

Original Paper

European Railroad Deregulation. Does It Work?

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Abstract

We analyzed the performance of the European railway public system over the period 2004 to 2014 in which the sector was subject to a substantial restructuring process and implementation of numerous deregulation and liberalization measures with the aim to revitalize the railway. This paper estimates simultaneously a model of stochastic production frontier and a model of technical inefficiency for 16 countries. The results show technological progress and improve on technical efficiency, but it is also noted the important cuts in inputs. The network heterogeneity shows that railroad systems with down network density and high percentage of electrified network are more efficiency. Likewise, we have analyzed the impact of subsidies and reforms implemented on railways efficiency. Maintenance subsidies improve efficiency due to reductions of incidents on the rail network, let more efficient and reliable service. While, operating subsidies have a negative effect because improve inefficient behavior. By the other hand, reforms have not had the expected results. We find that vertical separation is not necessary to achieve efficiency gains. The opening passenger market seems to lead to a greater efficiency gain, but freight market shows negative results although this result can be influenced by unfavorable economic context.

Keywords

Efficiency, Subsidy, Liberalization, Vertical Separation

1. Introduction

Railroad has historically national considerations that they prevailed over international ones. This industry was characterized by state-owned monopoly railway companies, where the companies are responsible for managing infrastructure and transport operations, so their national market has been developing without competition. This has led to a fragmental railroad system and gradual loss of market share to other forms of transport.

Europe needs strong transport connections to drive trade and economic growth. Over the past decades, European Commission (EC) (Note 1) has launched a series of reforms to improve economy efficiency railroad. The aim is to become railway transport in a real alternative to road and air transport and to create a single European transport area. The reforms have helped to strengthen the wider European Union (EU) (Note 2) internal market by opening up national markets previously dominated by public monopolies. So barriers to access, unnecessary differences in technical and administrative standards (prices, taxes and others charges) that distortion competition across EU countries are gradually being removed.

There are many studies in the literature analyzing productivity and efficiency in the railroad sector.

However, the processes of vertical separation and liberalization within the railroad sector are relatively recent in many European countries; as a result, there is very little conclusive empirical evidence on the effects of these processes on productivity and efficiency. There is not unanimity in the results obtained by studies that have been carried out on the impact of European policies. The reason may lie in the lack of adequate and consistent data due to differences in the definition of the variables or differences in the estimation methods used. Among the studies carried out, it is worth mentioning among others: Driessen et al. (2006) found that vertical separation did not seem necessary to increase productive efficiency while competition may have a negative effect. Wetzel (2008) did not find positive effects with the vertical separation of the railway operators. As for the opening of markets in the case of freight transport improved efficiency, the same did not happen in the case of passenger transport that has a negative sign. Asmild et al. (2009) found that reforms have improved technical efficiency, yet the benefits of complete separation are unclear. Growitsch and Wetzel (2009) showed that railway systems that have remained integrated are more efficient than those that have opted for an institutional separation. Cantos et al. (2010) found that vertical separation processes had a positive effect on productivity efficiency. However, this gain on efficiency becomes greater when combined with liberalization measures. Friebel et al. (2010) found that vertical separation and liberalization increases efficiency. Cantos et al. (2012) they found that vertical separation alone did not produce significant improvement on efficiency; in the case of liberalization increases efficiency, although the better way to increase efficiency is by combining vertical separation and liberalization reforms. Beria et al. (2012) did not find significant differences between an integrated rail system and separate companies, while liberalization improves efficiency in some cases. And Mizutani et al. (2015) showed that optimal rail structure depends on intensity and type of traffic on the network. Countries should be free to choose between vertical integration and vertical separation.

This study, hence, has two principal objectives. The first is to measure the technical efficiency of European railroads in this period. The second is to assess the impact exogenous operating characteristics on technical efficiency, particularly the variables related to subsidy, the degree of separation between infrastructure management and operations, and the degree of market opening.

The remainder of the paper is organized as follows. In the next section briefly shows background European mobility. Section 3 provides an overview of legislative changes in the sector. Section 4 presents the methodology and Section 5 describes the data used in the study. Efficiency results and explanatory factors are examined in Section 6 and finally Section 7 concludes the paper.

2. European Mobility

Transportation facilitates the mobility of people and freight, and therefore it plays a very important role in the well-being of society and in economic growth. An efficient and effective transport system for passengers and freight is vital for all EU society. The increase in transport demand influences the transport system, the competitiveness of the economy and the quality people life.

In general, the demand for transport has increased significantly during the last decades. Changes in production methods and distribution channels have significantly influenced demand for different modes of transport. Tables 1 and 2 show the volume of freights and passengers transported by mode in the period 1995-2014. The data are shown on tonne-kilometers (TKM), it is a measure of freight carried by a mode of transport, like road, railroad, maritime, inland waterways, pipeline, etc. It represents the transport of one tonne of freight by a given transport mode over a distance of one kilometer; and passenger-kilometers (PKM), is the unit of measurement representing the transport of one passenger by

a defined mode of transport over one kilometer.

Table 1. Freight Transport EU-28 by Mode (Billion Tonne-Kilometers)

Year	Road	Maritime	Railroad	Inland Waterway	Oil Pipeline	Air	Total
1995	1,288.66	930.37	388.12	122.12	114.91	1.77	2,845.95
1996	1,302.58	941.74	393.86	119.78	119.33	1.82	2,879.11
1997	1,351.68	968.53	411.25	127.87	118.90	1.93	2,980.16
1998	1,414.20	1,000.19	394.34	131.06	126.34	1.99	3,068.13
1999	1,460.62	1,029.42	385.31	128.78	124.85	2.03	3,131.01
2000	1,509.49	1,066.76	405.46	133.92	127.11	2.16	3,244.91
2001	1,552.52	1,083.00	388.05	132.61	133.94	2.17	3,292.28
2002	1,602.84	1,100.05	385.98	132.59	129.73	2.12	3,353.31
2003	1,607.68	1,118.72	394.38	123.62	131.69	2.14	3,378.22
2004	1,750.92	1,158.50	419.33	136.91	133.26	2.22	3,601.14
2005	1,794.60	1,198.09	416.02	138.78	137.59	2.28	3,687.36
2006	1,857.75	1,224.41	438.16	138.58	136.57	2.35	3,797.82
2007	1,924.96	1,189.90	452.00	145.07	128.45	2.43	3,842.81
2008	1,891.13	1,163.92	442.76	146.13	124.94	2.38	3,771.26
2009	1,699.76	1,062.37	363.54	130.53	121.82	2.23	3,380.25
2010	1,755.31	1,117.78	393.53	155.52	121.13	2.31	3,545.59
2011	1,743.85	1,133.15	422.10	141.97	118.37	2.28	3,561.73
2012	1,692.58	1,113.13	406.67	149.99	114.90	2.27	3,479.53
2013	1,719.45	1,088.61	406.50	152.75	111.81	2.24	3,481.36
2014	1,725.49	1,122.12	410.79	150.88	112.89	2.24	3,524.42

Source: EU Energy and Transport in figures 2016.

