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Do reforms improve efficiency in European railways sector? An empirical analysis with non-parametric approaches

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Abstract: The aim of this paper is to analyse the impact of the deregulating and restructuring measures on technical efficiency in European railways sector in the period 1991-2012 for 23 railways companies. We use to analyse efficiency, recent order-*m* methodology and the proposed comparison, the railways company with herself. The main results, based on the analysis of panel data in the second stage reveal that; the introduction of competition within the sector (in both passenger and freight markets) has had a positive impact in the efficiency, the impact of vertical separation has not produced effect. Finally, we found that the implementation of the three reforms worsens the efficiency levels.

Key words:deregulating, restructuring, technical efficiency, European railways, order-*m*
JEL: L92, C61, L5

1. Introduction

After World War II many railways were nationalized in Europe. The railway organization was responsible for the provision and management of transport for both passengers and goods and, the provision of infrastructure services necessary by domestic companies. Since then the railway companies in different countries have conducted simultaneous processes of liberalization and privatization. From the late 80's and early 90's actions begin to make changes in the management of the railways firms. The Commission of the European Union, aiming to revitalize and promote rail traffic over other modes of transport, communication presented in 1990 without legislation, entitled "Policy Railway Community". The proposals in this communication were developed in several subsequent directives are grouped into so-called "Railway Packages" as reflected in Table 1.

Table 1. Railways Package

Railways Package	Directive	Objetive
First	Directive 1991/440	Community measure to improve the competitiveness of rail transport. Its main aims are to create railways independent of the State and managed on commercial lines and to begin the integration of the market for rail transport services.
	Directive 1995/18	It refers to the criteria for the granting, maintenance and modification by a member state license for railway companies or established in the EU and to provide the services referred to in Directive 91/440.
	Directive 1996/48	Relative to the interoperability of the trans-European high-speed.
	Directive 2001/12, 2001/13, 2001/14, 2001/16	Relative to, ensure the independence of infrastructure managers establishing a transparent regulatory regime for capacity allocation and access charges for rail infrastructure across the EU
Second	Directive 2004/49, 2004/50,	Relative to, safety principles, harmonized

	2004/52 Regulation (EC) 881/2004	interoperability requirements, particularly for high speed train and open access for freight services.
Third	Directive 2007/58, 2007/59, Regulation(EC) 1371/2007	Relative to, promotion of an internal market for rail services covered on competition and the protection of passenger rights.
Fourth	Directive 2012/34	Relative to, promotion of an internal market for rail services covered on competition and the protection of passenger rights European single space (planning of infrastructure investment, daily exploitation, timetabling)

Sources:http://ec.europa.eu/transport/media/infringements/directives/railen
http://ec.europa.eu/transport/modes/rail/packages/2013_en.htm
own elaboration

Management decisions taken following different railway directives mentioned, has led to different organization models. (Cantos et al., 2012: 67) mention that the rail industry in Europe was restructured into two levels: The vertical dimension which involves the relationship between infrastructure and operations, and the horizontal dimension, which covers the relationship between the various services that use the infrastructures. In other words, the restructuring measures can be classified depending on the extent of vertical separation introduced after the change, and on the degree of competition (and private participation) allowed in the industry after the reform.

The objective of this article is to analyse European railways´ efficiency in the simultaneous processes of liberalization and privatization carried out by last two decades.The effects of railway regulation have been studied in the literature, but the results provided are not conclusive. Table 2 shows some of the most representative works that analyse the relationship between organizational reform and efficiency of railway companies. As can be seen, studies have a significant heterogeneity, in the time periods analysed, methodologies, data and results. In general, there is a greater presence of works that find a positive relationship between regulation and efficiency. For example, Gathon andy De Jorge-Moreno and Suarez (2014) among others. Also (Mulder et al., 2005); (Rodriguez et al., (2005), (Driessen et al. 2006), Growitsch and Wetzel (2009) found a negative relationship or increased costs related. Finally, (Friebel et al., 2003); Wetzel (2008); (Asmild et al., 2009) and (Frietbel et al., 2010) found mixed results.

