Has been improved the efficiency in the European railways companies?

Justo de Jorge * and Cristina Suarez**

May 2001

Abstract:

The aim of this paper is to estimatee the (in)efficiency for European railways,throuh an econometric estimation of frontier functions. The methodology used is the panel data methods. The statistical source cover 19 companies observed over the period from 1965 to 1998. We estimate two different specifications, the first is a "factor requirements function" and the second is a more flexible functional form "quadratic function". Our results indicate that the mean of the efficiency indicator are around of 0.6 and 0.4 for the factor requirement specification and the quadratic specification, respectively, and a great rate of technological progress.

* UNIVERSIDAD DE ALCALA
Departamento de Ciencias Empresariales
Plaza de la Victoria, 2
28802 Alcalá de Henares (Madrid)
España
Tel: + 34-91-8854293
Fax: + 34-91-8854227
e-mail justo.dejorge@uah.es

** UNIVERSIDAD DE ALCALA and PIE-FEP
Departamento de Fundamentos Económicos e Historia Económica
Plaza de la Victoria, 2
28802 Alcalá de Henares (Madrid)
España
Tel: + 34-91-8854202
Fax: + 34-91
e-mail cristina.suarez@uah.es

1.- Introduction

The public business industry is cause of constant argument and preoccupation for government's officials, as well as for society as a whole. European railway companies have been part of this argument over the time. This is consequence of the amount of public expenditure demanded by this industry both because of their importance in politically desirable and strategic areas and for its impact on other industries. In fact, railway companies share by themselves a big portion of the Gross National Product, total employment and direct investment.

There is a long tradition in the measurement of production characteristics, and performance, in railways. From Klein's (1953) seminal study on US railways to the recent studies using frontier analysis techniques (Gathon and Perelman (1992), Coelli and Perelman, (1996)), the majority of this research is devoted to detailing partial productivity analysis (British Railways Board and University of Leeds, 1979; Nash, 1985), and total factor productivity (TFP) comparisons based on the estimation of multi-output cost functions Caves et al. (1981).

Three features common to almost all railway companies influence the analytical framework used in many of the above studies. First, multi-output production since passenger and freight services are provided simultaneously and share to a great extent the same input. Second, all railway companies benefit from some degree of (natural) monopoly, even if the other transportation models indirectly compete with them. Third, railroad passenger transportation, and to a lesser extent, freight transportation, are public services, which are often strongly regulated.

The three characteristics described above are common to all 19 European railway companies considered in this study. Our research spans from 1965 to 1998, and over this timeframe several important facts in the environment conditions where these companies operate have occurred. The research's aim is to analyze what consequences had those events on the efficiency of our sample European railway companies.

All of the companies in this paper “produce” both passenger and freight services and, with the one exception of the privately owned Swiss company BLS, all were public-owned during our sample period. All companies held a natural monopolistic position on the railroad transportation, although in return their activity was constrained in varying degrees by public authorities. The initiative to change the environment within which railway firms dwell is part of the overall framework set by the European Union on transportation. Thus, directive 91/440/CEE enables a certain freedom of access for third parties to the infrastructure of some services like groups of railway companies interested in providing international services involving third countries, or supplying multi-modal services regarding international freights. It is to be highlighted, though, that a further extension of these rights is still under study.

Also, the above directive defines as an objective the split of the operation of the transportation business from the operation of the railway infrastructure (at least at the accounting level). In this regards, some railway companies have accomplished restructuring processes with the aim of trusting the planning and/or operation of the infrastructure to other “entities” different from the ones realizing the operation of the transportation services. Sweden was the first in taking the initiative - in 1988 a new public organism was created (the Banverket) completely different from the Swedish railways, whose decisions on investments and price are set based on criterions of cost and social advantages. The United Kingdom was second in following this role model: in April 1994, Railtrack was created as a government firm, independent from the British Railways. The British example, though, is completely opposite to the Swedish, since Railtrack is a service company, receiving no government subsidies, and private-owned (the public sell-out of all the shares of Railtrack took place in May 1996). Simultaneously, the services offering was privatized by simply selling out the freight and mail transportation, and licensing the passenger transportation. It is to this service activities where all government subsidies are adressed.

German railways with the birth of DBAG after Germany’s reunification are currently in this process after 1994; in Spain, RENFE changed in 1990 to a more decentralized organization consisting of some strategic business units; in Netherlands, since 1994, two groups have been born, one accounting for the infrastructure, and the other aiming for the commercial business.

