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Abstract

The processes of vertical and horizontal separation within the railway sector are relatively recent in many European countries, and, as a result, little analytical research has been carried out on their impact. The purpose of this working paper is to analyze the effects of these organizational reforms on efficiency, productivity and technical change in 16 national railway systems in Europe over the period 1985-2004. Results indicate that in general, the reforms appear to have been beneficial, although evidence of significantly higher efficiency levels and greater productivity growth is only found in countries that have completed both vertical and horizontal separation processes.

Key words

Railways, vertical and horizontal separation, productivity, efficiency.

Resumen

Los procesos de separación vertical y horizontal en el sector del transporte ferroviario son todavía relativamente recientes en muchos países europeos y, en consecuencia, los estudios sobre sus efectos son escasos. Este documento de trabajo pretende analizar los efectos de estas reformas organizativas en la eficiencia, la productividad y el cambio técnico en 16 sistemas nacionales ferroviarios europeos durante el período 1985-2004. Los resultados indican que, en general, las reformas habrían sido beneficiosas, aunque la evidencia respecto a una mejora significativa de los niveles de eficiencia y del crecimiento de la productividad sólo se obtiene para los países que han completado ambos procesos de separación: vertical y horizontal.

Palabras clave

Ferrocarril, separación vertical y horizontal, productividad, eficiencia.

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C O N T E N T S

1. Introduction

WITHIN the transport sector, the railway industry's entry into the reform and liberalization process that has spread across Europe since the 1990s has been tardier and more protracted than other industries. With the exception of the United Kingdom, European countries have opted to reform their railway industries slowly and gradually. The industry has been restructured on 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 infrastructure.

The main initiator of the vertical dimension was European Directive 91/440, which brought in separate accounting systems for railway infrastructure and operations. Since then, most countries moved firstly towards independent management, and in a second stage, towards complete vertical separation. Sweden was a pioneer in introducing this measure: in 1988 Sweden separated into two totally independent bodies the ownership and management of infrastructure (in the hands of a state agency, Banverket) and the ownership and management of operations. Specifically, up to 2004 (the year the present study ended), countries such as Italy, Ireland, Austria, Spain and Belgium still maintained their railway infrastructure and operations in a vertically integrated structure, although the infrastructure was by then managed independently.

In contrast, reforms to the horizontal dimension have been much scarcer. Leaving aside the thorough restructuring process in the case of the United Kingdom, the changes that have been introduced are very heterogeneous. The Netherlands, as well as separating the industry at a horizontal level, has introduced a tendering system for its regional passenger services, and a free entry system for the freight sector. Since 1996, Sweden has allowed new operators to enter the freight sector, a move that was extended to the passenger sector in 2000. Denmark and Norway separated their passenger and freight services in 2001 and 2002, respectively. All these countries had previously separated their industries vertically.

However, there are also two cases of railway industries with clearly different structures. Germany, without totally separating infrastructure from rail operations, reformed its services by introducing a franchising system in

the passenger service and allowing operators to enter the freight sector. Switzerland is another similar example where freight operators have entered the system, although the vertically integrated structure of the industry has been maintained.

There are many studies in the literature analyzing productivity and efficiency in the railway sector. However, most of the vertical, and particularly horizontal, separation processes have taken place in recent years, and, as a result, there is very little conclusive empirical evidence on the effects of these processes on productivity and efficiency. In general terms, the first studies in this field (see Gathon and Perelman, 1992; Oum and Yu, 1994; Gathon and Pestieau, 1995) indicated that the countries with the most liberalized railway sectors were the most efficient [1].

Likewise, more recent studies obtain results in a similar vein. Cantos, Pastor and Serrano (1999) also conclude that companies with a higher degree of autonomy and independence are the most efficient, are more technologically advanced and achieve higher gains in productivity. Similarly, Cantos and Maudos (2001) estimate efficiency in costs and revenue, and show that companies need to move towards more commercial policies that also encourage their competitiveness.

Friebel, Ivaldi and Vibes (2003) carried out an initial analysis of some of the restructuring measures in the sector for the period 1995-2000, focussing on measures designed to separate the industry vertically. Their results suggest that, in general, the reforms have furthered more efficient behavior; however, these reforms must be carried out sequentially if they are to be effective. In addition, Driessen, Lijesen and Mulder (2006) study the efficiency of a sample of European companies for the period 1990-2001. These authors do not come to a decisive conclusion on the impact of vertical separation of infrastructure and operations. They find that vertical separation does not seem to be necessary to achieve an increase in productive efficiency, although tendering processes do appear to favor an increase in efficiency. In all events, these authors recognize certain data definition problems, and particularly, acknowledge that many of the predicted effects may still not have been in evidence, since the sample period ended in 2001.

In this context, this study offers a contribution to the debate, in which, as we have seen, initial results are not altogether conclusive. The study is based on a sample of European countries with data for the extensive period

1. An excellent survey can be found in Oum, Waters and Yu (1999) covering many of the results obtained in the previous literature.

of 1985-2004, and uses non-parametric techniques (Data Envelopment Analysis [DEA] and the Malmquist index) to calculate technical efficiency indexes and productivity growth, while also disaggregating their various components. This latter aspect is important, as we aim to determine the impact of changes in the sector not only in efficiency, but also in the overall evolution of productivity and its components (technical change and changes in efficiency).

Our results suggest that the processes of vertical separation have had a positive effect on efficiency for the European railway systems. However, these gains in efficiency become much higher when horizontal separation processes have also been completed. Results also show that these separation processes also lead to gains in productivity, and once again, greater increases in levels of productivity are seen when horizontal separation reforms are introduced in railway operations. By contrast, no significant gains are observed in productivity or efficiency when only operations are reformed, but the vertically integrated structure of the industry is maintained.

The working paper is structured as follows. Section 2 briefly describes the evolution of the railway industry in Europe. Section 3 presents the methodology, and section 4 describes the data used in the study. Section 5 provides estimations of efficiency levels and productivity growth and its components. Section 6 provides, in a second stage, an econometric analysis of the effect of the separation processes on efficiency and productivity. Finally, section 7 presents the main conclusions of the study.

