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An econometric evaluation of the management of large-scale transport infrastructure in Spain during the great recession: Lessons for infrastructure bubbles

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ABSTRACT

This paper reviews the way that air, rail, and toll motorways infrastructure have evolved in Spain since the beginning of the century, when all these types of transport have been subjected to a far-reaching economic crisis. Investments made in infrastructure during this time will also be analyzed in relative terms and compared to other countries in the European Union, as will the various policies applied to each of these modes of transport. The methodology applied in this paper is of the bottom-up type, in the sense that a thorough univariate–uniequational analysis is performed before proceeding to more complex, multivariate models. We found that the policy to drop fare prices for the HSR (*AVE*) has had an almost 14% positive effect on the number of passengers per kilometer for HS and long-distance trains, but it has also had a negative effect of as much as 16.7% on the number of domestic air passengers. The increase in airport taxes has not affected any of the endogenous variables, or major public investments in air terminals and new HSR lines, except for the Madrid–Barcelona *AVE* and Barcelona's T1. Domestic air transport has been seen to be more sensitive to the economic cycle than the other modes of transport. This paper contains a set of results that justify the need to use full and accurate "economic modeling" in the planning and management of what is generally very costly transport infrastructure.

1. Introduction

The specialized literature has traditionally shown that GDP and transport infrastructure form a virtuous circle according to which any increase in a country's GDP raises demand for transport services (Annema and De Jong, 2011; Dargay et al., 2007), which in turn leads to an increase in investment in transport infrastructure. For Kim (2002), a 1% increase in GDP results in a similar 0.99% increase in money allocated to transport infrastructure. This increase then leads to greater GDP growth both in countries that are developed (Köhler et al., 2008) and those that are not (Ding, 2013). GDP and transport can be seen to be very closely bi-directionally related, although this relationship weakens when economic development grinds to a halt (Beyzatlar et al., 2014).

From the beginnings of industrialization, investment in transport has been one of the main conditions for countries' embarking on economic development (Rostow, 1960). The belief that investment in transport generates economic growth has often been used as justification for allocating resources to the sector. However, this general relationship is being questioned today (see, for example, Banister and Berechman, 2003) and depends on the type of infrastructure being promoted (see, for example, Bonatti and Campiglio, 2013). Whether this is the case or not, there are many examples of countries that are currently banking on investment in infrastructure, and primarily in transport, to drive their economic development forward. Some transport infrastructure-based plans can currently be found all round the world, especially in Asia. This is the case in Thailand, for instance, with a €50,000 m investment according to the Royal Thai Embassy (2015), as well as in China, Japan and India, with €65,000 m, €35,000 m and €25,000 m investments, respectively, to name but a few examples.

However, if there is a single country that epitomizes this policy during the recent period of growth seen during the first decade of the 21st century, it is Spain. During this period the country generated what has been considered a giant transport infrastructure bubble and become a paradigmatic case of oversupply and of mismatch with demand (Albalate et al., 2015), with a 15 year plan (2005–2020) called the PEIT that envisaged a €249,000 m investment in transport infrastructure (Ministry of Development, 2005). Changes in the economic situation forced the investment to be downscaled (see Fig. 1), meaning that the PEIT had to be replaced with the PITVI, a new 12 year plan (2012–2024) that estimates an investment of €138,000 m in transport

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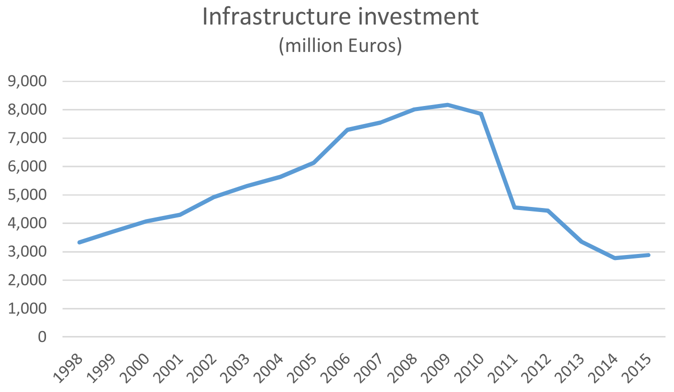

Fig. 1. Spanish State investment in infrastructure. Data on investments in infrastructure made by the Ministries of Development and the Environment.
Source: SPEG (1998-2015).

infrastructure (Ministry of Development, 2015). Parallel to this, the European Union has put forward the Junker Plan, which plans to devote €220,000 m to transport, energy and telecommunications infrastructure (European Commission, 2014), made possible by the ease with which inflation has been contained within the Eurozone (Dracos and Kouretas, 2015).

The present paper analyzes the way that Spanish economic infrastructure has evolved at the beginning of the century (focusing on airports, high speed rail (hereinafter, the *AVE*) and turnpikes or toll highways (hereinafter, *toll motorways*)). To justify the economic relevance of this case study, the evolution of Spanish transport infrastructure is analyzed in relative terms and compared to other countries in the European Union. The Spanish HSR has become the largest HSR network in the EU and the OECD (Albalate and Bel, 2011) and the same is true of the Spanish motorway network, which is also the largest in the EU (Eurostat, 2015). Similarly, the Spanish airport financing and management model and the high number of airports per capita are unparalleled among medium-sized and large continental countries in Europe and the OECD (Bel and Fageda, 2011).

Subsequently, a study is conducted of the traffic sensitivity of the various types of infrastructure under analysis in the face of the extreme conditions presented by an adverse economic cycle.

After this spectacular investment process, actions and strategies began to be implemented to optimize the effects (de Ureña, 2012) of this infrastructure and adapt it to an adverse economic cycle. In fact, the main objective of the present study is to evaluate the effects of the main measures taken in this respect during the current economic crisis. Especially noteworthy are the steep increases in airport fees and the reduction in AVE fares. In fact, the public sector can be seen to have used totally antagonistic strategies: while the strategy for air transport has clearly been to maximize short term profits by raising airport charges in tandem with more sophisticated strategies to capture non aeronautical revenue (a good example of this is the latest pricing policy for long term car parks) and the downsizing of the workforce, attempts have been made to incentivize demand for high speed rail by reducing fare prices significantly. Meanwhile, slight increases have been seen in toll motorway fees that have generally been in keeping with the low inflation rate during the period.

Lastly, the possible effects of some of the most emblematic infrastructure works are analyzed as control variables, specifically the AVE line from Madrid to Barcelona and the new and extremely costly extensions to Madrid and Barcelona-El Prat airports (approx. €6200 m and over €3000 m, respectively).

This article is organized as follows: Section 2 describes the way that large transport infrastructure has evolved in Spain. Section 3 explains the variables and the methodology used. Section 4 sets out and discusses the empirical findings. Finally, Section 5 presents the study conclusions.