Other relevant facts, like the impact of technological evolution is felt in this last decade with the introduction of high-speed trains. This means the arrival to the transportation market of a "product" whose features transform the traditional railway into a strong competitor of the other transportation means. This newcomer also requires a significant investment in infrastructures - countries like France, Germany or Spain are good examples of the effect of this technological evolution.

This paper is organized as follows: section 2 reviews the theoretical concepts in efficiency panel literature; section 3 presents the data set and the main features of the European railway industry; in section 4 we present the results of this study; conclusions are finally presented in section 5

2.- The Stochastic frontier with panel data approach

To measure the (in)efficiency for European railways, we choose the stochastic and parametric frontiers, and we have computed it through panel estimation techniques. This type of frontier and the computation method present advantages with respect other alternatives, for example the deterministic frontiers[1]. First, the deterministic frontiers are based on the assumption that the only type of explanation for the deviation between the observed output and its frontier output is due to its own inefficiency. This idea it is difficult to maintain at the empirical level due to it ignores the possibility that the observed output can differ from the potential because of two other factors: stochastic shocks and measurement error in the variables.

[1] The works of Førsund, Lovell and Schmidt (1980) and Kalijaran and Shand (1999) are excellent surveys of efficiency frontiers.

Second, the mathematical programming methods have two disadvantages with respect to specifying a statistical relationship between the outputs and the inputs. On the one hand, the frontier estimation is made over a subsample of the whole and then these methods are extremely sensitive to the existence of outliers. On the other hand, the estimated coefficients lack statistical properties, so it is not possible to make any statistical inference or establish hypothesis contrasts from them.

We can represent the technology with two specifications (we explain the specifications below), but for simplification the general form is:

$$
\begin{aligned}
y_{it} &= \alpha + \sum_k x_{kit} \ \beta_k + \varepsilon_{it} \qquad && i=1,\dots,N \\
\boldsymbol{e}_{it} &= v_{it} - u_i && t=1,\dots,T \qquad (1) \\
& && k=1,\dots,K
\end{aligned}
$$

where y_{it} denotes the input; x_k represents the outputs and some variables characterising the technology; and β_k stands for the parameters to be estimated. Finally, $\boldsymbol{e}_{it}$ is a composed error term: v_{it} is a disturbance term with the usual characteristics (iid, $N(0,\sigma_v^2)$) that captures the random factors that can explain the divergence between the observed and the potential input enumerated above and u_i captures the time-invaring latent individual effects. Schmidt and Sickles (1984) assume that these individual effects are indicators of the firm's (in)efficiency. Then, the u_i's are positive and iid with mean μ and variance σ_u^2 and they are independent of v_{it}.

Therefore, the parameter μ represents the latent average inefficiency level of technology. We can also assume (or not) a particular distribution for u_i, and we can assume (or not) that inefficiency is correlated with the explanatory variables . The technical efficiency measurement of an *i*th firm will be obtained from $ET = e^{-u_i}$.

This model is a simple generalization of the stochastic frontier models and they respond exactly to the usual literature of panel data models with individual effects. The only difference with the standard panel data models is that in (1) the individual effects (u_i) are one-sided. Following Schmidt and Sickles (1984) the model can be managed in the following way. Since we know that E(u_i) = μ >0, we can define:

$$\alpha^* = \alpha - \mu$$

$$u_i^* = u_i - \mu$$

and consequently u_i^* is independent and identically distributed with E(u_i^*) = 0. Therefore, the model (1) can be expressed as follows:

$$y_{it} = \alpha^* + \sum_k x_{kit}\ \beta_k + v_{it} - u_i^* \qquad (2)$$

Now, the two errors have mean zero and therefore we can directly apply all the results of panel data models. As a result, we can use the different estimators proposed in the econometric literature of panel data, the fixed effect model or the random effect model. The choice between these two models, as is well known, will depend on the possible correlation between the individual effects and the observable explanatory variables.

If this correlation exists the parameters of the model (2) can be estimated with the within groups estimators. The individual effects can be defined as $\alpha_i = \alpha^* - u_i^* = \alpha - u_i$ and their estimation will be obtained from the within estimators of the parameters of the model (β_k^{WG}).

