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DEMAND FOR SUBURBAN RAILWAY SERVICES IN SPAIN

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Abstract

During the 1990s, significant changes have taken place in the Spanish passenger railway market. This paper focuses on the factors which influence the demand for suburban services. Using panel data from 11 cities in which RENFE operates those services, a demand function is estimated. As expected, demand for such services is shown to be more elastic with respect to quality (measured as frequency) than to prices. When the whole sample is segmented according to city size, a reestimation of the model for each subsample shows that the difference between those two elasticities increases with city size.

INTRODUCTION

During the 1990s European railways have continued to lose market share in favour of alternative transport modes. Besides, railway companies as a whole have not been able to reduce their large deficit. Given that in most cases these companies are public, transfer of funds from the public budget has been required. Measures taken in order to reduce their losses have been designed along two main dimensions. In the first place, the European Commission is forcing railway companies to separate their service operating activities from those related to infrastructure management[1]. The objective is to clarify the way in which infrastructure maintenance and improvement are financed. In some countries, such as the United Kingdom or Sweden, management of railway infrastructures has been handed to newly created companies, which are independent from service operators. In other cases, the creation of such companies is still being discussed.

Secondly, in order to improve their management some railway companies have undergone organizational reforms which have resulted in the setting up of new units responsible for each area of the railway market with a high degree of autonomy. The objective of such reforms is to identify those market segments where losses appear and to improve the results of each business unit.

As a result of such restructuring process, it becomes very important to determine with precision which are the characteristics of each of the markets in which railway companies operate. The research on which this paper is based attempts to improve the understanding of the factors influencing demand for suburban railway services in Spain. In the last years, those services have become the main source of revenue for RENFE, the Spanish national railway company. A better understanding of the demand for such railway services is needed not only to improve RENFE's economic results, but also in order to design transport policies concerned with the increasing congestion caused by private car use in metropolitan areas.

The paper is organised as follows: in section two the organisational changes undertaken by RENFE and the evolution of demand for its different services are briefly summarised. Section three discusses different issues related to the estimation of transport demand and presents the panel data model used here. Section four discusses estimation results. In the first place, a model for the whole set of cities with suburban railway services is presented. Afterwards, the sample is divided in two parts in order to test for different price and quality elasticities in cities of different size. The last section summarises the conclusions.

CHANGES IN THE SPANISH RAILWAY MARKET

In 1982 British Rail led the way in the reorganisation of its internal structure with the creation of a new organisational scheme based on the different kinds of services offered by the company, instead of the previous one based on the geographical areas on which the services were provided. Several other railway companies, RENFE among them, followed BR in the late 80s and beginning of the 90s. As a result of RENFE's reform, the company is now organised around different business units (*Unidad de Negocio* or *UNe*), each one of them responsible for a different area of the railway market. Seven of the *UNes* are transport operators (High Speed Trains, InterCities, Suburban Services, Regional Railways, Cargo, Combined Transport and Parcels) while eight more are in charge of providing the services required by the previous ones, maintaining the infrastructure and managing the stations. Each *UNe* calculates its economic results independently, with RENFE's accounts being obtained as a result of their consolidation. This accounting separability among *UNes* rises the issue of which method should be chosen for valuing the transactions which take place among them. The concept presently used is that of transfer price, which is based on the opportunity cost of providing the service to the company considered as a whole (Nash and Preston, 1995).

Besides having reorganised itself in such way, RENFE is also trying to improve its management and deficit-control with other measures, such as agreement with the subsidy-provider State of the so-called *Contrato-Programa*. These contracts establish the medium-term performance objectives that the company will try to achieve, as well as the subsidies that the State will provide to each of the business units. In 1998 the third *Contrato-Programa* (1994-1998) expires.