2. The case of Spain

During the years of great economic growth in Spain, at the time of the real estate boom, large investments were made in transport infrastructure: from 471 km. of track at the beginning of 2003, Spanish HSR jumped to being the second longest with 2383 km. in 2014 (Fig. 2). There are currently another 2135 km. under construction or in the planning stage, and only China's HSR system is greater in length (Albalate and Bel, 2011). Fig. 3 compares HSR kms per thousand billion € of GDP and per million inhabitants in Spain, with the Eurozone and the European Union. At the same time, airports were built in nearly all the provinces, including seven new airports since 2007 that raised the overall number from 41 to 48. As far as road transport is concerned, new motorways were built. Some of these were public, while others were the result of public–private collaborations, with the case of the Madrid radials standing out. Toll motorways increased from 1739 km in 2001 to 2529 km in 2008.

This growth put the Spanish AVE in the international spotlight. However, its planning was criticized for there having been no prior analysis (Albalate and Bel, 2012) despite the fact that detailed planning had been regarded as a necessity since the 1960s, given the complexity of decision making in transport infrastructure (Levinson et al., 2012) and its high cost (De Rus and Nombela, 2007). Yet this investment trend, with not even the briefest of cost-benefit analyses being done beforehand, was not only the case in Spain. By way of example, most of the 30 Trans-European Transport Network's priority projects analyzed by Proost et al. (2014) were also at fault. Another similar example can be found in Asia, where Utsunomiya and Hodota (2011) also concluded that it is difficult to justify the investments made from the economic point of view.

On the political level, the justification of such large investment in the AVE was underpinned by the disproportionate stress put on the supposed positive effect of infrastructure on regional economic growth (see Hong et al., 2011, for example, on this relationship). In fact, political discourse justified the AVE with the tens of thousands of new jobs that would be generated by the increased numbers of travelers (see Martin and Nombela, 2007). Another objective was to reduce the environmental and social costs of air and road transport (congestion, pollution, noise and traffic accidents) (see Román and Martín, 2011 regarding this case, and Kremers et al., 2002, as a general example of the importance of including environmental costs in transport planning).

As can be seen in Fig. 4, there are 48 airports in Spain included one autonomous airport in the province of Lleida. Of these, the first four in terms of numbers of passengers took almost 60% of the 187 million passengers in 2013, while the last 22 barely reached 1% all together. According to Lozano and Gutiérrez (2011) this last group of airports struggle to reach any level of efficiency, with seven accruing a debt of €15,000 per passenger in 2013, while in the case of Huesca–Pyrenees airport this rose to €232,000.

Unfortunately, data are only available for 2010 to compare the situation of the Spanish airport system with nearby countries'. However, in 2010 Spain had 1.01 airports per million inhabitants and 43.48 airports per every thousand billion € of GDP. The mean values for these indicators in the Eurozone countries were 0.69 and 24.04 respectively, while they stood at 0.61 and 24.00, respectively, for EU28 countries. The differences are even greater when compared with the three largest European economies by size and population: the values for France were only 0.56 and 18.01; those for Italy were even lower, 0.39 and 14.32, and there is practically no comparison with the figures for Germany, 0.23 and 7.33 (ACI-Europe, 2010).

Most of the investment in toll motorways was made between 2001 and 2007 (see Fig. 5). Several of the State motorways as well as the radial motorways around Madrid were built in collaboration with the private sector, that is, in public–private partnerships, as is the case in other countries (Leruth, 2012).

The expectation was that, as a whole, this air, rail and road infrastructure would lead to increased competition (see, for example,

Fig. 2. AVE lines.
Source: ADIF, 2015.

Jiménez and Betancor, 2012). Yet there are also many people who claim (see, for example, Ferreiro et al., 2013) that this expansionary procyclical fiscal policy eventually contributed to exacerbating the crisis. For example, the recent economic crisis has had a general effect on demand for air transport (Martín et al., 2013; Voltes-Dorta and Pagliari, 2012), and some airports in Spain have ended up with no flights at all. This was the reason for the closure of Ciudad Real airport in 2012, and for Castellón airport not coming into operation until 2015, with one single flight to date. Another significant example is Murcia Airport. Construction of the airport finished in 2012 but it has still not been opened. As for the AVE, in 2012, before the drastic cutback in fares, 88 of the 206 routes between the 22 stations in operation had five or fewer passengers per day, and ten had fewer than ten passengers per year (Tremosa i Balcells, 2013).

In the case of the toll motorways, the best illustrations of the excess capacity are the group of radial motorways round Madrid (the AP36, AP41, R2, R3, R4 and R5 to be precise), and the comparison of (total) motorway km per thousand billion € of GDP and per million inhabitants in Spain with the Eurozone and the European Union (see Fig. 6). In 2012 these radial motorways had accrued debts to the value of €3800 m, while only taking in €49.5 m in revenue (Romero and Méndez, 2012), which led to the concessionaires who were running them to file for

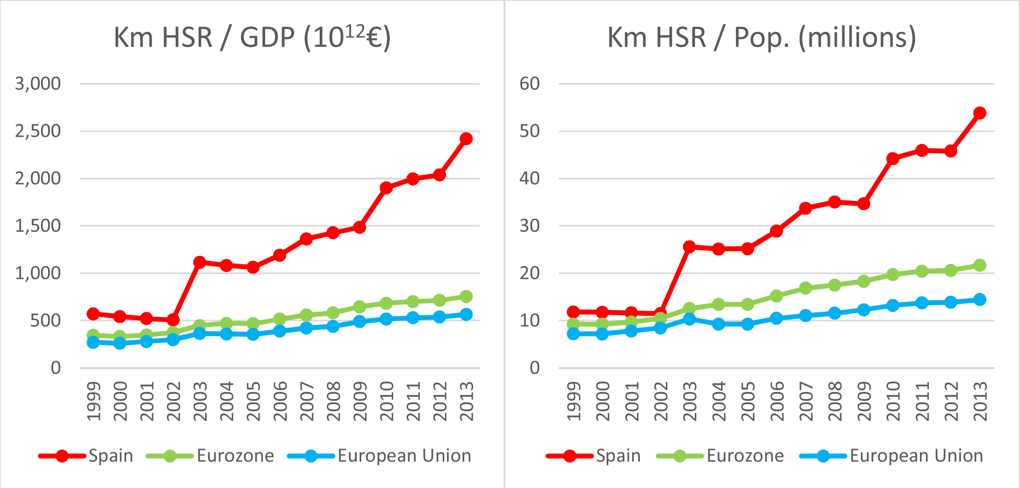

Fig. 3. HSR Km per GDP (Chain linked volumes, index 2010 = 100, thousand billion €), and per million inhabitants. Source: UIC High Speed Department, 2014; Eurostat, 2015. Prepared by authors.

