimum prices for Ouigo and Iryo. This may be explained by the small number of budget *Avlo* high speed trains that Renfe is running next to its regular *AVE* high speed trains, with its aggressive pricing strategy to compete with the on average lower prices for Ouigo and Iryo services. The sixth column presents the maximum ticket price that corresponds to a particular number of days to departure. Maximum prices for Renfe seem to be higher than maximum prices for Ouigo and Iryo. It must be noted that fully booked trains are collected in the dataset but without a ticket price and those observations were dropped for the regression analyses. Right before a train sells out, ticket price is at its maximum but this price is not observed when the train has sold out. This implies that the collected ticket price averages are negatively biased, in other words: the price averages in this paper are conservative or lower than what they would have been in reality.

In the next columns the number of daily departures is shown. Matching the tender packages in which the total available capacity for train paths was divided in the market, Renfe runs approximately 60 percent of all trains (this does not equal market share by definition! That depends on the load factor, more on this in section 4.1). Ouigo and Iryo run approximately 10 and 30 percent of all trains, respectively. On weekends and holidays all railway undertakings may run a reduced schedule, which is shown in the tables. There are also busy days on which more train run. In particular, Renfe expends its schedule relatively more than Ouigo and Iryo on these days. Renfe is by definition of the tender packages Renfe allowed to run 32 daily trains per direction (thus 64 in total), Ouigo 5 per direction (thus 10 in total) and Iryo 16 per direction (thus 32 in total). Mind that the railway undertaking may not have bidden full capacity in the tender for the capacity packages, which may put restrictions on additional trains operators would like to run. Hence, it cannot be concluded that railway undertakings choose their supply as a strategic variable in the market; the Spanish Ministry of Transport and the railway undertakings did this during the tendering process for the market. The number of daily trains is a result of this tendering process for the market and not a result of strategic behaviour in the market, e.g. to deter entry. The last column shown the number of observations. Since Renfe runs more trains than the other railway undertakings, there are more observations for Renfe compared to Ouigo and Iryo. Iryo has more observations which were made 2 months ahead of departure. This is caused by the set up of the data collection procedure. Last, differences in the number of observations may be caused by missing observations as a result of, for example, labour union strikes; maintenance on booking site; and ticket sales that have not been opened yet or been temporarily closed due to waiting for definitive timetable regarding engineering works).

Table 1a. Characteristics Renfe between 26 September 2022 and 26 January 2023.

	Price (in €)					Daily departures				
Days to dep.	Avg.	Med.	SD.	Min.	Max.	Avg.	Med.	Min.	Max.	Obs.
1 day	99	94	38	9	232	41	40	30	52	3,763
3 days	93	91	36	5	232					4,313
1 week	80	80	33	7	233					4,867
1 month	68	68	28	9	196					4,283
2 months	56	57	26	7	161					4,969
Full sample	78	80	36	5	233					22,195

Table 1b. Characteristics Ouigo between 26 September 2022 and 26 January 2023.

	Price (in €)					Daily departures				
Days to dep.	Avg.	Med.	SD.	Min.	Max.	Avg.	Med.	Min.	Max.	Obs.
1 day	59	55	28	15	139	10	10	8	10	1,013
3 days	53	45	27	15	139					1,130
1 week	46	39	23	6	139					1,158
1 month	36	29	17	15	119					944
2 months	30	25	14	9	139					1,114
Full sample	45	39	25	6	139					5,359

Table 1c. Characteristics Iryo between 26 September 2022 and 26 January 2023.

	Price (in €)					Daily departures				
Days to dep.	Avg.	Med.	SD.	Min.	Max.	Avg.	Med.	Min.	Max.	Obs.
1 day	46	46	17	15	102	18	18	8	20	894
3 days	42	38	17	14	99					946
1 week	41	38	17	14	116					1,095
1 month	39	37	17	11	103					1,154
2 months	30	28	13	14	122					2,188
Full sample	38	36	17	10	122					6,395

The daily average ticket price for each railway undertaking with booking date in the period from 26 September 2022 up to and including 26 January 2023 is shown in Figure 2a-e. Every figure corresponds to a particular number of days to departure, for which the observations of the ticket prices have been made. As the railway undertakings are profit maximizing companies, daily average ticket prices differ over the days. On days with more demand for travel (e.g. Fridays, Sundays and days around Holidays) prices tend to be higher than on other days. For each booking horizon, as also became clear in Table 1a-c, average ticket prices for Renfe seem higher than for Ouigo and Iryo. There is no indication that the prices for Renfe converge to the prices for Ouigo and Iryo when the booking date is approaching the travel date. On the other hand, average ticket prices for Ouigo and Iryo seem approximately similar on most days which could indicate that Ouigo and Iryo engaged in aggressive price competition. Over time, especially after the entry of Iryo, for all booking horizons, a decreasing trend in average ticket prices of all railway undertakings can be observed, again indicating that the railway undertakings have engaged in price competition. It is also indicated that price peaks on busy travel dates (e.g. around the Christmas and New Year Holiday) are lower after entry of Iryo compared to the situation before its entry, holding for all booking horizons.

Figure 2a. Daily average prices for Renfe, Ouigo and Iryo, 1 day to departure.

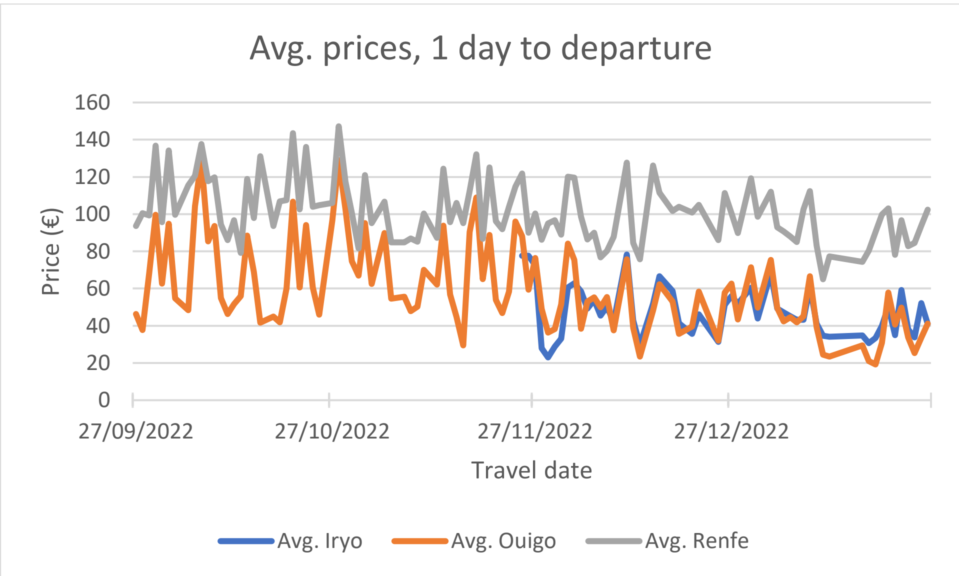


Figure 2b. Daily average prices for Renfe, Ouigo and Iryo, 3 days to departure.