2. Evolution of the Railway Sector in Europe

THE main problem facing the European railway sector at the end of the 20th century, both in terms of passengers and freight, was the gradual steady loss of market share to other forms of transport, which led to high financial losses in the sector. Nash and Rivera-Trujillo (2004) provide a thorough description of these problems, and how policies at a European level have attempted to deal with the situation.

Given that the main reason behind the problems affecting the sector was lack of competition, European policies have favoured vertical separation of infrastructure and operations. Although it is accepted that infrastructure (characterised by its high levels of sunk costs) may be managed under monopoly conditions, competition can be introduced into operations in two different ways. The first option consists of directly facilitating the free entry of new companies into the railway network. The alternative is to foster competition for the market by means of a franchising or concessions system in which the franchised companies compete for the right to use the infrastructure during a certain period of time, which is in all cases notably shorter than the infrastructure concession period. This second option has proved to be very attractive in the European context, in which many railway services are heavily subsidised. Finally, the vertically separated structure may encourage private sector entry, thereby promoting a more competitive environment.

However, this new structure can also have serious drawbacks. As Nash and Rivera-Trujillo (2004) point out, the entry of various companies using the same infrastructure leads to obvious problems in a schedule design that must efficiently assign slots among companies and operations, and at the same time satisfy all of them. These problems significantly affect service quality, since coordination is lost as a result of the separate management of infrastructure and operations.

Furthermore, because each company controls certain routes, the risk remains that each one will operate as a monopoly on their own particular

lines. In addition, companies operate with significant economies of density, with the result that excessive fragmentation may lead to important inefficiencies (Cowie, 2002, detected this problem in the British case). Finally, incompatibilities in operating companies' fare policies may represent a problem for users who need to travel on various routes managed by different companies.

Positions supporting disparate opinions on the efficiency of separating infrastructure and operations are therefore not difficult to find. Evans (2003) states that the process leads to gains in efficiency, transparency and greater competition. Other authors (Pfund, 2003), however, believe the disadvantages clearly outweigh the benefits of separation. In the same vein, as noted above, the initial empirical studies to approach the subject (Friebel, Ivaldi and Vibes, 2003; Driessen, Lijesen and Mulder, 2006) provide no conclusive results.

Very little analysis has been conducted on the changes stemming from the horizontal restructuring of the industry, in part due to the recent implementation and limited scope of many of these measures. In particular, Driessen, Lijesen and Mulder (2006) find that processes of competition *for* the market (through concessions) encourage efficiency more than processes that foster competition *in* the market (through free entry), and that greater managerial independence does not encourage greater efficiency. These results contradict those from the previous literature (Gathon and Pestieau, 1995; Cantos, Pastor and Serrano, 1999; Friebel, Ivaldi and Vibes, 2003), evidencing the need for further analysis of all these measures.

3. Methodology

WE use the Malmquist productivity index (Malmquist, 1953) to measure productivity of railway companies. However, we do not focus solely on productivity, but also on the relation between efficiency and productivity, i.e., we define productivity growth as the change in output due to change in efficiency (catching-up effect) and technical change. In other words, our approach distinguishes between changes in how far an observation is from the frontier of technology, and the shifts in the production frontier, since the Malmquist-type index of total factor productivity is potentially very useful to calculate productivity growth in the presence of inefficiency. To calculate this index [2], we must describe the technology in period t that transforms production input levels. Hence:

$$F^t = \{(y^t, x^t): x^t \text{ can produce } y^t\} \qquad t = 1, \ldots T, \tag{3.1}$$

where $y^t = (y_1{}^t, \ldots, y_N{}^t) \in R_N{}^+$ is the output vector and $x^t = (x_1{}^t, \ldots, x_M{}^t) \in R_M{}^+$ the input vector corresponding to period t. Following Caves, Christensen and Diewert (1982), an alternative representation of technology can be given by the distance function:

$$D^t (x^t, y^t) = Sup \{\vartheta^{t,t} : (x^t / \vartheta^{t,t}, y^t) \in F^t\} = (Inf \{\vartheta^{t,t} : (x^t \vartheta^{t,t}, y^t) \in F^t\})^{-1}. \tag{3.2}$$

This function is defined as the maximum reduction necessary in the input vector for a company to obtain the same level of outputs, but now located on the frontier. In addition, the distance function must be defined in relation to technologies for different periods. Hence:

$$D^t (x^{t+1}, y^{t+1}) = Sup \{\vartheta^{t,t+1} : (x^{t+1} / \vartheta^{t,t+1}, y^{t+1}) \in F^t\}. \tag{3.3}$$

The distance function $D^t (x^{t+1}, y^{t+1})$ measures the maximum reduction in inputs so that, given the set of outputs, the observation from period

2. See Malmquist (1953). The calculation of this index is explained in greater detail in Cantos, Pastor and Serrano (1999).

$t+1$, (x^{t+1}, y^{t+1}) is feasible in period t. Similarly, it is possible to define the distance function of an observation in period t (x^t, y^t), to make it feasible in relation to a technology current in period $t+1$, $D^{t+1}(x^t, y^t)$.

On the basis of the above concepts, the Malmquist productivity index to analyze productive change between periods t and $t+1$, taking the technology of period t as our reference, is defined as:

$$M^t(y^{t+1}, x^{t+1}, y^t, x^t) = \frac{D^t(y^t, x^t)}{D^t(y^{t+1}, x^{t+1})} \cdot \tag{3.4}$$

If $M^t > 1$, it indicates that productivity for period $t+1$ is higher than for period t, since the reduction of the input vector of period $t+1$ to reach the frontier of period t is higher than that applicable to the inputs of period t. On the other hand, if $M^t < 1$, it indicates that productivity has declined between period t and $t+1$.