Table 2. List of authors who analyze the effects of reforms on efficiency

Authors	Period	Nº	Method	Results
Gathon & Perelman 1992	1961-1988	19	Factor requirement frontier	Positive correlation between institutional managerial autonomy and technical efficiency
Oum & Yu (1994)	1978-1989	19	DEA + Tobit	Greater managerial autonomy tends increase technical efficiency
Gathon & Pestiau 1995	1961-1988	19	Translog SFA	Deregulation increase efficiency
Cantos et al. 1999	1973-1990	17	DEA + Tobit	Autonomy increase efficiency
De Jorge-Moreno & García 1999	1984-1995	21	DEA	For the companies who adopted reforms, they have not experienced a worsening of their efficiency
Cantos & Maudos 2001	1973-1990	12	Translog Cost	Important relationship between infrastructure and operations
Friebel et al. 2004	1980-2000	12	SFA	Gradual implementation of reforms improved efficiency, whereas multiple reforms implemented simultaneously had, at least, neutral effects
Mulder et al. 2005	1990-2003	-	Partial efficiency	For Dutch passenger transport, authors find that the institutional change not improved the efficiency of the main operator NS

Rodriguez et al. 2005	1970-1990	17	SFA (Distance function)	The regulation significantly increases the costs of European railway companies
Driessen et al. 2006	1990-2001	13	DEA + Tobit	Vertical separation does not seem to be necessary to achieve an increase in efficiency
Wetzel 2008	1994-2005	31	SFA (Distance function)	Vertical separation does not reveal influence on efficiency, while the estimated results for third party access rights differ between passenger and freight transport as well as between international and domestic services.
Asmild et al. 2009	1995-2001	23	MEA (Multidirectional efficiency analysis)	The reform initiatives generally improve technical efficiency, although the variable for complete separation is not statistically significant
Growitsch & Wetzel 2009	2000-2004	27	Bootstrapping DEA	Vertical separation raises costs, economies of scope exist
Cantos et al. 2010	1985-2005	16	DEA	Vertical separation has had a positive effect on efficiency
Frietbel et al. 2010	1995-2000	11	SFA	Reforms improve efficiency but only where they are sequential and not in a package
Cantos et al. 2012	2001-2008	23	DEA & SFA	The best way to foster an increase in efficiency is always by combining vertical and horizontal reforms in the rail industry
Mizutani & Uranishi 2013	1994-2007	30	SFA(Cost F.)	Horizontal separation reduces railways cost. Vertical separation, effects change according to train density
Urdánoz & Vibes 2013	1980-2005	11	SFA(Cost F.)	Significant positive effect of implementing the reforms on cost reducing activities.
Lérida & Tránchez 2014	1991-2011	23	DEA+ Bivariate analysis	Positive association between efficiency and liberalization
De Jorge-Moreno & Suarez 2014	1984-2005	17	Bootstrapping DEA+ Non-parametric reg.(GAM)	The reforms generate increased railway efficiency

Sources: Own elaboration

This work introduces additional features to studies that analyze the effects of reforms in the railways in Europe. In this analysis, we compare the single analysis by firms, with the whole sample firms. The reason for this approach is that, we pay special attention to heterogeneity of firms (size, different levels of specialization passenger-freights, different technologies in rolling stock and infrastructure, different organization models etc.). We use different methodological approaches to estimate the technical efficiency, and obtain robust results. Finally, we estimate the determinants of efficiency and deep into the effects of reforms in different railway companies. To achieve the aim, we use a broad time 1991-2012 and refer the analysis to 23 railway companies.

The study is organized as follows. In the next section 2, we show the methodology used. Section 3 presents the data used in our analysis. Section 4 shows the main results. Finally, section 5 show main conclusions.

2. Data and variables

The information used to elaborate the database was the *Union International des Chemins de Fer* (UIC) data on 23 railway companies for the period 1991–2012. At present, it is the key source of information from which most industry analysis and academics obtain their information on railways. It is especially made to ensure comparability and consistency using common definitions. In addition to the above database, we use information from the annual reports of the railway companies to complete the data. Table 3 shows the variables used as outputs and inputs. As can be seen, there is significant heterogeneity among most companies (countries).

Table 3. Average values for variables (1991-2012)

	Pass-km (mill)	Ton-km (mill)	Empl (thous)	Roll	Km of railw
Austria	13678	15591	69	22734	5750
Belgium	7536	7495	37	15783	3890
Bulgaria	3315	5686	38	22502	4440
Czech Rep.	10140	18845	86	53797	9669
Denmark	9871	3041	12	4038	2304
Finland	3181	9605	17	13007	7144
France	95036	43118	159	51977	32464
Germany	62409	77500	262	157058	36689
Greece	1417	2917	8	6495	2595
Hungary	8146	6002	51	18526	7597
Ireland	1365	369	7	1627	2075
Italy	41866	19223	110	60939	17027
Luxembourg	903	471	7	3058	276
Netherlands	12784	7136	21	3198	2781
Norway	4623	2441	8	3610	6074
Poland	18545	50818	172	107661	19917
Portugal	3851	2099	31	3927	3019
Romania	11260	16995	128	99220	11527
Spain	25000	43750	34	21403	15268
Sweeden	10832	14064	15	10490	11732
Slovenia	873	17327	9	5880	1277
Switzerland	12882	13727	29	14639	3239
Slovak Rep.	2789	9905	38	21234	3689
Average	17741	17156	59	31128	9773