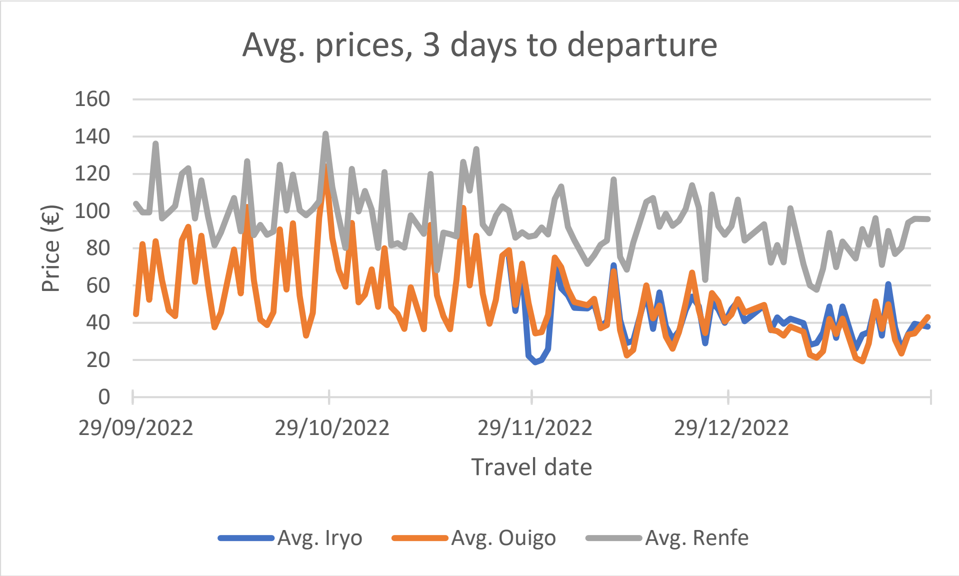


Figure 2c. Daily average prices for Renfe, Ouigo and Iryo, 1 week to departure.

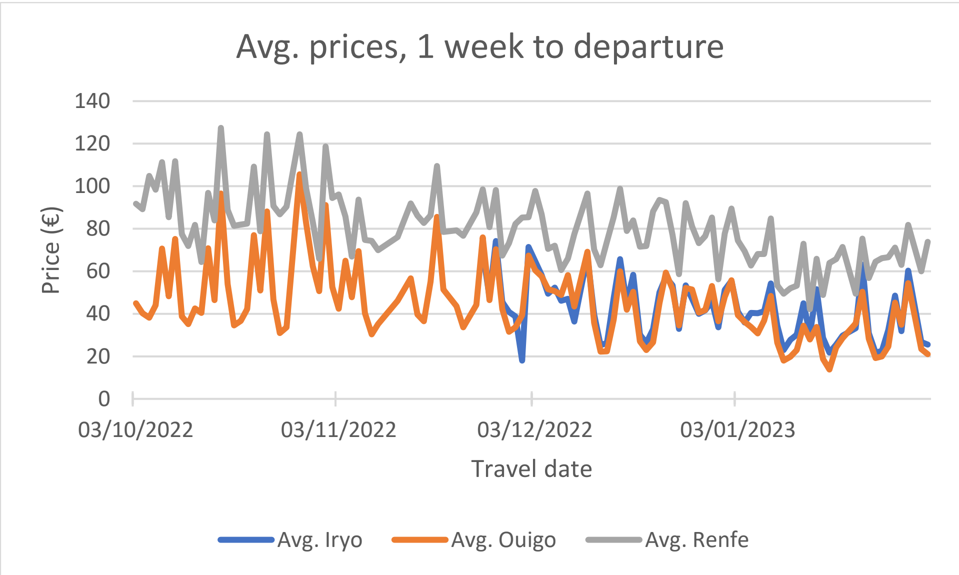


Figure 2d. Daily average prices for Renfe, Ouigo and Iryo, 1 month to departure.

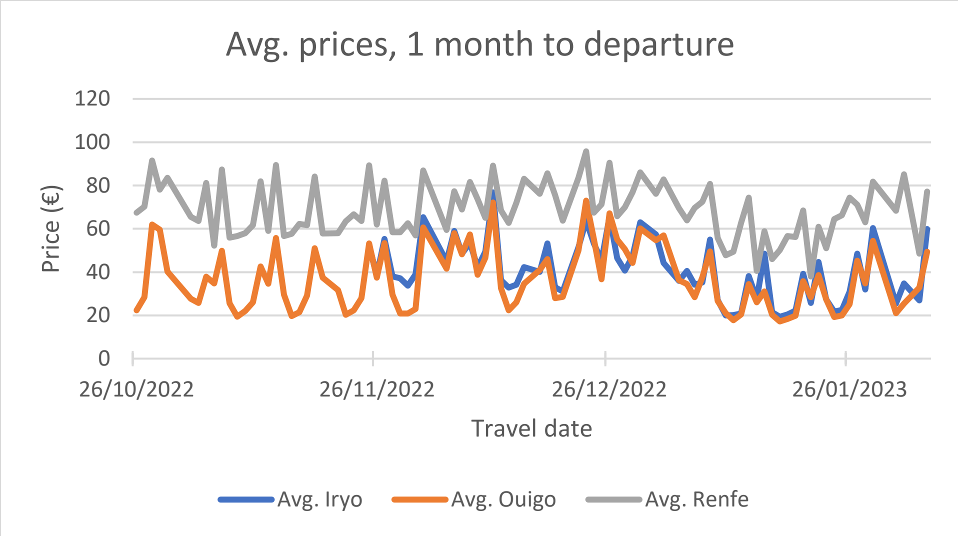
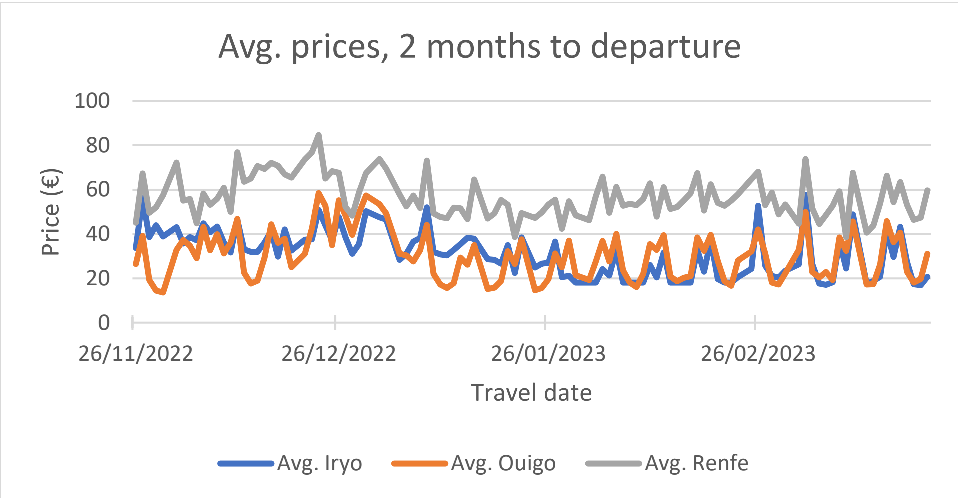


Figure 2e. Daily average prices for Renfe, Ouigo and Iryo, 2 months to departure.