From this estimation of the N independent terms $(\hat{\alpha}_1, \hat{\alpha}_2, ..., \hat{\alpha}_N)$ we can obtain an estimation of the independent term and the level of (in)efficiency (u_i) from a simple procedure:

$$\hat{\alpha} = \max(\hat{\alpha}_i)$$

$$\hat{u}_i = \hat{\alpha} - \hat{\alpha}_i$$

$$ET_i = e^{-\hat{u}_i}$$

This translation is necessary in order to obtain positive values for all the u_i. This is in fact a translation of the frontier suggested by Greene (1980). With this operation the technical efficiency index of the most efficient firm will be equal to one.

The second way to estimate (2) proposed in the panel data literature is the random effects models that can be estimated with the Generalized Least Squares estimator (GLS). These models must be used when unobservable individual effects are not correlated with the regressors because they are more efficient than the within estimators. Thus, the problem of this estimator lies in the necessity to assume that the individual effects (efficiency level of the firms) and the explanatory variables are not correlated.

From this GLS estimation of the parameters $(\hat{\beta}_k^{GLS})$, we can recover the individual effects from the residuals, and with them we make the same operation as in the fixed effects models to recover the technical efficiency index.

3.- Data Set and European railways activity description

We have used for this study an unbalanced panel data on 19 companies observed over the period from 1965 to 1998. The physical data used is derived from data published by the International Union of Railways (UIC, 1965-1998). These railroad companies were selected on two basis: availability of data, and comparability. When gathering data for each individual company, the UIC tries to insure the highest homogeneity and comparability in the definition and the measurement of both inputs and outputs. On table 1 we reproduce the individual mean values of the variables for all the companies. As it shown here, the sample includes the Turkish company, partially outside Europe, and two companies for Switzerland, one of them (BLS) being private.

Some interesting facts can be outlined from Table 1. First, the large scale variations across railways. The largest firms, BR (United Kingdom), DB (Germany), and SNCF

(France) are more than one hundred times bigger, in terms of tracks, than the smallest companies, BLS (Switzerland) and CFL (Luxembourg). Second, we observe important differences across firms in the output formation. Considering the percentage of passenger and goods transported by each firm over the total, some firms, like VR (Finland), SJ (Sweden) and NSB (Norway), show some degree of balance between goods and passenger services. Conversely, though, is the specialization in passenger transportation observed in CP (Portugal), DSB (Denmark) and NS (Netherlands). The average mileage traveled vary greatly throughout the different countries; however, it seems there is a certain correlation between actual movements made and size of the whole network. Other variables not shown in table 1, such as electrical powering of the network, might highlight meaningful information about the technological level. For instance, we find companies like BLS and CFF (both Swiss) with levels of a 100% powered network, and firms like CH (Greece) or TCDD (Turkey) with a 0% powered network, since they function merely on diesel power.

The transportation system is a production process whose output is the realization of displacements in the space. This production process needs the interaction of two factors: physical capital, and human capital; the former being itself shaped by two elements: infrastructure, and operation (utilization). The interaction between these last two elements is more prominent in railways than in any other transportation means.

Infrastructure is made up of a bound of elements (tracks, primarily) needed for the actual movement – they enable the actual displacement of vehicles. The tools for the running of the infrastructure are: the number and lay-out of main, waiting and detour tracks, and the stations, which perform functions related to traffic (arrivals and departures), movement of traffic units from one train to another (i.e. passengers' transfers, or freight maneuvers), and holding of cars in case they are needed in a new track/convoy. All these elements integrating the infrastructure mean an investment which remains unchanged in the long run, since variation of the amount of physical capital implies high costs in terms of material resources and time needed for implementation and putting into service.

The rest of the factors (human resources, and operation of mobile material) are somewhat more variable in a shorter run. From the human resources point of view, the technological context of railways has numerous distinct characteristics that influence the managers-employees relationship. In this sense, train operational divisions use reduced teams which perform in active collaboration, away from any stiff and supervisory control. In other regards, complex equipment is used with a very high capital/worker ratio.