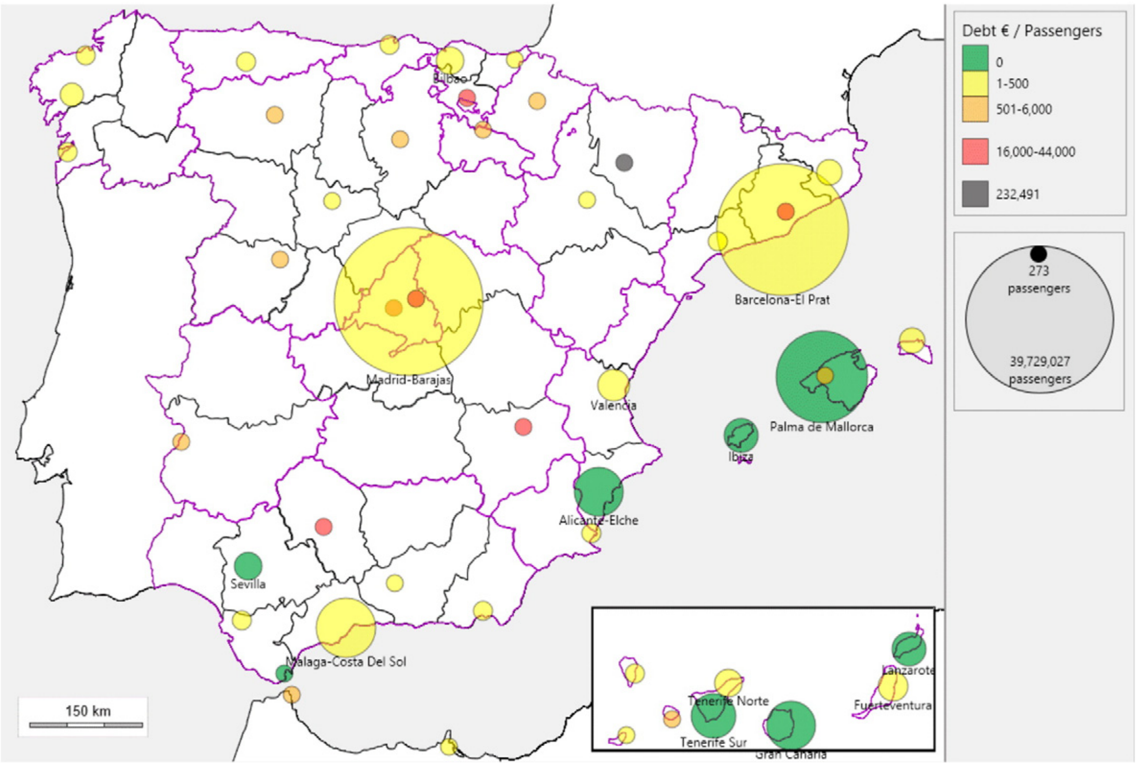

Fig. 4. Spanish airports and big heliports (Ceuta and Algeciras).
Source: prepared by authors.

bankruptcy. Predictably, the State bailed the concessionaries out by creating a new public company, which in 2014 took over the debt of over 4600 million Euros with a 50% "haircut" and replaced it with a 30 year bond, albeit with no State guarantee (Romero, 2014). A large part of this debt can be laid at the door of a disastrous expropriation system for the construction of the radial motorways. The private constructors estimated the cost of expropriations at less than €400 m and many are being reviewed by the courts, which are coming down in favor of those whose property was expropriated. The final cost is expected to exceed €2000 m.

Owing to these circumstances and the budgetary constraints imposed on Spain by the European Union (Ali, 2012; Trachanas and Katrakilidis, 2013), the Spanish Government has had to take decisions to rationalize the management of the transportation infrastructure. What is noteworthy is the disparity between the decisions depending on the mode of transport. It was decided to significantly lower AVE fares in February, 2013, for example (Ministry of Development, 2013), to make them more accessible to the less well off; it should be taken into account that the Gini index had gone up in Spain by a greater amount than in any of the other vulnerable countries in Europe (D'Errico et al., 2015). While this has led to a 19.15% increase in the number of passengers (Gómez-Pomar, 2013), it has made it even more difficult to cover high speed rail costs. In fact, RENFE's (the Spanish national rail company) passenger division closed its accounts in 2014 with a negative bottom line of €147.6 m compared to a positive bottom line of €40 m in 2013 (Renfe Viajeros S.A., 2014).

Another option that was experimented with was privatizing the running of the railways and this was trialed on the Madrid–Valencia–Alicante–Murcia line (Spain, 2014). However, for Cowie and Loynes (2012) this type of decision could put up short term running costs before bringing them down in the long term. Apart from this specific case, there has been a slow process that began in 2005 with the end

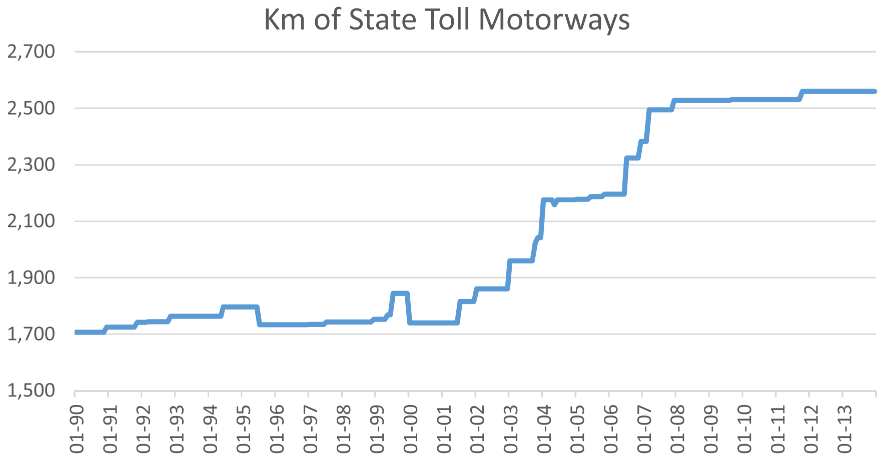

Fig. 5. Km of State Toll Motorways in Spain. Source: Ministry of Development, 2014a. Prepared by authors.

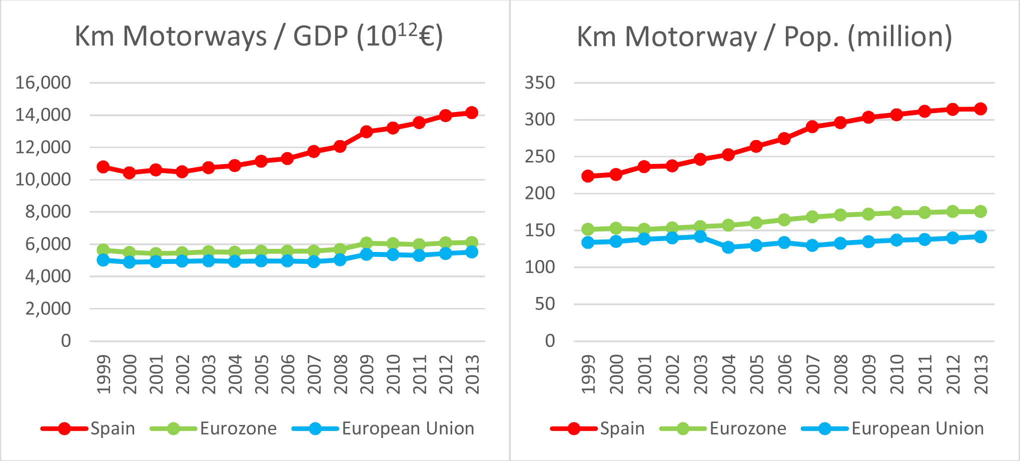

Fig. 6. Km of Motorway per GDP (Chain linked volumes, index 2010 = 100, thousand billion €), and per million inhabitants. Source: Eurostat, 2015. Prepared by authors.

goal of allowing private operators to enter the market and provide rail services with either their own trains or by hiring them from the public sector. Despite being legally defined in 2005, this liberalization has been extremely slow in coming, probably influenced by the fear of the same dysfunctions occurring as in the United Kingdom's liberalization process (see for example, Jupe and Funnell, 2015). At the current time, autumn 2015, the most likely hypothesis is that during the first phase only one private operator will be allowed to enter the market and compete with the State operator, Renfe.