Visual inspection of the graphs in Figure 2a-e indicates that the ticket prices of Renfe, Ouigo and Iryo are related. In Table 2 the correlation among the lowest available prices for each departure for Renfe, Ouigo and Iryo is presented. Every row represents a number of days ahead of departure for which data was collected and also the correlation for the full sample is shown. The correlation among ticket prices provides insight in the relationship between ticket prices among carriers and thus strategic pricing behaviour. For computation of the correlation coefficients, a pairwise correlation approach between the railway undertakings was followed among the average price for all departures on a particular day, given the booking horizon of full sample. All correlation coefficients are significant at 1 percent level. The highest correlation is found among Ouigo and Iryo ticket prices, which is consistent with Figure 2a-e. This suggest an intense strategic reaction on ticket pricing behaviour between those two carriers. The correlation among Renfe and Ouigo ticket prices and among Renfe and Iryo ticket prices is present but not as high as the correlation among Ouigo and Iryo ticket prices. This may indicate that incumbent Renfe is not as strongly engaging as Ouigo and Iryo in strategic pricing behaviour, although the presented correlation coefficients among Renfe prices are still substantial. For future research it is recommended to also consider the correlation among lagged ticket prices, so that conclusions can be drawn whether railway undertakings take into account competitor's ticket prices from the previous period when setting own prices. It must also be noted that as part of yield management of the railway undertakings a major share of the correlation among ticket prices for different railway undertakings may be explained by natural price peaks on busy travel days (e.g. Fridays, Sundays and Holidays) and lower prices on less busy travel days (e.g. normal weekdays) and not by strategic price interaction among carriers. In addition, there is no indication that the correlation among railway undertakings is higher when the day of departure is approaching and thus there is no indication that competition is tightening shortly ahead of departure.

Table 2. Correlation among ticket prices for Renfe, Ouigo and Iryo.

	Correlation		
Days to departure	Renfe-Ouigo	Renfe-Iryo	Ouigo-Iryo
1 day	0.769***	0.641***	0.817***
3 days	0.796***	0.552***	0.849***
1 week	0.798***	0.670***	0.919***
1 month	0.739***	0.759***	0.922***
2 months	0.622***	0.620***	0.697***
Full sample	0.814***	0.683***	0.864***

*** p<0.01, ** p<0.05, * p<0.1

4. Methodology

In order to identify the impact from the entry of railway undertaking Iryo on the Madrid-Barcelona high speed line on the ticket prices for all carriers that operate on this line, several OLS regressions were run using different formats of the data as described in section 3.

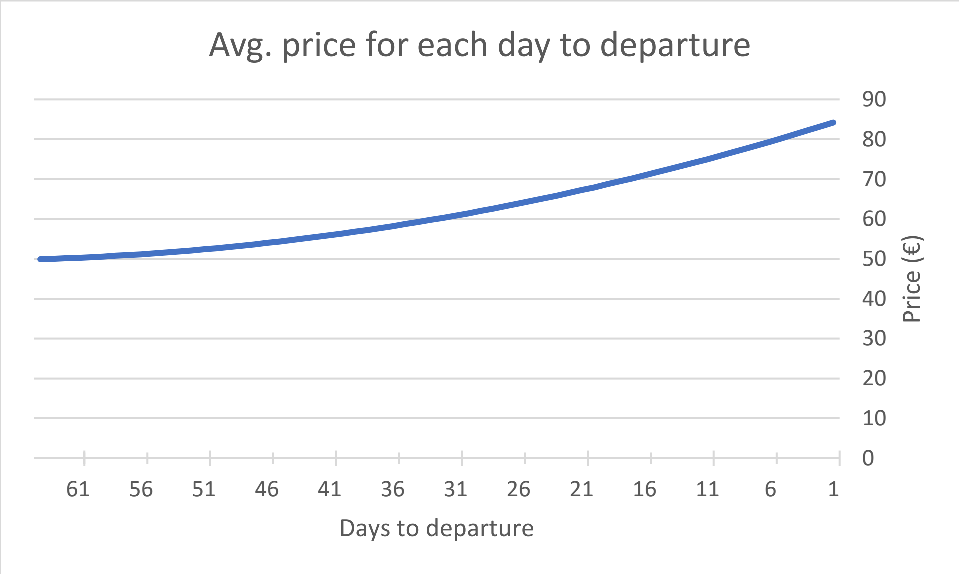
First, the pricing of the railway undertakings before and after entry of Iryo was investigated separately. In order to do this, a regression was run for each railway undertaking: equation (1) for Renfe, equation (2) for Ouigo and equation (3) for Iryo, each with formatted data only including the observations for the relevant railway undertaking. Let $\ln(P_{citd})$ be the logged price of a ticket for railway undertaking c, with train or departure time i, on departure date t, observed d days ahead of departure. α is a constant. For equations (1) and (2) only, let $Entry_{cit}$ be a treatment dummy variable with value 1 from date $t = T$, where T equals 25 November 2022, the moment that Iryo starts operating trains on the Madrid-Barcelona high speed line, and 0 otherwise. Hence, the corresponding coefficient indicates the average price change for train tickets after the entry of Iryo, in equation (1) the price change in Renfe tickets is measured and in equation (2) the price change for Ouigo tickets. In equation (3), no dummy treatment variable measuring the average price change after entry of Iryo is included because, logically, price data for Iryo is only observed after entry of Iryo and including the dummy treatment variable would have lead to omission of this variable. The variables Day and Day^2 account for the days to departure at the moment of observation (the difference between booking date and travel date) and its square. In much previous research (e.g. Vigren, 2017) this combination of Day and its squared is used to account for the negative correlation between price and booking day, to be specific: the convex linear relationship that is shown in Figure 3. It is often found that booking a train ticket further ahead of departure gives a lower ticket price than booking a train ticket shortly before departure, e.g. caused by the increase of load factor towards departure and cheaper tickets having been sold out. This correlation is represented by the Day variable. However, this negative relationship between price and booking day is non-linear and convex. This means that ticket prices tend to increase more when the booking date approaches the travel date. The convex curve in Figure 4 illustrates the relationship between average ticket price and number of days to departure for the full sample, both taking into account pre-entry of Iryo and post-entry of Iryo observations. Indeed, it can be observed that the decrease in average price is diminishing when the number of days to departure is increasing. An intuitive interpretation for the convexity is that ticket prices do not approach zero and railway undertakings set minimum ticket prices above zero. ε_{citd} represents the error term.

$$\ln(P_{citd}) = \alpha + \beta_1(Entry_{cit}) + \beta_2(Day) + \beta_3(Day^2) + \varepsilon_{citd} \qquad \text{with } c = \text{Renfe} \qquad (1)$$

$$\ln(P_{citd}) = \alpha + \beta_1(Entry_{cit}) + \beta_2(Day) + \beta_3(Day^2) + \varepsilon_{citd} \qquad \text{with } c = \text{Ouigo} \qquad (2)$$

$$\ln(P_{citd}) = \alpha + \beta_2(Day) + \beta_3(Day^2) + \varepsilon_{citd} \qquad \text{with } c = \text{Iryo} \qquad (3)$$

Figure 3. Average ticket price for each day to departure for all railway undertakings.



