ECONOMIC DISCUSSION PAPERS

Efficiency Series Paper 04/2008

Explaining Occupancy Rates in the European Railways: a Reduced-Form Approach

Luis Orea, Ana Rodríguez-Álvarez y Subal Kumbhakar

Departamento de Economía

Universidad de Oviedo

Available online at: www.uniovi.es/economia/edp.htm

UNIVERSIDAD DE OVIEDO

DEPARTAMENTO DE ECONOMÍA

PERMANENT SEMINAR ON EFFICIENCY AND PRODUCTIVITY

EXPLAINING OCCUPANCY RATES IN THE EUROPEAN RAILWAYS: A REDUCED-FORM APPROACH

Luis Orea[♣], Ana Rodríguez-Álvarez[♠] and Subal Kumbhakar[♦]

Efficiency Series Paper 04/2008

Abstract: Occupancy rates of vehicles are often used to analyze the firm performance in the transport industry. The occupancy rates tend to be low in many of the European countries and there are important differences in occupancy rates among countries. To understand better the reserved capacity that transport companies are maintaining in the European railway sector, we propose using a reduced-form approach to identify the determinants of the observed occupancy rates. Our results suggest that demand uncertainty, adjustment costs, "fidelity" strategies and social obligations are important determinants of annual rates of passenger.

Key words: occupancy rates, excess capacity, European railways

[♣] Corresponding author. Departamento de Economía, Universidad de Oviedo, Spain.
e-mail: lorea@uniovi.es

[♠] Departamento de Economía, Universidad de Oviedo, Spain.

[♦] SUNY at Binghampton.

1. Introduction

The European rail industry grew rapidly during mid 20th century since governments and regulators encouraged spreading railways services. These services were considered as a catalyst to overcome geographical barriers in certain areas, aid in the economic development of undeveloped zones, and as a guarantee of minimum transport services for a particular segment of the population. In the last 30 years, both passenger and freight transport in Europe have steadily grown at the rate of 2% to 3% annually. However, railways in the EU are not doing so well. Figure 1 shows that the rate of growth of rail passenger transport is positive but it lags behind other means of transport, viz., cars and air transport. As a consequence rail's share in passenger transport decreased from 10% to 6% during the period 1970-2001 (see Table 1). In the case of freight transport the trend is also downward, but more dramatic. Figure 2 shows that a falling trend in the European railways activity started in the 1980s. The loss in market share is not only in relative terms but even in absolute terms. Rail freight transport decreased by 0.6% annually, while freight transport in general rose by 4%, and road transport increased by 7%. As shown in Table 2, rail's market share in freight transport dropped from 21% to 7.8% during the period 1970-2001.

This reduction in rail services in the 1980s can be attributed to the rapid development of alternative modes of transportation, especially by road, and other factors, such as regulation, that restrict the industry's adaptation to changing conditions of economic environment. Di Pietrantonio and Pelkmans (2004) distinguished between exogenous and endogenous reasons. Among the exogenous reasons, a long-run trend is the transformation of the European economy from an industrial to a service-based one. Within industry, a widespread adoption of just-in-time production processes has taken place, which inevitably entails flexible sourcing and adaptable transportation means. Besides these economic trends, one might consider as exogenous the impact of a strong policy preference for road-based transportation. As an endogenous reason, they mentioned almost total lack of adaptation to dynamic markets and changed customer requirements. Markets in the EU and their associated trade flows have increasingly become cross-border while rail services were always kept national and costs are seen as very high, hindering the intermodal shift to rail. In addition, most of the complaints about rail services concern the lack of competitive pressure.

Table 1. Passenger transportation market shares in EU15

Year	*Cars*	*Buses &* Coaches	*Tram +* Metro	*Railway*	*Air*
1970	73.8	12.7	1.6	10.4	1.6
1980	76.1	11.8	1.2	8.4	2.5
1990	79	9.3	1	6.7	4
1991	78.8	9.3	1.1	6.8	4.1
1995	79.5	8.7	0.9	6.2	4.6
1996	79.3	8.8	0.9	6.3	4.7
1997	79.2	8.7	0.9	6.3	4.9
1998	79.1	8.6	0.9	6.2	5.2
1999	78.8	8.5	0.9	6.2	5.5
2000	78.1	8.6	1	6.4	5.9
2001	78.2	8.6	1	6.4	5.9

European Commission - Energy & Transport in Figures 2003

Table 2. Freight transportation market shares in EU15

Year	**Road**	*Rail*	**Inland waterways**	*Short sea shipping*	*Oil Pipelines*
1970	31.0	21.1	7.8	35.3	4.9
1975	33.7	17.7	6.7	36.5	5.4
1980	33.2	15.2	5.7	41.2	4.9
1985	36.6	14.7	5.4	39.4	3.9
1990	40.6	11.1	4.8	40.1	3.4
1991	42.5	9.8	4.4	39.9	3.4
1992	42.6	9.2	4.4	40.4	3.5
1993	43.2	8.7	4.4	40.1	3.6
1994	43.3	8.7	4.4	40.1	3.4
1995	43.5	8.4	4.3	40.6	3.2
1996	43.7	8.3	4.2	40.6	3.2
1997	43.5	8.6	4.2	40.7	3.1

European Commission - Energy & Transport in Figures 2001

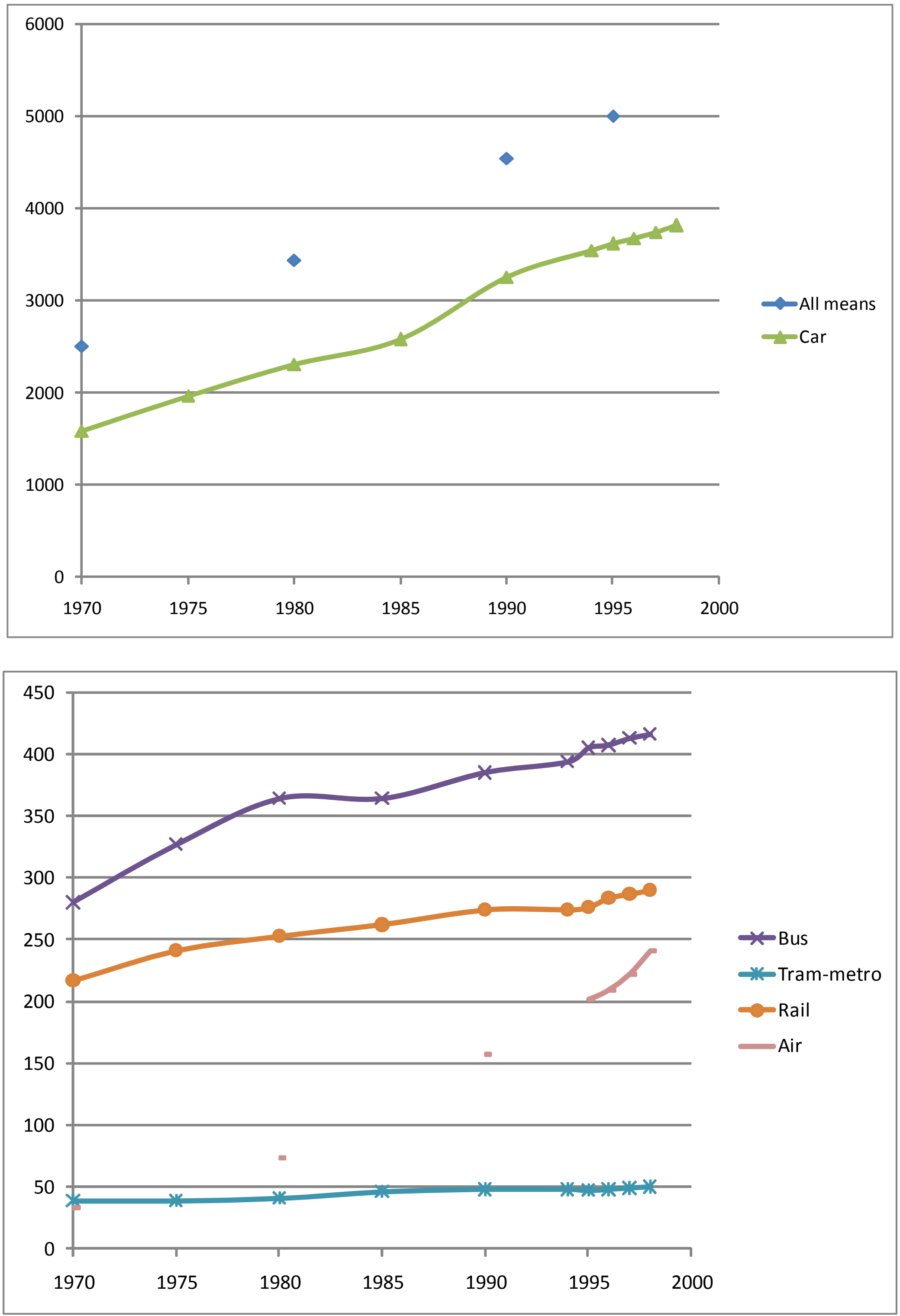

Figure 1. Passenger transport by modes in the EU (1970 – 1998)
Note: Passenger transport in 1000 millions of passenger-kilometers.
Source: European Commission - Energy & Transport in Figures 2001