Table 1 - Passengers-km. carried by RENFE (millions)

	High Speed	Intercity	Regional	Suburban	Total
1979	-	7623	5048		12671
1980	-	8287	5240		13527
1981	-	8897	5364		14261
1982	-	9151	5552		14703
1983	-	9437	5655		15092
1984	-	9730	5844		15574
1985	-	9816	6163		15979
1986	-	9340	6306		15646
1987	-	9251	2903	3240	15394
1988	-	9432	2364	3870	15716
1989	-	8627	2323	3765	14715
1990	-	8455	1975	4595	15025
1991	-	7991	1900	5131	15022
1992	513	7793	2154	5842	16305
1993	1098	6389	2082	5665	15234
1994	1192	5748	2024	5889	14853
1995	1294	5813	2074	6132	15313
1996	1350	5828	2109	6318	15605

Sources: IETC (various years), and RENFE's *Informe Anual* (1996)

Simultaneously to those modifications in the company's structure and in the framework of its relations with the State, some large changes have taken place in the relative contribution of the different passenger services to the total number of RENFE's customers. As shown in table 1, intercity services have lost a great part of the importance that they had at the end of the 70s, while suburban services have become since 1994 the main provider of customers[2]. Although the aggregation, until 1987, of data for regional and suburban services does not allow us to obtain conclusions for a long period of time for those services, it is obvious that suburban services have increasingly gained importance as providers of passengers for RENFE.

In this context of continuous operating losses, changes in the composition of passenger railway demand and a reorganised company structure which seeks a greater managing independence in each *UNe*, it becomes necessary to increase the knowledge of the demand characteristics of each of the markets in which RENFE operates. It is expected that a better understanding of the factors influencing demand will help the company in the planning of its operations.

This paper focuses on suburban services. As shown above, those services are the main source of customers for RENFE. Besides, given all the congestion problems that private road traffic generates in metropolitan areas, the design of transport policies that allow for improvements in metropolitan public transport is of great interest. With the aim of improving our knowledge about the factors that influence the generation of trips in those railway services, an econometric estimation of the demand function is undertaken, using monthly data from for the period between January 1991 and December 1995[3] for all 11 cities in which RENFE operates commuter services.

Applied research on transport demand in Spain has not yet focused on the problem of railway services at a metropolitan scale. The demand for other transport modes, such as bus (De Rus 1991) or intercity railways (Bel 1994a, 1994b, 1995, 1997; Cantos and Ortí, 1995) has received much more attention. At an international level, Voith (1991, 1997) has analysed the demand for suburban services similar to those studied here. However, the panel Voith uses takes the station, and not the urban network, as unit of analysis and uses yearly data. Goodwin and Williams (1985) report on several studies in the United Kingdom which undertake the estimation of different railway demand functions. Values for demand elasticities in different transport modes can be found in the two surveys of empirical studies by Oum *et al.* (1992) and Goodwin (1992).

TRANSPORT DEMAND FUNCTION

As table 2 shows, there are important differences in the size of the city networks included in the panel. While Madrid, Barcelona and Valencia have very extensive networks, those in other cities consist of a single line. This section discusses several issues related to the estimation of a transport demand function, such as its correct identification, the choosing of functional form, the selection of explanatory variables and specification strategy, and the modelling of individual effects in the panel data model.

Table 2 - RENFE's suburban networks for commuter services

				Passengers (millions)				
City	Lines	Stations	Network Kms.	1991	1992	1993	1994	1995
Madrid	10	83	373.5	144.3	169.2	173.5	165.1	171.8
Barcelona	4	103	440.1	64.5	72.8	70.6	75.2	79.2
Bilbao	3	39	75.2	26.2	24.5	23.8	24.0	23.5
Valencia	6	69	411.5	14.5	17.3	19.0	20.6	21.1
Oviedo	4	45	148.6	5.1	5.5	5.8	5.7	6.2
Málaga	2	23	67.2	10.1	7.5	7.1	7.3	7.3
Seville	3	21	163.7	3.2	6.1	3.3	3.9	4.4
S.Sebastián	1	29	80.6	6.8	7.4	7.5	8.1	8.6
Murcia	2	27	194.1	2.5	3.1	2.8	2.7	3.0
Cádiz	1	7	48.2	1.2	1.7	1.7	2.0	2.3
Santander	1	19	80.6	1.0	1.0	1.0	1.0	1.1

Source: RENFE.