The consolidated data for EU-28 show an increase on demand for freight transport by 23.8%. However, this growth has been very heterogeneous between different modes of transport. The data can be divided into two periods, one from 1995 to 2007, coinciding with a period of economic growth, and another from 2008 to 2014, which coincides with the global financial crisis that began in mid-2007 and from 2010 to 2013 Euro crisis. This crisis has affected the countries of the Euro area and it has made difficult or impossible for some euro area countries to refinance their public debt without assistance from third countries, also it has affected the banking system and the economic system in general.

In the period 1995-2007 there has been an increase on demand by 35%, meantime railroad has showed an increase by 16.5%. In the case of rail freight, it can be seen that the volume in 2002 was slightly lower than 1995. The increase was concentrated in the period 2003-2007, with an increase by 6.3% in 2004 compared to the year before.

The period 2008-2014 is characterized by an economic recession that has reduced the demand for transport. During this period the volume of freight transported has dropped by an average of 6.5% and railroad has reduced by 7.2%. It is important to note that in 2009 the freight transported decreased by 12% compared with 2007 as a consequence of the global financial crisis. Subsequently, freight transported was recovered until 2011, when the effects Euro crisis reduced transport demand levels again.

The railroad modal share evolution was set at 11.7% in 2014, compared with 13.6% in 1995 and road increased from 45.3% to 49.0%, while maritime dropped from 32.7% to 31.8%. The remaining modes have maintained their market shares with the exception of pipeline which was slightly reduced. If the modal share land transport is analyzed, road has increased from 67.3% in 1995 to 71.9% in 2014, while railroad has dropped from 20.3% in 1995 to 17.1% in 2014, pipeline has decreased from 6% to 4.7% and inland waterway showed slightly decline.

The data show the serious problems of freight transport by railroad to be an alternative mode of transport to the road. The globalization of transport logistics and the expansion of road transport with a door-to-door service coupled with the inability to respond and adapt adequately to new customer needs, capacity problems, lack of technical interoperability and problems of reliability in the delivery freight have led market share decline of freight transport on the railroad.

Table 2. Passenger Transport EU-28 by Mode (Billion Passenger-Kilometers)

Year	Road	Railroad	Tram & Metro	Air	Maritime	Total
1995	4,553.79	350.32	71.89	347.90	44.40	5,368.31
1996	4,627.94	348.78	72.76	368.01	44.00	5,461.49
1997	4,717.88	349.81	73.40	392.15	43.60	5,576.83
1998	4,832.91	350.74	74.51	411.25	43.10	5,712.51
1999	4,954.73	358.49	76.19	427.34	42.60	5,859.34
2000	5,011.41	371.51	78.39	459.51	41.70	5,962.52
2001	5,113.73	373.59	79.07	455.49	42.00	6,063.89
2002	5,194.66	366.13	80.32	447.45	43.31	6,131.87
2003	5,245.25	362.44	80.63	465.55	43.11	6,196.98
2004	5,316.22	368.79	83.29	495.71	42.61	6,306.63
2005	5,255.47	377.39	83.88	529.90	41.72	6,288.35
2006	5,296.33	389.34	85.73	552.02	42.27	6,365.69
2007	5,358.25	395.59	87.68	575.15	43.44	6,460.10
2008	5,377.40	410.70	91.07	563.30	43.48	6,485.94
2009	5,429.86	403.74	90.90	525.00	42.54	6,492.03
2010	5,367.12	405.30	92.18	539.48	40.48	6,444.56
2011	5,353.28	414.52	93.37	579.80	39.11	6,480.08
2012	5,263.86	419.58	94.63	573.51	41.97	6,393.55
2013	5,323.81	424.22	95.39	582.55	39.03	6,464.99
2014	5,419.33	428.21	101.56	605.27	37.51	6,591.88

Source: EU Energy and Transport in figures 2016.

In reference to passenger transport, they have been increasing in EU since 1995. Regarding railroad, this growth has been especially important for High Speed Rail (HSR) (Note 3), from 33 million PKM in 1995 to 111 million PKM in 2014. HSR achieved 26% of the passenger share market for EU-28 in 2014. In countries such as France and Spain the share amounted to 60.3% and 53.8%, respectively.

The data show that there has been an increase on demand by an average of 22.8% for EU-28. Railroad has increased its demand by 22.2%, however; air and tram & metro have increased by 74.0% and 41.3%, respectively. The market share evolution shows that road has dropped from 84.8% in 1995 to 82.2% in 2014 and maritime has presented a slight decline, while air has increased from 6.5 % in 1995

to 9.2% in 2014 and tram & metro showed a slight increase. Finally, railroad share was the same. If the modal share of land transport is analyzed, railroad has increased from 7.0% in 1995 to 7.2% in 2014 and tram & metro has enhanced from 1.4% to 1.7%, while road has reduced from 91.5% to 91.1%. Summarizing, the total transport demand on freight and passenger transport has been increased by 23.8% and 22.8%, respectively, for EU-28. In case of railroad, the growth has been by 5.8% and 22.2%, in a context of liberalization and with an unfavorable economic situation from 2007 to 2013. These increases on railroad demand have not led an increase on the share market of rail transport which highlight the important structural problems of the railroad and especially on freight transport. The data show that freight transport by road and passenger transport by road and aircraft are the main competitors of railroad.

3. Legislative Changes in the Sector

Over the last decade, the road transport has undergone a great increase, while railroad transport is suffering the gradual loss of market share in Europe, especially in freight; couple with serious financial problems of the railroad. It is necessary to implement reforms to convert railroad into a mode of transport capable of competing with the road. Since the beginning, railroad has had a strategic character for states. It has been developed in a national market without competition. Therefore, European railroad sector was characterized by state-owned monopoly railroad companies without an integrated cross-border railroad system. The companies were in charge of managing the infrastructure and the provision of passenger and freight transport services. The services provided were low quality, efficiency and productivity.

For EC, railroad is a sustainable and environmentally friendly mode, with aim to address its problems, is developing a series of directives that they intend to revitalize and liberalize the railroad. The reasons led to the beginning of this process have been:

- Loss of railroad market share;
- Increasing financial requirements, the need for a new refinancing of the railroad;
- The need for transform national railroad systems into a single system by improving the interoperability of inter-community networks;
- The rebalancing between different modes of transport, attributing to each of them the economic, environmental and social costs that correspond to them.

The deregulatory and liberalizing policy began in the early 1990s, which has intensified noticeably during the first decade of this century. Thus, the presence of the former state monopolies has been considerably reduced, even disappearing in some countries. The EC policy has focused on:

- Separation of infrastructure management from the provision railroad services.
- Implementation of interoperability among the national railroad systems.
- Assurance third-party access to the infrastructure.
- Introduction of independent railroad regulatory systems.

These directives have been incorporated in the legislation of different countries in an unequal way, in some cases not respecting the dates of transposition envisaged, and even when it has occurred, its application has not been total.