Second, the datasets for all railway undertakings are aggregated to identify the impact from the entry of railway undertaking Iryo on the Madrid-Barcelona high speed line on the ticket prices for all railway undertakings that operate on this line. The intuition behind this aggregation is that in theory passengers do not prefer one railway undertaking over another if all characteristics (e.g. price, quality of service, departure time, travel time and frequent rider loyalty programmes) are the same among the railway undertakings. For policy analysis it is then interesting to evaluate the impact from entry of Iryo on all available train departures on the Madrid-Barcelona high speed line. In practice, passengers may have preferences for a particular railway undertaking caused by other factors than price such as the aforementioned quality of service, departure time, travel time and frequent rider loyalty programmes. The choice was made not to include so-called entity fixed effects or railway undertaking fixed effects because of collinearity with the price variable (e.g. lower quality of service may correlate with a lower ticket price). It is not necessary to control for departure time and travel time of each train because in the tender process for capacity, the Spanish Ministry of Transport developed the train schedule and allocated capacity instead of that this is a decision from the railway undertakings themselves. All available departure times were equally distributed over the railway undertakings during all moments of the day, as were the train paths with different stopping patterns leading to different travel times. All railway undertakings run the same proportion of non-stop services and services that call in e.g. Zaragoza and Tarragona at all times of the day. As a result, preferences regarding departure time and travel time do not differ among the railway undertakings. Also, every railway undertaking uses the same fare structure for all its trains. This means that ticket prices for trains on more popular departure times increase more already further away from the day of departure. The fare differences between carries are included in carrier dummies in later extensions. The OLS regression in which the data is aggregated for all railway undertakings is presented in equation (4). Variables and interpretation of the coefficients are almost the same as with equations (1)-(3). Exemptions are that now the subscript c indicating the railway undertaking has disappeared and that the coefficient corresponding to the dummy treatment variable $Entry_{it}$ must be interpreted as the average price change for train tickets for all railway undertakings after the entry of Iryo. Equation (5) shows how the average price change can be computed. Interpretation of this equation is the average price change over all booking horizons (i.e. all observed number of days to departure).

$$\ln(P_{itd}) = \alpha + \beta_1(Entry_{it}) + \beta_2(Day) + \beta_3(Day^2) + \varepsilon_{itd} \quad (4)$$

$$\Delta p = \exp\left(\widehat{\beta_1} + \widehat{\beta_2} \cdot Day + \widehat{\beta_3} \cdot Day^2\right) - 1 \quad (5)$$

An extension is that dummy variables representing the railway undertakings are added to the equation. With the introduction of these carrier dummies it is possible to identify the impact of entry from Iryo on each railway undertaking's average ticket prices. In the equation, the price change for Renfe is used as base, which is why there is no carrier dummy for Renfe. The corresponding regression is shown in equation (6). Interpretation of the coefficient of the treatment dummy variable $Entry_{it}$ is the average price change for train tickets for Renfe after the entry of Iryo (the same holds for the interpretation of the coefficients corresponding to Day and Day^2). In order to show the average price change for train tickets for Ouigo and Iryo (or in case of Iryo the price difference compared to Renfe), the coefficients corresponding to the carrier dummies for $Ouigo$ and $Iryo$ must be added to the coefficient that corresponds to the dummy treatment variable $Entry_{it}$. In other words: the coefficients corresponding to the $Ouigo$ and $Iryo$ dummies show the difference in average ticket prices from Ouigo and Iryo compared to Renfe.

$$\ln(P_{itd}) = \alpha + \beta_1(Entry_{it}) + \beta_2(Day) + \beta_3(Day^2) + \beta_4(Ouigo) + \beta_5(Iryo) + \varepsilon_{itd} \quad (6)$$

A second extension in the inclusion of dummy variable for the day in the week, as is shown in equation (7). Herewith, Monday is used as base. Interpretation of the coefficients corresponding to the variables $Entry_{it}$, Day, Day^2, $Ouigo$ and $Iryo$ is the same as presented above, but now for Monday. The dummy variables for the other days of the week indicate the change of average ticket prices on these days compared to Monday.

$$\ln(P_{itd}) = \alpha + \beta_1(Entry_{it}) + \beta_2(Day) + \beta_3(Day^2) + \beta_4(Ouigo) + \beta_5(Iryo) + \beta_6(Tue) + \beta_7(Wed) + \beta_8(Thu) + \beta_9(Fri) + \beta_{10}(Sat) + \beta_{11}(Sun) + \varepsilon_{itd} \quad (7)$$

Another extension is to allow the day coefficients to change after the moment that Iryo enters (i.e. from $t = T$). This extension allows to identify how the average ticket price changes on each number of days to departure after the entry of Iryo. Interpretation of the coefficients corresponding to the interaction variables $Entry_{it} * Day$ and $Entry_{it} * Day^2$ is change in average ticket price for each number of days ahead of departure when Iryo has entered the market. These coefficients must be added to the coefficients that correspond to Day and Day^2 from $t = T$, i.e. from the moment that Iryo has entered the market. Until that point, the coefficients corresponding to the interaction variables should be ignored. The regression without carrier dummies is presented in equation (8) and the regression with carrier dummies in equation (9).

$$\ln(P_{itd}) = \alpha + \beta_1(Entry_{it}) + \beta_2(Day) + \beta_3(Day^2) + \beta_4(Entry_{it} * Day) + \beta_5(Entry_{it} * Day^2) + \varepsilon_{itd} \quad (8)$$

$$\ln(P_{itd}) = \alpha + \beta_1(Entry_{it}) + \beta_2(Day) + \beta_3(Day^2) + \beta_4(Ouigo) + \beta_5(Iryo) + \beta_6(Entry_{it} * Day) + \beta_7(Entry_{it} * Day^2) + \varepsilon_{itd} \quad (9)$$