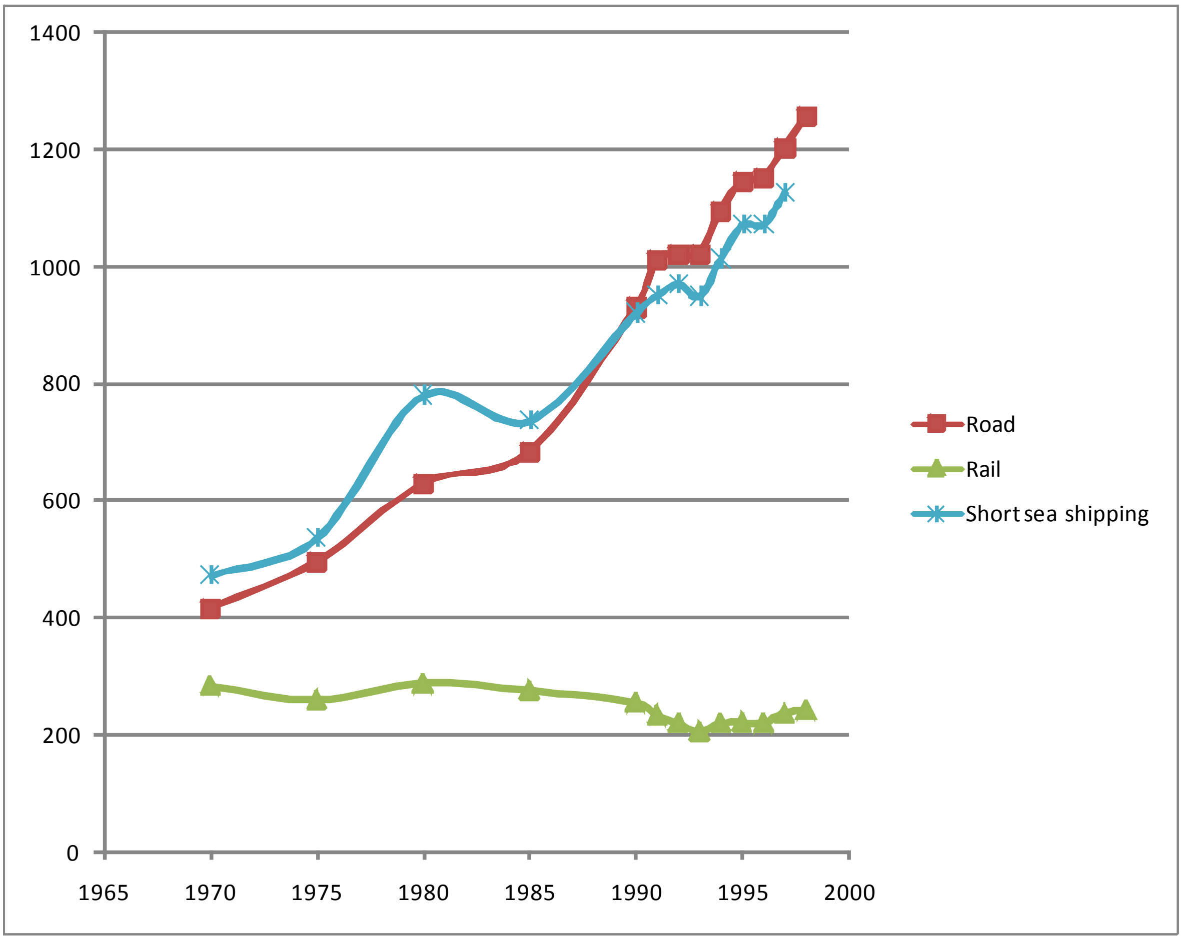

Figure 2 - Freight transport by modes in the EU (1970 – 1998)
Note: Freight transport in 1000 millions of tone-kilometers.
Source: European Commission - Energy & Transport in Figures 2001

To mitigate the declining market share and worsening financial performance of railways, in 1984 the European Commission proposed using decentralised methods of management by sectors or business units, separating accounts and clearing targets to increase profitability or reduce losses.[1] In 1991, the Directive 91/440 presented by the European Commission advocated a system of competitive access to the infrastructure, based on the principle of vertical disintegration between infrastructures and operations.

[1] This was the approach adopted in Britain form the early 1980s to 1994, where the five business sector were given their own directors, separated accounts and clear targets to increase profitability/reduce the scale of losses. Costs were allocated to the business sector on the basis that each sector was responsible for the costs of assets (including infrastructure) and staff. Following the British experience, many European Railways, such as Spain, The Netherlands and Germany have reorganized on a business sector basis (OECD, 1998). These measures were mainly cost or input oriented (see Kumbhakar et al, 2007). For instance, management contract in 1984-1986 in Spain provided an agreement to close 882 km of lines and to reduce the workforce by 15,000 in the course of four years.

This approach is explained by the fact that infrastructure costs are largely sunk and infrastructure provision exhibits natural monopoly characteristics.[2] After this, various Directives were presented by the European Commission (1995, 1996, 1998, and 2004). Finally, Directive 12/2001 required separate accounting for passenger and freight transport services and the White Paper, 2001 (Commission of the European Communities) established that full competition across Europe will take place by 2008.[3]

An important indicator that is often used to analyze firm performance in the transport industry is the occupancy rate, measured as the percentage of occupied seats or as the ratio passenger-km to train-km.[4] A low occupancy rate is often viewed as an indicator of low firm efficiency, financial and sustainability problems, and high environmental costs. Additionally, when the occupancy rate is low, an extra passenger does not lead to a proportional increase in the offered services (in terms of vehicles) so that the marginal costs are lower than the average costs. However, low occupancy rates might have also positive effects on welfare because when the occupancy rate is high, travelers tend to have problems with space (also for luggage) and moderate levels of discomfort due to (over)crowding might appear. This is perhaps the reason why suppliers of public transport intentionally plan their activities in such a way that occupancy rates stay considerably below 100%. When trains are long and almost full, it might take longer for passengers to find a seat, especially when they enter it from the 'wrong' side. This may lead public transport companies to add some capacity to save the passengers from the mental stress of finding an empty seat.

---

[2] The most radical experience in the process of vertical separation is the British railways which after strong improvements in the later 1980s began to deteriorate in the early 1990s. The infrastructure was placed in the hands of a new company, which was privatised in 1996. Less extreme experiences are in Germany and Netherlands (for details see Cantos *et al.*, 2002 and OECD, 1998).

[3] As Claes *et al*. (2003) point out, all of these directives are designed to liberalize the European rail systems, but they do not mandate specific means to achieve liberalization. Each member country must decide how to comply with the directives.

[4] It is worth noting that the occupancy rate is a *conditioned* measure of capacity utilization in the sense that it is calculated with respect to those vehicles that have been *activated* in order to provide transport services. Railway companies maintain inactive (i.e. stopped in the garage) part of their locomotives and rail vehicles mainly for maintenance reasons. That is, the equipment that should be revised or repaired is substituted for others that previously have been revised and repaired. In addition, railway companies might maintain inactive part of their rolling stock in order to offer the necessary flexibility to obtain a train on short notice if a new service has to be provided. Hence, another indicator of firm performance that can be examined is the excess capacity associated with the existence of inactive vehicles. Unlike the occupancy rates that are more associated with economic and social issues, its main determinants depend on technical issues and the existence of good maintenance programs.

Although the demand of passenger transport has been increasing in the last decades, the occupancy rates tend to be low in many industrialized countries. For instance, Rietveld *et al*. (2001) showed that the average (peak plus off-peak) occupancy rate of railway services in the Netherlands is about 40%. This means that there is substantial excess capacity and occupancy rates are low, especially outside the peaks periods. Moreover, as shown in Figure 3, the occupancy rate in the European Union declined between 1980 and 1998. Figure 4 shows a similar evolution for most of the EU Member States, with the exception, for instance, of Netherlands where their occupancy rates have increased markedly by more than 30 % between 1980 and 1998. [5] Figure 4 also shows that there are significant differences among countries in the occupancy rates in passenger transportation.

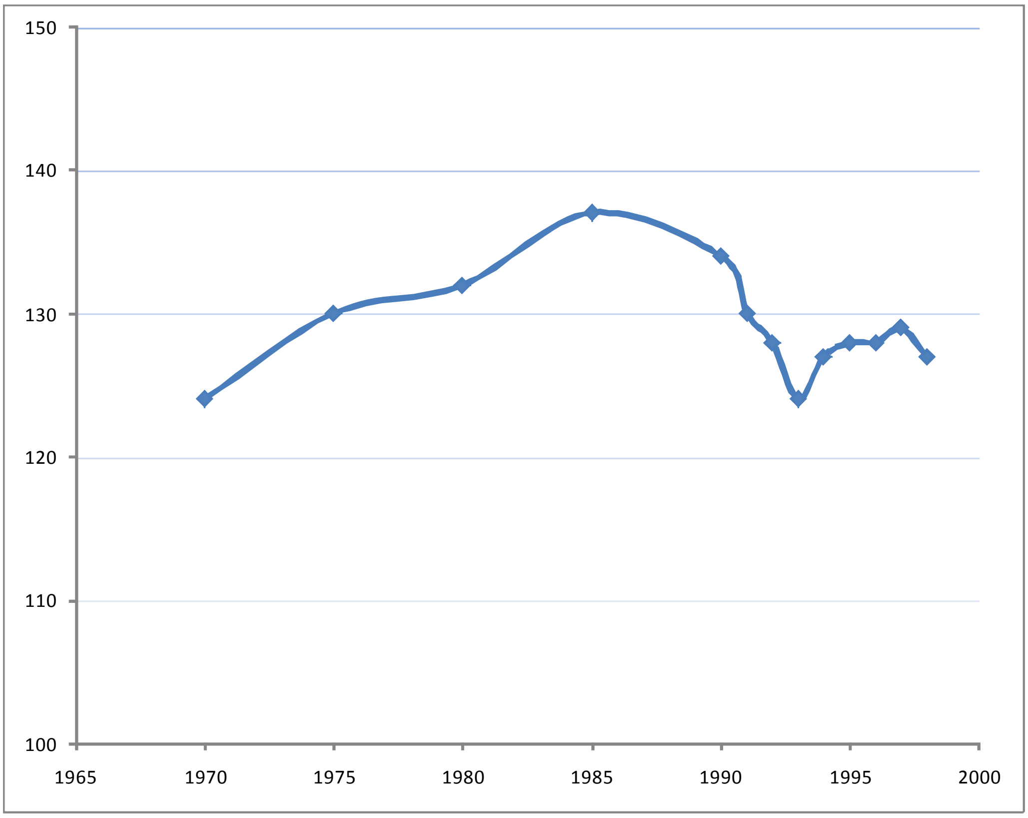

Figure 3. Passenger occupancy rates in the UE-15

Note: Occupancy rate measured by the number of passenger-km per trains-km.
Source: European Commission - Energy & Transport in Figures 2001

[5] This is probably due to increasing congestion on the roads, improved efficiency of the Dutch railways (i.e. closing down less profitable lines) and more seats per train (Dutch Railway Company, 2000).