In reference to the mobile material (locomotives, etc), these interact with the infrastructure – in the case of electric-powered tracks, not only with the track, but also with the aerial installation (electric overhead distribution). This illustrates the possibility of utilization of two different technologies for the mobile material: the electric powering, and the diesel powering. In both cases impressive technological advances have taken place, particularly with regards to the electric powering, thanks to the use of computers and electronics in the microprocessors and semiconductors fields. These advancements have fostered more efficient control and regulation systems, with more efficient energy usage. These technological advancements not only are reflected on the spawning of high-speed trains, but also in the train units used by the different firms in their regular short and long distance services. Maybe, the most significant impact of the technological evolution could be appreciated in the substitution of labor by capital (most firms have experienced major adjustments in the enrollment over the period studied), and in the need for a more specialized and trained work force.

Table 1. **SAMPLE DESCRIPTIVE STATISTICS** (mean, maximum and minimum values)

			Total Labor			Tracks Km			Load Factors		Mean Distances		Railway Stock	
									Pass./year	Ton/year	Passeng	Tons		
Railways	Country	Period	Max.	Min.	Mean	Max.	Min.	Mean	million	million	km.	km.	Passengers	Wagons
BLS	Switzerland	1965-1998	1895	1734	1864	245	235	244	18423	6929	29	50	239	248
BR	United-Kingdom	1965-1995	173931	88140	136590	16964	16528	16647	737571	125313	43	127	12074	36308
CFF	Switzerland	1965-1998	37903	32025	36400	2994	2909	2973	251508	46981	43	162	4179	25303
CFL	Luxembourg	1965-1998	3528	2964	3248	275	270	272	10707	15655	22	38	125	2625
CH	Greece	1965-1998	12845	11070	12070	2497	2461	2476	11700	3370	156	174	770	10702
CIE	Ireland	1965-1998	6760	5001	5708	1947	1917	1942	23984	3180	50	186	321	1974
CP	Portugal	1965-1998	22123	12930	19342	3613	2396	3198	217799	6556	26	243	1254	4871
DB	Germany	1965-1998	323508	212468	253031	41573	26387	29605	1109752	276631	41	219	16064	264898
DSB	Denmark	1965-1998	18409	14227	15525	2476	2306	2390	142189	7866	34	224	1633	4763
FS	Italy	1965-1998	216136	128151	186551	16420	15942	16076	419047	59898	106	328	14471	100560
NS	Netherland	1965-1996	28348	26165	26991	2852	2739	2795	264953	18797	44	161	2303	7229
NSB	Norway	1965-1998	15832	9602	12899	4242	4023	4109	35698	22264	62	125	951	6124
OBB	Austria	1965-1998	68032	58374	64027	5797	5336	5646	170503	58758	45	200	3704	35062
RENFE	Spain	1965-1998	72076	38958	53064	13466	11781	12658	263016	27019	64	390	4014	37341
SJ	Sweden	1965-1998	31859	13567	22206	11485	9782	10674	80286	52254	74	345	1825	29441
SCNB	Belgium	1965-1998	52265	37415	42979	4194	3368	3555	144292	67482	45	123	3371	30344
SCNF	France	1965-1998	239688	167204	200637	34688	31775	33701	791066	140732	77	362	15644	156758
TCDD	Turkey	1966-1998	48125	33443	42427	8549	8169	8333	131933	14480	49	545	1357	21384
VR	Finland	1965-1998	24324	15135	19821	5979	5880	5891	43251	33387	73	244	1010	16069

Source: UIC 1965-1998

4.- Model specification and results

We estimate two different specifications. The first is a "factor requirements function" (suggested by Diewert (1973, 1974)) and the second is a more flexible functional form "quadratic function"[2]. We use these types of function due to railways produce multiple outputs, we could alternatively use a dual cost function but this approach requires data on input prices, which are not very reliable in a context of heavily regulated conditions.

The factor requirement production function can be represented by:

$$y_{it} = \alpha + \sum_{k} x_{kit}\ \beta_k + \gamma\, t + \varepsilon_{it}$$

$$\varepsilon_{it} = v_{it} - u_i \tag{3}$$

where y_{it} represents the logarithm of labour, x_{1it}, x_{2it} and x_{3it} represent the outputs: the logarithm of passengers, the logarithm of freight and the logarithm of km of lines, respectively. There are also the variables x_{4it} and x_{5it} which are the percentage of electrification and the percentage of double km of line, respectively, we assume that they are a good proxy for the technology chosen by the railways. And t is a variable added to measure the Hicks-neutral technical change that is common among firms.

The composed error term combines v_{it}, which is assumed to be normally distributed and uncorrelated with the u_i and with the explanatory variables, with u_i, which captures the level of inefficiency of the firm and so it will be greater or equal to zero.