Only two periods are considered in all the above definitions. However, when we wish to analyze the productive change of a longer time series, the use of a fixed technology may cause problems the further we move away from the base year. In order to solve these problems researchers usually calculate indices based on pairs of consecutive years, taking as a base the technology of the two periods t and $t+1$ and calculating the geometric mean of the two indices. We use this approach and rewrite the expression to obtain the following expression that breaks down the Malmquist index into the catching-up effect to the frontier (efficiency change) and technical change (movement of the frontier) (see Caves, Christensen and Diewert, 1982):

$$M(y^{t+1}, x^{t+1}, y^t, x^t) = \underbrace{\frac{D^t(y^t, x^t)}{D^{t+1}(y^{t+1}, x^{t+1})}}_{\text{Catching-up effect}} \underbrace{\left[\left(\frac{D^{t+1}(y^{t+1}, x^{t+1})}{D^t(y^{t+1}, x^{t+1})}\right)\left(\frac{D^{t+1}(y^t, x^t)}{D^t(y^t, x^t)}\right)\right]^{1/2}}_{\text{Technical change}} \tag{3.5}$$

$$\underbrace{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}_{\text{Productivity change}}$$

The first component of expression (3.5) is the catching-up effect between periods t and $t+1$ and it will be greater than unity if there have been efficiency gains. Likewise, if the second component is greater than unity, it indicates that technical progress has occurred.

Finally, we use Data Envelopment Analysis (DEA) methodology to calculate the distance function. Specifically, we must estimate $D^t\,(x^t, y^t)$, $D^{t+1}\,(x^{t+1}, y^{t+1})$, $D^t\,(x^{t+1}, y^{t+1})$ and $D^{t+1}\,(x^t, y^t)$. We follow the standard procedure in non-parametric approach, in which it is assumed that for each period t, a set of K railway systems $(k = 1, ..., K)$ produces M outputs $(m = 1, ..., M)$ with an N input vector $(n = 1, ..., N)$ inputs (x_{nk}^t). The problem to be solved is therefore:

$$\begin{aligned} \left[D^t\,(x_j^t, y_j^t)\right]^{-1} &= Min\vartheta_j^{t,\,t}, \\ s.t. \sum_{k=1}^{K} \lambda_k^t y_{mk}^t &\geq y_{mj}^t \qquad m = 1,...,M, \\ \sum_{k=1}^{K} \lambda_k^t x_{nk}^t &\leq x_{nj}^t \vartheta_j^{t,\,t} \qquad n = 1,...,N, \\ \lambda_k^t &\geq 0, \qquad k = 1,...,K. \end{aligned} \tag{3.6}$$

The remaining distance functions are then solved in a similar way.

Once productivity gains and the various components of productivity have been calculated, the second stage then consists of testing whether vertical and/or horizontal separation have had a significant effect on gains in productivity and efficiency in railway systems.

4. Data and Variables

THE data correspond to a sample of sixteen European railway systems from 1985 to 2004. The information was taken from the reports published by the *Union Internationale des Chemis de Fer* and completed with data published in the companies' statistical memoranda. Specifically, the different railway systems established in each country are evaluated. Thus, in the first years of the sample, the systems were run by one single company with vertically integrated infrastructure and operations, and horizontally integrated operating services. Over the years, as many of the railway systems began to be separated both vertically and horizontally, different companies took over the management of the railway system. In this case, the data corresponding to all the companies making up the railway system are aggregated for each variable.

Two outputs and four inputs are considered. The variables selected as outputs are the number of passengers-km transported (PKT) for passenger transport, and tonnes-km transported (TOKT) for freight transport. In the case of input variables, the following are considered:

a) Number of employees in all the railway systems making up the railway system (EMP).
b) A representative measure of the passenger train supply calculated as the number of coaches, railcars and multiple-unit trailers available for passenger transport (PASMAT).
c) A representative measure of freight train supply calculated as the annual fleet wagons strength for freight transport (FREMAT).
d) Number of km of railway infrastructure in each country (LLT).

Table 4.1 summarises the information for each variable included in the analysis. Table 4.2 presents the information on the most relevant changes to occur in the various railway systems, described above in section 2, and which will be taken into account in the efficiency and productivity analysis. Regarding the degree of vertical separation between infrastructure and industry services three levels have been defined (from

TABLE 4.1: Values for the variables (1985-2004)
(average)

	PKT (millions)	TOKT (millions)	EMP	LLT (km)	PASMAT (thousands)	FREMAT (thousands)
Switzerland	11,629	8,467	33,456	2,983	4,044	23,578
Luxembourg	263	627	3,331	273	137	2,710
Ireland	1,314	540	9,890	1,936	358	1,816
Greece	1,755	1,484	11,938	2,440	708	42,861
Portugal	4,843	2,071	15,730	3,050	1,276	4,387
Germany	55,937	67,122	239,466	32,979	18,349	234,778
Denmark	4,982	1,828	16,925	2,314	1,578	3,758
Italy	45,,227	22,530	153,540	16,038	13,008	84,959
Netherlands	12,967	3,337	26,357	2,794	2,510	5,348
Norway	2,352	2,572	11,955	4,099	843	4,526
Austria	8,497	14,280	59,718	5,658	3,444	29,464
Spain	16,664	12,835	43,454	12,536	3,945	32,188
Sweden	6,061	16,785	23,650	10,342	1,579	22,318
Belgium	7,054	8,849	44,656	3,483	3,374	24,681
France	62,662	53,401	192,670	32,177	15,700	135,926
Finland	3,219	8,964	17,406	5,864	993	14,546

Note: Up until 2004 data was only gathered on West Germany. From then onwards data has been incorporated on the railway industry in unified Germany.
Source: Reports from Union Internationale des Chemins de fer (UIC) and companies' statistical memoranda.

a lower to a higher degree): accounting separation, organizational separation (advance in the separation without fostering complete independence), and institutional separation (which corresponds to totally independent ownership and the complete separation of infrastructure and services).