A final extension is made to show the change in average ticket prices over time during the period in which the data has been collected. In equation (10) dummies are included indicating the week in which the travel date is situated, corresponding to the observations of ticket prices on a particular booking day with a particular number of days to departure. The week dummies run from week 39 in 2022 (26 September-2 October) up to and including week 4 in 2023 (23 January-29 January). The dummy variables $\sum_{n=39}^{N}(Week_n)$ have value 1 when a particular travel date is in week n and 0 otherwise. In equation (10) the week dummies are shown in a summation for notation purposes. In week 47 in 2022 Iryo entered the Madrid-Barcelona high speed line. This week is set as base while running the regression. Interpretation of the coefficients has changed compared to the previous equations. The coefficient corresponding to the dummy variable $Entry_{it}$ must approach zero by design of the regression (i.e. week 47 when Iryo entered is set as base). The coefficients corresponding to the the week dummies $\sum_{n=39}^{N}(Week_n)$ must be interpreted as the average price change compared to week 47, i.e. the point that Iryo entered the Madrid-Barcelona high speed line. The coefficients corresponding to the Day and Day^2 variables must be added to the coefficients corresponding to the dummies $\sum_{n=39}^{N}(Week_n)$ and $Entry_{it}$ to compute the price difference when considering the number of days ahead of departure.

$$\ln(P_{itd}) = \alpha + \sum_{n=39}^{N}(\beta_1(Week_n)) + \beta_2(Entry_{it}) + \beta_3(Day) + \beta_4(Day^2) + \varepsilon_{itd} \quad (10)$$

4.1 Discussion on endogeneity

There may be problems with endogeneity, i.e. cases in which an explanatory or independent variable correlates with the error term. In this section the following concerns are discussed: timing of the entry decision, selection bias in the Madrid-Barcelona high speed line and possible changes in supply in relation to exogenous shocks.

First, the timing of the entry decision may be a problem for external validity of this paper. Although the competition among three railway undertakings on the Madrid-Barcelona high speed line may look like open access competition, this is not the case. As is described in section 1, railway undertakings had to decide whether they were interested in entering the Spanish high speed market during the tendering process for capacity allocation. If a particular railway undertaking was interested in running trains on the Spanish high speed network, it had a particular chance to win one of the tree packages with track capacity and enter the market as a result. After winning one of the packages, railway undertakings were obligated to enter the market and run (nearly) all the number of trains that were included in the bids for capacity. To summarize, the entry decision from Iryo was made in advance of the period in which the data collection took place. In addition, Ouigo entered the Madrid-Barcelona high speed line before the data collection started, probably already impacting the pricing strategy from incumbent Renfe. Hence, due to the many conditions that railway undertakings are under, external validity of this paper is rather limited. Conclusions that are drawn from this evaluation of entry of a new railway undertaking in the special situation on the Madrid-Barcelona high speed line cannot be simply overtaken to opening of the railway market elsewhere. However, this issue does not effect the internal validity of this paper.

Second, selection bias in the treatment of the Madrid-Barcelona high speed line may be a concern. On the Madrid-Barcelona high speed line passengers are transported between the two biggest cities in Spain, including a substantial part of the Spanish economy. Before the opening of the Madrid-Barcelona high speed line in 2007, the air route between Madrid and Barcelona was the busiest route in the world with more than 960 weekly flights. Also, the Madrid-Barcelona high speed line sees substantially more business traffic than other high speed lines in Spain. Probably, the Madrid-Barcelona high speed line was the most profitable route for Renfe before the entry of Iryo (and Ouigo). This implies that the average price change after entry of Iryo is probably positively biased when generalizing the specific Madrid-Barcelona high speed case to other situation in which opening of the railway market is studied (i.e. the found price changes may be bigger on the Madrid-Barcelona high speeds line than on, e.g., the Madrid-Valencia and Madrid-Malaga high speed lines). However, this is not a problem for studying the impact on average ticket prices of the entry from Iryo on the Madrid-Barcelona high speed line.

Third, problematic for the estimates that are found in this paper would be exogenous shocks (such as demand shocks or changing governmental policies) leading to a short-term change in supply of capacity on the Madrid-Barcelona high speed line. For unbiased results, those exogenous shocks must be adapted in the ticket price and must not be adapted by adding or cutting supply leading to biased observations for the ticket price. Railway undertakings could change their supply of trains in two ways, namely by adding more trains to the schedule or by adding carriages to already existing trains. Adding more trains to the schedule is not possible because of the capacity allocation process in Spain that is related to the tender process for capacity. The outcome of this tender process obligates railway undertakings to run a specific number of daily trains in each direction. Running additional trains or reducing the number of trains is simply not allowed. In addition, by design of the tender procedure railway undertakings had incentives to supply more trains than necessary compared to passenger demand, decreasing the need for more trains as a result of exogenous shocks. This is supported by the data that is used for this paper. Before the entry of Iryo to the Madrid-Barcelona high speed line, there were a lot of trains fully booked when trying to book a ticket one day ahead of departure. After the entry of Iryo which came with a substantial increase in train supply, it is very rare for trains to be fully booked. Regarding adding carriages to already existing trains, adding carriages on high speed trains is not as easy as adding carriages to a regular train. High speed trains run with trainsets and not with carriages, so in order to accommodate more demand on an existing train that is getting fully booked, another trainset must be added to the train. Most high speed trains on the Madrid-Barcelona corridor run with one trainset with a length of approximately 200 meters. Adding another trainset means doubling the length of the train as no shorter trainsets are used on this route. Apart from these practical issues when adding a trainsets, capital costs for trains are a substantial part of total costs in operating trains. Often, railway undertakings do not have spare trainsets to increase train supply on short-term. Another obstacle for adding a trainset is that the Spanish infrastructure manager *Adif* compiles the schedule for all trains, including the circulation of trains. Thus, it is not easy to alter the length of trains since it may be difficult to acquire train paths that are needed for shunting the additional trainset. To summarize, there is no indication that the estimates for the coefficients in this paper are biased by railway undertakings that change the supply of trains on the short-term.

4.2 Discussion on identification

A limitation of this paper is that the coefficients that are presented cannot be interpreted causally. For causal interpretation of the results, it would have been necessary to compare the treated observations (i.e. when the dummy variable $Entry_{it}$ equals 1) to non-treated observations. Then, a on-path test and a difference-in-difference approach could have been used to identify the causal effects on average rail ticket prices of the entry of Iryo. In that case, time fixed effects could have been added to the equations in order to correct for unobservable variables such as demand shocks and change in governmental policies. In other literature on competition in the railway market control groups formed of other railway lines that did not encounter entry were introduced. This means that in addition to price data on all departures on the Madrid-Barcelona high speed line, price data should have been available on comparable routes where no treatment (i.e. entry of a railway undertaking) would take place. However, for two main reasons this control data is not available. The first reason is that there are no comparable non-treated routes in Spain. By design of the tender process, railway undertakings have to run train on all major corridors of the Spanish high speed network. The second reason is that all other railway lines in Spain that were not tendered are under PSO and operated by incumbent Renfe with regulated ticket prices and thus not suitable to act as a control group. To summarize, as a result of not being able to compare the treated group (Madrid-Barcelona high speed line) to a control group (other comparable lines without treatment) and include time fixed effects, the results in this paper are descriptive and not causal. However, the correlations that are found are of substantial magnitude and significance that careful conclusions can be drawn. Tabel 6 and Figure 5 provide insight on the weekly variation in ticket prices.[2]

[2] For defence, a table with daily residuals for the equation $\ln(P_{itd}) = \alpha + \beta_1(Day) + \beta_2(Day^2) + \beta_3(Ouigo) + \beta_4(Iryo) + \varepsilon_{itd}$ is prepared. This equation does not include a treatment dummy variable for entry, but an indication for the impact of entry from Iryo on average ticket prices is shown by the differences in daily residuals. The pattern in daily residuals is consistent with the results in Table 5 on the weekly average price differences in the pre-entry and post-entry periods.