Identification

A demand function cannot be properly estimated if it is not well identified. In the context of this analysis, if some of the explanatory variables can be modified by the operator as a response to expected or observed changes in demand, the estimated coefficients for those variables will be biased. If that is the case, the problem can be solved by simultaneously estimating the supply and demand functions. However, in the particular railway sector on which we focus, this problem will not arise. This is because given that it is a very regulated sector, the operator cannot modify the variables under its control in the same way that a profit-maximizing firm would in a completely deregulated situation. RENFE is allowed annual price changes, usually in accordance to the rise of the Consumer Price Index. Quality of services, measured by services' frequency, can be modified more easily. However, besides those taking place in the summer months, monthly changes in demand are not taken into account to modify frequencies, which is our proxy for service quality. RENFE is forced by its status of public-service provider to maintain a minimum frequency of services independently of demand decreases. We are thus confident about the exogeneity of the explanatory variables in the demand function and carry out its estimation independently of the supply function.

Functional form

The demand function is estimated under the assumption of constant elasticity, thus using a log-lineal functional form. This can be justified theoretically, as can be done with alternative functional forms such as the linear or translogarithmic ones (Deaton and Muellbauer, 1980). The applied literature on transport demand shows a predominant use of the log-linear functional form. According to Oum (1989), this is due to the simplicity with which coefficients can be interpreted and to the importance that models based on the log-linear functional form, such as gravity or abstract mode models, gained in transport economics in the 1960s and 70s. Wardman (1994), among others, criticises this practice, and recommends the use of alternative functional forms which do not impose the constant elasticity restriction.

In the research on which this paper reports an alternative to the log-linear functional form was searched for using Box-Cox transformations of all the variables. However, this procedure did not provide a better alternative because of perfect multicolinearity problems among the transformed variables before an optimal value of the transformation parameter could have been obtained. Since the value of the transformation parameter at which perfect multicolinearity appeared was closer to 0 (log-linear specification) than to 1 (linear specification), the log-linear functional form was kept.

Explanatory variables

The use of an aggregate demand function such as the one estimated here can be justified in terms of the representative consumer assumption. Given that the demand we look at is that of a transport mode, it is not enough to include prices and income level as explanatory variables. We need to look at two additional issues. On the one hand, the relevant cost when choosing a transport mode is the generalised cost, in which both monetary and time costs are included. Because of this, the set of explanatory variables includes a measure of non monetary costs. On the other hand, given that transport demand is derived from demand over goods and services whose consumption requires the customer to travel, it is also needed to include variables that reflect that original demand.

The original theoretical model would therefore be reflected in the following demand function:

$$D_{it} = f(p_{it}, q_{it}, m_{it}, s_{it}) \tag{1}$$

where each variable's subscripts refer to the city (i) and the time period (t), and the variables are defined as:

D_{it} = commuter travel demand
p_{it} = vector of monetary prices in different transport modes
q_{it} = vector of quality levels in different transport modes
m_{it} = income level
s_{it} = other socioeconomic variables which indirectly affect transport demand

Specification

The search for a model specification is based on the general-to-specific simplification strategy. This strategy implies looking for a representation of the data generating process which is as simple as possible, starting from the most general one (Pagan, 1990). Initially, thus, the explanatory variables of the model include measures of prices and quality of travel in train and private vehicle, economic activity and rainfall levels, as well as as dummy variables to take into account the effects of exceptional events (Seville's Universal Exhibition and Barcelona's Olympic Games, both in 1992). At each step in the simplification process it is decided if an exogenous variable should or should not be excluded. This decision is taken according to the variable's explanatory power, its relative variability and the interpretation problems which it may cause in case of multicolinearity problems.

Fixed or random effects

The initial specification of the panel data model includes both individual and temporal effects. It is thus a model of the form

$$y_{it} = \alpha_i + \lambda_t + \Sigma_j \beta_j x_{jit} + e_{it} \qquad (2)$$

Individual effects (α_i) capture the effects on demand that do not change with time and which are characteristic of each of the 11 cities in the panel. Temporal effects (λ_t), on the other hand, are common to all cities, but change with time. Therefore, the estimation of the model includes the estimation of 10 individual and 59 temporal effects, besides the coefficients of the explanatory variables mentioned in the previous sub-section.