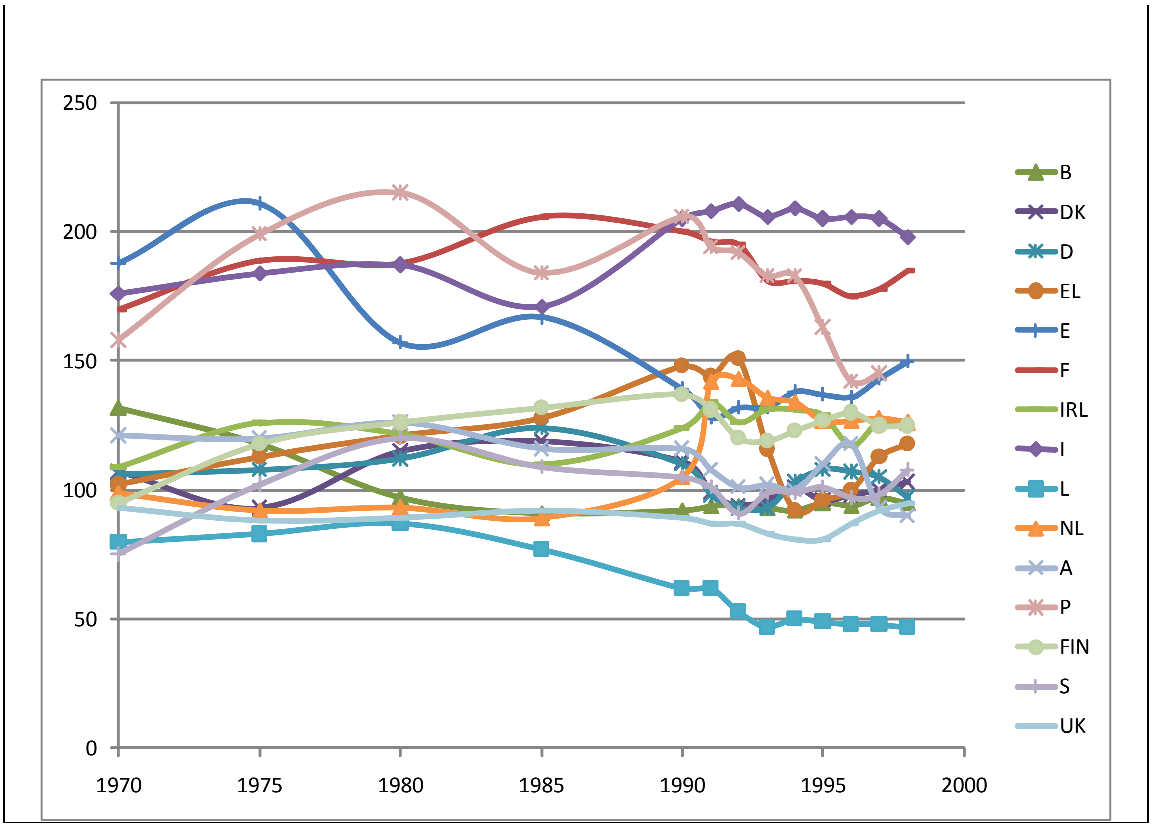

Figure 4. Passenger occupancy rates by EU Members States Note: Occupancy rate measured by the number of passenger-km per trains-km. Source: European Commission - Energy & Transport in Figures 2001

The main objective of the present paper is to identify the determinants of occupancy rates. This allows us to understand better the reserved capacity that the European railway companies are maintaining. There are many reasons that might also explain why railway companies are maintaining different levels of excess capacity or low occupancy rates. As it is explained in the next section, the occupancy rates might depend on technical indivisibilities, adjustment costs, demand uncertainty, service obligations, etc. Since these factors are partially idiosyncratic for each country, low occupancy rate might not be directly associated with inefficient behavior!

Previous studies do not empirically examine the determinants of the observed occupancy rates. The empirical literature in railway transport has analyzed railway firm performance, using unobserved indexes of efficiency.[6] Most of the previous studies

[6] These indexes were obtained by estimating both primal (e.g. production and distance functions) and dual (e.g. cost and revenues functions) representations of the technology. These functions were in turn estimated using both parametric (e.g. Coelli and Perelman, 1999, 2000,

measured firm inefficiency via parametric and non-parametric frontier techniques, but they do not explain their inefficiency scores.[7] In addition, these scores involve not only capital stocks, which are associated to infrastructure or rolling stocks' management, but also variable inputs such as labor or energy.[8]

Since several phenomena might be behind the observed occupancy rates, we have not chosen a particular (and likely partial) structural model based on an explicit modeling of firms' behavior to explain the observed occupancy rates in passenger transport. Instead, in this paper we propose using a reduced-form approach to model occupancy rates as a function of their determinants. Because our data is quite aggregate we have limited information on most determinants, so we are forced to use proxy variables and to take advantage of the panel data estimators in order to captured country-specific factors that are not observable to the researcher.

2. Determinants of occupancy rates[9]

Occupancy of trains depends on several things such as: the attractiveness of a route, the time of day, the time of year, etc. In addition to all these the low occupancy rate is also associated with the nature of the investment process. Indivisibilities in transport vehicles and high adjustment costs may imply low occupancy rates. For example, although carriages may be coupled and de-coupled, such coupling and de-coupling takes time and that the costs may be so high that it is more efficient to accept low occupancy rates on the part of the line with low demand. Moreover, once a company decides to invest in vehicles of a certain size, it cannot easily change its size even if it appears that the vehicles are bigger for the market in which it will be used. It is almost impossible to change the composition of vehicles, i.e. the number of the various types

---

and Christopoulus et al. (2001, 2002), and non-parametric (e.g. Cowie and Riddington, 1996; Cantos and Maudos, 2000; and Cantos *et al.* 2002) frontier techniques.

[7] Only a few papers, such as, Oum and Yu (1994), Gathon and Pestieu (1995), Cantos et al. (1999), Driessen *et. al.* (2006), and Wetzel (2008), try to explain inefficiency scores using the regulation and firms' autonomy level, population and network density, traffic structure, and other control variables.

[8] It is worth mentioning that some of the papers cited in the previous footnote (e.g. Oum and Yu, 1994, and Driessen *et. al.*, 2006) used some measure of occupancy as a determinant of their (overall) efficiency scores.

[9] This section is partially inspired by Rietveld *et al.* (2001).

of seats (smoking versus non-smoking, first class versus second class), according to short term fluctuations in demand for vehicles.

The acquisition of locomotive and rail vehicles has very high fixed cost. This cost is mostly sunk because once a vehicle (i.e. a locomotive) is bought, there is not a well developed market where it can be easily sold or rented. Lack of technical interoperability of locomotives and the need for multiple conformity assessment reduce the opportunities from reselling the equipment in second-hand markets.[10] On the other hand, increasing the size of a fleet takes time because adding new locomotives and rail vehicles may last some years. In addition, suitable second-hand locomotives are often not available. The purchase of a second hand locomotive from a foreign undertaking does not offer an option as the procedure to adapt the locomotive to the national technical standards and to obtain a "general admission" would cost almost as much as the locomotive itself (di Pietrantonio and Pelkmans, 2004).

The existence of adjustment cost for both increasing and decreasing the size of the fleet explains why the investments in new vehicles are quite slow. The slowness of the investment in locomotives and vehicles may lead to high (low) occupancy rates if the demand has been increasing (decreasing) in the previous years. That is, the evolution of occupancy rates is countercyclical as illustrated in Figure 5.

Anticipation of future increases in demand, however, may lead to low occupancy rates given the quasi-fixed nature of the investment in vehicles. The standard situation is illustrated in Figure 6. In this figure, expected demand is increasing which fits with the observed evolution of railway services over three decades. We also assume in this figure that capital decisions are made at the beginning of each period. In absence of adjustment costs firms will *instantaneously* adjust their capital stocks to the actual demand (see the yellow line), which fluctuates around the actual demand. In this case, capital stocks would only depend on the present demand because the future is not a relevant variable in deciding the actual level of capital. But, if capital is not a completely

[10] It should be noted, however, that "old" vehicles are often being recomposed and resold to emerging economies, such as Mexico, Chile, Turkey, etc. This suggests that the second hand markets nowadays are less rigid than used to be decades ago, and hence the fixed cost are less sunk.

variable input, administrators take into account the expected increase in the demand, and the selected capital stocks will be those indicated by the red lines. Note that in Figure 6 this investment in capacity does not satisfy the demand most of the years. If they are risk-averse and for social or political reasons they want to guarantee rail services with a small probability of failure, the target value is the expected future demand *plus* a measure of demand uncertainty. In this case, the selected capital stock will be that indicated by the green lines, and, since the expected demand is increasing, the excess capacity is higher at the beginning of each period than at the end.