The quadratic production function can be represented by:

$$y_{it} = \alpha + 2\sum_{k=1}^{3} x_{kit}^{1/2}\ \beta_k + \sum_{l=1}^{3}\sum_{j=1}^{3} x_{lit}^{1/2} x_{jit}^{1/2}\ \beta_{lj} + \sum_{k=4}^{5} x_{kit}\ \beta_k + \gamma\, t + \varepsilon_{it}$$

$$\varepsilon_{it} = v_{it} - u_i \qquad \text{con } j \neq l \text{ y } \beta_{lj} = \beta_{jl} \tag{4}$$

[2] See Bjurek et al (1990) for an application of these types of function.

The process of estimation proposed is the following, first, we estimate the model equations (3) and (4) with the Within Group estimators. These estimators are consistent when the individual effects (inefficiency) are correlated with the other variables in the model or when this correlation does not exist. Second, we obtain Generalized Least Squared estimators. These estimators are more efficient than the Within Group, when none of the variables are correlated with the individual effects. If this correlation exist, Within Group estimations are required. To determine the most suitable estimation, a Hausman test to decide whether to use is provided.

Table 2 presents the estimated coefficients for the two models. We introduce in the regressions, also, two variables to control for the mergers and spin offs in the European railway companies.[3] As can be observed, the results of these estimations are so good.

[3] In 1994, there was a merger in Germany, and the spin offs were in Netherland in 1994 and Sweden in 1988.

Table 2
Estimations for alternative models

	Dependent variable: y_{it}											
	Factor Requirement Function						Quadratic Function					
	WG			GLS			WG			GLS		
Variables:	Coefficient	t-statistic		Coefficie nt	t-statistic		Coefficient	t-statistic		Coefficient	t-statistic	
x_1	0.079	(1.54)		0.113	(2.94)	**	-			-		
x_2	-0.044	(-1.10)		-0.033	(-1.27)		-			-		
x_3	0.605	(5.22)	**	0.829	(15.61)	**	-			-		
$2(x_1^{1/2})$	-			-			2.432	(2.36)	**	1.887	(1.72)	*
$2(x_2^{1/2})$	-			-			-7.567	(-5.07)	**	-6.381	(-4.94)	**
$2(x_3^{1/2})$	-			-			0.759	(0.45)		2.701	(1.74)	*
$x_1^{1/2}x_2^{1/2}$	-			-			1.411	(1.46)		1.573	(1.94)	*
$x_1^{1/2}x_3^{1/2}$	-			-			-3.145	(-4.77)	**	-2.799	(-3.91)	**
$x_2^{1/2}x_3^{1/2}$	-			-			3.634	(4.56)	**	2.643	(3.50)	**
x_4	-0.002	(-2.19)	**	-0.001	(-1.71)	**	-0.003	(-3.01)	**	-0.002	(-2.26)	**
x_5	0.011	(4.05)	**	0.013	(9.04)	**	0.009	(3.66)	**	0.012	(8.60)	**
t	-0.017	(-11.33)	**	-0.018	(-17.74)	**	-0.016	(-10.92)	**	-0.018	(-16.64)	**
Mergers	-0.133	(-1.84)	*	-0.221	(-3.14)	**	-0.064	(-0.75)		-0.178	(-2.32)	**
Spin offs	-0.384	(-3.95)	**	-0.382	(-8.53)	**	-0.378	(-4.02)	**	-0.372	(-8.46)	**
Constant	-			2.461	(5.90)	**				8.692	(1.23)	
Hausman test	10.165						18.511**					

Note: *, ** indicate significance at 10 and 5% respectively. All results are robust to heteroskedascity.

The first in Table 2 is the factor requirement specification. On the basis of the Hausman test, GLS is the adequate estimation due to the absence of correlation between the individual effect and the explanatory variables. As can be observed, the estimations corresponding to the two outputs (passengers and km of lines) are statistically significant and have the expected sign, positive. This indicates that a higher loading of the trains implies a higher demand for the supplied transportation capacity and implies more labour consumption.

The electrification variable and the percentage of double km of lines are proxies for the technology chosen by the railway companies and have the expected signs. The first variable indicates that is labour saving and the second one implies more labour consumption. The rate of technical progress reveals a productivity growth of 1.8% each year. This variable is included in order to capture the general improvement in productivity not controlled by the other variables in the model.