The opposite decision was taken for air travel, with increases in airport charges and the privatization of the management agency, AENA, albeit with the State remaining as the majority shareholder, while investments in airport infrastructure to be reduced. The first of these decisions, to put up airport charges, would foreseeably lead to a fall in the number of passengers, which would in turn lead to a fall in revenue from concessions (Gillen and Mantin, 2014). The second, privatizing airports, is usually associated with improving the efficiency of airport management (Ohri, 2012) in the long term. The bottom line is that all the readjustments made because of the privatization process enabled AENA, the public company that manages the majority of Spanish airports, to end the 2014 fiscal year with a gross operating profit (EBITDA) of over €1800 m. This is a record result for the company and led to its February 2015 listing on the stock exchange being a huge success, with swift, major capital gains.

3. Data and methodology

For our analysis we have used a broad database that can be split into groups of variables:

A) Endogenous variables: four monthly variables, from 1999 to 2013, in Fig. 7:
   - a.1) Domestic: Domestic air passengers (in millions, taken from AENA, 2015; data divided by two to avoid double entries).
   - a.2) International: International air passengers (in millions, AENA, 2015).
   - a.3) Road:Sum total of kilometers covered by vehicles that use State toll motorways per month (in billions, taken from the Ministry of Development, 2014a).
   - a.4) Train: Number of High Speed Rail and Long Distance passengers by kilometric distance of each journey (in billions, taken from the Ministry of Development, 2014b).

Seasonal components in these time series variables are clearly of a stochastic nature, since it can be seen that the repetitive pattern typical of the seasonal component is not an exact replica year on year. This stochasticity is assumed naturally in the models used in this paper (see the models below and the Appendix A).

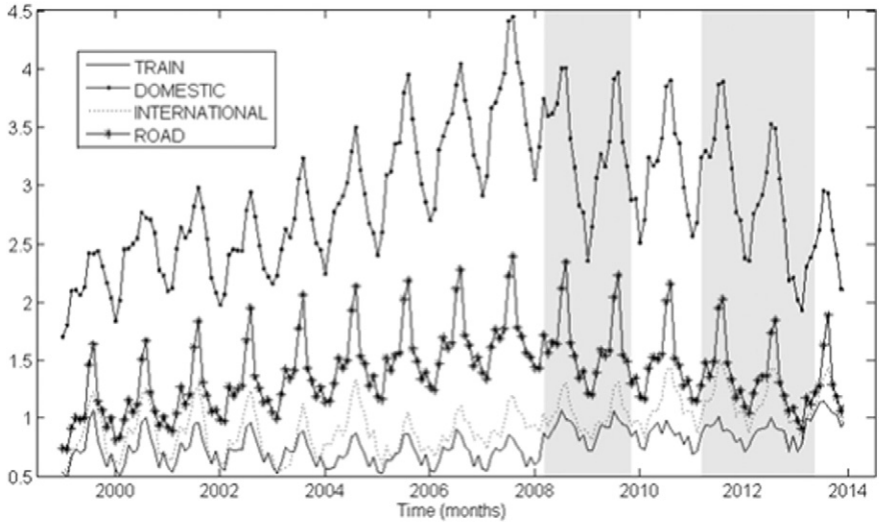

Fig. 7. Monthly endogenous variables from1999 to 2013. The shaded areas indicate periods of recession in Spain.

B) Exogenous variables: a broad set of variables is included in the models to estimate a number of intervention variables and any outlier effects seen in the data. The most important, with their definitions, are:

b.1) Easter: Traffic campaigns around this vacation period are especially intense in Spain. The problem is that it is a moving festival and causes distortions in the time series. Consequently, it is defined by assigning different weights to the days in question depending on the expected traffic density. Maximum weights are assigned to Friday before Palm Sunday, Palm Sunday, Holy Wednesday and Easter Sunday. Medium weights are assigned to the Saturday before Palm Sunday and Holy Thursday. Weights of zero are assigned to all other days.

Summer and Christmas vacations are responsible for much of the standard seasonality of the time series, while moving holidays, like Easter, produce distortions in seasonality. All the other holidays in Spain are always on fixed dates, which means that they do not need to be treated specifically along with Easter.

b.2) Trading: The number of trading days in a month in excess of weekend days, assuming that in each week there should be five working days and two days at the weekend. For each month this variable takes a value that equals the number of working days minus the number of weekend days multiplied by 2.5.

b.3) Leap: Dummy variable to take into account the effect of 29 day Februaries.

b.4) Price Rail: Permanent effect of reductions in high speed rail fares, which consist of an 11% general reduction from 8th February 2013 for several types of tourist fares, a 35% discount for 10 trip passes valid for more than 4 months, a 30% discount for young people and a 20% discount for multiple trips. All these discounts are modeled as a pair of one-zero dummy variables, one and one in February 2013 (Price Rail (Feb2013) in tables), as the discounts did not start at the very beginning of the month; and the second dummy variable becomes one from March 2013 onwards (Price Rail (Mar2013–)). Since this variable implies price reductions, a positive effect is expected in the model for train transport, but with negative crossed effects for other transport modes.

b.5) The Madrid–Barcelona High Speed Rail service that started on February 2008 in direct competition with the fast air shuttle service. In the same line as the previous variable, this is divided into two sets, one for February 2008 alone and a second from March 2008 onwards. A positive effect would be expected on train passengers and a negative effect on the rest of the modes.

b.6) T1: Opening of new T1 terminal at Barcelona-El Prat Airport.

b.7) Eyjafjallajökull volcano eruptions: These minor volcanic eruptions caused enormous disruption to air travel across Europe during several days in April 2010. A negative effect is expected on international flights (see Castillo-Manzano et al., 2012).

b.8) Economic cycle: The effect of the international economic crisis felt in many different parts of the economy is modeled here as a dummy variable in months when the economy was in recession, i.e., periods when the Gross Domestic Product grew at a negative rate during at least two consecutive quarters. For these periods, a decrease in passengers is expected as a type of income effect. In the case of Spain these two periods are March 2008 to November 2009 and March 2011 to May 2013 (see shaded areas in Fig. 7). The dummy variables are deterministic time ramps.

b.9) 9/11: This variable is for the effect of the September 11, 2001 terrorist attack. Following Castillo-Manzano et al. (2015) the effect is assumed to be negative but not permanent, i.e., it is strong at the beginning and then decays over time (transitory change). See explanation below.

b.10) MARCH2004: On 11th March 2004 there was also a terrorist attack at one of the main rail stations in Madrid. It is expected to reduce train passengers during the remainder of that month and possibly during several following months.

b.11) Other empirically determined variables: In the case of international flights some other variables had to be included to produce serially independent Gaussian residuals. These were generally linked to winter storms, such as the cases of February 2003 (modeled as a transitory change, similar to b.9), December 2003 (one-off) and January 2005 (one-off). The algorithms used to automatically detect outliers were those developed in Gómez and Maravall (2000). As the diagnostics show, all the residuals in the models presented below are free from outliers.