The deregulation and liberalization policy began with Directive 91/440/EEC and continued with Directives 95/18/EC, 95/19/EC and 96/48/EC. The main measures of these Directives were: the accounting separation of infrastructure management from the provision of railroad transport services, access rights for third-party that provide international combined services, established the rules on the

licensing of railroad undertaking license and allocation and charging of infrastructure capacity, at last, defined measures to enhance the interoperability on HSR network. Transposition of these directives into national law was compulsory for all member states not later than January 1993 and June 1997. Subsequently the so-called “Railway Packages” were implemented beginning from 2001. “First Railway Package” is composed of Directives 2001/12/EC, 2001/13/EC and 2001/14/EC. The aims of this package were to expand measures to increase liberalization and access to infrastructures by establishing the rules on capacity allocation and infrastructure access fees. So the main points were: independent organizational entities had to be specific between infrastructure management and transport operations. Member states were free to decide between separate divisions within a single undertaking, that is, a holding structure or complete institutional separation by a separate entity, it implemented accounting separation between freight and passenger transport services, they guaranteed the right access for international rail freight services over the Trans European Rail Freight Network (TERFN), the railroad undertaking’s license was valid throughout EU territory, required the establishment of independent regulatory bodies within member states, and defined measures to enhance the interoperability between the national railroad systems. The whole package had to be ratified into national law not later than March 2003. “Second Rail Package”, consists of Directives 2004/49/EC, 2004/50/EC and 2004/51/EC, and Regulation 881/2004. The objectives were to strengthen safety, interoperability, the opening of the rail freight market and the creation of European Railway Agency. This second package provided for the liberalization of international rail freight services to be liberalized before January 1st, 2006; and one year later the domestic market for each country. The transposition deadlines for the directives were April and December 2005, respectively. “Third Rail Package” is composed of Directives 2007/58/EC, 2007/59/EC, Regulations (EC) 1370/2007 and (EC) 1371/2007. This package was more oriented to the transport of passengers and it aimed to revitalize international transport and reinforce the rights of international passengers, launched the opening of international passenger transport on January 1st, 2010; the duration of public service contracts (Note 4) was limited and should not exceed 15 years. Moreover, it established the conditions and procedures for the certification of train and locomotives drivers. These directives had to be enacted not later than June and December 2009. Directive 2008/57/EC of June 17th, 2008 was a consolidated text of the interoperability HSR (Directive 96/48/EC) and the conventional rail system (Directive 2001/16/EC). The existence of these two directives was not justified whenever the procedure for developing the technical specifications for interoperability and for certification of interoperability constituents is identical in the two systems. Finally, Directive 2012/34/EC had the following objectives: member states should decide to separate their divisions within a company into a holding company structure or a complete institutional separation with an infrastructure manager located in an entity separate from transport operations; ensure the key functions of licensing, slot allocation and royalty collection are entrusted to entities that do not provide rail transport services; the accounting separation between passenger and freight services; and access to RTTFM is guaranteed.

European transport policy has placed more emphasis on freight transport because of the advantages it offers over other mode of transport. Thus, the greatest benefits are derived from the segregation freight operations from infrastructure management. The passenger transport is only operated commercially if it does not damage the services of the Public Service Obligation (PSO) (Note 5) and sufficient capacity is available and the rates are sustainable to be able to provide such service.

In general, the reforms have had the following objectives. First, it has been the opening of the rail market combined with some degree of vertical disintegration of infrastructure management and

operation of services. Freight transport was opened up step by step to competition, providing transport companies with non-discriminatory access to infrastructure. This process ended in 2007 with the opening of the internal markets of each Member State. Subsequently, EC initiated the opening of international passenger transport on January 1st, 2010. Second, EC has fostered the creation of an interoperable network with the aim of harmonizing and improving the currently fragmented railroad system and the implementation of common safety and security.

4. Methodology

The European integration process raises a number of questions about the effects it may have on railroad efficiency of Member States. In this paper, a parametric approximation of the stochastic frontier is used, in which the deviation between the observed and maximum possible level of output.

$$Y_{it} = f(X_{it}\beta + v_{it} - u_{it}), \quad i = 1, \dots, N, \quad t = 1, \dots, T \quad (1)$$

Where Y_{it} is the production in period t and for the productive unit i , X_{it} is a vector of explanatory variables and β is a vector of parameters to be estimated.

The technology is represented by a logarithmic transcendental (Translog) production function. We adopt this form because unlike a Cobb-Douglas form, which assumes the same production elasticities, the same scale elasticities and substitution elasticity equal to unity for all firms, the Translog does not impose such restrictions and is more flexible (Coelli et al., 2005). The production technology can be fully described by the input distance. The choice of the input distance function rather than an output distance function is driven by the nature of production and regulation in the railroad industry. We assume that firms have a higher influence on the usage of inputs than on outputs. This assumption is supported by the substantial proportion of state-controlled public transport requirements within rail passenger transportation and by the decreasing market share of rail transportation within both passenger and freight transport sector over the last decades (Coelli & Perelman, 2000).

Following Coelli and Perelman (1999, 2000) the Translog input distance function may be defined as:

$$\ln D_{it}^I = \alpha_0 + \sum_{m=1}^M \alpha_m \ln y_{mit} + \frac{1}{2} \sum_{n=1}^M \sum_{m=1}^M \alpha_{mn} \ln y_{mit} \ln y_{nit} + \sum_{k=1}^K \beta_k \ln x_{kit} + \frac{1}{2} \sum_{k=1}^K \sum_{l=1}^K \beta_{li} \ln x_{kit} \ln x_{lit} + \sum_{k=1}^K \sum_{m=1}^M \theta_{km} \ln x_{kit} \ln y_{mit} + \xi_1 t + \frac{1}{2} \xi_{11} t^2 + \sum_{m=1}^M \rho_m \ln y_{mit} + \sum_{k=1}^K \psi_k \ln x_{kit} \quad (2)$$

Where D_{it}^I is the input distance term; i and t are respectively, firm and time indices, y_{mit} and x_{kit} denote the output and input quantity, and α , β , θ , ξ , ρ , ψ are unknown parameters to be estimated. The input distance function must be symmetric and homogenous of degree +1 in inputs. Symmetric requires the restrictions:

$$\alpha_{m,n} = \alpha_{n,m} \quad (m, n = 1, \dots, M) \quad \text{and} \quad \beta_{li} = \beta_{il} \quad (l, i = 1, \dots, L) \quad (3)$$

The restrictions required for homogeneity of degree +1 in inputs are:

$$\sum_{k=1}^K \beta_k = 1, \quad \sum_{l=1}^K \beta_{kl} = 0, \quad \sum_{k=1}^K \theta_{km} = 0, \quad \sum_{m=1}^M \rho_m = 0, \quad \sum_{k=1}^K \psi_k = 0 \quad (4)$$

In order to estimate the distance function we apply Stochastic Frontier Analysis (SFA), a method simultaneously introduced by Aigner et al. (1977) and Meeusen and van den Broeck (1977). SFA involves specifying a parametric form which estimates a distance function with a composed error term, $\varepsilon_{it} = v_{it} - u_{it}$. The component v_{it} accounts measurement errors and other random factors, and it is assumed to be symmetric, identically distributed random term and independent of v_{it} as $\sim N(0, \sigma_v^2)$. The component u_{it} is a non-negative random error term which representing technical inefficiency, we assume a truncated normal distribution $u_{it} \sim N^+(\mu, \sigma_u^2)$.