When estimating a panel data model it is necessary to choose between treating individual effects as fixed or random. The later option offers the advantage of being based on a more general assumption, so after estimating the model it is possible to evaluate the acceptability of imposing the fixed effects restriction with a Hausman test. However, some authors (Mundlak, 1978, Hsiao, 1988; Nerlove and Balestra, 1992) recommend that the election be made according to the use to be given to the estimation, since it affects the kind of inference that the researcher may want to carry out. They argue that the fixed effects model is appropriate in the case that the population object of study is the same as the sample with which the model is estimated, or when the purpose is to predict over particular individuals in that sample. Random effects, on the contrary, should be used in those situations when we want to carry out inference not conditioned to the particular sample used for the estimation. Given that our commuters' demand function is estimated with a sample equal to the whole population, we treat the individual effects in the model as fixed.

RESULTS

Estimated models

The general-to-specific simplification process results in a model specification in which only price and quality of railway services, dummies for the Olympic Games in Barcelona and Expo'92 in Seville, as well as individual and temporal effects, appear as explanatory variables. Among other absences with respect to the initial general specification, this model does not include as explanatory variables the characteristics of transport modes competing with commuter railways, such as the private car. It cannot, however, be concluded from this absence that those modes do not compete with each other. Estimation of discrete choice models with individual data would be needed in order to analyse the process of choosing among different transport modes. This has not been possible here given the aggregate nature of the data employed. The conclusion which can be reached from that absence is simply that changes in the prices of petrol (used to measure car costs) and in the density of roads in the corresponding province (a proxy for quality of car use) do not have a significant influence on the evolution of aggregate suburban railway demand.

First column in table 3 shows the results of estimating this model, while individual effects are reported in table 4. The most interesting coefficients for the analysis of travel generation in suburban services are the ones related to prices and quality. In both cases the elasticities obtained show that demand is inelastic with respect to both attributes.

The estimation of the model including 59 temporal effects is not considered the best possible one, given that it is expected that the seasonal effects affecting demand will show a regular pattern year after year. Besides that, the inclusion of such a number of temporal effects does not allow us to include an additional explanatory variable which may capture other factors affecting demand. Those factors could be summarised as urban decentralization processes, improvements in the quality of stations and income growth. There is evidence that all those processes are taking place in Spanish cities during the considered period, and it would be expected that they would affect positively the demand for suburban railway services. However, no monthly data at the geographical level we work with is available to reflect them separately, so it is not possible to include them as explanatory variables in the model. In order to measure the importance of those factors, it was decided to include an arithmetic trend among the exogenous variables and capture the seasonal effects with monthly dummies. This is impossible if all temporal effects are also kept in the model specification.

Table 3 - Estimation results

	1. Individual and temporal effects		2. Individual effects		3. Individual effects and AR(1)	
Endogenous variable: ln passengers-km.						
Observations:	656		656		644	
Explanatory variables:	**coef.**	**t statistic**	**coef.**	**t statistic**	**coef.**	**t statistic**
Train price	-0.451	-12.36	-0.453	-13.64	-0.376	-10.45
Train quality	0.505	11.47	0.462	11.57	0.487	10.17
Barcelona Olympics	0.206	1.94	0.262	2.67	0.186	1.96
Seville Expo'92	0.478	7.28	0.533	8.73	0.447	5.68
Trend			0.005	13.28	0.005	7.38
June			-0.073	-3.69	-0.067	-4.16
July			-0.075	-3.77	-0.065	-3.66
August			-0.196	-9.68	-0.184	-11.26
October			0.064	3.28	0.062	4.44
December			-0.095	-4.84	-0.105	-7.33
AR(1)						
R^2	0.99		0.98		0.99	
Adjusted R^2	0.98		0,98		0.99	
Standard Error	0.139		0.134		0.114	
Res. Sum of Squares	11.27		11.54		8.12	
Ln L	401.92		988.44		1024.53	
F	788.08		6928.27		8525.92	

Train price: natural logarithm of revenue per passenger-km. Train quality: natural logarithm of frequency of offered train places per km. of network. Trend: arithmetic trend common to all cities. AR(1): estimated ρ. Other variables are dummies for the Olympic Games in Barcelona (July and August 1992), World Expo in Seville (April to October 1992), and monthly dummies. See table 4 for intercept terms.