5. Results

This section shows and elaborates on the results from the models in equations (1)-(10). The results from equations (1)-(3) are presented and elaborated in Table 3a-c. The results from equations (4)-(7) are presented and elaborated in Table 4 and in Figure 4. The results from equations (8)-(9) are presented and elaborated in Table 5. Last, the results form equation (10) are presented and elaborated in Table 6 and in Figure 5. Robust standard errors are shown between parentheses and significance of the coefficients and statistics is presented with the stars (*** p<0.01, ** p<0.05, * p<0.1).

In Table 3a-c the results from equations (1)-(3) for Renfe, Ouigo and Iryo, respectively, are shown. Starting with Renfe in Table 3a, an average price decrease of 16.1 percent for Renfe tickets on the Madrid-Barcelona high speed line was observed after the point that Iryo entered. The results must be interpreted as the average price decrease for all booking horizons, both pre-entry from Iryo and post-entry from Iryo. The coefficients for the *Day* and *Day*^{2} variables indicate a convex relationship between ticket price and the number of days before departure, meaning that the average ticket price for Renfe decreases diminishing when booking further ahead of departure. The constant has no economical meaning and thus should not be interpreted. The regression is based on all observations that were collected for Renfe, after having dropped the missing observations and fully booked trains. All coefficients are significant at 1 percent level but the R^2 is low, which can be partly explained by the absence of time fixed effects and thus more variance in the residuals.

Table 3a. Results from equation (1) for Renfe. Dependent variable is ln(P).

VARIABLES	(1)
Entry	-0.161***
	(0.00718)
Day	-0.0160***
	(0.000656)
Day^2	0.000122***
	(1.07e-05)
Constant	4.562***
	(0.00593)
Observations	22,195
R-squared	0.181

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In Table 3b the result for Ouigo are presented: an average price decrease of 29.0 percent for Ouigo tickets on the Madrid-Barcelona high speed line was observed after the point that Iryo entered. The results must be interpreted as the average price decrease for all booking horizons, both pre-entry from Iryo and post-entry from Iryo. The coefficients for the *Day* and *Day*^{2} variables indicate a convex relationship between ticket price and the number of days before departure, meaning that the average ticket price for Ouigo decreases diminishing when booking further ahead of departure. The constant has no economical meaning and thus should not be interpreted. The regression is based on all observations that were collected for Ouigo, after having dropped the missing observations and fully booked trains. All coefficients are significant at 1 percent level but the R^2 is low, which can be partly explained by the absence of time fixed effects and thus more variance in the residuals.

Table 3b. Results from equation (2) for Ouigo. Dependent variable is ln(P).

VARIABLES	(2)
Entry	-0.290***
	(0.0147)
Day	-0.0184***
	(0.00129)
Day^2	0.000177***
	(2.04e-05)
Constant	4.058***
	(0.0126)
Observations	5,359
R-squared	0.241

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In Table 3c the result for Iryo are presented. Note that no treatment dummy variable *Entry* is included. Different to Renfe and Ouigo, the expected convex relationship between ticket price and the number of days before departure is not present with Iryo when considering the coefficients for the *Day* and *Day*^{2} variables. Only a negative relationship can be found, meaning that the average ticket price for Iryo keeps decreasing when booking further ahead of departure, which is likely not to be true in practice. The constant has no economical meaning and thus should not be interpreted. The regression is based on all observations that were collected for Iryo, after having dropped the missing observations and fully booked trains. All coefficients are significant at 1 percent level but the R^2 is low, which can be partly explained by the absence of time fixed effects and thus more variance in the residuals.

Table 3c. Results from equation (3) for Iryo. Dependent variable is ln(P).

VARIABLES	(3)
Day	-0.00350***
	(0.00109)
Day^2	-4.71e-05***
	(1.68e-05)
Constant	3.699***
	(0.00941)
Observations	6,277
R-squared	0.130

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In Table 4 the results for equations (4) and (6)-(7) are presented. In model (4) and (6)-(7) the datasets for all railway undertakings are aggregated to identify the impact from the entry of railway undertaking Iryo on the Madrid-Barcelona high speed line on the ticket prices for all railway undertakings that operate on this line. In equation (4) there is an average price decrease of 30.7 percent for tickets with all railway undertakings on the Madrid-Barcelona high speed line after the point that Iryo entered compared to the ticket prices before the moment of entry. Using equation (5) it is possible to compute the average price difference over all booking horizons. The results must be interpreted as the average price decrease for all booking horizons, both pre-entry from Iryo and post-entry from Iryo. In equation (6) the carrier dummies *Ouigo* and *Iryo* were added to the equation compared to equation (4). Base level is the price change for Renfe; that is the coefficient for *Entry*. Here, there is an average price decrease of 19.3 percent for tickets with Renfe on the Madrid-Barcelona high speed line after the point that Iryo entered compared to the ticket prices before the moment of entry. This result is approximately similar to the results from equation (1). When considering the carrier dummies, it can be found that there is an additional price reduction of 58.6 percent for tickets with Ouigo and an additional price reduction of 58.7 percent for tickets with Iryo on the Madrid-Barcelona high speed line over all booking dates (i.e. the pre-entry and post-entry periods) that should be added to the coefficient of *Entry* to compute the average price differences. For example, in the pre-entry period Ouigo tickets are on average 58.6 percent cheaper than Renfe tickets. In the post-entry period prices for Renfe tickets decreased on average 19.3 percent. In the post-entry period it holds as well that Ouigo tickets are 58.6 percent cheaper on average compared to the lower average ticket prices for Renfe. A relevant future of the model would be allowing for interaction between the *Entry* variable and the carrier dummes, to allow the carrier dummies to change among the pre-entry period and the post-entry period. The result for Ouigo differs from the result in equation (2) because in equation 6 the price change after entry is compared to prices from all railway undertakings before entry and thus also includes Renfe ticket prices that tend to be higher than Ouigo ticket prices, while equation 2 measures the price change compared to Ouigo tickets only. The coefficients corresponding to the carrier dummy variables are approximately similar between equations (6) and (7), which is consistent with the research design. In equation (7) dummies for the day of the week were added compared to equation (6). Coefficients of the variables *Entry*, *Day, Day^2, Ouigo and Iryo* stayed approximately the same. This is consistent with the fact that interpretation of the aforementioned coefficients in equation (7) is equal to the interpretation of those coefficients in equation (6). For interpretation of the coefficients corresponding to the dummies for the day of the week, Monday is used as base. It is shown that Friday and Sunday are the most expensive travel days. Average tickets prices are 27.7 percent and 27.5 percent higher on Friday and Sunday, respectively, compared to average ticket prices on Monday over all booking dates. Tuesday is the cheapest travel day. Then, average prices are 9.1 percent lower compared to Monday. The *Saturday* coefficient is not significant, indicating that there is no difference in average prices between Saturday and Monday. The coefficients for the *Day* and Day^2 variables indicate a convex relationship between ticket price and the number of days before departure, meaning that the average ticket price decreases diminishing when booking further ahead of departure. The coefficients corresponding to the variables *Day* and Day^2 are approximately similar between equations (4) and (6)-(7), which is consistent with the research design. The constant has no economical meaning and thus should not be interpreted. The regression is based on all observations that were collected, after having dropped the missing observations and fully booked trains. All coefficients (except the dummy for *Saturday*) are significant at 1 percent level. The R^2 is improving while more explanatory variables are added to the equations which is intuitive.