C) Other variables that were initially considered but were not significant in the models:

c.1) The most important is "Price Plane": four dummy variables that introduce the substantial increase in airport fees implemented by AENA from 2010 to 2013. Although the fare increases were not the same for every airport, the mean behavior of price increases was 24.43% from 2010 to the second semester of 2011; a 28% increase from the second semester of 2011 to the end of the year; 36% during the first semester of 2013 and 8% in the second semester of 2013. The accumulated increase was 67.49%, and at the airports with most traffic, which were already the most expensive—Madrid and Barcelona—it was as much as 95%.

However, this is not so outrageous if we consider that Spain had been one of the countries with the lowest airport fees in the EU (ACETA, López Colmenarejo, 2012).

c.2) Large airport infrastructure construction: several major infrastructures were built in the considered period, namely Terminal 4 in Madrid in February 2006; Terminal 1 in Barcelona in June 2009; Terminal 3 in Malaga in March 2010 and Terminal 2 in Valencia in August 2012. Apart from the new terminal in Barcelona, none resulted in a clear increase in the number of passengers.

c.3) Large rail infrastructure construction: similar to the previous effects. A substantial building effort was made in rail infrastructure, none of which was significant with the exception of the Madrid–Barcelona line already cited in b.5). Some new lines came into operation from 1999 with 15 new rail stations built, some of which no longer operate today.

The methodology applied in this paper is of the bottom-up type, in the sense that a thorough univariate–uniequational analysis is performed before proceeding to more complex, multivariate models. ARIMA is one of the most extended and straightforward techniques for univariate modeling. Here we extend it with regressors modeled as transfer functions (TF) since we have an ample set of dummy variables related to the four endogenous variables.

All TF considered here are of order one, with the general formulation given in Eq. (1), where B is the lag operator, so $B^m x_t = x_{t-m}$.

$$z_t = \frac{b_1}{(1+a_1 B)} u_{t,1} + \frac{b_2}{(1+a_2 B)} u_{t,2} + \cdots + \frac{b_m}{(1+a_m B)} u_{t,m} + \frac{\theta(B)}{\alpha(B)} a_t \qquad (1)$$

where z_t is any of the endogenous variables; a_j and b_j $(j = 1, 2, \cdots, m)$ are coefficients to estimate; u_j $(j = 1, 2, \cdots, m)$ are the exogenous dummy-like variables in the list above; and $\frac{\theta(B)}{\alpha(B)} a_t$ is a general ARIMA model that turned out to be an airline model except in one case (see Table 3).

The previous formulation is quite convenient, as it includes the following particular cases depending on the values of a_j: additive effect or outlier (AO, $a_j = 0$); level shift (LS, $a_j = -1$); transitory change (TC, $-1 < a_j < 0$).

The previous formulation is extended with the use of the multivariate unobserved components (UC) model class that allows for a time series to be decomposed into economically meaningful, unobserved, components, see Eq. (2).

$$z_t = T_t + S_t + TF(u_t) + v_t \tag{2}$$

z_t, T_t, S_t and v_t are the four endogenous time series and trend, seasonal and irregular components, respectively. $TF(u_t)$ measures the effects of the explanatory variables in matrix u_t through TF models, as in Eq. (1).

The UC analysis is carried out in the State Space framework composed of Eq. (2) and the dynamic specification of all the unobserved components involved. See examples in the Appendix A. One interesting feature of these models is that, as they are multivariate, it is possible to estimate how strong or weak the comovements are in the components across different output variables. This is an additional source of information not available in many other models. For example, it is possible to detect strong positive or negative relationships between trends, while the irregular components are not correlated at all. All the technicalities as to this methodology can be seen in the Appendix A along with some key references, e.g., Harvey (1989), Pedregal and Young (2002), and Durbin and Koopman (2012).

Methodologies of this type have been widely used across many different scientific disciplines, especially Economics and Engineering. Some examples are: Nogales and Conejo (2007), Taylor et al (2007), Tawadros (2011), Hindrayanto et al. (2013), Carnero and Pedregal (2013), Trapero et al. (2013), Young (2014), Pedregal et al (2014), Yoon (2015), and Castillo-Manzano et al. (2014, 2015).

4. Results and discussion

Table 1 shows the results with the ARIMA-TF models. Columns are the endogenous variables while rows are the exogenous variables. Several conclusions may be drawn from Table 1:

1. The ARIMA specifications show that the preferred model is the so-called “airline” model, i.e., an ARIMA $(0, 1, 1) \times (0, 1, 1)_{12}$, with the only exception of Rail passengers, which required an additional MA (2) parameter. From a statistical point of view all models are correct, since the residuals clearly show that there are no remaining serial correlation, gaussianity or heteroscedasticity problems.
2. There are some Easter, trading and leap year effects with different degrees of influence and significance. The most important is the Easter effect, which is noticeably less important for domestic flights.
   In greater detail, the positive sign of the Trading variable for domestic air passengers may possibly be attributable to business reasons accounting for most of the traffic in Spain on workdays, while tourism is a more important motive for international air transport, and tourism is obviously more positively related to weekends (or, one and the same thing, more negatively related to workdays). It is not significant for other modes of transportation because the business versus tourism motivations for traveling are more balanced.
   Regarding the null effect of the leap variable on the Road variable, the number of trips on toll motorways on any single day in February is not high enough to be detected statistically for the level of noise

Table 1
Estimation results of ARIMA-TF models. Trend, slope, seasonal and irregular represent disturbance variances corresponding to each unobserved component. Q(p) are the Ljung-Box Q statistics for p lags. KSL is the Kolmogorov–Smirnov–Lilliefors gaussianity test (P-values in brackets). H is a variance ratio homoscedasticity test that compares the variance in the first and third parts of the sample (P-values in brackets).