Finally, mergers and spin offs dummies are included to control for differences among companies. These variables are statistically significants and are labour savings.

The second in Table 2 is the quadratic specification. On the basis of the Hausman test, WG is the adequate estimation due to the null hypothesis is rejected. The coefficients estimated with this specification are very similar with the factor requirement specification.

Table 3 reports the level of technical efficiency for the 19 railway companies. Presented below the name of the models, in brackets, are the names for the best method for each estimation, based on the econometric contrasts. Furthermore, in Figure 1 we present the histograms of efficiency indicator distributions. These efficiency measures have been calculated as indicated in section 2. Remind that the technical efficiency index of the most efficient company will be equal to one, and the degree of labour over-utilization is indicated by values lesser than one.

Table 3
Technical efficiency indicators for European railway companies

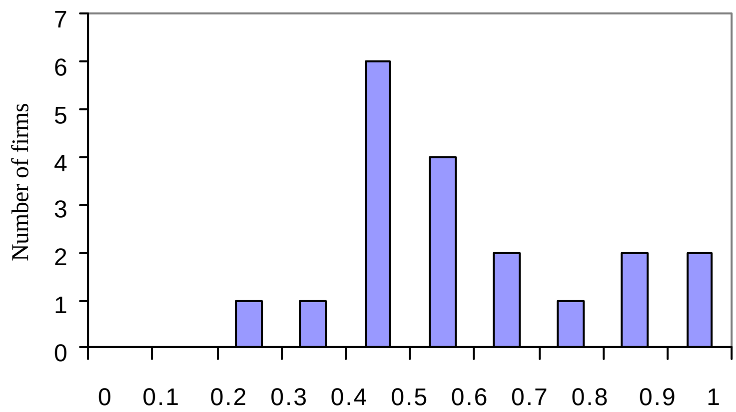
Railways	Country	Factor Requirement Function (GLS) Efficiency measure	Rank	Quadratic Function (WG) Efficiency measure	Rank
BLS	Switzerland	0.519	10	0.059	19
BR	United Kingdom	0.492	13	0.570	5
CFF	Switzerland	0.780	5	0.443	7
CFL	Luxembourg	0.594	8	0.089	18
CH	Greece	0.478	14	0.155	16
CIE	Ireland	0.279	19	0.089	17
CP	Portugal	0.612	6	0.264	10
DB	Germany	0.843	3	0.946	2
DSB	Denmark	0.497	12	0.202	14
FS	Italy	0.993	2	1.000	1
NS	Netherlands	0.466	15	0.254	11
NSB	Norway	0.403	17	0.191	15
OBB	Austria	1.000	1	0.611	3
RENFE	Spain	0.513	11	0.413	8
SJ	Sweden	0.346	18	0.221	13
SCNB	Belgium	0.601	7	0.378	9
SCNF	France	0.554	9	0.607	4
TCDD	Turkey	0.817	4	0.448	6
VR	Finland	0.428	16	0.221	12
Mean		0.590		0.377	
Std. Deviation		0.205		0.271	
Correlation			0.751		

The mean of the efficiency indicator with the factor requirement specification is 0.59 and 0.38 with the quadratic specification. The heterogeneity with the second specification is greater among railway companies. The extremely wide dispersion with this specification appear correlated with the scale. The most and least efficient companies are the biggest (FS and DB) and the smallest (BLS) of the panel, respectively. It must be noted that individual fixed effects tend to capture differences between companies existing at the cross-section level. At the opposite, the factor requirement specification with the random effects model appear not be correlated with the scale and the standard deviation is inferior.

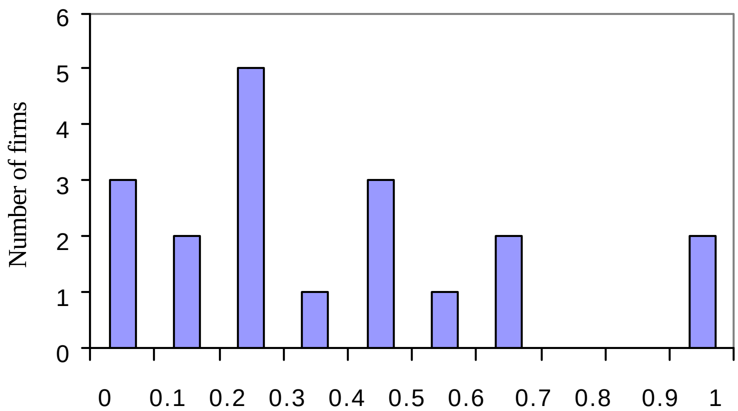
In the Figure 1, we can observe the histograms, and they display a great dispersion with the quadratic specification. The factor requirement specification presents a low level of dispersion with respect to the mean and it has a high efficiency mean.