We can write the stochastic frontier function production by imposing the homogeneity restrictions in equation 4 and normalizing the Translog input distance function by one of the inputs (Lovell et al., 1994). Where $x^* = x_{ki}/x_{Ki}$, the function may be defined as:

$$-\ln x_{kit} = \alpha_0 + \sum_{m=1}^M \alpha_m \ln y_{mit} + \frac{1}{2} \sum_{n=1}^M \sum_{m=1}^M \alpha_{mn} \ln y_{mit} \ln y_{ni} + \sum_{k=1}^K \beta_k \ln x_{kit}^* + \frac{1}{2} \sum_{k=1}^K \sum_{l=1}^K \beta_{li} \ln x_{kit}^* \ln x_{lit}^* + \sum_{k=1}^K \sum_{m=1}^M \theta_{km} \ln x_{kit}^* \ln y_{mit} + \xi_1 t + \frac{1}{2} \xi_{11} t^2 + \sum_{m=1}^M \rho \ln y_{mit} + \sum_{k=1}^K \psi \ln x_{kit}^* t + v_{it} - u_{it} \quad (5)$$

Assuming that the environmental factors directly affect technical efficiency, the inefficiency effect model is specified as:

$$\mu_{it} = \delta_0 b + \sum_{j=1}^J \delta_j z_{jit} \quad (6)$$

Where μ_{it} is the mean of the truncated normal distributed inefficiency term; z_{jit} denotes the j -th ($j = 1, 2, \dots, J$) environmental or regulatory factor of the i -th firm in the t -th time period expected to influence technical efficiency, and δ are unknown parameters to be estimated.

We follow the model specification of Battese and Coelli (1995) in order to investigate the influence or regulatory and environmental conditions on efficiency. This model suggests estimate the distance function and the determinants of the inefficiency in an only step. So the model I (Note 6) is made by the estimations of equations (5)-(6) that is performed simultaneously using the Maximum Likelihood method.

$$-\ln net_i = \alpha_0 + \alpha_1 \ln pkm_{it} + \alpha_2 \ln tnm_{it} + \frac{1}{2} \alpha_{11} (\ln pkm_{it})^2 + \frac{1}{2} \alpha_{22} (\ln tnm_{it})^2 + \alpha_{12} \ln pkm_{it} \ln tnm_{it} + \beta_1 \ln(emp_{it}/net_{it}) + \beta_2 \ln(roll_{it}/net_{it}) + \frac{1}{2} \beta_{11} (\ln(emp_{it}/net_{it}))^2 + \frac{1}{2} \beta_{22} (\ln(roll_{it}/net_{it}))^2 + \frac{1}{2} \beta_{12} \ln(emp_{it}/net_{it}) \ln(roll_{it}/net_{it}) + \theta_{11} \ln(emp_{it}/net_{it}) \ln pkm_{it} + \theta_{12} \ln(emp_{it}/net_{it}) \ln tnm_{it} + \theta_{21} \ln(roll_{it}/net_{it}) \ln pkm_{it} + \theta_{22} \ln(roll_{it}/net_{it}) \ln tnm_{it} + \xi_1 t + \frac{1}{2} \xi_{11} t^2 + \rho_{1t} \ln pkm_{it} + \rho_{2t} \ln tnm_{it} + \psi_{1t} \ln(emp_{it}/net_{it}) t + \psi_{2t} \ln(roll_{it}/net_{it}) t + v_{it} - u_{it} \quad (7)$$

and,

$$\mu_{it} = \delta_0 + \delta_1 \ln(net_den_{it}) + \delta_2 \%net_elect + \delta_3 \ln(pas_use_{it}) + \delta_4 \ln(fre_use_{it}) + \delta_5 \ln(ope_sub_{it}) + \delta_6 \ln(inf_sub_{it}) + \delta_7 ins_sep_{it} + \delta_8 org_sep_{it} + \delta_9 fre_ope_{it} + \delta_{10} pas_ope_{it} + \delta_{11} Time_{it} \quad (8)$$

One of the main reasons for the use of this methodology is the possibility of analyzing the determinants of the evolution productive unit inefficiency in terms of a set of explanatory variables that can vary in time, as in the specification previous. In this way, the assumption is made that the effects technical inefficiency are identically distributed and are not correlated with the error term necessary to obtain the predictions of the inefficiency values. This one-step approach can provide more reliable predictors of firm-specific efficiency than using a two-stage approach. Kumbhakar et al. (1991) and Reifschneider and Stevenson (1991) shown that the two-stage approach assumes the efficiency scores to be distributed independently and identically in the first-stage production frontier estimation, while in the second-stage they are assumed to be a function of the environmental factors, suggesting they are not identically distributed. As a result, biased efficiency predictors are obtained. However, one-step inefficiency estimations can be hardly compared with inefficiencies obtained with the other techniques.

The reason is that these inefficiencies are the inefficiency explained by the set z of explanatory variables. The inefficiencies obtained from the other techniques are estimate of total inefficiency. If inefficiency is poorly explained by the set z of explanatory variables, the levels of inefficiency cannot be properly compared.

The model estimates are obtained by maximum likelihood estimation, the technical efficiency of the i – th firm in the period t – th is predicted by the conditional expectation of $\exp(-u_{it})$, given the random variable ε_{it} Coelli and Perelman (1999).

$$D_{oi} = E[\exp(-u_{it}/\varepsilon_{it})] = \left\{ \exp\left[-\mu_{it} + \frac{1}{2}\sigma_*^2\right] \right\} * \left\{ \Phi\left[\frac{\mu_{it}}{\sigma_*} - \sigma_*\right] / \Phi\left[\frac{\mu_{it}}{\sigma_*}\right] \right\} \quad (9)$$

Where $\Phi(\cdot)$ represents the distribution function of the standard normal random variables;

$$\mu_{it} = (1 - \gamma)\left[\delta_0 + \sum_{j=1}^J \delta_j z_{jit}\right] - \gamma\varepsilon_{it}; \sigma_*^2 = \gamma(1 - \gamma)\sigma^2; \text{ and } \gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2} \quad (10)$$

The predicted efficiency scores range between zero and one. A score of one defines an efficient firm operating on the best-practice frontier, whereas a score lower than one represents the degree of a firm's inefficiency. The γ -parameter corresponds to the estimated contribution of the inefficiency term to the variance of the total error term. A value of one indicates that all deviations from the best-practice frontier are due to inefficiency, while a value of zero indicates that all deviations from the best-practice frontier are by noise.

5. Data Description

The European integration process raises a number of questions about the effects it may have on railroad efficiency of Member States. The aim of this paper is to analyze how reforms launched by EU have improved the efficiency of former incumbent. Likewise, we include several exogenous variables analyze how they influence on efficiency.

The sample data is limited to the former state railroad undertakings or their successors. In order to compare observations between countries, samples are generated by aggregating the data of the successor undertakings in countries where there is more than one company. For example, in Spain there are two companies, Adif manages the infrastructure and Renfe runs transport operations. Meanwhile, there is only one company called Deutsche Bahn in Germany.