	Rail	Domestic	International	Road
Easter	0.0777^{***}	0.0168^{***}	0.0701^{***}	0.0815^{***}
Trading		0.0008^{*}	-0.0025^{***}	
Leap	0.0406^{***}	0.0203^{**}	0.0254^{**}	
Price Rail (Feb2013)	0.0976^{**}	-0.0285^{*}		
Price Rail (Mar2013–)	0.1306^{***}	-0.1876^{***}		
AVE Barcelona(Feb2008)	0.0806^{**}			
AVE Barcelona (Mar2008–)	0.2105^{***}			-0.0714^{***}
T1 Barcelona-El Prat		0.0452^{*}		
Eyjafjallajökull			-0.0919^{***}	
Cycle (Mar2008–Nov2009)		-0.0024^{**}		
Cycle (Mar2011–May2013)	$-0.0018.^{**}$	-0.0126^{***}		-0.0021^{***}
9/11 (TC)			-0.1924^{***}	
9/11 Denominator			-0.6961^{***}	
MARCH2004	-0.0820^{***}			
MARCH2004_{t-1}	-0.0701^{**}			
MARCH2004_{t-2}	-0.0592^{**}			
FEB2003 (TC)			-0.1253^{**}	
FEB2003 Denominator			-0.9403^{***}	
DEC2003 (AO)			-0.1144^{***}	
JAN2005 (AO)			-0.1301^{***}	
MA1	-0.527^{***}	-0.2017^{**}	0.2008^{**}	-0.6008^{***}
MA2	-0.3579^{***}			
MA12	-0.3775^{***}	-0.4609^{***}	-0.4879^{***}	-0.3886^{***}
$\sigma^2 \times 1000$	1.429	0.941	2.153	0.896
Q(4)	2.412	2.269	2.026	1.998
Q(8)	10.436	5.355	3.767	2.545
Q(12)	12.766	6.457	11.874	3.754
Q(24)	19.988	17.842	29.090	17.296
KSL	0.0530	0.044	0.044	0.0436
	(0.229)	(0.456)	(0.449)	(0.464)
H	0.958	0.798	0.947	0.854
	(0.873)	(0.414)	(0.839)	(0.562)

* Indicate statistical significance at 10%.
** Indicate statistical significance at 5%.
*** Indicate statistical significance at 1%.

present in the data and the length of the series. It is well-known that it is possible to make any coefficient insignificant by arbitrarily increasing the variance of any perturbation in a regression, i.e., by burying the signal in noise. Another interesting case is that, for example, the estimated parameter of an AR (1) of the type $y_t = 0.1y_{t-1} + a_t$ is never significant for samples smaller than, approx., 50 observations. In other words, small parameter values in dynamic models can only be estimated with big samples.

3. High speed rail price policies (Price Rail variables in Table 1) had a very positive effect on rail passengers, with an increase of 10.25% in February 2013 alone, and a permanent 13.95% increase being estimated from March 2013 onwards. What is also relevant is that these variables had a greater negative effect on domestic flight passengers, since they resulted in a 2.81% reduction in February that subsequently rose to 16.69%.

   There were no further effects on international flight passengers or on motorway traffic. This last effect, the null effect of HSR price policies on the Road variable, may be attributable to imperfect substitution between the two transport modes. That is, while a perfect air transport equivalent to most of the frequent HSR routes nearly always exists in Spain, the same is not true for HSR and toll motorways.

   There are major toll motorway transport corridors on both the inter-regional (such as the Catalonia–Basque Country and the Valencia–Murcia–Almeria Great Mediterranean Axis) and intra-regional (Seville-Cadiz, Costa del Sol, and Campomanes-Astorga, among others) scales that have no HSR equivalents. Besides these, there is also the Galician motorway, for example, where the two types of transport do exist side by side, but only for such short distances that the HSR does not really make much sense, as its competitive distance is usually between 450 and 550 km.
4. Some additional findings are rather remarkable. In addition to the previous finding, the increase in airport fees does not affect any of the endogenous variables. It seems especially relevant that they do not affect domestic flight passengers, but cross effects between these prices and the rest of the endogenous variables were not detected, either.
5. The pessimistic environment of the economic crisis at the times when the price changes occurred had an additional negative effect on rail and domestic flight passengers (in addition to roads). The first dip in Spain's "W" shaped recession was not detectable in the case of Rail passengers, mainly because the period (from March 2008) coincided with the opening of the Madrid–Barcelona high speed line, which had a very positive effect (see next point). The second dip was detected by our ARIMA-TF model, however, and in fact produced a loss of 422,370 rail passengers by kilometer between March 2011 and January 2013 (about 4% of all passengers in 2012), the month before rail prices were drastically reduced. Despite this price effort, the number of passengers by kilometer continued to fall up to the end of the recession in May 2013, with the total number of passengers by kilometer lost in 2012 standing at 594,810, i.e., 5.71% of passengers.
6. Of all the large airport and rail infrastructure built during the period, only the opening of the Madrid–Barcelona line and the construction of Terminal 1 at Barcelona-El Prat airport were found to be significant with respect to total passengers. In fact, the Madrid–Barcelona line increased the number of rail passengers by kilometer by 8.39% in February 2008 and had a permanent effect of 23.43% thereafter.

   Substitution between high speed rail and domestic flights in the connection between Madrid and Barcelona is treated in other specific papers (Pagliara et al., 2012), but what can be seen from the present study is that the effect is not sufficiently great to have a noticeable impact on the total number of domestic flight passengers. It should also be borne in mind that we are working with aggregated data for the whole airport system, and so a significant negative effect on Barcelona and Madrid airports is perfectly compatible for this HSR line as long as it is not large enough to ultimately make the result for the whole aggregated airport system significant.

   The efficiency with which the Madrid–Barcelona air link has traditionally operated should also be taken into account—it has never been an ordinary air connection like any rest. For example, passengers with tickets for this route have been able to turn up at the airport and get on the first available flight without being restricted to any kind of timetable or schedule. Passengers on this route—the so-called "shuttle"—also have special amenities and facilities at each of the airports (check in and baggage drop, and police controls) that cut journey time down.

   To summarize, this result would confirm the hypothesis that during the LCC era, with its cheap tickets and point-to-point connections, substitution between HSR and air transport is not as great as it had been during the times of the Networks Carriers—unless HSR prices plummet, as they have in Spain.

   Nonetheless, it is not easy to understand why the new terminal area at Barcelona-El Prat has had such a clearly significant effect, while the new multi-million Euro T4 terminal at Madrid-Barajas airport, with a cost of over 6200 million €, has not. Some possible explanations could be that the new Barcelona terminal was linked to an expanding airline—Vueling—while the one in Madrid was linked (in part, by Grandfather Rights) to Iberia, a company that has been through its umpteenth crisis during these past years; secondly, when the new terminal at Barcelona airport came into service the fees there were clearly below the European average for a hub of its type, and so Ryanair transferred many of its flights there that had previously been flying in and out of secondary airports in the area—Girona and Reus, to be precise—while this was not the case in Madrid; thirdly the dynamism is not the same in the two hinterlands; the city of Barcelona seems to have withstood the economic crisis better than Madrid (especially the first years of the crisis).
7. International flights are affected solely by international events, such as the 11th September effect, volcano eruptions, and so on. However, domestic policy prices, the Spanish recession and public works, etc., are all found not to be significant in determining this variable.
8. Finally, the effect on total rail passengers of the 11th March 2004 terrorist attack at one of the main rail stations in Madrid needs to be highlighted. The reduction during March and the following two months was measured as 7.87% in March, 6.77% in April and 5.75% in May. The effect dissipated thereafter.

