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The impact of competition on productive efficiency in European railways

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Abstract in English

This paper empirically explores the relationship between competition design and productive efficiency in the railway industry. We use Data Envelopment Analysis (DEA) to construct efficiency scores, and explain these scores, using variables reflecting institutional factors and competition design. Our results suggest that competitive tendering improves productive efficiency, which is in line with economic intuition as well as with expectations on the design of competition. We also find that free entry lowers productive efficiency. A possible explanation for this result is that free entry may disable railway operators to reap economies of density. Our final result is that more autonomy of management lowers productive efficiency. Most of the incumbent railway companies are state owned and do not face any competitive pressure. As a consequence, increased independence without sufficient competition and adequate regulation may deteriorate incentives for productive efficiency.

Key words: Rail transport, Efficiency, competition design

JEL code: D24, H42, L22, L25, L33, L92

Abstract in Dutch

In deze studie maken we een empirische analyse van de relatie tussen institutionele vormgeving en productieve efficiëntie bij de spoorwegen. We gebruiken Data Envelopment Analysis (DEA) om efficiëntiescores te bepalen, en verklaren die scores vervolgens uit variabelen die de institutionele vormgeving weergeven. Uit onze analyse komt naar voren dat concurrentie om het spoor, door aanbesteding, leidt tot een hoger efficiëntieniveau. Concurrentie op het spoor, door de toegang vrij te geven, leidt daarentegen tot een afname van de efficiëntie. Een mogelijke reden hiervoor is dat vrije toegang ten koste van economies of density gaat. Tot slot concluderen we dat meer autonomie voor het management van spoorondernemingen ten koste gaat van de efficiëntie. Spoorwegondernemingen zijn veelal staatsbedrijven die niet hoeven te concurreren. Autonomie voor het management zonder concurrentie of effectieve regulering kan ten kosten gaan van de prikkels om efficiënt te werken.

Steekwoorden: spoorwegen, efficiëntie, institutionele vormgeving

Een uitgebreide Nederlandse samenvatting is beschikbaar via www.cpb.nl.

Contents

Summary

Railways in Europe are in the process of restructuring, involving an increase of competition between operators, which is thought to bring about a higher level of productive efficiency. The design of competition may influence the relationship between competition and efficiency. This paper empirically explores the relationship between competition design and productive efficiency in the railway industry. We use Data Envelopment Analysis (DEA) to construct efficiency scores, and explain these scores, using variables reflecting institutional factors and competition design. We choose DEA for our analysis because this technique can take into account multiple inputs and outputs, without having to rely on consistent accounting data.

In the beginning of the nineties, Belgium, The Netherlands, Japan, and Sweden had railway systems that were considerably more efficient than the systems of the other countries in the analysis. By the end of the 1990s, railway systems have grown towards each other, and the countries in our analysis form a relatively homogenous group in terms of relative productive efficiency.

Japan has a special position within the countries in our sample. Not only is it the only country outside Europe in our analysis, it is also a country with a very efficient rail system. This brings about a big drop in relative efficiency levels for countries that are comparable to Japan in terms of size. A drawback of the use of a non-parametric method like DEA is that we can use neither parameters nor test statistics to assess the reason behind Japan's high efficiency score. As there is no clear theoretical argument to either include or exclude Japan, we further investigate the sensitivity of the results to the inclusion of Japan.

We analyse the relationship between our DEA-based efficiency scores and the design of competition using a limited dependent variable model. Our results suggest that competitive tendering improves productive efficiency, which is in line with economic intuition as well as with expectations on the design of competition. We also find that free entry lowers productive efficiency. A possible explanation for this result is that free entry may disable railway operators to reap economies of density. Our final result is that more autonomy of management lowers productive efficiency. Most of the incumbent railway companies are state owned and do not face any competitive pressure. As a consequence, increased independence without sufficient competition and adequate regulation may deteriorate incentives for productive efficiency.

1 Introduction

Like many network industries, railways in Europe are in the process of restructuring, involving an increase of competition between operators. Rivalry between suppliers is supposed to reduce prices to marginal costs (allocative efficiency), reduce marginal costs to the lowest achievable level (productive efficiency) and encourage innovation to reduce future costs as well as to improve quality and variety of products (dynamic efficiency). In practice, the relationship between competition and efficiency is not always straightforward.

Competition design may well influence the relationship between competition and efficiency, especially but not exclusively in the case of network industries. The design of competition is not straightforward in the case of railways. Issues that are subject to debate include forms of competition (e.g. for the market vs. in the market), vertical organisation (e.g. separation vs. integration) and the role of government (such as ownership and public service contracts).