Sources: UIC and own elaboration

In the present study, we chose the following outputs and inputs widely used in the literature;

- Outputs: number passenger-km transported (*PKT*) and tones-km transported (*TKT*).
- Inputs: numbers of workers (*LAB*), numbers of kilometers of track (*LT*), a representative measure of the rolling stock calculated as the number of coaches, railcars, locomotives (ROLL)

In relation to the variables associated with the reforms carried out by the railway companies, we use the variables mentioned by (Cantos et al., 2012). Table 4 shows the information related to the reform, year, and country; the full separation between rail infrastructure and rail operations (VERT); the introduction of a franchising system (competition formarket) in passenger services (PASSTEND). The entry of new operators is allowed in the freight sector (competition in the market) regardless of whether the industry has been separated vertically or not(FREEOPEN).

Table 4. European rail reforms and their time implementation

	VERT	PASSTEND	FREEOPEN
Austria	-	-	-
Belgium	-	-	-
Bulgaria	2003	-	2005
Czech Rep.	2006	-	-
Denmark	1997	2001	2000
Finland	1995	-	-
France	1997	-	2006
Germany	-	1997	1997
Greece	-	-	-

Hungary	2007	-	2007
Ireland	-	-	-
Italy	-	-	2001
Luxembourg	-	-	-
Netherlands	1998	1999	1998
Norway	1996	-	-
Poland	-	-	-
Portugal	1997	-	-
Romania	2005	-	2005
Spain	2005	-	-
Sweeden	1989	1989	1996
Slovenia	-	-	-
Switzerland	-	-	2005
Slovak Rep.	2002	-	-

Sources: Nash and Rivera-Trujillo (2004), Driessen et al. (2006),
IBM and Humboldt University of Berlin (2004), Cantos et al. (2010)and Cantos et al. 2012)

3. Methodology

In this section, we present the methodology to carry out the objective. Applied empirical work on the measurements of individual firms' efficiency measurement is always confronted with the high sensitivity of the results to the different approaches. As mention (Bruni et al., 2009) with enrichment of the DEA literature, practitioners have acknowledged the need to incorporate data variability and uncertainty within the deterministic DEA models with the aim to address measurement errors, as well as the inherent stochastic nature of production process(Talluri et al., 2006). Therefore, with the aim of reflecting a robust image of the railways company's operations, we apply different non-parametric approaches on different assumptions. To this end, we will compare the efficiency by means of DEA and order-*m*.

As already mentioned, we compare the single analysis by firms, with the whole sample firms. The analysis of efficiency at individual level is used by Parker (1999) on the relation between British Airport technical efficiency and privatization. Since we work with 21 observations for the years available, there is a problem associated with the degrees of freedom between the observations and the number of variables. Following El-Mahgary and Ladhelma (1995) the minimum of observations is not less than three times the number of outputs over inputs [21> 3 (2 + 3)].

In section, 3.1 we explain the non-parametric methodology for estimating traditional data envelopment analysis (DEA) and order-*m* efficiency. Section 3.2 shows the empirical model through panel data analysis. Section 3.3shows the econometric model to estimate the determinants of efficiency.

3.1- DEA method

We follow the standard procedure in the non-parametric approach DEA. The mathematical process consists of solving, for a set*N* railway system (1,...,*N*) and period *t*, a linear program that determines -when we adopt a factor orientation- the minimum quantity of factors required achieve the quantity of production observed. Each railway companies (S) produces a vector of $y = (y_1,\ldots,y_j,\ldots y_n) \in R_+^n$ outputs, using a vector de inputs $x = (x_1,\ldots,x_j,\ldots x_n) \in R_+^n$. In this study, we choose input oriented DEA based on market conditions and variable returns to scale (VRS), applying the BCC (Banker et al., 1984) model. The linear program is show in equation 1.

$$\text{Min}\,\theta^{VRS}$$

s.t.: [1]

$$\sum_{j=1}^{N} y_{sj}\lambda_j \geq y_{si}, \quad s = 1,...,S$$

$$\sum_{j=1}^{N} x_{mj}\lambda_j \leq \theta x_{mi}, \quad m = 1,...,M$$

$$\lambda_j \geq 0; \sum_j \lambda_i = 1; \quad j = 1,...,N$$

The value of the efficiency obtained for each railway company θ^{VRS}, by construction, satisfies $\theta^{VRS} \leq 1$. Efficiency values obtained $\theta^{VRS} < 1$ are considered technically inefficient, while those $\theta^{VRS}=1$, are assigned as technically efficient, as railway companies that obtain these values will be in the frontier. Additionally, we have estimated the efficiency with constant returns to scale (CRS) applying the model (Charnes et al. 1978) if railwayscompanies operating in the optimum scale. In this case, we removed the restriction $\sum_j \lambda_i = 1$ from the linear programming exercise defined in [1] and we obtained technical efficiency under CRS, θ^{CRS}.