Data set were received from several sources: Railisa database and synopsis of the International Union of Railways (UIC), Eurostat database, the annual reports of the rail operators and infrastructure manager, website of the Statistical Office and the data published in the Rail Liberalization Index 2004-2007-2011. This study is conducted with a multi-output technology and multi-input production, so we do not include countries which freight division was sold, for example, Netherland and Denmark. We have to exclude other European countries from our analysis as consequence of poor data. Moreover, since each country has unique characteristics that directly affect the efficiency manner. Railroad systems are included with different shapes and sizes: vertically integrated, separated legally, with varying degrees of openness, systems where the carriage of passengers or freight or mixed predominates, with significant grants to transport operations and to maintenance of infrastructure. Data includes some characteristics of railroad infrastructure and operations for 16 European countries from 2004 to 2014. Likewise, we select this time frame because it covers the implementation of liberalization reforms in the majority of countries.

Railroad systems can offer a variety of services, in order to collect the characteristics of service production, we select as outputs: the number TKM and PKM transported, as Oum and Yu (1994) point

out these outputs measures, compared to other measures like passenger train-km and freight train-km, also take into account the possible influence of government and regulatory restrictions on capacity allocation.

Regarding the inputs, we choose: the number of employees (*emp*) (Note 7) in state railroad companies, the number of rolling stock (*roll*) used for both freight and passengers, and network length (*net*) as a proxy for capital stock. We considered *net* as a long-lived asset and a quasi-fixed built in the past and financed by capital grants from the government.

The data set are obtained from a sample of 172 observations. The estimations are found from an unbalanced data panel model for the period 2004-2014, where all values have been updated to 2014. As we can see in Table 3, all variables show a significant amount of variations due to heterogeneity of the sample railroad systems. For example, in France, Italy and Spain railroad undertakings provide mainly passenger services; meanwhile in Austria, Czech Republic and Germany they concentrate on freight services. Furthermore, the network length of Germany's railroad system is 123 times longer than in Luxembourg. Also, an important part of the variation is a function of time. The sample shows an increase on PKM (Note 8) by 10.6%, while TKM reduced by 3.4%. In the same period the number of employees and rolling stock decreased by 11.2% and 22.1%, respectively.

Table 3. Descriptive Statistics

Variable	Mean	Std. Dev.	Max.	Min.
Passenger-km (10^9)	18.81	25.95	88.75	0.27
Tonne-km (10^9)	18.33	24.48	113.63	0.08
Nu. Employees (10^3)	54.94	67.40	296.09	3.00
Nu. Rolling Stock (10^3)	26.78	32.03	138.59	1.04
Network Length (10^3)	9.91	9.97	34.72	0.28
Network Density (10^{-2})	6.26	3.30	12.05	1.26
% Electrified Network (10^{-2})	60.52	23.63	100	2.71
Use Passenger (10^2)	7.55	4.56	22.55	1.87
Use Freight (10^2)	10.07	7.15	34.09	0.02
Operative Subsidy (10^3)	1.28	2.33	10.38	0.02
Infrastructure Subsidy (10^3)	0.65	0.65	2.62	0.00

Source: UIC, Eurostat, annual reports and statistical office.

Our model of technical inefficiency includes several exogenous environmental variables. So we included variables relative to network characteristics: network density and percentage of electrified network. Network density (*net_den*) is the network length in km divide by square area km of the country. This variable should reflect the impact of differences in network structure and density on the production process and on the input requirements. As Farsi et al. (2005) showed that high density networks have a more complex shape than less dense networks and are usually in areas located in areas with higher population density. Percentage electrified network (*%net_elect*), it is probable that a higher degree of electrification will improve efficiency levels, and it is to be expected that this will reduce the levels of labour and energy consumption and provide more speed and less environmental impact. We included two variables relate to intensity of use. Passenger use (*pas_use*) is the number of PKM divide by the country's population. Freight use (*fre_use*) is the number of TKM divide by the country's

population.

For European railroads, public grants provide essential funds for infrastructure maintenance and to boost passenger and freight transport that depends on political decision of States. Railroad tends to be an instrument of policy decisions rather than truly independent companies, even if companies emphasize independently and are free to behave commercially. So subsidies represent an important instrument used to promote capital intensive transport mode like railroad. In the case of subsidy for maintenance or renewal of the rail network (*inf_sub*), the infrastructure manager receives an amount of money from the state for maintenance or renewal of the rail network. Operating subsidy (*ope_sub*), as a rule, they are state compensation to railroad undertaking for the provision of PSO. Countries provide public service contracts through public procurement procedures or directly. These contracts are related to the provision of passenger transport service suburban and middle distance.

Key elements in the European railroad reforms have been to promote a step-by-step market opening mainly concerning freight transport combined with some degree of vertical disintegration of infrastructure management and operation of services, unbundling of other railroad functions, and introduction of infrastructure access charging (Di Pietrantonio & Pelkmans, 2004). Thus, our paper uses two dummy variables. We consider whether the incumbent has chosen an institutional separation, that is to say, there is an unbundling vertical. The other variable is relative to the opening degree of railroad systems. These two variables are beyond the control of state undertakings, but significantly affect their levels of efficiency.

One factor that may impact benchmarking analysis and railroad efficiency is the difference in railroad system structure. In reference to the degree of separation of infrastructure management and transport operations, European legislation does not require the complete separation of infrastructure from operations. What it does require is that if infrastructure management is not an independent organization, a separate organization should be in charge of allocation of capacity and the establishment of fees. The degree of separation extends from purely accounting separation to a complete ownership. The implementation of European Directives has given rise to the following organizational models. First, full separation between the areas of infrastructure and operations, both companies are legally independent. In the countries there is vertical separation, a state-controlled firm owns the infrastructure and provide network access and services to numerous railroad undertakings. Second, partial separation, two different entities were created. However, infrastructure maintenance and some infrastructure enhancement are still managed by company makes transportation operations based on a contract. Third, partial integration, there are some countries that have chosen the legal, organizational and accounting separation within a holding company. They argue that institutional separation would diminish the advantages of vertical integration and would not be effective in raising economic welfare. Fourth, there is an accounting separation only. The company keeps the same structure of former incumbent.

By the other hand, competition requires the commitment of governments to promote competition by removing barriers of access to the network and guarantee fair competition between different railroad undertakings. The design of competition is not straightforward in the case of railroad. The reforms have been moderate in Europe and have consisted mainly of new undertakings entering the freight sector and of a franchising system in passenger services (Cantos et al., 2012). The market opening is still very different in Europe, where network access is legally guaranteed for domestic and foreign rail freight transport undertakings in Europe. Differences exist in granting permission for domestic services in passenger transport. In this segment only Sweden and Great Britain have fully liberalized their markets, while Austria, Czech Republic, Germany, Italia and Netherland have opened their own market to a

limited extent. We use IBM studies on market opening rail in Europe in 2004, 2007 and 2011 and EU Energy and Transport in figure 2016 to classify the degree of market opening between all European countries.