Empirical evidence on the impact of competition on productive efficiency in railways is not overwhelming. Although many studies on efficiency measurement have been conducted, only a few link the results to changes in competitive environment. Oum and Yu (1994) find that railway systems highly dependent on public subsidies are significantly less efficient and that systems with high degree of managerial autonomy achieve higher levels of efficiency. Gathon et al. (1995) discover that in the pre-liberalisation period (1961- 1988), technical efficiency of European railways was negatively related to the degree of government influence. Friebel et al. (2003) conclude that sequential reforms have efficiency improving effects, whereas reforms introduced in a package have neutral effects at best.

This paper adds to the literature by exploring the empirical relationship between competition design and productive efficiency. To do so, we construct efficiency scores using Data Envelopment Analysis (DEA), and regress these scores against variables reflecting institutional factors and competition design.

The remainder of this paper is organised as follows. Section 2 discusses the existing literature on efficiency in railway operations, followed by a brief discussion on efficiency measurement methods. We discuss the data used in section 4. Sections 5 and 6 contain the empirical analysis of this paper and section 7 concludes.

2 Competition and productive efficiency in railways

Jovanovic (1982) shows, both theoretically and empirically, that efficient firms grow and survive, while inefficient firms decline and fail. So, competitive selection improves efficiency by selecting those firms with low marginal costs that maximise total surplus. Empirical work by Olley and Pakes (1996) gives strong support to the selection effect of efficiency. Using sophisticated econometric techniques to analyse the telecommunication industry in the US during the period 1963-97, the authors find that the selective process of entry and exit is the major driver behind this result. More recent literature confirms the intuition that exit and entry play a role in increasing efficiency (Disney et al., 2000).

Because of the structural peculiarities of the railway industry, competition within this industry may differ from many other industries. The high level of economies of density make it uneconomical to double networks in most countries, indicating that these networks may be natural monopolies. In some countries, in particular at the American continent, infrastructure competition exists between parallel tracks (e.g. Canada) as well as tracks having different destinations or different origins (e.g. Mexico).

Downstream competition can be organised in two ways. Operators may compete for passengers on the same lines (known as competition on the tracks) or operators may compete for temporal regional monopolies through tendering procedures (known as competition for the tracks). Competition on the tracks - is economically possible “where the size of the market is large in comparison to the minimum efficient scale of operation” (UN, 2003). In other words, economies of density may stand in the way of efficient competition on the tracks. In Europe, this form mainly exists in freight transport but hardly in passenger transport. Where competition has been introduced in passenger transport in Europe, this is mainly done by competition for the tracks by tendering procedures for franchises.

The Australian Productivity Commission (1999) finds a positive effect of free entry in Australian railways on productive efficiency, although they warn that this result is somewhat speculative due to the complex nature of structural reforms. Friebel et al. (2003) find that reforms, in particular introduction of free entry, have a positive effect on railroad efficiency but that the impact of reforms depends on the sequencing: “the introduction of multiple reforms in a package has at best neutral effects, but sequential reforms improve efficiency.” Asensio et al. (2005) conclude that the degree of intermodal competition negatively affected productive efficiency of railways in a number of Spanish cities.

Oum and Yu (1994) perform a comparative efficiency study of the OECD countries’ railways. Like the last two studies, this study predates the reforms in Europe. Their data deals with the period 1978-89. The aim of this study is to identify the implications of public subsidy and the degree of managerial autonomy in technical performance. The authors estimate technical efficiency by using a DEA model, assuming constant returns to scale. Two alternative output measures are used: 1) revenue-output measures (passenger-/ton-km) and 2) available output measures (passenger/freight train-km). They estimate the effects of policy and other variables beyond the control of management, using a Tobit regression model. The main (new) finding of this paper was that railway systems with high dependence on public subsidies are significantly less efficient than similar railways with less dependence on public funds.[1]

Gathon and Perelman (1992) find a high correlation between individual technical efficiency and autonomy, defined by an indicator representing managerial freedom with respect to authorities. Gathon and Pestieau (1995) also find that managerial autonomy is an important determinant of the government-owned railway's performance.

Cowie and Riddington (1996) examine methods of assessing rail efficiency. The authors note that as there is effectively no international trading and no common accounting practise, comparative international efficiency is best based on physical measures rather than value measures.[2] Cowie and Riddington, commenting on the studies previously mentioned, argue that there are clear reasons why the Dutch railways are more efficient than the Austrian railways (with a very low efficiency). They claim that this result follows from the high utilisation of the infrastructure in the Netherlands (i.e., economies of density). Interestingly, Gathon and Perelman (1992) find diseconomies of density in the use of trains.

A paper by Cantos, Pastor and Serrano (1999) investigates the importance of output specification. Their results show that alternative output specifications lead to different results. Nonetheless, these differences can be brought substantially closer when output variables are corrected to account for the impact of the load factor.