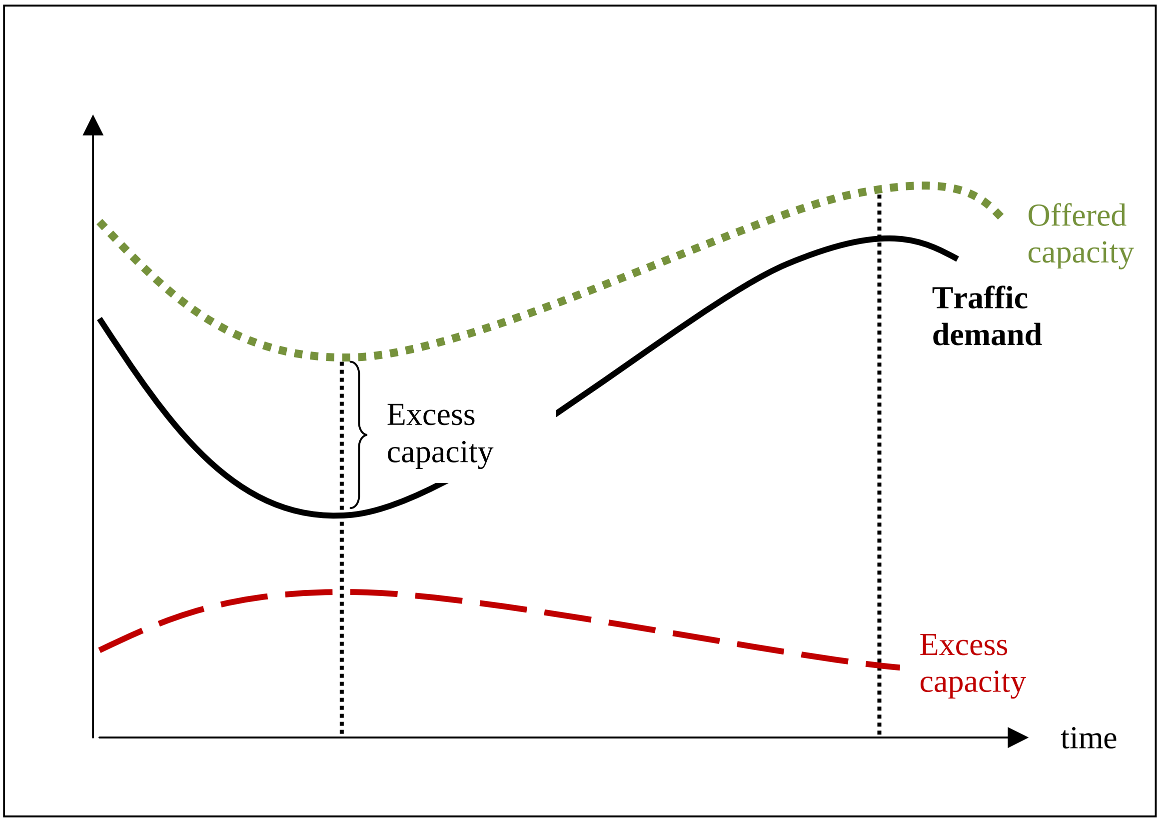

Figure 5. Excess capacity and traffic demand evolution

Another reason for low occupancy rates when the demand is increasing is consumers' preferences. For instance, some public transport companies serve recently developed neighborhoods that are not yet completed to offer services for residents from the very first day they start living there. It is the fear that residents will develop a 'car oriented culture' so that public transportation will not be used when it is offered at a later stage.

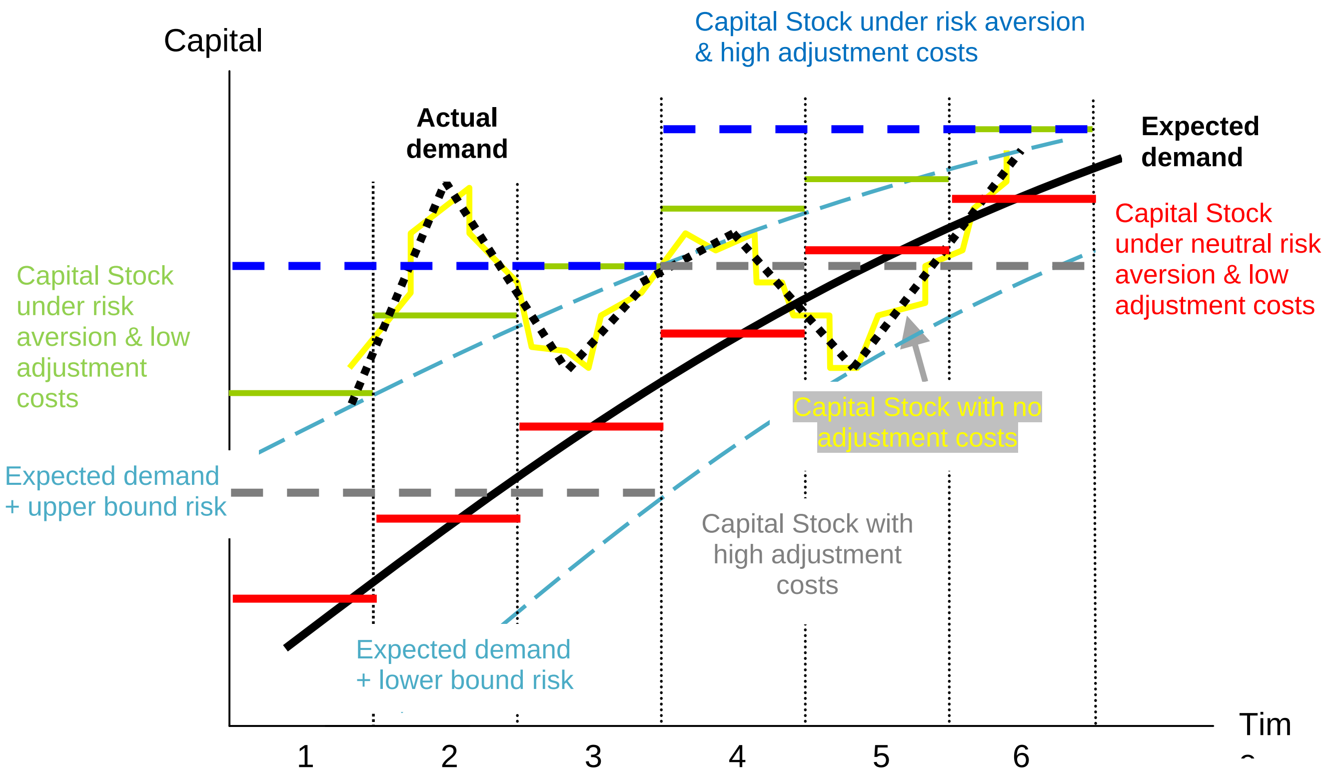

Figure 6. Capital stocks evolution under different levels of risk aversion and adjustment costs

The aforementioned "fidelity" strategy in undeveloped areas can be also imposed by the regulator for social or political reasons. As a result of public service obligations the railway firms are obliged to supply services during virtually all relevant hours of the day. Consequently, trains tend to be rather empty early in the morning and late in the evening. Similar public service obligations arguments can be made for the zones with low demand or sparsely populated areas.

Spatial imbalances of demand for transport lead to the situation that when trains are needed to bring passengers (or goods) from A to B during the morning peak, these trains will meet little demand for the return trip during the same peak. Thus when they make the return trip to point A they may be rather empty (this is the so-called *back-haul problem).* Some public transport companies have a policy of using quite regular timetables (for example one train per hour). This implies that when during part of the day there is less demand the company will not respond by reducing its frequency.

One of the characteristics of railways is that they face uncertain demand for the services that they offer in a particular day, week or month. Most public transports do not require the advance reservation of a seat. Hence suppliers face the problem of planning routes without knowing exactly the number of passengers. Since public place a high value on railway transportation availability and wish to prevent queuing and congestions, railway administrators (regulators) are likely risk-adverse. Faced with the possibility of peaks in demand, a large part of which are predictable, these risk-adverse administrators will maintain a certain level of excess capacity (i.e. low occupancy rates) above the average level of demand. [11]

Hence, we expect a negative effect of (a measure of) demand uncertainty on occupancy rates. Other type of uncertainty may also yield low occupancy rates. Trains usually offer four types of seats: smoking versus no-smoking and first class versus second class. This is an extra reason of low occupancy rates, because public transport companies tend to follow the policy that for each of the segments there should be sufficient capacity. Thus even when total demand is known but the shares of the various segments are not known (i.e. there is segment-specific uncertainty), there would be a tendency to supply more seats than necessary.

Traffic forecasts are routinely used to build rail infrastructures and plan activities. Hence, overoptimistic demand forecasting might also lead to higher levels of quasi-fixed inputs and, hence, low capacity utilization rates. Mistakes do happen and there is enough evidence to argue that overoptimistic demand forecasting is common.[12] Thus,

---

[11] The vertical distance between the green and red lines in Figure 6 measures "inefficiency" due to firms' risk aversion behavior. The interesting thing here is that this apparent inefficiency depends on the adjustment costs. Imagine that the adjustment costs increase and, hence, firms can only invest in capital every three periods. The risk-averse firm now will increase its capital stock up to the dotted blue lines. The capital stock chosen by the "risk-neutral" firm will be indicated by the dotted grey lines. Note that the increase in adjustment cost and the increase in time among investments always lead to an increase in apparent "inefficiency" of the risk-adverse firm (the difference between the dotted blue and grey lines).

[12] Flyvbjerg *et al.* (2006) conclude that the traffic estimates used in decision-making for rail infrastructure development are consistently and significantly inflated. Particularly, in their study that involves 25 rail projects shows that for 72% of all rail projects passenger forecasts are overestimated by more than two-thirds. For example, Bangkok Sky train was hugely

deviations (i.e. inefficiency) from a proper planning of railway services are also a determinant of capital stocks and occupancy rates.[13]

Finally, occupancy rates for trains vary across train types. To examine this, as a first approximation, one can use the estimates in Table 3 for occupancy rates (yearly average), based primarily on German and Danish data.

Table 3. Occupancy rates by traffic type

Traffic type	**Link**	**Occupancy rate (%)**
Urban Transport	Urban train (Copenhagen)	28
(dominant rust hours)	Typical value	30
Regional transport/InterRegional	West Link (Denmark)	37
	East Link (Denmark)	39
	Typical Value	40
Intercity (IC)/International(EC)	Danish Intercity links	56
	Danish International traffic	45
	German EC average	45
	Typical value	50
High-Speed trains (1997)	Germany	45
	Italy	44
	Netherlands	46
	Spain	61
	Sweden	52
	Belgium	47
	France	58
	Finland	39

Source: Infras, 1998 and UIC, 1999

overdimensioned because the passenger forecast was 2.5 times higher than actual traffic. Don Pickrell (1992) provides similar evidence in a detailed review of the main urban rail projects in 8 US cities. It shows that the forecast that led local governments to advocate for 10 rail transit projects over the competing but less capital intensive options, grossly overestimated rail transit demand. In 7 out of 8 cities, actual demand was less than half of its forecasted level. Regarding road infrastructures, traffic forecast for some of the most publicized toll roads projects exceeds actual traffic from 25% (Cuernavaca-Acapulco in Mexico) to as much as 60% (M1-M15 Highway in Hungary or the average for the Mexican toll road program). Most of Asia's BOTs projects for toll roads were based on very optimistic growth assumptions pre-dating the fallout at the end of the 1990s (see Trujillo *et al.* 2002).