3.2. - Order-*m* estimator

Cazals et al. (2002) proposed the non-parametric order-*m* estimator as an alternative based on the expected minimum frontier of order-*m* (alternatively expected maximum output). According to Wheelock and Wilson (2007) order-*m* estimators do not impose the assumption that the production set is convex, and in addition they permit noise (with zero expected value) in input measures. Note that DEA estimates of the production frontier can be severely distorted by extreme values. Further, for given numbers of inputs and outputs, the order-m estimator requires far less data in order to produce meaningful efficiency estimates than DEA. The core idea of order-*m* is to set up a conditional frontier that does not envelop all firms in the population, but just a share of them. This share is determined by the integer value *m* which can be fixed by the researcher[1]. Here, the condition for the input-oriented case is that the firm is considered with an output level that is equal to or greater than the firm's interests. The radial distance of a firm (x_o , y_o) interior to the order-*m* frontier represents the proportional reduction in the input it needs, in order to become efficient to a randomly drawn sample of firms which have an output level of $Y \geq y_o$. For a multivariate setting consider $X^1,....X^m$ are *m* (p-dimensional) random firms drawn from the conditional distribution function of *X* given $Y \geq y_o$. The random variable is showed in equation 2 as:

$$\bar{\theta}_m(x_o, y_o) = \min_{i=1,..,m}\left\{\max_{j,..,p}\left(\frac{X^{i,j}}{x^{i_o}}\right)\right\} \quad [2]$$

With $X^{i,j}\,(x^{i_o})$ as the *jth* component of X_i(of x_o respectively) measures the distance between point xo and the free disposal hulls $X^1,....X^m$. The latter are generated from the conditional distribution function of *X* given $Y \geq y_o$. The order-*m*efficiency measure of firm$_o$ (x_o , y_o) is then defined in equation 3 as:

$$\bar{\theta}_m(x_o, y_o) = E[\bar{\theta}_m(x_o, y_o) \,|\, Y \geq y_o] \quad [3]$$

Because the distribution of the population is unknown, the calculation of the order-*m* frontiers requires the use of the empirical distribution functions. In a multivariate case this calculation involves a numerical integration which is easier to solve by Monte-Carlo approximation. For details of the methodologies see Simar (2003).

In short, the order-*m* estimation of an input-oriented score is straightforward. For an observation, all sample observations which dominate the observation to be evaluated in the input are selected. From this sub-sample, several samples of size m are drawn with the replacement. Note that this does not automatically include the observation itself. Then, $\bar{\theta}_m$, is calculated as defined in equation 2. Because the observation itself is not a necessary part of the order-*m* sample and because there will not necessarily be any other observations dominating the observation to be evaluated in the input, scores greater or less than unity may result.

3.3. - Econometric model to estimate the determinants of efficiency.

The proposed methodology for the analysis of the determinants of efficiency is the data panel. Equation 4 shows the model used.

$$\theta_{it} = \alpha_i + \beta_1 X_{1it} + e_{it} \text{ i=1,...,t=1,.....,T} \quad [4]$$

Where, θit, is the estimated efficiency. In the results section, we discuss on efficiency used in the second stage.In principle, they could be used the following efficiency measures;

- BCC approach for both, as whole sample railway companiesθ_{group}^{VRS}, and as individual levelθ_{ind}^{VRS}. We use also the CCR model, as complementarily manner.
- Order-m approach for both, as whole sample railway companies θ_{m_group}, and as individual level θ_{m_ind}

X_{lit} is a vector of variables that capture the reforms carried out in the period of analysis and control variables. The equation 4 can be rewritten disaggregated manner as:

$$\theta_{it} = \alpha_i + \beta_{1it}LT + \beta_{2it}DENS + \beta_{3it}\,D\_VERT + \beta_{4it}D\_PASSETEND + \beta_{5it}D\_FREEOPEN + e_{it} \quad [5]$$

$$\theta_{it} = \alpha_i + \beta_{1it}LT + \beta_{2it}DENS + \beta_{3it}\,D\_VERT + \beta_{4it}D\_PASSETEND + \beta_{5it}D\_FREEOPEN + \beta_{6it}D\_COMB + e_{it} \quad [6]$$

Where,*LT* is the length of rail track. *DEN*, is the density of the country (population divided by the area). These two variables are control. *D_VERT* is the dummy variable that takes a value of 1 for countries that separated at an organic level the ownership and the management of infrastructure from that of rail operations.*D_PASSTEND* is a dummy variable that takes a value 1 whena franchising system has introduced in passenger services. *D_FREEOPEN* is the dummy variable that takes a value of 1 when the entry of new operators is allowed in the freight sector. In equation 6 we introduce COMB variable that captures the effect of making the three reforms. This variable takes value 1 for the years where all three types of reforms have been undertaken.