TABLE 4.2: Relevant changes in the structure of the sector

	Vertical dimension	Horizontal dimension
Switzerland (CFF)	Accounting separation	Entry FO (2000)
Luxembourg (CFL)	Accounting separation	None
Ireland (CIE)	Accounting separation	None
Greece (CH)	Accounting separation	None
Portugal (CP)	Institutional separation (1997)	None
Germany (DB)	Organizational separation	Entry FO and franchising process PO (1997)
Denmark (DSB)	Institutional separation (1997)	Horizontal separation (2001)
Italy (FS)	Accounting separation	None
Netherlands (NS)	Institutional separation (1998)	Entry FO (1998), Franch. process PO (1999)
Norway (NSB)	Institutional separation (1996)	Horizontal separation (2002)
Austria (OBB)	Accounting separation	None
Spain (RENFE)	Accounting separation	None
Sweden (SJ)	Institutional separation (1988)	Entry FO (1996), Entry PO (2000)
Belgium (SNCB)	Accounting separation	None
France (SNCF)	Institutional separation (1996)	None
Finland (VR)	Institutional separation (1996)	None

Source: "Railway time-series data 2004", Railway Technical Publications, Nash and Rivera-Trujillo (2004), Driessen, Lijesen and Mulder (2006) and IBM and Humboldt University of Berlin (2004).

Notes:

– FO denotes freight operations.

– PO passenger operations.

– Between brackets we denote the year where the reforms were introduced.

5. Results

BELOW, we detail the indicators obtained from our study. Firstly, we present the efficiency indicators, followed by the Malmquist index and its components (technical change and change in efficiency).

Table 5.1 summarises the average efficiency indicators obtained for the various sub-periods in the whole sample for each country. The last four rows include the results for four different country groups: 1) countries that have only introduced vertical reforms (France, Finland and Portugal); 2) those that have introduced both vertical and horizontal reforms (Netherlands, Sweden, Norway and Denmark); 3) countries with only horizontal

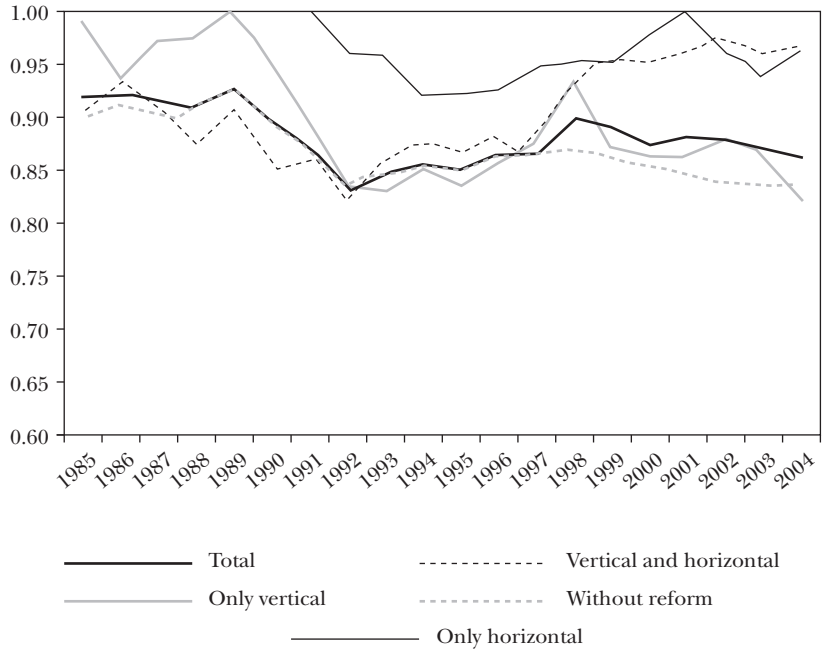
TABLE 5.1: Technical efficiency
(averages)

	1985-1990	1990-1995	1995-2000	2000-2004	1985-2004
Switzerland	1.000	1.000	1.000	1.000	**1.000**
Luxembourg	1.000	0.983	0.885	0.751	**0.908**
Ireland	0.784	0.733	0.731	0.630	**0.723**
Greece	0.586	0.446	0.519	0.585	**0.532**
Portugal	0.990	0.814	0.728	0.647	**0.800**
Germany	1.000	0.920	0.889	0.935	**0.937**
Denmark	0.779	0.721	0.742	0.840	**0.772**
Italy	0.803	0.816	0.830	0.868	**0.829**
Netherlands	1.000	1.000	1.000	1.000	**1.000**
Norway	0.810	0.695	0.880	0.998	**0.844**
Austria	0.996	0.986	1.000	1.000	**0.995**
Spain	0.969	0.825	0.945	1.000	**0.934**
Sweden	1.000	1.000	1.000	1.000	**1.000**
Belgium	1.000	0.999	0.898	0.762	**0.926**
France	0.994	0.887	0.948	0.927	**0.945**
Finland	0.925	0.899	0.940	1.000	**0.939**
Total	**0.915**	**0.858**	**0.871**	**0.872**	**0.880**
Without reform	**0.904**	**0.856**	**0.855**	**0.837**	**0.865**
Only vertical	**0.970**	**0.867**	**0.872**	**0.858**	**0.895**
Vertical and horizontal	**0.897**	**0.854**	**0.905**	**0.960**	**0.904**
Only horizontal	**1.000**	**0.960**	**0.945**	**0.968**	**0.968**

reforms (Germany and Switzerland); and finally, 4) the remaining countries (those that have not introduced significant reforms, Ireland, Greece, Luxembourg, Italy, Spain, Austria and Belgium). In any case, given the low number of countries in the different groups analyzed, the results should be intepreted with caution, such as a first approximation in the analysis of the impact on productivity and the components in the changes which have taken place in the European railway structure.

Likewise, graphic 5.1 represents the evolution of the efficiency levels for each of the country groups defined above. Some interesting conclusions can be drawn from the information provided in table 5.1 and graphic 5.1. Firstly, in general terms, levels of efficiency in railway systems are clearly seen to deteriorate between 1988 and 1992, while from 1993 to 1998 they were relatively stable and similar across all countries. From 1998 onwards, a marked divergence occurs in the evolution of railway system efficiency. It should be noted that by this year, the vertical separation process had been completed in in many of the sample countries, and from this moment onwards, horizontal separation processes began to be developed in some of them (i.e., Netherlands, Sweden, Norway and Denmark). We can conclude that the greatest improvements in efficiency levels occur in these countries, i.e., those that have restructured their rail networks both vertically and