Table 4. Organizational Models and Degree of Separation in European Railroad System

Degree of separation	Degree of opening market	
	High	Down
Full separation	Bulgaria, Denmark, Great Britain, Netherland, Norway, Romania, Sweden	Finland, Greece, Portugal, Slovakia, Spain
Partial separation	Czech Rep. Austria, Belgium, Estonia,	France
Partial integration	Hungary, Germany, Italy, Latvia, Poland	Lithuania
Full integration	Ireland, Luxemburg, Slovenia	Switzerland

Source: European Commission (2009).

The Table 4 shows the organizational models and degree of market opening. Regarding Czech Republic and France, we do not consider an institutional full separation. In fact, such a mix or hybrid structure is more similar to an organizational separation with separated divisions for infrastructure management and operations within a holding company, as example Germany or Italy. In the case of Spain, its railway system was separated in 2005. In reference to the degree of liberalisation, Czech Republic, Belgium and Norway are moved from down to high degree of opening market in this period. So we define our four dummy variables as:

ins_sep: takes a value of one for countries, which the ownership of infrastructure is separated fully and institutionally from that of operations during the years of sample.

org_sep: takes a value of one for countries, which keeps infrastructure and operations within the same undertaking.

fre_ope: takes a value of one when the entry of new undertakings is allowed in the freight railroad sector, regardless of whether or not the industry has been separated vertically.

pas_ope: takes a value of one when the entry of new undertakings is allowed in the passenger railroad sector, regardless of whether or not the industry has been separated vertically.

6. Empirical Result

This paper uses a parametric mathematical program called Frontier 4.1, developed by Coelli (1996) to estimate the efficiency levels of the sample. The parameter estimates for the function input distance oriented represented by equations 7 and 8. Therefore, in order to obtain accurate technical efficiency scores, it is crucial to estimate an appropriate functional form of the production function underlying the frontier. Using the generalized likelihood test, we evaluate several alternative specifications of our model. The test statistic, λ , is defined by

$$\lambda = -2[\ln L[H_0] - \ln L[H_1]]$$

Where $L[H_0]$ and $L[H_1]$ are the log-likelihood value of the restricted model under the null hypothesis and the unrestricted model under the alternative hypothesis, respectively. If the null hypothesis is true, then λ is approximately chi-squared distributed with degree of freedom equal to the number of

parameters assumed to be zero in the null hypothesis.

The generalized likelihood-ratio test for model I are reported in Table 5. The null hypothesis refer to the parameters of the stochastic production frontier that technical inefficiency are absent from the model, that no technical change occurs, that a Hicks neutral technical change occurs, and that the Cobb-Douglas form is an adequate representation of the input distance function.

Table 5. Test of Hypotheses

Null Hypothesis	Log-Likelihood	λ	Critical value $\chi^2_{0.99}$	Decision
Model I	204.01			
$H_0: \alpha_{mn} = \beta_{kl} = \theta_{km} = \lambda_{tt} = \rho_{tm} = \psi_{tk} = 0$	60.81	286.40	30.58	Reject H_0
$H_0: \lambda_{tt} = \lambda_{tt} = \rho_{tm} = \psi_{tk} = 0$	32.17	343.68	16.81	Reject H_0
$H_0: \rho_{tm} = \psi_{tk} = 0$	184.72	38.58	13.28	Reject H_0
$H_0: \Upsilon = \delta_0 = \dots = \delta_9 = 0$	30.68	346.66	24.04*	Reject H_0

* The test statistic λ has a mixed chi-squared distribution for the hypothesis involving $\Upsilon = 0$. The critical value is obtained from Table 1 in Kodde and Palm (1986).

All maximum likelihood estimates of the models are obtained by using the software package Frontier 4.1 (Coelli, 1996).

Source: Author.

Given that technical inefficiency is possible not exist in the industry, if the null hypothesis is not rejected, the Υ value is zero and the coefficients of frontier production can be estimated using the classical model of Ordinary Square Minimum. Conversely, if the null hypothesis is rejected the Υ value is different zero, that implies the existence of an inefficiency effect and the estimates by maximum likelihood are adequate. The results of hypothesis test (Table 5) show that technical inefficiency effects are absent from the model, is rejected by the data. The γ -coefficient is close to one (see Table 6), indicating that most of the deviations from the best-practice frontier are as result of technical inefficiency (u_{it}) and random error is close to zero. The test results demonstrate that our model specification of a Translog inefficiency frontier model with non-neutral technological change is an adequate representation of the data.

The results of the stochastic production frontier model, equation 7, and the technical inefficiency model, equation 8, are shown in Table 6. A positive sign in the parameters of the first equation implies that the inputs tend to increase the level of production; while a negative sign in the second model represents a negative effect on inefficiency, that is, a positive effect on efficiency.

The estimated coefficient of the first-order terms and the time variable stochastic frontier production function are reported in the upper of Table 6. All variables are normalized by their sample means, the first-coefficient can be interpreted as output and input elasticities. All the first-order coefficients are statistically significant at the 5 percent level and show the expected signs. The estimated input distance function is decreasing in outputs and increasing in inputs. Furthermore, the input distance function is homogeneous of degree one in inputs, so the input change weights sum to unity in this index. The β parameters reveal that input elasticities for employees, rolling stock and network length are respectively 0.652, 0.301 and 0.047 (Note 9), which implies an intensive use of labour in the European railway sector. However, the output weights do not sum to unity. The negative of the inverse of the sum of the first-order output coefficients is 1.22, indicating increasing returns to scale at the sample

average firm. The coefficient of time (t) is 0.026 so implies technological progress at a rate of 2.6% for the sample average firm in the mid-year of the sample. Cantos et al. (1999) found that railroad is a sector in which increases in productivity are closely linked to technological advances. Thus the introduction of new modern trains, the application of new technologies in traffic management and improvements in the infrastructure of track and services, constitute a mechanism for improving efficiency and productivity railroad. Finally, the value of γ equal to 0.887 this means that most of the variation component due to error is technical inefficiency term.