[13] If mistakes are simply a matter of incomplete information and inherent difficulties in predicting a distant future demand, then one would expect mistakes to be symmetrically distributed. In this case, a capacity utilization equation can be estimated using OLS or other traditional and symmetric estimators. However, existing studies almost all conclude that there is a strong tendency for traffic forecasts to be overestimated (see Flyvbjerg *et al.*, 2006 and the references therein). Thus, it seems that deviations from optimal planning do not follow a symmetric distribution, but bad planning of activities are biased towards an increase in the stock of capital. In order to check whether there is a tendency to over build the stock of capital a model with a one-sided (and positive) random term, altogether the traditional symmetric random term, can be estimated.

The occupancy rates in urban traffic lines are 30%. In regional trains it is higher, about a 40 %. In intercity/international trains the OR reach the 50% limit. While regular trains are on average 30-40% full, the occupancy rate of high-speed trains is generally higher, varying for different countries and connections (e.g. about 80 % for the TGV Paris-Lyon). The occupancy rates are higher in long lines mainly because their demand is less uncertain and social obligations are not as severe as in urban lines.

3. Empirical specification and data

3.1. Reduced-form equation

In this paper we propose estimating a reduced-form equation in order to model passenger and freight occupancy rates as a function of their determinants, X and Z, respectively. For the passenger transportation, the occupancy rate is measured as the ratio of passenger-km to trains-km, i.e.

$$OR = \frac{N \cdot d}{S \cdot D} \tag{1}$$

where Y=N·d, $N=\Sigma^{M}_{m}N_m$ is total number of passengers in a particular year, which we assume is formed by M periods of time, N_m is the number of passengers in period m, d_m is the average distance travelled by passengers in period m, $d=\Sigma^{M}_{m}(N_m/N)\cdot d_m$ is the average distance travelled by passengers, $S=\Sigma^{M}_{m}S_m$ is total number of trains (or services) offered by a railway company, S_m is the number of trains (or services) offered in period m, D_m is the average distance travelled by each train in period m, and $D=\Sigma^{M}_{m}(S_m/S)\cdot D_m$ is the distance travelled on average by each train in its whole route.[14]

The equation to be estimated can be written in logarithmic form as:

$$lnOR_{it} = ln(Y_{it} / T_{it}) = X_{it}'\alpha + u_i + \varepsilon_{it} \tag{2}$$

[14] By construction, the distance traveled by passengers should be less than the distance traveled by trains (i.e. $d<D$). In addition, the total number of trains offered in a particular period of time cannot be by construction higher than the size of the fleet, F. That is, $S_m<F$ or $S<M\cdot F$.

where $Y=N \cdot d$ stands for passenger-km, $T=S \cdot D$ stands for trains-km, X is a vector of observable variables that we expect are affecting the occupancy rates, α is a vector of parameters to be estimated, u_i is a random term that captures unobservable country-specific determinants (such as public service obligations, back-haul problems, inefficiency, etc.) which we assume to be time-invariant, and ε_{it} is a traditional random term that captures random shocks that affect the occupancy rate and measurement errors in variables.

The above model can in turn be expressed as a "capacity equation" or an "input demand equation" which consist in expressing the logarithm of capacity supply (i.e. lnT_{it}) as a function of traffic demand (i.e. lnY_{it}), and the vector of observable variables, X_{it}. That is,

$$\ln T_{it} = f(Y_{it}, X_{it}, \alpha) + u_i^{'} + \varepsilon_{it}^{'} \quad (3)$$

where $u_i^{'} = -u_i$ and $\varepsilon_{it}^{'} = -\varepsilon_{it}$.[15] Ignoring the unobservable country-specific effects, Urdánoz and Vibes (2006) have recently estimated using OLS an equation similar to (3) with traffic demand and a time trend as explanatory variables.

In the next section, we present the results for different specifications of the above model. The first one is a basic OLS model where control variables and country specific effects are not included. The second model is also estimated by OLS with control variables (such us uncertainty, risk aversion, past demand evolution, etc.), but it does not control for unobservable time-invariant variables. The next two models take into account for country-effects and they are estimated using the random effects (RE) and fixed effect (FE) estimators. In our application, both have their own pros and cons. The RE model allows us to control for unobservable effects holding our time-invariant explanatory variables. The FE parameter estimates are consistent if the unobservable variables are correlated with the explanatory variables, but the coefficients of the time-invariant explanatory variables cannot be identified from the time-invariant fixed effects. In addition, FE models tend to exaggerate "error-in-variables" bias, which is the difficulty in detecting the statistically influence of an explanatory variable when that variable is measured with error (Griliches,

[15] Note that if X_{it} does not include the log of traffic demand, the expected coefficient of lnY_{it} in (3) is one by construction.

1979; Griliches and Hausman, 1986). In our application we have several variables that are measured with error, and in particular, the expected demand rate of growth. For these reasons, all the estimated parameters should be interpreted with caution.

3.2. Explanatory variables

As determinants of the passenger occupancy rates we employ the following variables. The variable *lnY* is captures the log of the demand level measured in millions of passenger-km. We include this variable in order to check the existence of adjustments costs. Under the assumption of no adjustments costs, capital stocks adjust exactly at the same rate as demand, i.e. the elasticity of capital stocks with respect to the demand is equal to one. Given (1), this implies that the parameter of *lnY* in (2) should not be statistically different from zero. However, because of the quasi-fixed nature of the investment and the high adjustment costs, it will generally be impossible to design a flexible investment strategy to adjust quickly to increases in demand. In this case, we expect an elasticity of capital stocks with respect to the demand less than unity. This also implies that the ratio of passenger-km to trains-km depends positively on the demand level.

It is also worth noting that the variable *lnY* also allows us to know if increases in demand are located in the more occupied routes or in routes that can be supplied using the vehicles that are already active. If increases in demand are located in routes that can be supplied using the vehicles that are already active this parameter should be positive and statistically different from zero.

We have included *Loccar*, i.e. the proportion of locomotives to railcars (mostly used in urban lines), as a proxy of the proportion of intercity or interregional traffic lines. As mentioned before, since the occupation in long traffic lines is higher than in urban lines, we expect a positive effect. Since the occupancy rate of high-speed trains is generally higher than regular intercity or urban trains, we have also included the proportion of high speed lines with respect the total length of lines, *HSpeed*.

We have included the rate of growth of demand during the previous 5 years in order to measure the effect on actual occupancy rates of the slowness of the investment in new vehicles. We expect a positive effect of this variable, indicating that the past increases (decreases) of the demand have yielded lower increases (decreases) in the size of the fleet due to the existence of adjustment costs. Since the adjustment costs might be higher when new vehicles have to be acquired (adding new locomotives and rail vehicles usually last several years) compared to when old vehicles are resold in the second markets, we distinguish between increases, *Growth(+)*, and decreases, *Growth(-)*.[16] This allows us to account for temporal asymmetries in the rolling stock investment process.

In order to capture the existence of a "fidelity" strategy or social obligations in recently developed neighborhoods we have included the future growth rate of the demand in the following 5 years, *FutureGr*. Under this kind of strategy or social obligations, the effect of future demand on occupation should be negative.[17]

To account for within-year demand uncertainty we have to construct a dispersion statistic, such as, the standard deviation, from daily, weekly or monthly data of railway demand. This information is not available because the data is quite aggregate. However, under the assumption that quantity volatility is correlated with price volatility, and changes in airline and railway transportation demand are highly correlated, we have constructed a monthly volatility variable, $ln\sigma$, using the estimated monthly variation of airfares published by Eurostat for each country during the period 1996-2008. This variable is time-invariant and is constructed as the log of the standard deviation of the coefficients we obtained for monthly dummies in an air transport price equation that we estimated separately for each country.[18]

[16] See footnote 7.

[17] This may also capture administrator's anticipation of future demand under non-static behavior. The expected demand used by administrators to make their decisions regarding capital stocks and capacity supply is not observed by the researcher. However, if a long panel data is available, the "real" demand in the future can be measured. The demand in period t+5 that administrators would have predicted in t is Y(+5). Since the variable *lnY(+5)* captures the "real" future demand growth, and not the demand growth expected by the administrators, we might have a problem of measurement errors in the variables and, hence, the coefficient of the future demand is likely downward biased.

[18] The model that has been estimated is:

$$ln\, p_{it} = \theta_0 + \theta_1 t + 0.5 \cdot \theta_2 t^2 + \sum_{m=1}^{12} \lambda_m D_m + \varepsilon_{it}$$

where p_{it} is the price of the air transport in a particular country.