Because of all these reasons, the model was re-estimated including the set of explanatory variables, 10 individual effects, a trend and all monthly dummies which are significant at a 5% level. The results, reported in table 3, column 2, show that price and quality elasticities are not significantly modified, which gives an indication of the robustness of the estimation. However, when the Durbin-Watson test is applied to this model, in 8 out of the 11 individual cases, it is not possible to reject the hypothesis of no first order autocorrelation among the residuals, while in 3 more cases the statistic lies in the inconclusive region. The model was therefore estimated again including a first-order autoregressive structure. The final model is, thus, the following:

$$
\begin{aligned}
\ln Y &= \alpha_i + \Sigma \beta \ln X + u_t \\
u_t &= \rho u_{t-1} + e_t
\end{aligned} \tag{3}
$$

where

$$E[e_t] = 0$$

$$E\left[e_t^2\right] = \sigma_e^2$$

$$Cov[e_t, e_s] = 0 \quad if\ t \neq s$$

Estimation results for this model are shown in column 3 of table 3, together with the previous ones. Estimated price-elasticity changes slightly with respect to the previous case, as do other coefficients, but again the robustness of the model is not put into doubt. The result obtained here of quality-elasticity being larger than price-elasticity in absolute values (0.48 vs. 0.37) is relatively frequent in demand estimations for urban transport (see, for instance, Hambergeer and Chatterjee, 1987; Benham, 1982; Wang and Skinner, 1984; Kyte *et al.* 1988; Gaudry, 1975). This result implies that in order to increase their patronage, operators would better increase their quality than reduce prices in the same percentage.

Individual effects

Besides the explanatory variables discussed above, a further influence in the demand levels for suburban railway services is the size of the market they serve. This is captured by the individual effects. It is expected that larger cities will obtain larger values for that intercept term. Table 4 presents the estimated individual effects for the model with trend and first order autocorrelation in the residuals. For the three largest cities (Madrid, Barcelona and Valencia), the ranking of individual effects is the one we would expect. For smaller cities that regularity is broken, with some smaller cities showing a intercept higher than that of more populated cities. This can be explained by the fact that for some cities the railway network does not cover the whole urban area, so city population would be an imperfect measure of the potential market for suburban railways. Seville is a good example. Despite being among the larger cities in in population terms, its individual effect is the third lowest in all estimations. As shown in table 2, Seville has a very low number of stations (21), comparable to that of much smaller urban areas such as Santander or Málaga.

Table 4 - Estimated individual effects

City	Model 1.Individual and temporal effects	Model 2. Individual effects	Model 3. Individual effects and AR(1)
Barcelona	13.49	12.96	12.53
Bilbao	11.69	11.19	10.74
Cádiz	10.41	9.93	9.55
Madrid	13.65	13.11	12.67
Málaga	11.39	10.90	10.48
Murcia	11.51	11.04	10.67
Oviedo	11.21	10.72	10.32
San Sebastián	11.28	10.78	10.37
Santander	10.26	9.79	9.42
Seville	11.02	10.54	10.17
Valencia	12.85	12.36	11.96

Sample segmentation

The estimation of a single demand function for all cities implies assuming that elasticities will be the same for all of them, independently of their size. It is possible, however, that city size have an influence on the values of elasticities, since commuters will not react in the same way to the same price or quality change in all settings. One of the main size-related factors that may influence railway demand is the degree to which the private car is considered as an alternative transport mode. Since size is assumed to worsen road congestion problems, and therefore make car a less atractive alternative to rail, it would be expected that railway elasticities change with size. In order to check this hypothesis, the panel is divided in two sub-samples, corresponding to the four largest cities (Barcelona, Bilbao, Madrid and Valencia) and the other seven (Cádiz, Málaga, Murcia, Oviedo, San Sebastián, and Seville).