Table 6. Parameter Estimates

Variable	Para meter	Model I		Model II		Model III		Model IV		Model V	
		Coef.	T- ratio	Coef.	T- ratio	Coef.	T- ratio	Coef.	T- ratio	Coef.	T- ratio
Production frontier											
Cte	α_0	0.6404***	16.53	0.6497***	15.24	0.5991***	14.67	0.4183***	7.83	0.3455***	17.42
ln vkm	α_1	-0.5957***	-9.03	-0.5313***	-13.29	-0.4195***	-6.45	-0.2217***	-7.54	-0.1598***	-12.14
ln tkm	α_2	-0.2242***	-3.24	-0.2516***	-5.14	-0.3342***	-4.86	-0.6006***	-18.42	-0.5889***	-44.63
ln (emp/net)	β_1	0.6516***	13.30	0.6132***	12.74	0.6383***	11.65	0.5605***	6.39	0.6620***	30.33
ln (roll/net)	β_2	0.3016***	6.91	0.2801***	6.56	0.2637***	5.91	0.4217***	4.71	0.3119***	16.55
t	λ	0.0269***	4.44	0.0274***	6.86	0.0132*	1.77	0.0297***	3.16	0.0292***	13.52
Inefficiency model											
Cte	δ_0	0.2472	0.42	0.4822***	8.15	0.5800***	9.59	0.3744***	-6.42	-0.2755	-0.47
ln (net_den)	δ_1	0.4433***	7.52	0.4458***	8.10	0.4767***	6.10				
%net_elect	δ_2	-0.3845***	-3.80	-0.4050***	-4.07	-0.2534**	-2.16				
ln (pas_use)	δ_3	-0.8416***	-7.80	-0.8777***	-9.51	-0.8426***	-8.38				
ln (fre_use)	δ_4	0.2672***	3.27	0.2732***	5.17	0.1446*	1.81				
ln (ope_sub)	δ_5	0.1512***	7.71	0.2126***	8.82	0.22506***	8.42			0.2448***	12.85
ln (inf_sub)	δ_6	-0.0127*	-1.83	-0.0098	-1.40	-0.0095	-1.28			-0.0713***	-7.36
ln (ins_sep)	δ_7	-0.0409	-0.07					-0.6737	-1.15	-0.5040	-0.86
org_sep	δ_8	0.2882	0.49					0.2992	0.51	0.2284	0.39
op_fre	δ_9	0.1555***	3.91	0.1191***	3.18			0.7937***	10.08	0.4147***	7.21
op_pas	δ_{10}	-0.1606***	-3.83	-0.1965***	-4.98			-0.2198***	-2.86	-0.1961***	-3.04
Time	δ_{11}	-0.0057	-0.69			-0.0196*	-1.84	-0.0185	-1.08	-0.0130*	-1.79
Sigma-squared	σ^2	0.0100***	7.77	0.0093***	8.41	0.0121***	7.28	0.0696***	13.19	0.0548***	12.75
Gamma	γ	0.8879***	25.26	0.8681***	28.30	0.9229***	29.18	0.9835***	32.95	0.9999***	201**
Mean TE		63.60		62.71		64.14		73.49		72.59	
Log-likelihood		204.01		195.22		177.76		69.12		112.14	

***, **, and *: Parameter is significant on the 1%, 5% and 10% level respectively.

The models are obtained by using the software package Frontier 4.1 (Coelli, 1996).

Source: Author.

The coefficients of the inefficiency model I are reported in the lower part of Table 6. The estimated coefficients of δ_7 , δ_8 and δ_{11} are statistically insignificant in model I, that is, institutional and organizational separation, and Time. Regarding the degree of vertical separation the incumbent,

institutional separation (δ_7), shows a negative and statistically insignificant coefficient, this mean that unbundling separation is not necessary to improve railroad efficiency. The Time variable, the negative coefficient points to an increase insignificant on technical inefficiency over time. The results indicate that a railroad's efficiency performance is down due to the deregulation measures do not have the expected effects, the high operative subsidies encourage inefficiency to remain in railroad's operation and the budget constraint to investment as a consequence of the Euro crisis. From 2004 to 2010 maximum efficiency increased by around 0.4 percent from 98.89% to 99.37%, later decreased by 0.85 percent up to 98.53% in 2013 for budget constraint in Euro crisis and in 2014 it increases again. While minimum efficiency decreased whole period by around 17 percent. Therefore, there is a lack of convergence of technical efficiency levels within the European railroad sector over time. Overall, the difference between the minimum and maximum technical efficiency scores significantly increased from 72.67% in 2004 to 77.3% in 2014.

Among the estimates for the environmental variables, the coefficients refer to network characteristics indicate a higher network density, δ_1 , leads to less technical efficiency. A greater network lets provide a better transport service so the consumption of inputs will rise as a consequence of the increase demand of outputs. In contrast, the coefficient of δ_2 is negative, which indicates that a higher percentage of electrified network leads to technical efficiency gains. Electrified network usually usages more efficient coordination systems than non-electrified railroad network. Regard intensity of use, passenger use (δ_3) increases railroad efficiency while freight use (δ_4) reduces it because the public rail systems have mostly focused on passenger transport and the liberalization of rail freight transport has not significantly increased the volume of freight transported. In reference to public subsidies have the expected signs, operating subsidy (δ_5) enlarges inefficiency because it encourages inefficient behaviour. Whereas, subsidy for maintenance or renewal of the rail network (δ_6) shows a negative coefficient, this means that the efficiency increases through the reduction of incidents on the network and let more efficient and reliable service.

The variables relative to liberalization, freight market opening (δ_9) does not reduce the inefficiency. Railroad does not increase modal share neither TKM transport. Nevertheless, it is noted that freight volume has dropped 2.13% by average from 2004 to 2014 in Europe and 2.03% for railroad. While passenger liberalization has a positive impact on efficiency, however, this result has to be taken with caution because the small number of countries that have opened up their domestic market and the short period of time.

The alternative models show the influence of exogenous factors and they are also reported on Table 6. Firstly, the value of γ equal is close to 1, that is, most of the variation component due to error is technical inefficiency term. All first-order coefficients of the alternative models are significant and show the expected sings. Considering the coefficients of the inefficiency model, the alternative models lead to analogous results. Compared to Model I, alternative models are rejected based on likelihood-ratio tests (Note 10). The model II omits variables relative to the degree of separation between infrastructure management and transport operations and Time. All coefficients are statistically significant and have the expected signs except δ_6 . The estimate coefficient for grants for maintenance or renewal of the rail network is not statistically significant. The data showed that network has increased by 0.5%. However, this increase has taken place on HSR (+69%), while the conventional rail has been reduced by 1.37%. The new high speed lines do not need as much maintenance or renovation during their first years of life as conventional network, so infrastructure manager needs less funds for maintenance or renewal network. Nevertheless, optimum network maintenance is essential for effective

and efficient transport service. Model III shows the influence of the environmental factors, where the coefficients of t , fre_use and $Time$ are statistically significant at 10 percent level only. Model IV analyses the impact of different railroad system structures and the degree of liberalization on railroad efficiency. Our results suggest that the process of vertical separation is not necessary to improve efficiency. In contrast, the opening market seems to lead to a greater efficiency on passenger market whilst, freight market shows a negative effect. Finally, Model V shows the measures aimed at the improvement, promotion and liberalization of the railway. European railroads tends to be an instrument of policy decisions, so public grants provide essential funds for infrastructure maintenance and to boost passenger and freight transport that depends on political decision of States. In this model public grants should be considered like an important element of as the Community's transport policy and not like an environmental variable. This model shows all coefficients are significant and they have the expected sign, except variables relative to railroad system structures.