The estimated coefficients for each country are shown in Table 4. The monthly variation in airfares is high as shown in Figure 7, and it seems to be correlated with changes in demand transport. For example, prices are higher in the summer months and in December when demand is probably higher compared to other times of the year. This within-year evolution was not found in the case of rail prices, which would be our preferred prices. It can be seen from Figure 8 that for three representative European countries, the evolution of rail prices along the year is almost zero because they are highly regulated. In some countries like Spain, they were increased at the beginning of the year following the general price index in their respective countries. In Figure 9 we also see that there are significant differences among countries in our volatility variable. For these reasons we believe that the short run demand uncertainty variable which has been constructed might work well. [19]

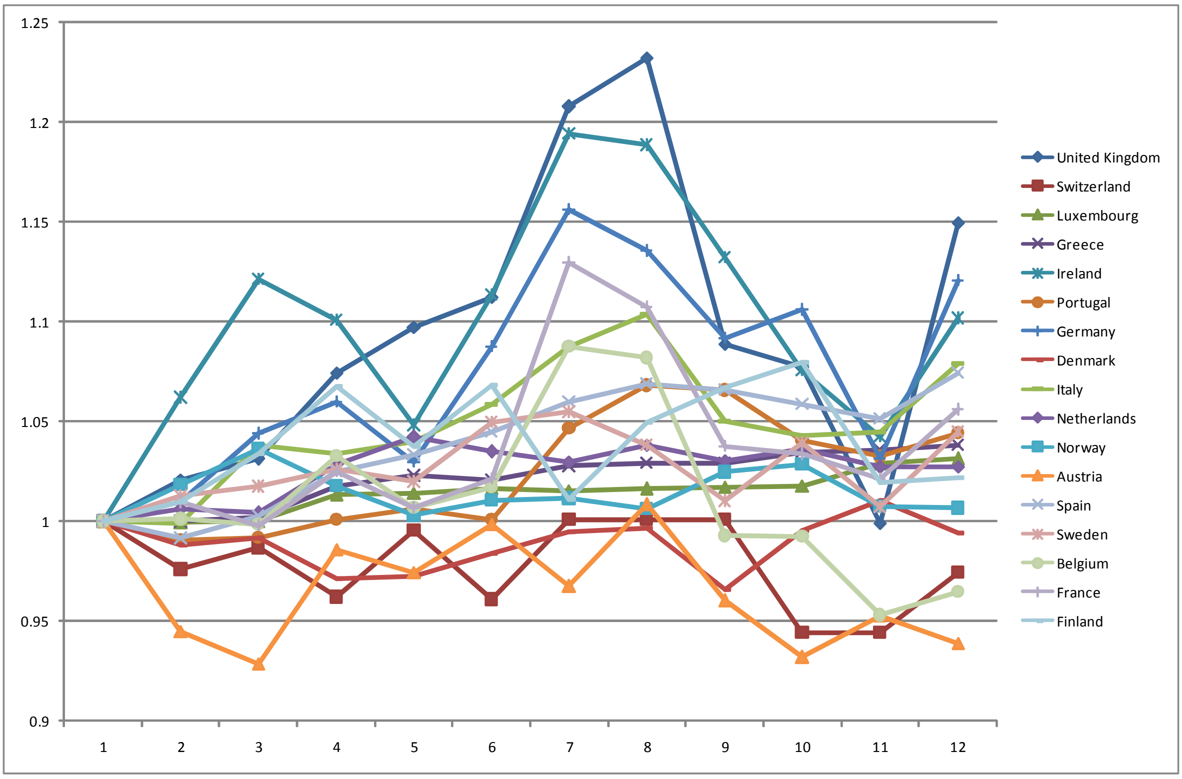

Figure 7. Monthly fluctuations of airfares

[19] Following Gaynor and Anderson (1995), and Hughes and McGuire (2003), we used the square prediction errors of a previously estimated autoregressive demand model to capture annual demand uncertainty. This demand model was estimated separately for passenger and freight transport demand using *GDP*, the *GDP* per capita and the average price paid by passengers or paid for each ton as explanatory variables the. The coefficient of the annual demand uncertainty in the occupation rate equations was, however, not statistically significant.

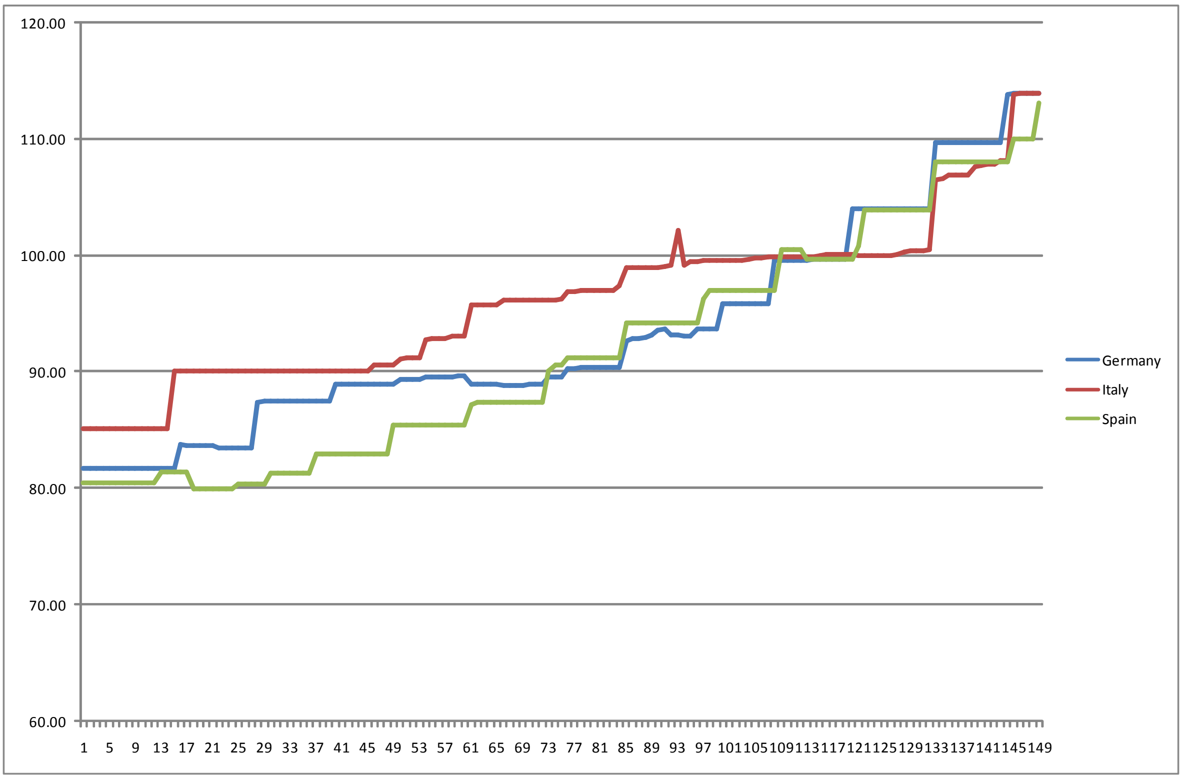

Figure 8. Evolution of rail prices in three representative countries

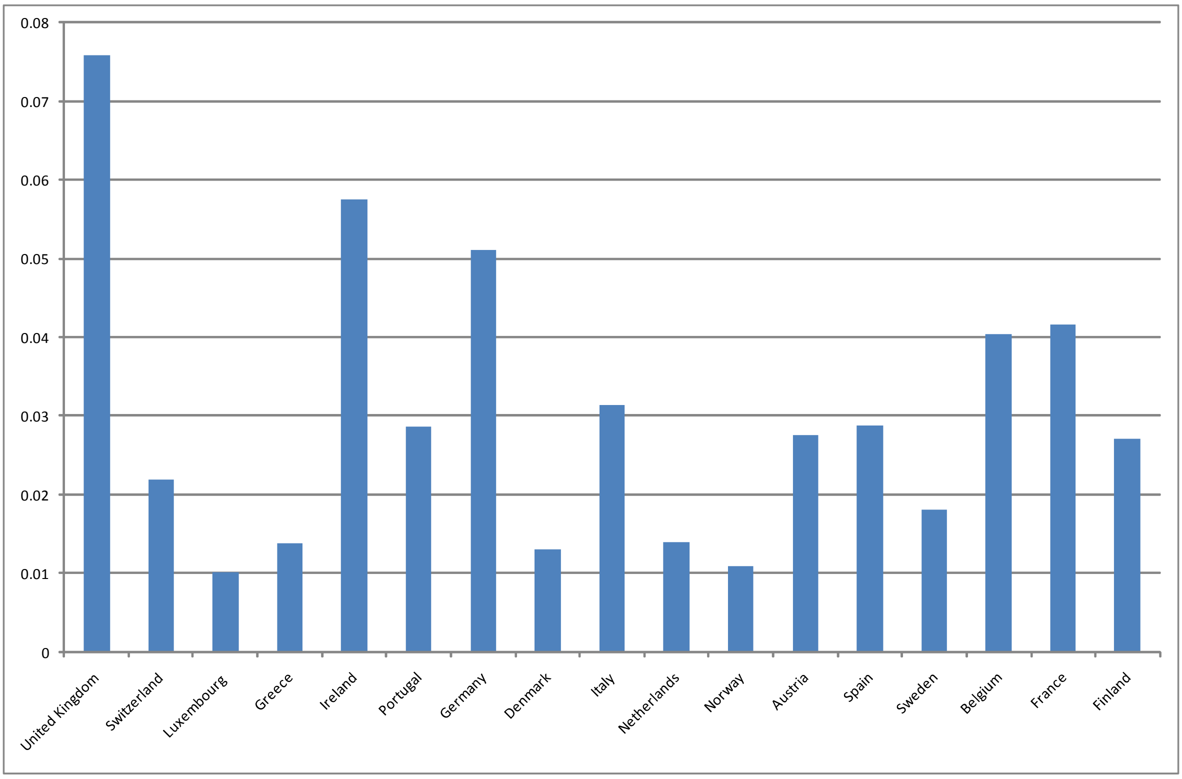

Figure 9. Estimated monthly volatility of airfares

Table 4. Air transport price equation (by country)