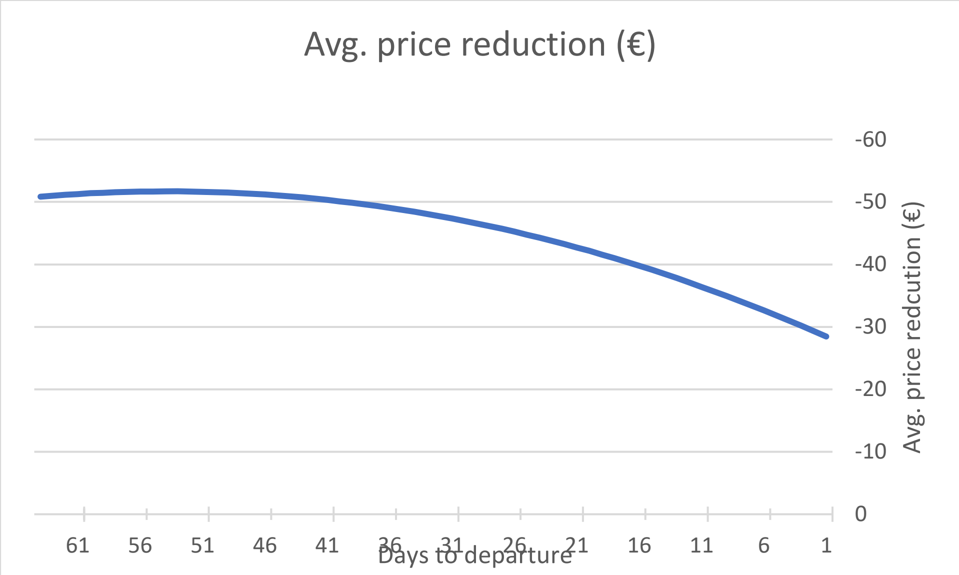
Table 4. Results from equations (4) and (6)-(7) . Dependent variable is ln(P).

VARIABLES	(4)	(6)	(7)
Entry	-0.307***	-0.193***	-0.199***
	(0.00683)	(0.00631)	(0.00605)
Day	-0.0130***	-0.0142***	-0.0141***
	(0.000593)	(0.000520)	(0.000498)
Day^2	8.37e-05***	0.000103***	0.000100***
	(9.42e-06)	(8.31e-06)	(7.98e-06)
Ouigo		-0.586***	-0.595***
		(0.00727)	(0.00664)
Iryo		-0.587***	-0.584***
		(0.00697)	(0.00652)
Tue			-0.0907***
			(0.00946)
Wed			-0.0631***
			(0.00932)
Thu			0.0487***
			(0.00907)
Fri			0.277***
			(0.00891)
Sat			0.0145
			(0.0102)
Sun			0.275***
			(0.00960)
Constant	4.440***	4.565***	4.515***
	(0.00583)	(0.00536)	(0.00777)
Observations	33,831	33,831	33,831
R-squared	0.184	0.379	0.428

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In Figure 4 the average monetary price reduction for all railway undertakings is presented for each number of days to departure in the post-entry period compared to the pre-entry period for all railway undertakings. The graph is based on equation (4) and thus not considering dummies for the railway undertaking and dummies for the day of the week. A concave relationship between average monetary price reduction and the number of days to departure is found. The smallest price reduction is right before departure of the train, namely 1 day ahead of departure. The average price reduction at that booking day is approximately 28 euro compared to the period before entry of Iryo. The biggest price reduction is found approximately 52 days ahead of departure. The average monetary price reduction at that booking day is approximately 51 euro compared to the period before the entry of Iryo.

Figure 4. Average price reduction in euro for each booking day.



In Table 5 the results for equations (8)-(9) are presented. In these equations, the variables *Day* and *Day*^{2} are allowed to interact with the variable *Entry*. This allows the coefficients corresponding to the *Day* and *Day*^{2} variables to change in the post-entry period compared to the pre-entry period. The results from equation (8)-(9) are somewhat doubtful. In equation (8) the coefficient for *Entry* decreases to an average price reduction of 43.2 percent, a more substantial average price reduction than the result form equation (4). As well for equation (9), the results are not consistent with the results from equation (6). Again, the coefficient for *Entry* decreases to an average price reduction of 32.9 percent, a more substantial average price reduction than the result form equation (4). However, the coefficients for the carrier dummies in equation (9) are consistent with the results in equation (6). What is interesting indeed, is the interpretation for the interaction dummies. Results in equation (8) and (9) are approximately similar, which is consistent with the research design. The coefficients for the *Day* and *Day*^{2} variables indicate a convex relationship between ticket price and the number of days before departure, meaning that the average ticket price decreases diminishing when booking further ahead of departure. The coefficients corresponding to the variables *Day* and *Day*^{2} as well as the interaction variables *Entry*Day* and *Entry*Day*^{2} are approximately similar between equations (8) and (9), which is consistent with the research design. In the post-entry period the coefficients for the interaction variables *Entry*Day* and *Entry*Day*^{2} must be added to the variables *Day* and *Day*^{2}. This means that in the post-entry period average ticket prices decrease less when booking a ticket more days ahead of departure compared to the pre-entry period. The constant has no economical meaning and thus should not be interpreted. The regression is based on all observations that were collected, after having dropped the missing observations and fully booked trains. All coefficients are significant at 1 percent level. The R^2 is improving while more explanatory variables are added to the equations which is intuitive.

Table 5. Results from equations (8)-(9) . Dependent variable is ln(P).