Table 5 shows the results of the estimation for each group of cities. In both cases after calculation of Durbin-Watson statistics, it was decided to include a first order autoregressive structure in the residuals[4]. In each case monthly dummy variables are included when significant. These results allow us to be more precise in the conclusions reached before. Demand elasticities with respect to price are not significantly different from the value obtained with the whole sample (-0.37 against -0.38 for large cities and -0.31 for small ones). In the case of elasticity with respect to quality, however, the value obtained for large cities (0.65) is significantly different from the one obtained for small ones (0.37) or from the average one (0.49). The difference among the latter is only marginally significant at a 5% level[5].

Table 5 - Estimation results for sub-samples

	Large cities		**Small cities**	
Endogenous variable: ln passengers - km.				
Observations:	231		413	
Explanatory variables	**coef.**	**t stat.**	**coef.**	**t stat.**
Train price	-0.382	-5.55	-0.312	-7.37
Train quality	0.656	8.32	0.372	6.53
Trend	0.004	5.37	0.005	5.65
Olympic Games Barcelona (dummy)	0.264	3.79	-	-
Expo'92 Seville (dummy)	-	-	0.485	5.64
June (dummy)	-0.088	-4.57	-0.049	-2.71
July (dummy)	-0.164	-7.41	-	-
August (dummy)	-0.377	-13.69	-0.094	-5.20
September (dummy)	-0.010	-4.91	-	-
October (dummy)	-	-	0.073	4.01
December (dummy)	-0.073	-4.25	-0.124	-6.61
AR(1)	0.468	7.53	0.555	13.21
R^2	0.99		0.95	
Adjusted R^2	0.99		0.95	
Standard Error	0.080		0.121	
Residual Sum of Squares	1,390		1,121	
Ln L	405.98		574.33	
F	3779.12		1144.99	
Large cities: Barcelona, Bilbao, Madrid and Valencia. Small cities: Cádiz, Málaga, Murcia, Oviedo, San Sebastián, Santander and Seville. See variables' definition in table 3. Individual effects not shown.				

How can the more elastic railway demand with respect to quality in larger cities be explained?. Our intuition is that, since congestion problems affecting private car users are more severe in those cities, quality improvements in railway services will also be more effective in attracting car commuters to the train. Given the congestion problems they face in large cities, car commuters will be readier to switch mode when offered more frequent services than their counterparts in smaller cities. RENFE is aware of this difference, as proved by the fact that it has managed to attract many new customers in the early 90s, mainly in Madrid and Barcelona, thanks to constant quality increases. The possibility of repeating this success in the near future, however, seems to be small, given the large amounts of funds required by new investments which would allow capacity increases in tracks which in many cases have to cope with different kinds of railway traffic.

CONCLUSIONS

In a context in which railway companies are reorganising their structure in order to allow for more management independence to each of their business units, this paper has provided empirical evidence about the characteristics of the demand faced by RENFE's unit in charge of suburban services. Recent changes in the railway passenger market have resulted in this market being the most important customer provider for the company.

Suburban railway services' demand is shown to be inelastic with respect to both prices and quality, although to a lesser extent with respect to this last variable. Segmentation of the sample according to city size, however, shows that the main difference between elasticities with respect to price and quality takes place in large cities. It is there where quality increases can be most effective in attracting non-railway commuters. This possibility, however, faces the need of important investments in the upgrading of the infrastructure.

ENDNOTES

[1] Directive 440/91 of the European Council.
[2] Series in table 1 may hide a breaking point since the definition of services and the procedures used to count customers have changed during the period shown. A particularly important change took place in 1991, simultaneously to the organisational restructuring discussed in the text. Given that after that date ticket sales have been computer-recorded in most of the network, it can be assumed that since then the series are homogeneous.
[3] Data for Barcelona between April and July 1991 are not reliable because of problems in the computer selling system, and are thus excluded.
[4] For nine cities the test rejects the null hypothesis of non-autocorrelation, and in two cases it lies in the indifference region.
[5] 5% confidence intervals for price and quality elasticities in the case of large cities are (-0.513, -0.247) and (0.504, 0.808) respectively. For small cities the intervals are (-0.943, -0.230) and (0.259, 0.483).

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