	UK		*Switze.*		*Luxemb.*		*Greece*		*Ireland*		*Portugal*		*Germany*		*Denmark*		*Italy*	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t
m2	0.021	0.74	-0.024	-0.41	-0.001	-0.07	0.000	0.00	0.062	1.43	-0.009	-0.49	0.010	0.94	-0.012	-0.53	-0.001	-0.03
m3	0.031	1.03	-0.013	-0.24	0.000	0.00	0.002	0.20	0.121	2.31	-0.008	-0.47	0.044	2.80	-0.009	-0.43	0.038	1.59
m4	0.074	2.44	-0.038	-0.80	0.013	1.49	0.018	1.77	0.101	1.99	0.001	0.03	0.060	5.47	-0.029	-1.32	0.034	1.33
m5	0.097	3.48	-0.005	-0.08	0.014	1.57	0.023	2.27	0.048	1.00	0.006	0.31	0.030	2.51	-0.028	-1.29	0.040	1.60
m6	0.113	3.84	-0.039	-0.70	0.016	1.87	0.021	2.03	0.114	2.85	0.001	0.05	0.088	7.12	-0.016	-0.75	0.059	2.07
m7	0.208	5.16	0.001	0.02	0.016	1.71	0.028	3.00	0.194	3.91	0.047	2.42	0.156	15.32	-0.005	-0.25	0.088	2.82
m8	0.232	5.09	0.001	0.02	0.016	1.76	0.029	3.21	0.189	4.09	0.068	2.96	0.136	14.12	-0.003	-0.16	0.104	3.30
m9	0.089	3.46	0.001	0.02	0.017	1.92	0.029	3.21	0.132	3.11	0.066	2.85	0.092	10.18	-0.034	-1.66	0.050	1.83
m10	0.077	2.89	-0.056	-1.26	0.018	1.98	0.035	3.62	0.075	1.76	0.041	2.37	0.106	8.19	-0.005	-0.26	0.043	1.77
m11	-0.001	-0.03	-0.056	-1.26	0.029	3.49	0.036	3.62	0.042	0.90	0.032	2.11	0.032	2.58	0.010	0.480	0.044	1.74
m12	0.150	4.66	-0.025	-0.48	0.031	3.58	0.038	3.96	0.102	1.90	0.044	2.72	0.121	10.14	-0.006	-0.32	0.079	2.73
t	0.039	5.84	1.046	4.60	0.037	22.90	0.080	37.58	0.054	7.06	0.070	16.84	-0.001	-0.29	0.021	4.92	-0.011	-2.34
t2	-0.006	-5.05	-0.104	-4.74	0.000	0.08	-0.006	-16.84	-0.004	-2.67	-0.007	-9.35	0.005	12.53	-0.001	-2.27	0.009	10.49
Const	4.379	164.21	-0.559	-0.48	4.231	620.1	4.118	448.31	4.245	107.5	4.310	301.68	4.292	488.36	4.457	259.6	4.168	187.9
R-squared		0.556		0.529		0.977		0.982		0.624		0.842		0.936		0.483		0.854
Obs.		148		42		149		149		149		149		149		149		149

Table 4. Air transport price equation (continued)

	Netherlands		*Norway*		*Austria*		*Spain*		*Sweden*		*Belgium*		*France*		*Finland*	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t
m2	0.006	0.54	0.018	0.49	-0.055	-1.17	-0.009	-0.59	0.013	0.66	0.001	0.05	0.010	0.79	0.010	0.34
m3	0.004	0.35	0.036	0.86	-0.072	-1.75	0.003	0.20	0.017	0.86	-0.002	-0.08	-0.002	-0.19	0.034	0.98
m4	0.029	2.55	0.018	0.50	-0.014	-0.30	0.025	1.70	0.026	1.36	0.033	1.13	0.025	2.23	0.068	2.50
m5	0.042	2.68	0.003	0.07	-0.026	-0.53	0.033	2.44	0.020	1.07	0.007	0.32	0.007	0.55	0.037	1.21
m6	0.035	3.07	0.011	0.30	-0.001	-0.03	0.045	3.08	0.050	2.14	0.017	0.65	0.021	1.79	0.068	2.82
m7	0.030	2.31	0.011	0.32	-0.032	-0.72	0.060	4.22	0.055	2.73	0.088	2.97	0.130	10.27	0.011	0.42
m8	0.038	3.38	0.006	0.18	0.008	0.200	0.069	5.10	0.038	1.91	0.082	2.96	0.107	7.64	0.049	1.91
m9	0.030	2.51	0.025	0.69	-0.040	-0.78	0.066	5.06	0.010	0.53	-0.007	-0.23	0.038	3.55	0.067	2.49
m10	0.036	3.31	0.028	0.77	-0.068	-1.26	0.059	4.62	0.039	2.21	-0.007	-0.26	0.034	3.27	0.080	2.90
m11	0.027	2.17	0.008	0.21	-0.047	-0.98	0.051	3.26	0.007	0.33	-0.047	-2.31	0.021	2.06	0.020	0.74
m12	0.027	1.79	0.007	0.17	-0.061	-1.26	0.074	5.01	0.045	2.48	-0.035	-1.10	0.056	5.46	0.022	0.77
t	0.036	12.30	0.100	13.01	0.123	4.70	0.066	21.75	0.029	7.01	0.096	8.03	0.020	8.88	0.071	11.79
t2	-0.001	-1.46	-0.013	-9.11	-0.022	-6.25	0.002	3.54	-0.004	-5.45	-0.020	-11.77	0.000	-0.21	-0.011	-10.36
Const	4.273	435.32	4.266	160.72	4.409	46.10	3.872	301.68	4.553	353.04	4.546	109.23	4.405	492.70	4.404	213.78
R-squared	0.933		0.660		0.683		0.985		0.319		0.864		0.893		0.545	
Obs.	149		149		101		149		149		114		149		149	

The expected coefficient of demand uncertainty will be probably higher the higher the managers' risk aversion. Since the aversion to risk might depend on the demand level, we have multiplied the short-run volatility variable with the demand level. This allows us to capture differences in administrators' risk aversion over time and/or across countries.

3.3. Sample and Data

The aforementioned model is estimated using data from the European Railways for the period 1971 to 1999. The data used in this paper are taken from the reports published by the *Union Internationale des Chemins de Fer* (UIC) and covers the railway companies from 17 European Union countries: the United Kingdom, Switzerland, Luxembourg, Greece, Ireland, Portugal, Germany, Denmark, Italy, Holland, Austria, Spain, Sweden, Belgium, France and Finland.

The sample means of all variables are presented in Table 5. The total number of companies included in the sample is 17 and the maximum number of observations is 510. The final number of observations in each model depends on available information (e.g. in Norway or UK) and the specific variables included in the equations. If, for example, we include a lead or a lag of 5 years, we lose 5 observations per country.

Table 5. Descriptive statistics

Variable	Obs	Mean	Std Dev	Min	Max
lnOR	486	-2.154	0.291	-3.038	-1.241
LnY	498	0.000	1.417	-3.468	2.409
$Ln\sigma$	510	0.000	0.579	-0.910	1.087
HSpeed	498	0.003	0.008	0.000	0.050
Loccar	345	0.677	0.141	0.338	1.000
$LnY \cdot Ln\sigma$	498	0.449	0.960	-1.972	3.154
Growth(+)	413	0.078	0.093	0.000	0.550
Growth(-)	413	-0.027	0.060	-0.512	0.000
FutureGr	413	0.042	0.141	-0.433	0.779

4. Empirical results

The parameter estimates for the passenger occupancy rate equation are presented in Table 6. Most of the explanatory variables are significant. The estimated country-specific effects (not shown in Table 6) are also significant[20] indicating that occupancy rates depend, as mentioned before, on many factors that are idiosyncratic to each country but not observable to the researcher. This suggests using panel data estimator in order to account for country-specific effects. The Hausman test rejects the null hypothesis of no correlation between the country-specific effects and the independent variables, suggesting that our preferred model is the FE.[21] Note, however, that in the FE model the coefficient of the (time-invariant) volatility variable cannot be identified, and the "error-in-variables" bias tends to be higher. Therefore, all the estimated parameters should be interpreted with caution.

Table 6. Passengers occupancy rate equation

	Model 1		**Model 2**		**Model 3**		**Model 4**	
Ind. Var.	Coef.	t	Coef.	t	Coef.	T	Coef.	t
Intercept	-2.155	-186.88	-2.379	-29.94	-2.208	-27.97	-2.246	-27.7
LnY	0.100	11.24	0.074	6.16	0.411	6.32	0.203	5.94
Lnσ	-	-	-0.016	-0.66	(dropped)		-0.202	-2.20
HSpeed	-	-	27.005	9.75	0.805	0.95	2.258	2.94
Loccar	-	-	0.298	2.92	0.277	3.44	0.256	3.18
LnY·Lnσ	-	-	-0.074	-6.49	-0.259	-3.01	-0.129	-2.72
Growth(+)	-	-	0.841	4.00	0.169	3.08	0.200	3.21
Growth(-)	-	-	-0.218	-0.92	-0.015	-0.18	0.034	0.35
FutureGr	-	-	-0.394	-3.69	-0.228	-5.98	-0.296	-7.86
Obs	486		257		257		257	
R-squared (%)	23.6		48.3		-		-	
σ_u	-		-		0.206		0.559	
σ_e	0.254		0.203		0.060		0.060	
Country-specific effects	No		No		Yes		Yes	
Estimator	OLS		OLS		FE		RE	
Hausman Test (d.f.)	-		-		13.87 (7)			

In the first model that uses OLS we find that the variable *lnY* has a positive and statistically significant effect on passenger occupancy rates. But, like in Urdánoz and

[20] A Wald test based on the FE model allows us to reject the null hypothesis that all country-specific effects are equal to zero. The value of the Walt statistic is 321.40. This test follows an F-distribution with (16, 233) degrees of freedom.

[21] See Hausman (1978).

Vibes (2006), the coefficient is rather small, suggesting low adjustment costs. The coefficient that they estimated for *lnY* in their passenger "capacity equation" was 0.87. This implies a coefficient equal to 0.13 in the occupancy rate equation, which is quite similar to that in the first column of Table 6. We get similar results when other explanatory variables are included.

However, the estimated coefficients in the two first columns of Table 6 might be downward biased due to the existence of unobservable variables which are likely to be correlated with some of the observed variables. Indeed, when country-specific effects are included we get a value that is two or four times higher than the estimated values using OLS. These higher values suggest the existence of high adjustments costs. It might also be the case that the increases in demand are in those routes where these additional demands can be met using the vehicles that are already active.

The proportion of locomotives to railcars, *Loccar*, has a positive effect on occupancy rates suggesting that occupation in long traffic lines is higher than in urban lines. This result is in line with our expectation.[22] The coefficient of *HSpeed* is also positive and significant when other control variables are included. This suggests that higher the proportion of high-speed trains, higher is the (aggregate) occupancy rates. Note, however, that the estimated magnitude seems to be highly upward biased when we do not account for unobservable country-specific effects, and that the coefficient is not statistically significant when a FE estimator is used. This last result might suggest that *HSpeed* is correlated with the country-specific effects.