Figure 1
Histograms of efficiency indicators

Factor Requirement Function (GLS)



Quadratic Function (WG)



6.- Concluding remarks

The aim of the paper is the analysis of the technical efficiency in a public business industry, specifically in the European railroads companies. The environment has been modified as a consequence of the EU directive 91/440/CEE, which mandates the split of the organizational structure of railway companies in two: operation and infrastructure. Also, the efficiency of the European railway firms has been affected by the reduction in their enrollment occurred over the period, the most representative cases being those of BR (UK), CP (Portugal), FS (Italy), RENFE (Spain) and SJ (Sweden) with almost 50 per cent of their employees dismissed, and SCNB (Belgium) and SNCF (France) to a lesser degree, and for this reason we believe that this research is important.

This paper has presented a method to quantify the efficiency level of the European railway companies using a sample of 19 firms in the time frame of 1965 to 1998. The use of unbalanced panel data techniques for efficiency frontiers take into account the possible correlation between efficiency and explanatory variables and it gives the mean of the efficiency indicator around of 0.6 and 0.4 for the factor requirement specification and the quadratic specification, respectively, and we obtain high correlation coefficient between these measures of technical efficiency. Furthermore, the two specifications used in our analysis appears very similar in their results, and a convenient ways of modelling the productive activity of firms that are highly regulated.

Finally, the proxies for the technology chosen by the railways companies have the expected sign, the electrification variable is labour saving and the percentage of double km of lines is more labour consumption.

References

Bjureck, H., L. Hjalmarsson and F. Forsund (1990), "Deterministic Parametric and Nonparametric Estimation of Efficiency in Service Production: A Comparison". *Journal of Econometrics*, vol. 46, pp. 213-227.

Caves, D. W., L. R. Christensen and J. A. Swanson (1981), "Productivity grothw, scale economies, and capacity utilization in US railroads, 1955-74". *American Economic Review*, vol.71, pp. 994-1002.

Coelli, T., Perelman, S. (1996): "Efficiency measurement, multiple-output technologies and distance functions: with application to European Railways". Working Papers. Liege University.

Diewert, W. (1973), "Functional Forms for Profit and Transformation Functions", *Journal of Economic Theory*, vol. 6, pp. 284-316.

Diewert, W. (1974), "Functional Forms for Reveneu and Factor Requirements Functions", *International Economic Review*, vol. 15, pp. 119-130.

Førsund, F., C. Lovell and P. Schmidt (1980), "A Survey of Frontier Production Functions and their Relationships to Efficiency Measurements". *Journal of Econometrics*, vol. 13, pp. 5-25.

Gathon, H.J. and S. Perelman (1992): "Measuring Technical Efficiency in European Railways: A Panel Data Approach", *The Journal Productivity Analysis*, vol. 3, pp. 135-151

Greene, W. (1980), "Maximum Likelihood Estimation of Econometric Frontier Functions". *Journal of Econometrics*, vol. 13, pp. 27-56.

Kalirajan, K. and R. Shand (1999), "Frontier Production Functions and Technical Efficiency Measures", *Journal of Economic Surveys*, vol. 13, pp.149-172.

Klein, L.R (1953), *A Textbook of Econometrics*. New York, Row Peterson.

Nash, C. (1985): "European Railways Comparisions- What Can We Learn?", in K.J. Bulton and D.E. Pitfield (eds.) *International Railway Econ*omics, Gower House, London, pp. 237-270.

Schmidt, P. and R. Sickles (1984), "Production Frontiers and Panel Data". *Journal of Business and Economic Statistics*, vol. 2, pp. 367-374.

UIC (1984-1993): *International Railway Statistics*. Chronological Railway Statistics.

UIC (1985-1994): *International Railway Statistics*. Chronological Railway Statistics.

UIC (1995-1998): *International Railway Statistics*. Chronological Railway Statistics.