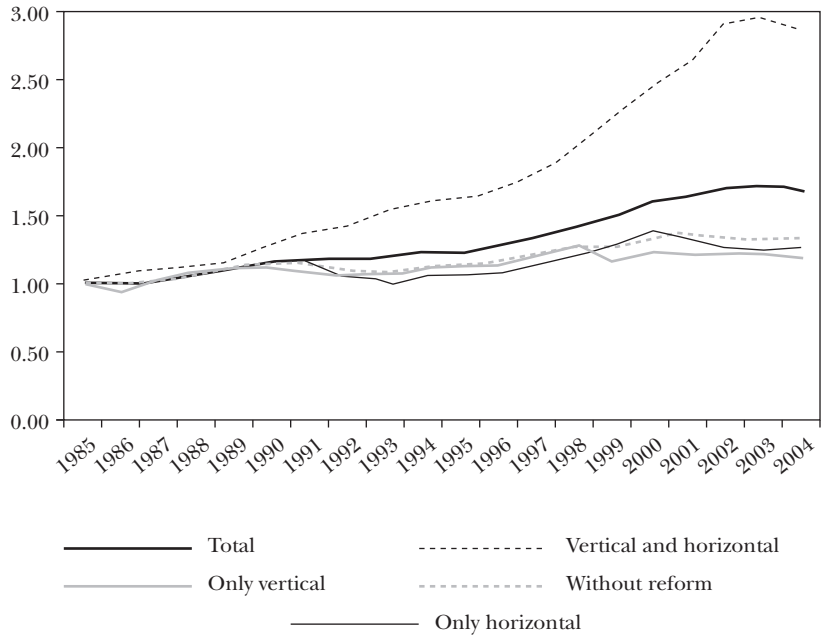
GRAPHIC 5.1: Technical efficiency (1985-2004)



horizontally. Similarly, countries that did not separate their industries vertically during the sample period emerge as the most inefficient, although the improved efficiency in countries that only restructured vertically are very modest compared to those that have also embarked on horizontal separation. Finally, the high efficiency level of the countries that only reform horizontally (Switzerland and Germany) is obtained because Switzerland is efficient during the whole sample period.

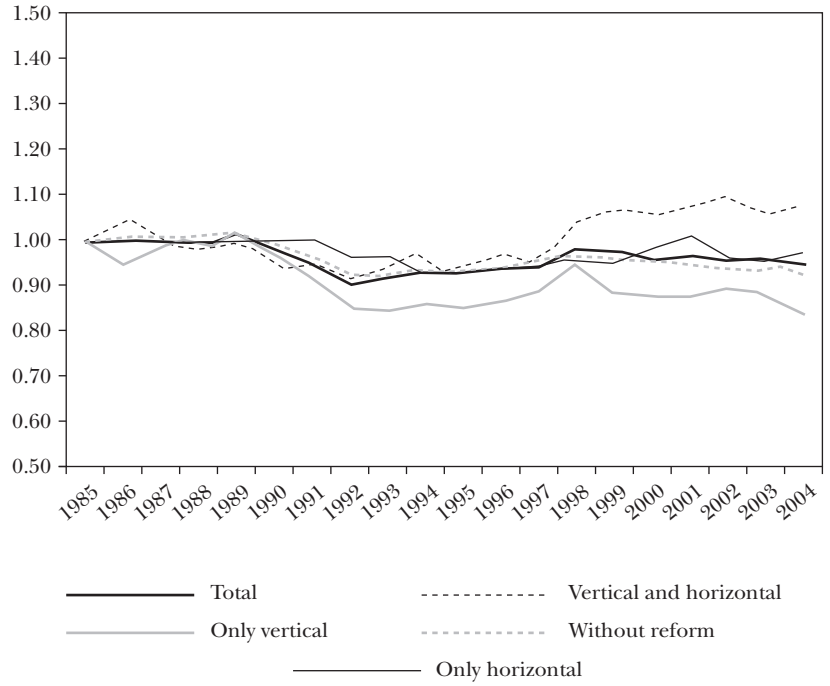
The results for the productivity index are presented in table A.1 of the appendix and show the average annual growth rates for the same subperiods as table 5.1, as well as the average for the whole period. Likewise, graphic 5.2 shows the accumulated productivity gains to facilitate interpretation of the results. Once again, the countries that have vertically and horizontally reformed their railway systems emerge as those with the greatest improvements in their productivity indices. In addition, we find that the pace of productivity growth begins to accelerate from 1995 onwards (the year in which most vertical separation processes began), particularly in countries that also introduced horizontal reforms in the industry. The rest of the railways systems have a very similar evolution in the productivity growth.

GRAPHIC 5.2: Productivity change (1985-2004)

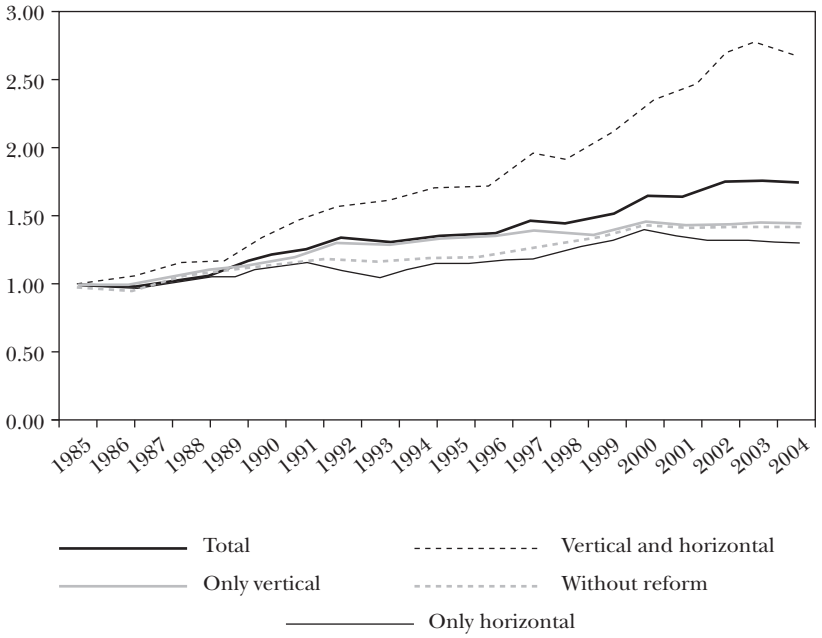


In section 3, we demonstrated how the Malmquist index enables productivity gains to be broken down into efficiency change and technical change. Tables A.2 and A.3 in the appendix present these results, while graphics 5.3a and 5.3b show the accumulated evolution of these components.