Table 2 completes the information in Table 1 with the addition of the full multivariate or vector version. The specific comments on this table are as follows:

1. A technical problem occurred that prevented the use of the models in their standard formulation, as proposed initially by Harvey (1989). In the standard formulation one covariance matrix is estimated for trends, one for trend slopes, one for seasonal components and one for irregulars. As the seasonal matrix is composed of several harmonics (see Eq. (4)), these covariance matrices may be the same for all harmonics, as is proposed in the standard model to produce parsimonious models, or they could be different, as has long been argued by Young et al. (1999). The interesting point in this case is that to obtain an acceptable model it was essential to estimate the different covariance matrices of the harmonics for the passenger data, since the constant parameter produced serially correlated residuals. In order to avoid the "curse of dimensionality", the seasonals are assumed to be independent among the variables. This is not a restrictive constraint since we are only interested in trend comovements. Table 3 presents the final variance estimates for each of the harmonics and time series, leaving no room for any doubt.
2. Models are correct from a statistical point of view. Residual variances are marginally better than those of the ARIMA-TF models. The core effects of the dummy variables are very similar to the ARIMA-TF

Table 2
UC vector model estimation results. Format identical to Table 1.

	Rail	Domestic	International	Road
Easter	0.0787***	0.0195***	0.0698***	0.0838***
Trading		0.0011*	-0.0029^{***}	
Leap	0.0528***	0.0209**	0.0241**	
Price Rail (Feb2013)	0.0895**	-0.0274^{*}		
Price Rail (Mar2013–)	0.1356***	-0.1620^{***}		
AVE Barcelona (Feb2008)	0.0582**			
AVE Barcelona (Mar2008–)	0.2091***			-0.0621^{***}
T2		0.0424*		
Eyjafjallajökull			-0.0850^{***}	
Cycle (Mar2008–Nov2009)		-0.0022^{**}		
Cycle (Mar2011–May2013)	-0.0023^{**}	-0.0064^{**}		-0.0020^{***}
9/11 (TC)			-0.1846^{***}	
9/11 Denominator			-0.7125^{***}	
MARCH2004	-0.0721^{***}			
MARCH2004$_{t-1}$	-0.0672^{**}			
MARCH2004$_{t-2}$	-0.0435^{**}			
FEB2003 (TC)			-0.0639^{*}	
FEB2003 Denominator			-0.9012^{***}	
DEC2003 (AO)			-0.1125^{***}	
JAN2005 (AO)			-0.1509^{***}	
$\sigma^2 \times 1000$	1.160	0.859	2.052	0.703
Q(4)	1.528	3.295	4.948	2.318
Q(8)	5.852	10.631	8.972	9.749
Q(12)	8.667	14.931	13.689	11.084
Q(24)	18.465	23.462	30.653	32.115
KSL	0.068	0.029	0.049	0.049
	(0.134)	(0.831)	(0.481)	(0.465)
H	0.872	0.847	0.855	0.824
	(0.861)	(0.894)	(0.906)	(0.458)

* Indicate statistical significance at 10%.
** Indicate statistical significance at 5%.
*** Indicate statistical significance at 1%.

model's. The most relevant values in this case are: i) Price Rail variables amount to an increase of 9.36% in February 2013 and a permanent 14.52% increase is estimated from March 2013 onwards; ii) the effect on domestic flight passengers is a 2.7% reduction in February and a 14.96% reduction from April onwards; iii) the second dip in the Spanish recession produced higher losses than the ARIMA-TF model, i.e., a loss of 537,610 rail passengers by kilometer up to January 2013 (5.16% of total passengers) and 756,570 passengers by kilometer (7.26%) up to May 2013; and iv) the Madrid–Barcelona high speed line added 5.99% passengers by kilometer in February 2008 and 23.26% from April onwards.

3. What is more relevant is the movement of the trends and the irregulars measured by the correlations estimated directly from the model: see Table 4. Once all other effects have been accounted for, the trend correlations between rail passengers and the other variables are always negative, implying that the long term behavior of rail passengers moves in the opposite direction to the other variables. However, both flight and road passenger trends move in the same direction. Nonetheless, the short term shocks measured by the irregular components move in the same direction for all the variables, implying that everything else not taken into account in the model (basically random shocks) affect all the variables in the same way.

Table 3
Estimated variances for seasonal harmonics for each time series.

	Rail	Domestic	International	Road
Harmonic 12	0.265	0.025	0.653	0.049
Harmonic 6	0.063	0.024	0.265	0.009
Harmonic 4	0.178	0.025	0.046	0.021
Harmonic 3	0.008	0.025	0.000	0.000
Harmonic 2.4	0.000	0.008	0.000	0.000
Harmonic 2	0.005	0.022	0.002	0.014

5. Conclusions

The results of our analysis of the Spanish State's public–private investment policy in recent decades show that the effect of the policy to reduce AVE fares has had an effect of an almost 14% rise in the number of passengers per high speed long-distance km, but that it has had a high negative effect of almost 17% on the total number of domestic air passengers. However, this measure has had no effect on road traffic or—as was to be expected—on international air passengers. Surprisingly, unlike the above, the political measure to charge the cost of airports to airlines and passengers by increasing airport fees has had no effect on the variables. This study therefore offers empirical evidence that there is still some margin for airport charges to be raised in airport systems where fees are low with no evident adverse effects on traffic. In fact, after the increase, Spain continues to be one of the countries with the lowest charges in the EU (ACETA, López Colmenarejo, 2012).

However, the hike in airport fees (67.5% on average and 95% in Madrid and Barcelona) has contributed to putting the traditionally negative accounts of the airport agency, AENA, in order, with €715 m profit in 2013 and €479 m in 2014. This has also enabled the debt that AENA amassed with the new air terminals to be reduced. In 2009 this stood €12,900 m, but had fallen to €11,300 m by 2014. This trend is expected to continue in as much as any large-scale investments have, as was predictable, been halted.

Unlike AENA, it does not look as though the reduction in the cost of AVE fares will enable the losses of the public rail operator, RENFE, to be settled in the short term. In fact, RENFE has once again seen its losses spiral above €200 m in 2014 (almost €150 m were due to the passenger division). This is even more serious when it is taken into account that AENA is shouldering the debt from building all the airports; RENFE is not burdened with the debt of constructing the HSR network, the debt for which has been transferred to another public company, ADIF, created ad hoc in 2005 for this precise reason. In fact, RENFE simply pays ADIF a charge for its trains' use of the HSR tracks. In 2014 this was €607 m. In

Table 4
Estimated trend correlations (shaded upper area) and irregular correlations (non–shaded lower area).

	Rail	Domestic	International	Road
Rail	–	−0.321	−0.099	−0.582
Domestic	0.991	–	0.128	0.422
International	0.957	0.963	–	0.650
Road	0.408	0.385	0.208	–

this case ADIF's debt is simply meteoric, having soared from some €5180 m in 2009 to almost €16,700 m in 2014, and it is expected to rise a further €2000 m in 2015, while €4000 m of new investments have been planned for 2016.

It is striking that the large public investments in air terminals and new HSR lines have had no significant effect on passenger numbers, except in the cases of Barcelona airport's T1 and the Madrid–Barcelona HSR line. The latter had a clearly greater significant negative effect on road traffic than on domestic air transport. To summarize, this result would confirm the hypothesis that during the LCC era, with its cheap tickets and point-to-point connections, substitution between HSR and air transport is not as great as it had been during the times of the Networks Carriers—unless HSR prices plummet, as they have in Spain.