4. Results

This section shows the results after applying the methodologies outlined in the previous section. Table 5 shows the results of a comparison among traditional, non-parametric (DEA) and robust non-parametric (Order- *m*) indices of railways companies' performance evaluation. Columns 2 to 5 refer to the DEA technique. The columns 2 and 3 compare the firms individually, while columns 4 and 5 do it as a group. The columns 6 and 7 refer to the Order-*m* methodology, comparing companies individually and in groups respectively.

Table 5. DEA and order-*m* efficiency estimate
railways companies 1991-2012

	Individual		Group		Individual	Group
	CRS	VRS	CRS	VRS	order-*m*	order-*m*
Austria	0,762	0,972	0,800	0,830	0,992	0,915
Belgium	0,885	0,929	0,677	0,707	0,989	0,941
Bulgaria	0,907	0,986	0,400	0,455	0,997	0,819
Czech Rep.	0,922	0,976	0,582	0,619	1,007	0,820
Denmark	0,325	0,944	0,666	0,834	0,958	1,004
Finland	0,912	0,986	0,771	0,822	0,988	0,999
France	0,887	0,966	0,758	0,985	0,985	1,000
Germany	0,846	0,939	0,685	0,993	0,949	1,000
Greece	0,780	0,966	0,262	0,652	1,001	1,013
Hungary	0,698	0,839	0,566	0,634	0,979	0,785
Ireland	0,919	0,952	0,356	0,991	1,003	1,041
Italy	0,980	0,995	0,581	0,785	1,008	0,964
Luxembourg	0,790	0,993	0,526	1,000	1,001	1,117

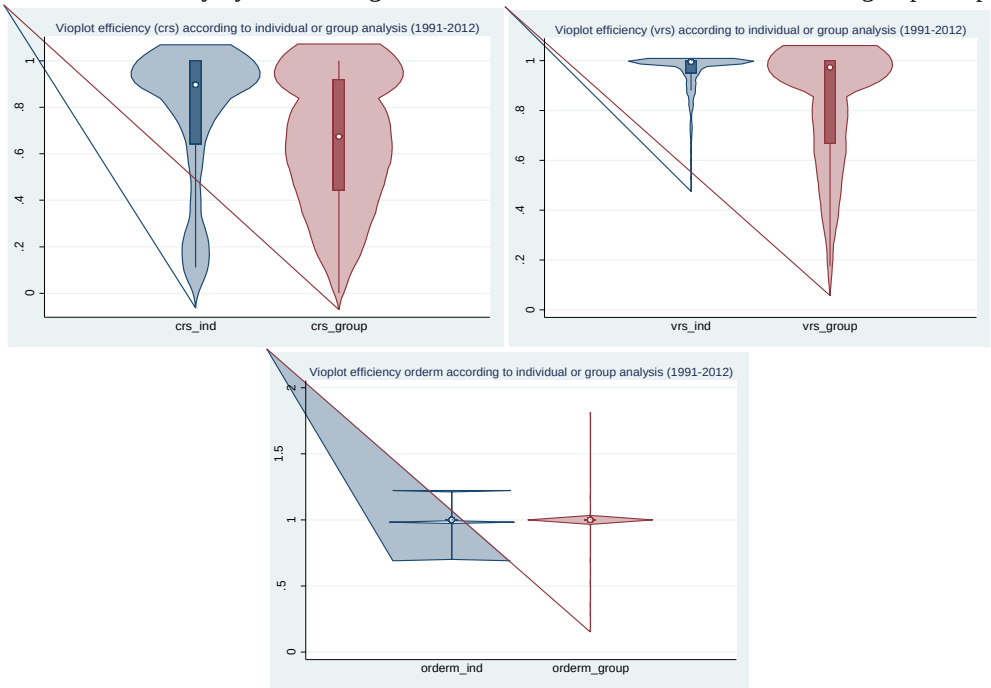
Netherlands	0,811	0,932	0,986	0,997	0,997	1,007
Norway	0,925	0,983	0,618	0,871	0,999	1,011
Poland	0,942	0,966	0,713	0,844	0,997	0,891
Portugal	0,967	0,984	0,503	0,752	0,999	1,001
Romania	0,874	0,990	0,462	0,525	1,000	0,820
Spain	0,250	0,969	0,668	0,711	0,992	0,985
Sweden	0,850	0,978	0,926	0,970	0,993	1,000
Slovenia	0,305	0,988	0,721	0,894	0,999	1,014
Switzerland	0,755	0,853	0,983	0,987	0,965	1,001
Slovak Rep.	0,305	0,988	0,871	0,976	0,981	1,001
Average	0,765	0,960	0,656	0,819	0,990	0,963