GRAPHIC 5.3a: Efficiency change (1985-2004)



GRAPHIC 5.3b: Technical change (1985-2004)



The evolution of technical change is very similar to that of productivity growth, thus demonstrating that countries which have taken their reform processes further (both vertically and horizontally) have greater technical progress and productivity growth. Similarly, technical progress emerges as the main source of growth in productivity.

Furthermore, during the whole sample period, efficiency only increased in countries that have totally reformed (vertically and horizontally) their respective railway systems. In the remaining countries, efficiency was even observed to fall over this period.

6. Analysis of the Second Stage

IN this section, we analyze the determining factors of the various indicators calculated above, and complement the descriptive analysis presented in the previous section. Our main objective is to test whether the vertical or horizontal separation processes have encouraged more efficient or productive behavior in railway systems.

The analysis of the second stage requires to define different dummy variables associated to the processes of vertical and horizontal separation, and that reflect the organizational and regulatory changes occurring in each railway system. To this end, three dummy variables were defined that describe two distinct levels in the reform process carried out in the sector. Information from the "Railway time-series data" for 2004 published by the Union Internationale des Chemins de fer (UIC) and from other relevant sources (Nash and Rivera-Trujillo [2004]; Driessen, Lijesen and Mulder [2006]; International Business Machines [IBM] and Humboldt University of Berlin [2004]) was consulted in order to reflect these changes. We distinguished the following levels of reform for the period 1985-2004:

— VERT: takes a value of 1 for countries that, during the years in which this situation was maintained, only separated at an organic level the ownership of infrastructure from that of operations, but did not introduce reforms in the industry's horizontal structure. The sector is thus characterised by its vertical separation into two different bodies: one being the owner of the infrastructures and the second consisting of all operations. This type of separation is defined as institutional separation.
— VERT + HORIZ: in addition to organically separating infrastructure from operations, some countries also introduced reforms in the downstream level. This variable includes the reforms that separated operations horizontally, or modified them by introducing a franchising scheme (introducing a system of competition *for* the market) or a free entry system (competition *in* the market). This

variable is independent of whether the companies are publicly or privately owned, and of their results (final number of train operating companies). Therefore, the variable only reflects the moment in which the reform process began in the sector at a horizontal level, regardless of the type and scope of the reform chosen. We opted to aggregate all this information in one variable since we do not have accurate information on the efficiency and relevance of the reforms carried out in each country, and consequently we preferred not to differentiate the types of reform brought in at a horizontal level. In summary, the variable takes a value of 1 for countries in the years in which both vertical and horizontal level reforms took place simultaneously.

— HORIZ: this variable reflects the countries that maintained a vertically integrated industry, but have introduced some kind of reform at the downstream level. This is the case of Germany, where, although some advances have been made towards vertical separation, no total separation has taken place in which infrastructure is completely divorced from operations to form two totally different bodies. However, reforms at the downstream level have taken place, with the entry of freight operators (from 1996 onwards) and the introduction of a franchising system for passenger services (from 1997 onwards) (see Lalive and Schmutzler, 2007). Switzerland also has a similar structure; the sector remains vertically integrated, although it was opened up to new freight operators in 2000. Thus, the variable takes a value of 1 after the year in which horizontal reforms were introduced in the sector in these two countries.

These control variables allow us to more accurately determine and isolate the extent to which regulatory changes affect levels of productivity and its components. The variables are as follows:

— %PAS: percentage of passenger trains-km of the total trains-km (both passenger and freight).
— DENS: quotient of the total number of trains-km and the number of km of track.
— OCPAS: average passenger occupation per train unit.
— OCFRE: average freight occupation per train unit.

Individual and temporal dummies were also included in all estimations, as well as the variable indicating the size of the network (LLT). The

first equation estimated was that explaining the determinants of the efficiency level. The dependent variable was defined as the logarithm of the inverse of efficiency. For this reason the efficiency indicator is a truncated variable and following habitual practice we have estimated a Tobit model. The results are given in table 6.1.

TABLE 6.1: Determinants of efficiency levels

	Parameter	T statistic
VERT	–0.0662	–1.976
HORIZ	0.1000	1.484
VERT + HORIZ	–0.2768	–4.163
LLT	–0.1835	–1.187
% PAS	–0.2717	–1.833
DENS	–0.3513	–2.882
OCPAS	–0.3998	–4.530
OCFRE	–0.1378	–3.000
Log likelihood	87.64	
Observ.	318	

It should be noted that, as the dependent variable was defined as the logarithm of the inverse of efficiency, a negative sign of the estimator indicates a movement towards the production frontier and therefore more efficiency. We may thus conclude that vertically separated railway systems improved their efficiency. Moreover, in railway systems that in addition to separating the sector vertically also reformed the industry horizontally, improvements are more substantial, with these railway systems achieving significantly higher efficiency levels. Specifically, the size of the coefficient associated with both vertical and horizontal reform is approximately four times that associated with vertical reform. This result may be interpreted to mean that, in conjunction with vertical separation, only when the horizontal structure of the industry is modified and systems of competition *in* or *for* the operations market are introduced (described in Section 2) will the higher competitive pressure in the sector also lead to more efficient behavior by operators [3]. Likewise, horizontal separation on its own would not have gener-

3. If we compare these results with the graphic 5.1, where the efficiency of countries with only vertical separation fell from 1998, we can conclude that vertical separation provoked higher increases in efficiency in countries which completed their restructuring process with horizontal reforms. It explains the statistical significance of variable VERT.

ated appreciable improvements, although it must be remembered that this is only the case of two railway systems, and it is therefore imprudent to conclude that this type of reform is ineffectual since the result is dominated by the very recent German experience. Finally, as expected, railway systems with greater traffic densities and higher average occupations are the most efficient.