The fact that the current paper contains a set of results that, on occasion, are not intuitive, but not illogical, either, is one of its strengths, as taken together these results justify the need to use full and accurate "economic modeling" in the planning and management of what is generally very costly transport infrastructure.

The economic crisis, which in Spain was double-dip, has affected domestic air passengers, HSR and road travel, although the last two were only affected by the second recession, and not the first. To summarize, the behavior seen shows that from the very beginning domestic air transport was much more sensitive to the crisis than the other two modes of transport. However, none of the main local variables tested, such as the Spanish economic crisis and the changes in HSR fares and airport charges, seem to have affected international air transport. Spain's relationship with the rest of the world apparently follows a dynamic that is completely extraneous to domestic variables. This is undoubtedly related to the country's status as a top international tourist destination.

From the perspective of economic logic, the decision to raise airport charges while lowering HSR fares is baffling. And this is even truer when it is taken into account that Spain has traditionally had the lowest HSR fares per km (Nash, 2009).

This strategy can only be understood in social and political terms, as the decision to make deep cutbacks in health and education and leave millions of workers unemployed and with no social protection (see, for example, Cervero-Licera et al., 2015 on the effects of these cutbacks on the public health system) was taken at the same time as the decision to continue extending the HSR network. To be precise, during the economic crisis (2009–2015) the budget for investment in rail in Spain, where over 90% of the investments are made in HSR, was in excess of €4100 m per annum. Obviously, these investments would have been even more difficult to justify at the beginning of 2012, when the trains were in a state of utter underutilization, and the traditional lower use made of the Spanish rail network (one fifth of passengers per km of other European lines, and as much as twenty times fewer than the Tokyo-Osaka line, see Albalate and Bel, 2011), coincided with the negative shock of the second Spanish recession (*Cycle (Mar2011–May2013)* variable in Table 1).

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Appendix A

Unobserved component models of the kind used in this paper are built in the State Space (SS) framework (see Castillo-Manzano et al., 2014, Castillo-Manzano et al. 2011 and Castillo-Manzano et al. 2013, for other applications of this methodology in transport policy). Models of this type are composed of two types of equation, i.e., State and Observation equations. Discrete-time, stochastic State equations reflect all the dynamic behavior of the system by relating the current value of the states to their past values as well as to the deterministic and stochastic inputs. In particular, in Eq. (2) the state equations for trends usually incorporate two unit roots in order to model the non-stationary part of the time series; seasonal components typically incorporate the periodic behavior of the series in the fundamental frequency of the seasonal period and all their harmonics and irregulars are considered as white noise. The Observation equations define how the state variables are related to the observed data (Eqs. (1) and (2) in the main text are in fact the observation equations of a multiple input transfer function and an unobserved components model, respectively).

The specific SS formulation used in this paper is:

$$\begin{cases} \boldsymbol{x}_{t+1} = \boldsymbol{\Phi}\boldsymbol{x}_t + \boldsymbol{\Gamma}\boldsymbol{u}_t + \boldsymbol{w}_t & \textit{State equations} \\ \boldsymbol{z}_t = \mathbf{H}\boldsymbol{x}_t + \mathbf{D}\boldsymbol{u_t} + \boldsymbol{v}_t & \textit{Observation equations} \end{cases} \tag{A.1}$$

where $\boldsymbol{x}_t$ is an n dimensional stochastic state vector; $\boldsymbol{w}_t$ and $\boldsymbol{v}_t$ are an n and scalar dimensional vectors of Gaussian system disturbances, i.e., zero mean white noise inputs with covariance matrix **Q** and **R** and independent of each other; and **Φ**, **Γ**, **H** and **D** are the so-called system matrices, some elements of which are known while others need to be estimated.

Given that model (A.1) may well be either model (1) or (2) in the main text, the well-known Kalman Filter (KF, Kalman, 1960) and state Fixed Interval Smoother (FIS) produce the optimal estimates of the first- and second-order moments (mean and covariance) of the state vector, conditional on all the data in a sample as it minimizes the mean squared errors (MSE). The unknown parts in the system matrices, **Φ**,, **H**, **D**, **Q** and **R**, may be estimated by Maximum Likelihood (ML) computed using the KF via "prediction error decomposition" (see details in Harvey, 1989; Pedregal and Young, 2002; Durbin and Koopman, 2012). In order to show the UC model in Eq. (2) more clearly, system (A.1) is extended in Eq. (A.2) with the addition of a further first order TF term.

$$\mathbf{x}_{t+1} = \left[\begin{array}{c} \mathbf{T} \\ \mathbf{F} \\ \hline \mathbf{S}_1 \\ \mathbf{S}_1^* \\ \mathbf{S}_2 \\ \vdots \\ \hline \mathbf{f}_1 \end{array}\right]_{t+1} = \left[\begin{array}{cc|ccccc|c} \mathbf{I} & \mathbf{I} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{I} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \cdots & \mathbf{0} \\ \hline \mathbf{0} & \mathbf{0} & \mathbf{I}\cos\omega_1 & \mathbf{I}\sin\omega_1 & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & -\mathbf{I}\sin\omega_1 & \mathbf{I}\cos\omega_1 & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{I}\cos\omega_2 & \cdots & \mathbf{0} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \hline \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \cdots & -a_1 \end{array}\right] \mathbf{x}_t + \left[\begin{array}{c} \mathbf{0} \\ \mathbf{0} \\ \hline \mathbf{0} \\ \mathbf{0} \\ \mathbf{0} \\ \vdots \\ \hline -a_1 b_1 \end{array}\right] I_t + \left[\begin{array}{c} \mathbf{w}_0 \\ \mathbf{w}_0^* \\ \hline \mathbf{w}_1 \\ \mathbf{w}_1^* \\ \mathbf{w}_2 \\ \vdots \\ \hline \mathbf{0} \end{array}\right]_t$$

$$\mathbf{z}_t = \mathbf{T}_t + \mathbf{S}_t + f(\mathbf{u}_t) + \mathbf{v}_t = [\mathbf{I} \quad \mathbf{0} \mid \mathbf{I} \quad \mathbf{0} \quad \mathbf{I} \quad \mathbf{0} \quad \cdots \mid \mathbf{I}]\mathbf{x}_t + b_1 u_{t,1} + \mathbf{v}_t \tag{A.2}$$

A comparison of systems (A.1) and (A.2) enables the system matrices to be identified. New elements apart from the previous elements appear in Eq. (A.2): $\mathbf{F}_t$ is a vector of trend "slopes" or trend rate of change; $\mathbf{S}_{it}$ $(i = 1, 2, \ldots, P/2)$ are the seasonal harmonics of known frequencies $\omega_i = 2\pi i/P$, whereby $\mathbf{S}_t = \sum_i^{P/2} \mathbf{S}_{it}$, with P being the fundamental frequency (12 observations per year in the case of monthly data with annual seasonality); $\mathbf{S}_{it}^*$ $(i = 1, 2, \ldots, 6)$ are additional blocks of states necessary for defining seasonal terms.

The additional dimension that incorporates the multivariate UC models with respect to the uniequational model is that the components' covariance matrices can be calculated, allowing the strength of between components correlation to be estimated.

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