Source: Own elaboration

By inspecting Table 5, several interesting features of performance measures emerge. The results comparing the DEA technique between CRS and VRS are well known. The latter consider the size and offer greater efficiency level. When results VRS Individual versus group (columns 3 and 5) are compared, overall efficiency levels are higher with the individual assessment (for example by observing the average values of the last row in Table 5). That is, although VRS considering the size differences between the railways companies, there is still the presence of heterogeneity. For the methodology order*m*, these differences are still significant (columns 6 and 7).

Figures 1, 2 and 3, as a complement of table 5, show different characteristics of the analysis. Figure 1, shows and entire distribution using box plots and violin[2] plots corresponding to mean efficiency for railways firms by methodologies and individual or group comparison. As can be seen the individual evaluation proposal, the dispersion it is significantly reduces, especially in the case of order-*m* methodology.

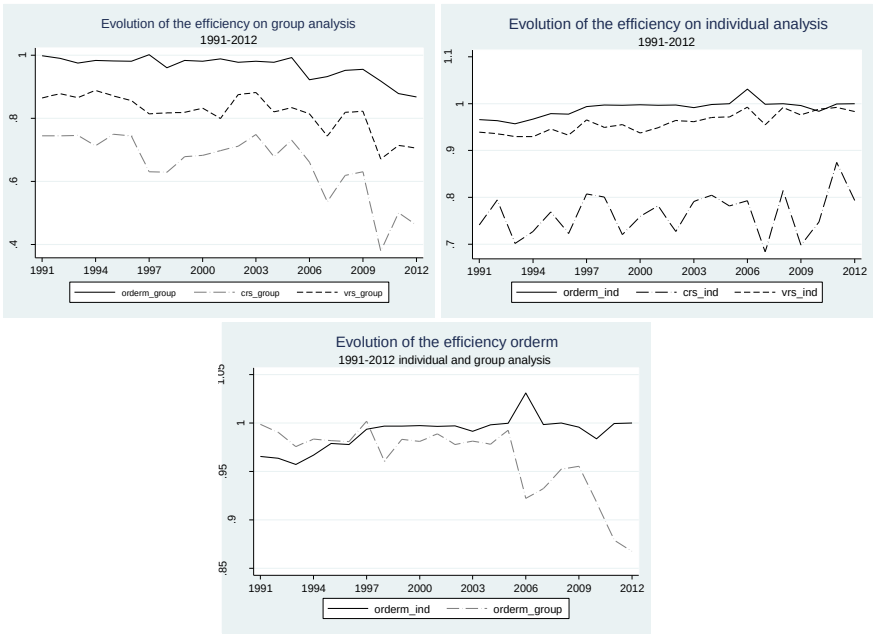
Figure 1. Mean efficiency by methodologies DEA-VRS and order-mindividual versus group comparison



Sources: Own elaboration

Figure 2, shows the evolution in the efficiency over time. The comparison is performed by comparing the methodology within each criterion, group and individual, on the top of the figure. While at the bottom of figure 2 shows the comparison between group and individual according methodology order-*m*.

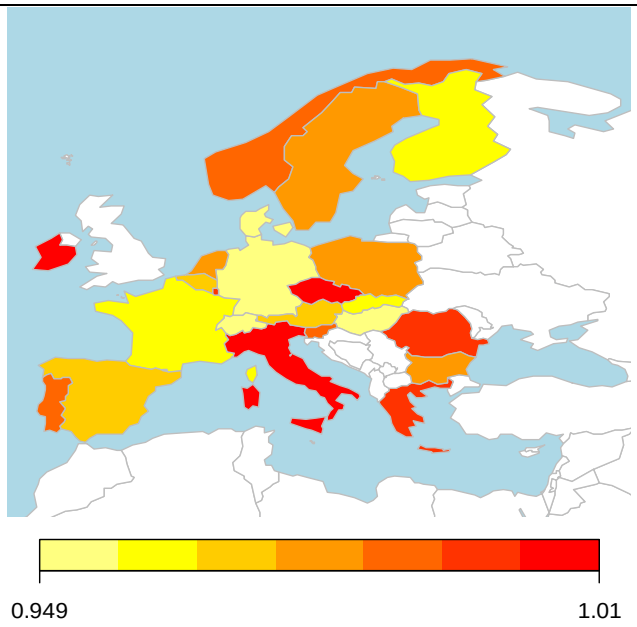
Figure 2. Evolution of efficiency by methodologiesand individual versus group comparison over time.