Table 6.2 shows the analysis of the determinants of accumulated productivity growth, obtained by means of the Malmquist index, i.e, the contributions of technical change and gains in efficiency (catching-up). In addition to the variables shown in the table, dummy variables for year and country are also included. The estimation in this case was made by means of ordinary least squares. Estimations 3.1 and 3.2 differ in that the latter also includes individual trends to capture the effect of country-specific factors that may affect its higher or lower growth, regardless of whether it carried out reforms or not. This second estimation seeks to avoid the risk of attributing positive effects to reforms, simply because the *best* railway systems, even without any reform, were those that have carried out more reforms than the rest.

The results from model 1 indicate that the railway systems with a vertically separated sector, as well as a horizontally separated industry (the Netherlands, Norway, Denmark and Sweden) achieved significant improvements in productivity, technical and efficiency change from the moment they implemented the first vertical reforms. Where only vertical separation was undertaken, the effects are also positive, although less so, and in the case of efficiency gains, the effect is not statistically significant. In the case of technical change and efficiency gains, no significant effects are appreciated when horizontal separation is introduced in isolation, without vertical separation. The effect on productivity would be slightly negative, although again, it should be kept in mind that in this case, it is very difficult to distinguish between effects that are inseparable from the reform and the specific experience of Germany and Switzerland from 1997 onwards [4].

As indicated above, there is a risk that positive effects associated with other company-specific aspects may be attributed to the reforms. This would be the case if the railway systems that performed better for other reasons

4. In addition to the specific case of Germany, which as mentioned earlier is due to its reunification, Switzerland is also a specific case because there are numerous, very small railways which are vertically integrated.

(and that foreseeably would still have been the best performers even without reforms) were those that were subjected to reform processes or to more intense, thorough reforms.

Model (2) of table 6.2 includes individual trends per country in order to control for those aspects that differentiate railway systems by affecting their productivity growth and which are unrelated to the reforms. As can be seen, the qualitative results hold. Again, railway systems that have separated the sector vertically and the industry horizontally (both reforms) would consequently have obtained significant improvements in the pace of technical change and efficiency improvements, as well as in productivity growth. In

TABLE 6.2: Determinants of productivity, technical and efficiency change

	Model (1)			Model (2)		
	Productivity growth	**Technical change**	**Efficiency change**	**Productivity growth**	**Technical change**	**Efficiency change**
VERT	0.120	0.088	0.032	0.058	0.030	0.028
	(3.89)	(3.67)	(1.51)	(2.74)	(1.68)	(1.27)
HORIZ	–0.071	–0.046	–0.025	–0.034	0.002	–0.037
	(–1.69)	(–2.08)	(–0.74)	(–1.09)	(0.08)	(–1.55)
VERT + HOR	0.535	0.403	0.132	0.194	0.083	0.110
	(9.79)	(12.64)	(3.35)	(5.24)	(2.74)	(2.84)
LLT	–0.150	–0.264	0.114	–0.109	–0.161	0.051
	(–1.17)	(–3.31)	(1.23)	(–1.03)	(–1.90)	(0.57)
% PAS	0.134	–0.145	0.279	0.221	–0.186	0.407
	(0.83)	(–1.64)	(2.54)	(2.10)	(–3.00)	(3.69)
DENS	0.287	–0.085	0.372	0.318	–0.220	0.539
	(2.44)	(–1.10)	(4.71)	(3.91)	(–4.44)	(6.73)
OCPAS	0.372	0.057	0.315	0.324	–0.047	0.371
	(4.21)	(1.05)	(4.50)	(4.27)	(–1.14)	(5.38)
OCFRE	0.171	0.076	0.094	0.159	0.032	0.126
	(3.32)	(2.31)	(2.26)	(4.35)	(1.72)	(3.47)
R^2	0.815	0.903	0.801	0.958	0.977	0.899
Observ.	318	318	318	318	318	318

the case of only vertical separation, productivity would be positively affected, although to a lesser extent, while efficiency gains and technical change would not be statistically significant. In the case of only horizontal separation, subject to the particular circumstances outlined above, in no case are the effects significant.

It can be seen that the extent of the effects of the reforms is substantially lower than in estimation (3.1). The effect of reforms on productivity would be less than half that of the initial estimation. The parameter estimated for the effect of vertical reform on productivity drops from 0.120 to 0.058, and the effect of carrying out both vertical and horizontal reforms falls from 0.535 to 0.194. The estimated extent of the effects on technical change and efficiency gains is similar. A sharper reduction is seen in technical change (the VERT coefficient drops from 0.088 to 0.030 and the VERT + HORIZ from 0.403 to 0.083). In the case of efficiency gains, the decrease is more moderate (the VERT coefficient drops from 0.032 to 0.028 and the VERT + HORIZ from 0.132 to 0.110).

All these results appear to suggest that the reform and deregulation processes eventually have positive effects on the sector. However, these effects do not seem to be immediate and appear to require both a maturation period and the implementation of a complete programme of reforms [5]. Hence, the full potential of the positive effects of vertical separation will only be felt when they are applied in conjunction with the horizontal separation of the industry. In fact, the results appear to suggest that in countries where horizontal reform does not seem to be contemplated in the short term, and as a consequence, where the threat of future competition has been less credible, vertical separation has had a weaker effect. By contrast, in countries with a deeper commitment to the processes of reform, and which include a second phase to horizontally separate the industry, vertical separation has already had positive results. Moreover, these positive results have doubtlessly spurred the move towards the next reform stage, thus obtaining additional improvements.

5. These results coincide with those obtained by Friebel, Ivaldi and Vibes (2003).

7. Conclusions

THE present study used non-parametric mathematical programming techniques to estimate levels of efficiency in a sample of European railway systems for the period 1985-2004. Productivity growth indexes and the components of productivity (technical change and change in efficiency) were also calculated. Results show that the countries with the greatest improvements in efficiency are those that have restructured their networks both vertically and horizontally. The analysis of the determinants of efficiency also shows that both processes of vertical and horizontal separation have positive effects on efficiency in railway systems, with a greater impact stemming from horizontal separation. In contrast, no significant changes in efficiency and productivity levels are observed in countries where the industry has only been reformed at a horizontal level, and vertical separation has not subsequently been introduced at an institutional level. However, since this is the experience of only two railway systems, we must be careful to conclude that this type of reform is ineffective since the result is dominated by the German experience.