The coefficient of *Growth(+)* is always positive and statistically significant. This suggests that past demand increases yielded lower increases in the size of the fleet. It might also indicate that either adding new locomotives and rail vehicles last several years or changing the size of the fleet is quite expensive. Note, however, that the coefficient of *Growth(-)* is not statistically significant. This suggests that reducing the stock of vehicles is not as expensive as increasing the rolling stocks. Furthermore, this result might, in turn, indicate that "old" vehicles are easily recomposed and resold to emerging capitalist economies, suggesting that the fixed cost of acquiring rail vehicles is not too sunk.

[22] We obtained similar results using the country size, measured in millions of squared kilometers, as a proxy for higher proportion of intercity or interregional traffic lines.

The coefficient of *FutureGr* is always positive and statistically significant. This might suggest several phenomena: viz., the existence of a "fidelity" strategy in recently developed neighborhoods, the existence of social obligations imposed by regulators or an anticipatory behavior of railways' administrators.

The effect of the monthly volatility variable, $ln\sigma$, is statistically significant and negative when individual company effects are taken into account. This means that within-year changes in demand are, as expected, important determinants of annual rates of occupation. Under neutral risk aversion this coefficient should not be statistically different from zero. Hence, its negative value also indicates that railways' administrators are risk averse. Finally, the interaction of the within-year demand uncertainty variable and demand level has a negative and statistically significant effect on annual occupancy rates. This means that $|\partial nOR/\partial n\sigma|$, i.e., the elasticity of occupancy rates with respect to short-run uncertainty in absolute values, is increasing with the demand level. This result suggests that large companies are more risk averse than small companies. Note, on the other hand, that passenger transport demand has increased over time. Hence, this outcome is consistent with an increase in risk aversion over time. If quality in transport services is inversely associated to queues, low frequency, crowded vehicles, etc. (i.e. issues that risk averse administrators try to avoid), this increase risk can in turn be interpreted as administrators preference towards quality issues.

5. Conclusions

Occupancy rates of vehicles are often used to analyze firm performance in the transport industry because these rates are either observable or can be easily computed using the available data. The occupancy rates tend to be low in many of the European countries and there are important differences in occupancy rates among countries. The occupancy rate in the European Union declined between 1980 and 1998, even though the demand of passenger transport has been increasing in the last decades.

While previous studies have analyzed railway firms' performance using non-observable indexes of efficiency, we identified some determinants of the observed occupancy rates. This allowed us to understand better the reserved capacity that the European railway companies are maintaining. To achieve this goal, we proposed using a reduced-form approach to model passenger occupancy rates.

Although occupancy rates depend on many factors that are idiosyncratic to each country and are not observable to the researcher, our results indicate existence of high adjustments costs in passengers transport. For example, we found that past demand increases yielded lower increases in the size of the fleet, indicating that adding new locomotives and rail vehicles is quite expensive. Reducing the stock of vehicles is not as expensive as increasing the rolling stocks because aged vehicles are easily sold to the emerging capitalist economies.

Our results also suggest, as expected, that occupancy in long traffic lines is higher than in urban lines and (aggregate) occupancy rates are higher; the higher is the proportion of high-speed trains. We also found evidence of the existence of “fidelity” strategies or social obligations in recently developed neighborhoods. Finally, we found that (within-year) volatility in demand is an important determinant of annual occupancy rates, and that the orientation to quality issues (i.e., risk aversion) increase with the railway services provided. Given that the passenger transport demand has increased over time, this result suggests that the orientation to quality issues has increased in the last three decades.

References

Cantos, P. and Maudos, J. (2000), "Efficiency, Technical Change and Productivity in the European Rail Sector: A Stochastic Frontier Approach", *International Journal of Transport Economics*, 27(4), 55–76.

Cantos, P., Pastor, J. M. and Serrano, L. (1999), "Productivity, Efficiency and Technical change in the European Railways: A Non–parametric Approach", *Transportation*, 26(4), 337–357.

Cantos, P., Pastor, J.M. and Serrano, L (2002), "Cost and Revenue Inefficiencies in the European Railways". *International Journal of Transport Economics*, 29(3), 279-308.

Christopoulus, D., Loizides, J. and Tsionas, E.G. (2001), "Efficiency in European Railways: not as Inefficient as one Might Think", *Journal of Applied Economics*, 4(1), 63-88.

Christopoulus, D., Loizides, J. and Tsionas, E.G. (2002), "Productivity Growth in European Railways: a New Approach", *Transportation Research*, part A, 36(7), 633-644.

Claes, M., Ch. Santini and J. Vergamini (2003), "The Liberalization of the European Railways" in *Global Initiatives in Management Anthology*. Kellog Scholl of Management, Northwestern University, Chapter 13, 145-159.

Coelli, T. and Perelman, S. (1999), "A Comparison of Parametric and Non-parametric Distance Functions: With application to European Railways", *European Journal of Operational Research*, 117(2), 326–339.

Coelli, T. and Perelman, S. (2000), "Technical efficiency of European Railways: a Distance Function Approach", *Applied Economics*, 32, 1967–1976.

Cowie, J. and Riddington, G. (1996), "Measuring the Efficiency of European Railways", *Applied Economics*, 28(8), 1027–1035.

Di Pietrantonio, L. and J. Pelkmans (2004), "The Economics of EU Railway Reform", *Journal of Network Industries* vol. 5, nº 3-4, 295-346.

Don Pickrell (1992), "A Desire Named Streetcar Fantasy and Fact in Rail Transit Planning", *Journal of the American Planning Association*, vol. 58 (2), 158-176.

Driessen, G., Lijesen, M. and Mulder, M. (2006), "The Impact of Competition on Productive Efficiency in European Railways", *CPB Discussion Paper* No. 71, CPB Netherlands Bureau for Economic Policy Analysis, The Hague, the Netherlands.

Dutch Railway Company, 2000: Jaarverslag 1999- statistische bijlage. Nederlandse Spoorwegen [Annual report 1999 - statistical annex. The Dutch Railway Company]. The Netherlands, 2000.

European Commission (1991), Directive 91/440/EC of the European Parliament and of the Council of 29 July 1991 on the Development of the Community's Railways.

European Commission (1995), "Toward Fair and Efficient Pricing". Green Paper.

European Commission (1996), "A Strategy for Revitalising the Community's Railways", White Paper, COM(96)421 final, Bruxelles.

European Commission, (1998), "Fair Payment for Infrastructure Use: a Phased Approach to a Common Transport Infrastructure Charging Framework in the EU". White Paper.

European Commission, (2001). Guideline 2001/14 on the Allocation of Railway Infrastructure Capacity and the Levying of Charges for the use of Railway Infrastructure and Safety Certification, Brussels

European Commission (2001), "European Transport Policy for 2010: Time to Decide", White Paper, COM(2001) 370, Bruxelles.

European Commission (2004), "With a Quality European Railway System the aim, the Commission is Proposing the Opening up of the Market for International Passenger Services in 2010", Commission Press Release, 3rd March 2004

Flyvbjerg, B., M.K. Skamris and S.L. Buhl, (2006), “Inaccuracy in Traffic Forecasts” *Transport Reviews*, 26(1), 1–24.

Gathon, H. J. and Pestieau, P. (1995), “Decomposing Efficiency into its Managerial and its Regulatory Components: The case of European Railways”, *European Journal of Operational Research*, 80(3), 500–507.

Gaynor, M. and G. F. Anderson (1995), “Uncertain Demand, the Structure of Hospital Costs, and the Cost of Empty Hospital Beds”, *Journal of Health Economics,* 14, 291-317.

Griliches, Z. (1979), "Sibling Models and Data in Economics: Beginnings of a Survey", *Journal of Political Economy*, 87(5), 37-64.

Griliches, Z. and Hausman, J. A. (1986), "Errors in Variables in Panel Data," *Journal of Econometrics*, 31(1), 93-118.

Hausman, J. A. (1978), “Specification Tests in Econometrics”. *Econometrica*, 46, 1251-1271.

Hughes, D. and A. McGuire (2003), “Stochastic Demand, Production Responses and Hospital Costs”, *Journal of Health Economics,* 22, 999-1010.

Infras (1998), “Intermodal Comparisons of Atmospheric Pollutant Emissions. MEET Project: Methodologies for Estimating Air Pollutant Emissions from Transport Deliverable”, No. 24. Infras, Bern, Switserland, October.

Kumbhakar, S., L. Orea, A. Rodríguez-Álvarez and M**.** Tsionas (2007), “Do we have to Estimate an Input or an Output Distance Function? an Application of the Mixture Approach to European Railways”, *Journal of Productivity Analysis*, 27 (2), 87-100.

OECD (1998), “Railways: Structure, Regulation and Competition Policy”, Directorate for Financial, Fiscal and Enterprise Affairs Committee on Competition Law and Policy.

Oum, T. H. and Yu, C. (1994), “Economic Efficiency of Railways and Implications for Public Policy: A Comparative Study of the OECD Countries Railways”, *Journal of Transport Economics and Policy*, 28(2), 121–138.

Rietveld, P., J. Dekkers and S. Van Woudenberg, (2001), "Choice of Frequency and Vehicle Size in Rail Transport: Implications for Marginal External Costs," *Tinbergen Institute Discussion Papers* 01-109/3, Tinbergen Institute.

Trujillo, L., E. Quinet, and A. Estache (2002), “Forecasting the Demand for Privatized Transport. What Economics Regulator should Know, and Why". *World Bank Policy Research, Working Paper,* nº 2446.

Union Internationale Des Chemins de Fer (2001): *International Railway Statistics*. 1970-1999. UIC, Paris.

Urdánoz, M. And C. Vibes (2006), “Cost Efficiency and Asymmetric Information in the European Railways Industry”, October, mimeo.

Wetzel, H. (2008), “European Railway Deregulation: The Influence of Regulatory and Environmental Conditions on Efficiency”, *Working Paper Series in Economics* No. 86, University of Lüneburg.