Sources: Own elaboration

We choose work at individual level and with order-*m* methodology. In relation with order-*m* Daraio and Simar (2007), mentioned the following advantages in its use: i) first, due to their ability to not envelop all data points, these robust measures of frontiers and the related efficiency scores are less influenced and hence more robust to extreme values and outliers, ii) as a consequence of their statistical properties, robust measures of efficiency do not suffer from the curse of dimensionality shared by most non-parametric estimators and by the DEA efficiency estimators, iii) Most important of all is the *managerial interpretation* of order-*m* measures of efficiency. In particular, the parameter *m* has a dual nature. It is defined as a trimming parameter for the robust non-parametric estimation. It also defines the levelof benchmark one wants to carry out over the population firms. Figure 3 show mean efficiency order-*m* by country in the period 1991-2012.

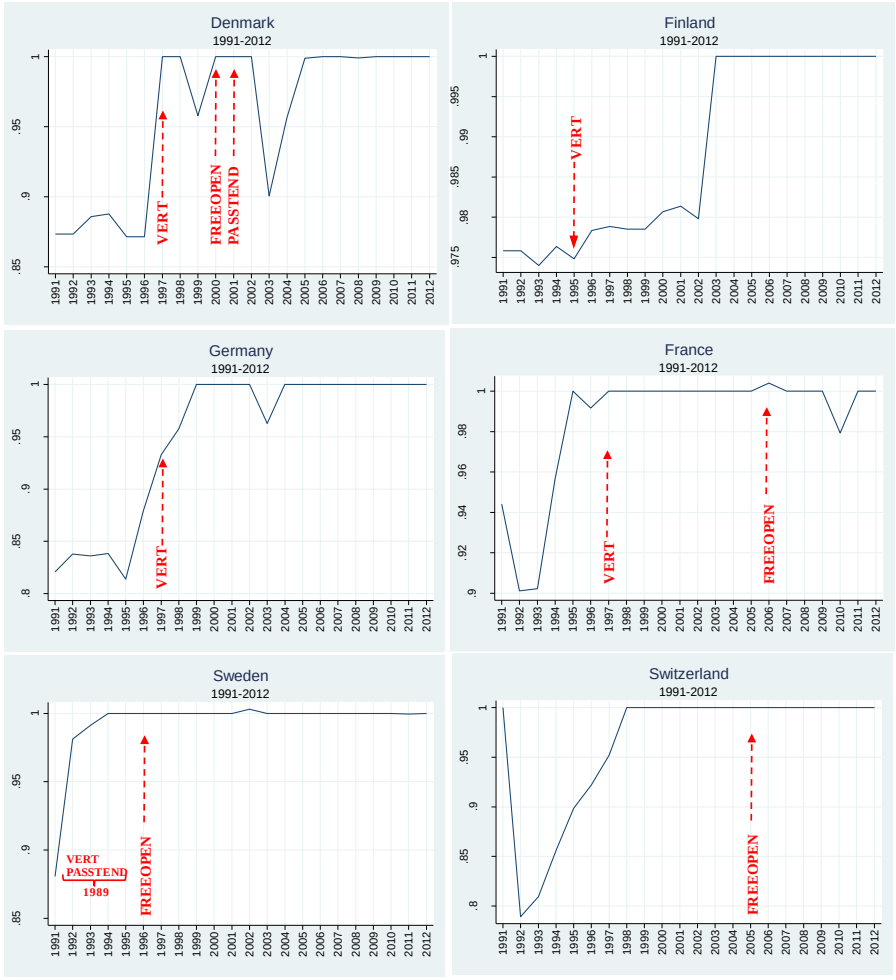
Figure 3. Mean efficiency order-*m*by country in the period 1991-2012



Sources: Own elaboration

We end this section with individualized evolution of the efficiency with m methodology and with some countries. Figure 3 shows the evolution of the efficiency of 6^3 of the 23 countries. In the top of the figure 3, shows the evolution of efficiency belonging to Denmark and Finland railways. Regarding the first, have executed three reforms (VERT, FREEOPEN and PASSTEND) and maximum efficiency remains constant from 2005. In the case of Finland, it is only carried out a reform (VERT) in 1995 and its peak efficiency remains constant from 2003.In the middle of Figure 4, the German railways carried out a reform (VERT) in 1997, its maximum efficiency level begins in 1999, although in 2003, a level loss occurs. In relate to the French railways, conducted two reforms (VERT, FREEOPEN) and its maximum efficiency level occurs from 1997, with two discontinuities, one in 2006 where that year appears as super efficiency, coinciding with the reform FREEOPEN and other discontinuity in 2010 where an efficiency loss occurs. Finally, at the bottom of the figure we show, Sweden and Switzerland, conducted a reform (FREEOPEN) in the analysis period. However, in the first railway, were made two reforms in 1989 (VERT and FREEOPEN). The maximum efficiency level appears in Sweden since 1994. In the case of the Swiss railways, its highest level of efficiency stems from 1998.