Secondly, an analysis of the determinants was carried out for each one of the estimated indicators. Once again, results suggest that both vertical and horizontal reforms in the sector encourage greater productivity, with a combination of both horizontal and vertical reform having the greatest impact on productivity. Likewise, we attempted to capture the effects of country-specific factors that may affect higher or lower growth in the railway system, regardless of whether or not it carried out reforms, by introducing a trend per country. When this effect was considered, the impacts of the reforms fell notably, although they remained significant. Finally, it should be mentioned that advances in productivity are essentially due to technical change.

On the other hand, since efficiency and productivity levels in countries that only introduced vertical reform are very similar to countries that have introduced no reforms, results suggest that the full potential of the positive effects of vertical separation will only be felt when they are applied in conjunction with horizontal separation of the industry. Hence, in countries that have not considered a total reform, which would encourage competi-

tion in the operations market, and where the threat of future competition is consequently less credible, vertical separation has had hardly any effect on efficiency and productivity. Our study therefore suggests that vertical separation is beneficial in as far as it prepares the industry for a horizontal reform that effectively leads to greater competition and fosters more efficient and productive behaviors on the part of railway systems.

In all events, although our research has updated all the available information, most reforms, particularly horizontal separation reforms, are relatively recent. It is therefore to be expected that the present paper will only reflect the initial partial effects brought about by these measures. These initial effects appear to be beneficial, although whether or not they are consolidated in the future requires further investigation. Future research should test the efficiency of the various horizontal level measures, distinguishing between measures that encourage competition *for* the market and those that encourage competition *in* the market.

Appendix

TABLE A.1: Productivity growth
(percentages and averages)

	1985-1990	1990-1995	1995-2000	2000-2004	1985-2004
Switzerland	3.524	1.158	5.427	–3.265	1.924
Luxembourg	2.434	–5.047	3.562	–4.494	–0.774
Ireland	3.289	–0.102	–3.555	–1.695	–0.487
Greece	–0.740	–3.217	13.677	–4.554	1.345
Portugal	0.903	2.126	–0.872	3.537	1.300
Germany	0.628	–3.458	4.761	–0.384	0.382
Denmark	6.679	2.191	13.750	2.177	6.306
Italy	3.851	2.730	0.253	3.367	2.498
Netherlands	5.509	3.881	8.892	3.338	5.492
Norway	1.881	9.599	8.264	6.089	6.435
Austria	1.880	0.888	3.859	4.509	2.683
Spain	2.222	3.286	6.613	1.788	3.549
Sweden	5.345	4.038	3.695	2.688	4.003
Belgium	2.483	–0.051	–2.039	3.482	0.814
France	0.822	–1.873	5.724	–7.493	–0.456
Finland	3.399	0.394	1.810	1.125	1.705
Total	2.828	1.388	5.227	1.368	2.761
Without reform	2.211	–0.176	3.655	0.051	1.496
Only vertical	1.737	0.277	2.125	–0.748	0.925
Vertical and horizontal	4.914	4.837	8.835	3.624	5.636
Only horizontal	2.117	–0.880	5.158	–2.083	1.206

TABLE A.2: Efficiency change
(percentages and averages)

	1985-1990	1990-1995	1995-2000	2000-2004	1985-2004
Switzerland	0.000	0.000	0.000	0.000	0.000
Luxembourg	0.000	–2.154	0.113	–8.059	–2.285
Ireland	1.489	–1.712	–4.486	–2.362	–1.761
Greece	–2.577	–5.925	10.764	–3.516	–0.357
Portugal	–1.172	–2.389	–5.050	2.829	–1.708
Germany	0.000	–3.333	2.447	–0.738	–0.411
Denmark	0.023	–2.440	3.930	1.726	0.733
Italy	1.312	1.661	–2.653	4.996	1.101
Netherlands	0.000	0.000	0.000	0.000	0.000
Norway	–5.696	3.428	4.920	0.240	0.660
Austria	–0.094	0.094	0.000	0.000	0.000
Spain	–1.808	–0.818	3.012	0.000	0.085
Sweden	0.000	0.000	0.000	0.000	0.000
Belgium	0.000	–0.160	–7.074	4.822	–0.977
France	–0.744	–3.384	3.130	–5.958	–1.572
Finland	–0.457	–1.733	3.020	0.000	0.202
Total	–0.556	–1.115	0.734	–0.302	–0.312
Without reform	–0.157	–1.210	0.077	–0.418	–0.429
Only vertical	–0.789	–2.490	0.683	–1.259	–0.955
Vertical and horizontal	–1.298	0.110	2.174	0.513	0.359
Only horizontal	0.000	–1.610	1.150	–0.358	–0.202

TABLE A.3: Technical change
(percentages and averages)

	1985-1990	1990-1995	1995-2000	2000-2004	1985-2004
Switzerland	3.524	1.158	5.427	–3.265	1.924
Luxembourg	2.434	–2.957	3.445	3.877	1.547
Ireland	1.773	1.638	0.974	0.684	1.297
Greece	1.886	2.878	2.630	–1.076	1.708
Portugal	2.100	4.625	4.401	0.689	3.061
Germany	0.628	–0.130	2.259	0.357	0.797
Denmark	6.654	4.747	9.449	0.443	5.532
Italy	2.506	1.052	2.985	–1.552	1.381
Netherlands	5.509	3.881	8.892	3.338	5.492
Norway	8.035	5.967	3.187	5.835	5.737
Austria	1.976	0.793	3.859	4.509	2.683
Spain	4.104	4.137	3.495	1.788	3.461
Sweden	5.345	4.038	3.695	2.688	4.003
Belgium	2.483	0.110	5.419	–1.278	1.808
France	1.578	1.564	2.516	–1.633	1.134
Finland	3.875	2.165	–1.174	1.125	1.500
Total	3.478	2.477	4.169	1.325	2.938
Without reform	2.386	1.068	3.440	0.422	1.896
Only vertical	2.537	2.810	2.024	0.126	1.961
Vertical and horizontal	6.408	4.713	6.361	3.032	5.230
Only horizontal	2.117	0.568	4.053	–1.727	1.389

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