VARIABLES	(8)	(9)
Entry	-0.432***	-0.329***
	(0.0119)	(0.0107)
Day	-0.0312***	-0.0354***
	(0.00286)	(0.00260)
Day^2	0.000446***	0.000549***
	(8.64e-05)	(7.83e-05)
Entry*Day	0.0230***	0.0261***
	(0.00295)	(0.00267)
Entry*Day^2	-0.000431***	-0.000518***
	(8.71e-05)	(7.89e-05)
Ouigo		-0.588***
		(0.00719)
Iryo		-0.587***
		(0.00694)
Constant	4.529***	4.664***
	(0.00987)	(0.00898)
Observations	33,831	33,831
R-squared	0.189	0.383

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In Table 6 the pattern of the weekly development average ticket prices for all railway undertakings is shown following from equation (10). Iryo entered the Madrid-Barcelona high speed line in week 47. This week is used as base and is thus excluded as dummy variable. Interpretation of the results is as follows. The coefficient corresponding to the treatment variable *Entry* was expected to drop and approach zero and did this indeed, since the point of entry of Iryo is set as base and weekly average price changes are displayed in comparison to this base. The coefficients for the *Day* and Day^2 variables indicate a convex relationship between ticket price and the number of days before departure, meaning that the average ticket price decreases diminishing when booking further ahead of departure. The coefficients corresponding to the variables *Day* and Day^2 are approximately similar between equation (10) and the results for equations (4) and (6)-(7), which is consistent with the research design. More interesting is the weekly pattern that is shown by the coefficients for the dummies that indicate the week in which the travel date is. The results are also plotted in Figure 5. A decreasing trend in average ticket prices for all railway undertakings can be observed over the weeks in which the observations were made. For example, in week 40 average prices were 19 percent higher compared to week 47 in which Iryo entered. This average weekly price gradually decreases until the point of entry in week 47. In the post-entry period the weekly average ticket prices further decreases, although with a small peak around the Christmas and New Year Holiday when passenger demand is extraordinary high. After the Holiday, average weekly prices drop substantially in week 2, 3 and 4 to price reductions of 49.2 percent, 43.6 percent and 42.0 percent, respectively. This pattern provides evidence that railway undertakings were anticipating to the point of entry of Iryo and that railway undertakings were decreasing ticket prices already before entry. This suggests that railway undertakings changed their pricing strategies in advance of the entry of Iryo to allow for offering lower ticket prices in anticipation of the entry. An important assumption herewith is that passenger number did not decrease in this period, as in that case lower passenger demand could have lead to lower ticket prices instead of a change in pricing strategy. This assumption holds, as is stated in an evaluation on the opening of the Spanish high speed rail market by the Spanish Ministry of Transport (e.g. CNMC, 2023). The substantial decrease in prices in weeks 2, 3 and 4 hint for a starting price war among the railway undertakings, which is supported by many marketing campaigns that were introduced in the period right after the Christmas Holiday.

Table 6. Results from equation (10) . Dependent variable is ln(P).

VARIABLES	(10)
Entry	0.0377*
	(0.0229)
Day	-0.0139***
	(0.000607)
Day^2	0.000124***
	(9.99e-06)
Week39	0.174***
	(0.0281)
Week40	0.191***
	(0.0220)
Week41	0.0493**
	(0.0211)
Week42	0.121***
	(0.0223)
Week43	0.171***
	(0.0211)
Week44	0.0969***
	(0.0207)
Week45	-0.0206
	(0.0222)
Week46	0.0739***
	(0.0216)
Week48	-0.190***
	(0.0203)
Week49	-0.141***
	(0.0188)
Week50	-0.234***
	(0.0206)
Week51	-0.154***
	(0.0204)
Week52	-0.110***
	(0.0198)
Week1	-0.208***
	(0.0193)
Week2	-0.492***
	(0.0203)
Week3	-0.436***
	(0.0206)
Week4	-0.420***
	(0.0228)
Constant	4.353***
	(0.0166)
Observations	28,138
R-squared	0.196

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 5. Average weekly price change over time.

6. Conclusions and discussion

In the previous sections the main research question is answered:

What is the impact of entry from railway undertaking Iryo on the Madrid-Barcelona high speed line on average rail ticket prices?

Evidence is provided that average rail ticket prices decreased for all railway undertakings that operate on the Madrid-Barcelona high speed line following the entry of Iryo on this line. There is evidence found that indicates the start of a strong price war among the railway undertakings. Although average ticket prices have decreased, the profitability of the railway undertakings is a concern for the sustainable future of the railway sector.

This main question is answered by the following sub-questions and hypotheses:

What is the impact of entry from railway undertaking Iryo on the Madrid-Barcelona high speed line on average rail ticket prices for railway undertaking Renfe?

Hypothesis: Average rail ticket prices for Renfe decreased after entry from Iryo.

Evidence is found that supports this hypothesis. An average price decrease of 16.1 percent for Renfe tickets on the Madrid-Barcelona high speed line was observed after the point that Iryo entered.

What is the impact of entry from railway undertaking Iryo on the Madrid-Barcelona high speed line on average rail ticket prices for railway undertaking Ouigo?

Hypothesis: Average rail ticket prices for Ouigo decreased after entry from Iryo.

Evidence is found that supports this hypothesis. An average price decrease of 29.0 percent for Ouigo tickets on the Madrid-Barcelona high speed line was observed after the point that Iryo entered.

What is the impact of entry from railway undertaking Iryo on the Madrid-Barcelona high speed line on average rail ticket prices for all railway undertakings?

Hypothesis: Average rail ticket prices for all railway undertakings decreased after entry from Iryo.

Evidence is found that supports this hypothesis. An average price decrease of 30.7 percent for tickets with all railway undertakings on the Madrid-Barcelona high speed line after the point that Iryo entered is found compared to the ticket prices before the point of entry from Iryo.

How do average rail ticket prices evolve over time for several numbers of days ahead of departure?

Hypothesis: Average rail ticket prices increase with a convex function when the departure date in approaching.

Evidence is found that supports this hypothesis. A concave relationship between average monetary price reduction and the number of days to departure is found. The smallest price reduction is right before departure of the train, namely 1 day ahead of departure. The biggest price reduction is found approximately 52 days ahead of departure.

How do average rail ticket prices change over time before and after the point that Iryo entered the Madrid-Barcelona high speed line?

Hypothesis: Average rail ticket prices decrease over time, both in the period before entry of Iryo (i.e. anticipation to entry) and in the period after entry of Iryo (i.e. indication for price war).

Evidence is found that supports this hypothesis. A decreasing trend in average ticket prices for all railway undertakings can be observed over the weeks in which the observations were made. In the last weeks of observations, average rail ticket prices decreased even further. This pattern provides evidence that railway undertakings were anticipating to the point of entry of Iryo and that railway undertakings were decreasing ticket prices already before entry and at the same time indicates a starting price war.

A limitation of this paper is that the coefficients and statistics that are presented in this paper are descriptive and cannot be interpreted causally by the lack of control groups. This concern is discussed in section 4.2. Other concerns include timing of the entry decision, selection bias in the Madrid-Barcelona high speed line and possible changes in supply in relation to exogenous shocks. Those concerns are discussed in section 4.1. For future research two main points are recommended. First, more detailed data on ticket prices should be made publicly available to evaluate policies. This would also help in drawing more causal conclusions. Second, it may be relevant to consider the correlation among lagged ticket prices, so that conclusions can be drawn whether railway undertakings take into account competitor’s ticket prices from the previous period when setting own prices.

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