Figure 4. Evolution of efficiency order-*m* methodologyby railways companies



Sources: Own elaboration

To analyze the determinants of efficiency we estimate equation 5 and 6. Table 6 shows the results. The value of the Hausman test indicates the validation of fixed effects in the model of panel data. In relation to the reform relating to vertical separation (VERT) has not proved to be significant in any of the two models. However, reforms referred to franchising (PASSTEND) and new entry systems (FREEOPEN) show a positive and statistically significant sign, indicating that reforms increase efficiency. The variable that captures the three reforms made (COMB) by the companies proved to be negative and statistically significant. This result is contrary to that obtained by (Cantos et al. 2012). In this regard, it is important to note that; i) there are only three companies that have made the three reforms (Sweden, Netherlands, and Denmark).

Table 6. Determinants of efficiency

	Order-*m*	
	Model 1 Coef.(t)	Model 2 Coef.(t)
Const.	1.317(11.1)	1.304(11.1)
LT	-0.039(-3.00)	-0.038(-2.90)
Dens.	-5.0e-07(-0.21)	-3.1e-07(-0.13)
VERT	0.008(0.95)	0.009(1.02)
PASSTEND	**0.049(2.77)****	**0.081(3.53)****
FREEOPEN	**0.052(4.79)****	**0.056(5.13)****
COMB	-	**-0.050(-2.18)****
Test Hausman	χ^2=83.9**	χ^2=78.6**
Adj R2	0.36	0.37
Nº obs.	506	506

**,* Statistical significance at 1% and 5% levelrespectively

Sources: own elaboration

The individual analysis shows that the efficiency behaviors over time have not been the same (see Figure 4) in the three companies. The Swedish railway company has maintained a high level of efficiency after having made three reforms. However, the Danish and the Dutch railway undertaking similar developments have remained unstable behavior after having made three reforms. In the Swiss railway company with a unique reform, the efficiency evolves favorably since 1992. In this work, a period is used, much higher than that of the authors (2.8 times). Finally, besides the individual analysis, the period, we use a different methodology, order-*m*.

5. Conclusions

The aim of this paper is to analyze the impact of the deregulating and restructuring measures on technical efficiency in European railways sector in the period 1991-2012 for 23 railways companies. European railways are occupying a significant market opening for the international transport of passengers as well as carrying out relevant organizational and technological changes.

Since the introduction of the first reforms in the railway sector, conducted by Sweden in 1989, a significant percentage of companies have continued the same process with different criteria, organizational and completion time. The diverse European directives have motivated the organizational change process. There is abundant literature analysing the effects of reforms using different sample sizes, methodologies and time horizon, however the results are inconclusive.

Some results of this study are in line with studies that find no obvious effect of vertical separation but if they find evidence those horizontal reforms (like the introduction of new operators in the freight sector or of franchising systems in the passenger sector) improved efficiency levels in railways companies. The main innovations of this paper relate to; i) the proposed individual analysis where each company is compared with itself in the railway sector, ii) the use of recent methodology for analysing the efficiency order-*m* and iii) we found that the implementation of the three reforms worsens the efficiency levels. This result is contrary to that obtained by (Cantos et al. 2012) with other methodologies and for a significantly shorter period.

Some limitations of this study should be noted. In line with Friebel *et al*. (2004), we can analyze the reforms in the law, but we cannot control for different types and intensities of implementations. Themethodology proposed in this paper and the horizon time used may improve some of the problems related to the database, but the one type of quantity variable and but it is need to continue investigate the effects of the reforms carried out by the railway companies given the economic policy implications

Notes.

1. We have obtained similar estimates for m = 25, 50, and 75(available from the authors on request).
2. Violin plots are a mix between box plots and density functions estimated non-parametrically via kernel smoothing to reveal structure found within the data. Box plots show four main features of a variable: center, spread, asymmetry and outliers. The density trace, which in the case of violin plots is duplicated for illustrating purposes, supplements this information by graphically showing the distributional characteristics of batches of data such as multi-modality (see Hintze and Nelson, 1998).
3. We have obtained different evolutions for other countries omitted (available from the authors on request

6. References

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