Table 7. Model II: Technical Efficiency Scores

Country	Railroad firms	Average efficiency by period (in %)			Average efficiency change (in %)		
		2004-07	2008-10	2011-14	2004-14	2004-06/2013-14	2013-2014
Belgium	SNCB	53.49	50.21	49.60 ^a			
Czech Rep.	SZDC/CD	27.80	28.95	32.59	29.52	17.23	1.38
Germany	DB	39.75	38.52	40.30	39.45	1.38	0.86
Ireland	CIE	96.82	96.63	97.13	96.84	0.32	2.38
Spain	ADIF/RENFE	94.17	96.19	96.03	95.41	1.98	2.56
France	RFF/SNCF	59.80	56.34	67.83	60.73	13.43	1.32
Italy	FS	53.10	55.05	65.73	57.25	23.79	3.89
Luxemburg	CFL	46.70	57.11 ^b	52.63 ^b	51.49		7.49
Austria	ÖBB	54.21	55.43	62.98	57.05	16.18	1.59
Poland	PKP	29.88	25.34	22.19	26.13	-25.74	-1.94
Portugal	REFER/CP	96.46	97.20	90.66	95.15	-6.01	8.91
Slovenia	SZ	38.01	34.95	31.00	34.98	-18.44	-4.41
Slovakia	ZSSR/ZSR	25.13	24.27	25.82	25.01	2.75	3.45
Sweden	BV/SJ	98.33	98.98	98.46	98.60	0.13	0.85
Norway	BANEVERKET/NSB	96.78	97.91	98.40	97.63	1.67	-0.06
Switzerland	CFF	96.02	96.90	96.57	96.49	0.57	2.75
	Mean	62.90	63.01	65.15	63.61	3.58	2.48

a: Belgium is not available 2013 and 2014.

b: Luxemburg is not available 2011 and 2012.

Source: Author.

The Table 7 reports the average technical efficiency scores of Model I per country for the period 2004-2014 as well as for three periods. Over the whole 11-year period, the best results are achieved by BV/SJ in Sweden (98.60), BANEVERKET/NSB in Norway (97.63) and CIE in Ireland (96.84). Meanwhile, ZSSK/ZSR in Slovakia (25.01), PKP in Poland (26.13) and SZDC/CD in Czech Republic (29.52) exhibit the worst results. Considering the sub-periods, REFER/CP in Portugal (97.20) taking over the third best place on the second sub-period and on the third sub-period the worst system is PKP in Poland (22.19). Moreover, the countries that exhibit a positive development over time are Austria,

Czech Republic, Italy and Norway. By the other hand, the countries that show a negative development over time are Poland and Slovenia. The countries with the best rate are characterized by down network density like in Sweden (0.022), Norway (0.013) and Ireland (0.27), and they reduce their overcapacity in very significant way. Likewise, the countries with high percentage of electrified network show better efficiency rate.

Comparing the first and last sub-periods, FS in Italy (20.02), SZCD/CD in Czech Republic (17.23) and ÖBB in Austria (16.18) show the highest percentage of technical efficiency growth. By the other hand, PKP in Poland (-25.74), SZ in Slovenia (-18.44) and REFER/CP in Portugal (-6.01) exhibit a technical efficiency decline. If we compare 2014 and 2013 the efficiency is improved by an average of 2.48%. All countries show positive rate except Slovenia, Poland and Norway with a decline of 4.41%, 1.94% and 0.06%, respectively.

7. Summary and Conclusions

The European railroad reform policy focused on the deregulation and liberalization. We analyze the impact of regulatory and other environmental factors on the technical efficiency of 16 European railroads from 2004 and 2014. The sample is composed by the former state railroad undertakings or their successors. Our paper is based on a multiple-output and multiple-input distance function model, including inefficiency effects.

The model suggests that European railway system is indeed characterized by increasing returns to scale, where the improved performance in European railroads was primarily driven by substantial cuts in labour usage and rolling stock. In reference to the variables related to network characteristic, we find the negative influenced of network density. This result can be explained by the higher cost for coordination and maintenance costs of a widely branched dense and passenger transport costs are higher than freight transport. By the other hand, higher percentage of electrified network improves the efficiency. Electrified network usually usages more efficient coordination systems than non-electrified railroad network and the high-speed lines improve efficiency. The results show that the most efficiency railroad systems are characterized by down network density and they usually have high percentage of electrified network.

The railway needs a lot of financial resources but they should be used in an efficient manner. Operating subsidy is needed to fund services that are considered of general interest. This subsidy is intended to make available to transport services users at affordable prices, lower than those required to cover costs. Since passenger transport market is closed to competition in most countries and State awards subsidies to transport companies. In this context of monopoly, inefficient behaviour is encouraged. Our paper shows that operating subsidies have negative effects on efficiency. While, subsidies for maintenance or renewal of the rail network are necessary to provide quality service and reliable and they have positive effects.

Regarding to estimate the influence of regulatory changes on efficiency growth, the processes of separation of infrastructure management and liberalisation within the railway sector are relatively recent in many countries. We do not find differences between separate companies and an integrated rail system, so vertical separation does not produces efficiency gains. The opening market has a positive effect on efficiency in some cases. The entry of new railway undertaking has significantly improved levels of efficiency in the industry. This is true in case of opening passenger transport, but we have to take account the reduced number of countries that they are opened their markets. According to the degree of market opening, the promotion of competition has not had the expected effects in the railroad

freight market and it has a negative effect on efficiency. This result can be explained by global financial crisis in 2007 and Euro crisis in 2010 that have reduced the global demand by 2.13% in Europe in the period 2004-2014 and for railroad freight has declined by 2.03%.

Summarizing, the results indicate that there has been a technology change and changes in technical efficiency. The reforms appear to have been beneficial in terms of efficiency gains, even though they have developed in an unfavourable economic context that may have affected the results. The conclusions drawn from this study has the limitation that all European countries are not included. It also does not take into account aspects such as the load factor or energy efficiency that is important issues to consider in future studies.

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Notes

Note 1. EC promotes the general interest of the EU by proposing and enforcing legislation as well as by implementing policies and the EU budget.

Note 2. The EU is a unique economic and political union between 28 European countries that together cover much of the continent.

Note 3. High Speed Rail is a new track that allows the traffic of trains at a speed equal to or greater than 250 km/h (160 mph) and existing lines in excess of 200 km/h (120 mph). This type of rail transport uses an integrated system of specialized rolling stock and dedicated tracks. Conventional rails are all tracks not classified as dedicated high speed lines or upgraded high speed railway lines.

Note 4. Public contracts awarded before December 4, 2007 on the base a public bidding process under which the exclusive right to transport passengers is granted.

Note 5. Public Service Obligations are passenger transport services that are considered of general interest. State imposes the rail undertaking performing unprofitable services, either by the route, frequencies, schedules or quality of rolling stock. The undertaking receives financial compensation for the cost incurred by the provision of such services.

Note 6. The *time* variable is included in both the stochastic frontier and the inefficiency effect model, within the stochastic frontier model it accounts for technology change while within the inefficiency effect model it accounts for changes in technical efficiency.

Note 7. Employees can perform different functions to rail transport, that is to say, they can perform other activities such as road transport or logistics services.

Note 8. Belgium is not included due to lack of data in 2014.

Note 9. Since x_3 has been used as a numeraire, the network length can be recovered as $e_3 = 1 - e_1 - e_2$.

Note 10. The test statistic λ equals 17.58 for Model II, 52.5 for Model III, 269.78 for Model IV and 183.74 for Model V. All values are greater than value 11.34 ($\alpha = 0.01$, degree of freedom = 3).