Cantos and Maudos (2001) estimate both cost and revenue frontier functions. In so doing, the authors are able to calculate the losses associated with both cost and revenue inefficiencies. Their empirical analysis shows the existence of significant potential losses of revenue. They argue that it is time for a re-orientation from cost efficiency and productivity towards a policy focus on revenue. Policies such as concessions/franchises are regarded as positive, since they are compatible with the recommendations above.

[1] Following Nash and Rivera-Trujillo (2004), a word of caution is in order. It could be that the direction of causality is the other way around. That is, inefficient railways require high subsidies to survive, whilst high costs and low productivity might be the result of public service obligations to provide services such as peak commuter services which are costly but socially desirable.

[2] As most European railways are not free to operate on purely commercial terms, the output measure should therefore not only reflect the physical nature of output, but also the public service obligations and the product they are actually selling (e.g., quality of service).

A recent study by Lan and Lin (2004) focuses on the non-storable nature of railway services, distinguishing between technical efficiency (a transform of outputs (seat kilometres) from inputs) and technical effectiveness (a transform of consumption (passenger kilometres) from inputs). Railway services' productive efficiency can be higher than its effectiveness (in terms of sales), because, once produced, outputs cannot be stockpiled for future sales. The authors find that the major decline of the rail industry should not be attributed to rail's poor performance in technical efficiency or service effectiveness; rather it is the consequence of higher level-of-service of other modes. In fact, their results indicate that the rail industry has a positive progress in recent years (1995-2001).

Rivera-Trujillo (2004) concentrates on freight transport during the period 1980-1999, which is the most important segment in North and South American railways. The countries included in the analysis are the United States, Canada, Brazil, Mexico and Chile. The results show that a great part of productivity improvement was due to technological change rather than technical efficiency change. Rivera-Trujillo notes that further research is needed to the selection and specification of the variables in order to obtain internationally agreed performance measures in the rail industry, as well as, on the whole period in which the recent rail reforms took place to determine their degree of success.

Relatively very few studies extend efficiency analysis to the impact of rail restructuring in the 1990s. A study by Friebel, *et al.* (2003) investigates to what extend free entry, independent regulation and the separation of infrastructure from operations affects railway performance of 11 European countries, over the period 1980-2000. Using production frontier analysis, the authors find that reforms have efficiency improving effects if implemented sequentially, while reforms introduced in a package have neutral effects at best. Moreover, their results show that full separation is not a necessary condition for increasing efficiency. This result seems to conflict with the firm belief of many policy-makers. Interestingly, Friebel et al. (2003) find that all smaller countries, except for the Netherlands, have been able to keep or raise their efficiency levels.

3 Methodology

Both parametric and non-parametric approaches to efficiency measurement are frequently used for estimating frontier functions.[3] The former are estimated by using econometric (statistical) methods, while the latter are assessed by applying mathematical programming. Essentially, two popular methods can be distinguished: stochastic frontier analysis (SFA) and data envelopment analysis (DEA). A common feature of both approaches is that information is extracted from extreme observations from a body of data to determine the best-practise production frontier. In contrast to other approaches that evaluate producers relative to an average producer, extreme point methods such as SFA and DEA compare each producer with only the ‘best’ producers. Although this characteristic lies at the hearth of frontier analysis, it also makes it vulnerable to outliers. An important assumption behind these two methods is that if a given producer is capable of producing Y units of output with X inputs, then other producers should also be able to produce the same if they were to operate efficiently. Another property of frontier analysis is that it is units invariant. That is, changing the unit of measurement does not affect the value of the efficiency measure.

SFA is a parametric method for estimating frontier functions and thereby measuring productive efficiency. SFA involves the use of econometric methods to estimate the production frontier, and measures the efficiency of a firm using the residuals from the estimated equation. Consequently, the approach requires the specification of a particular functional form (e.g., Cobb-Douglas or translog) to describe the technology or efficiency frontier. Since deviations from the frontier are treated as stochastic rather than deterministic, SFA is less sensitive to outliers than deterministic methods. Furthermore, the parametric nature provides researchers with interesting information, such as cost or input elasticities, provided the functional specification is correct.

One of the main drawbacks of SFA is that the approach is only well developed for single-output technologies. For multiple-output technologies, researchers have to create a combined variable for either inputs or outputs. In the case consistent accounting rules, costs may well serve as a combined indicator for inputs, which explains why many SFA-applications are based on (translog) cost functions. An alternative approach would be to formulate production as a weighted sum of passenger and freight kilometres and estimate the production function for different sets of weights. Further research may be aimed at exploring this possibility.

[3] In his seminal paper, Farrell (1957), drawing upon the work of Debreu (1951) and Koopmans (1951), suggested a measure of productive efficiency which reflects the ability of a firm to obtain maximal output from a given set of inputs. The pioneer of modern efficiency measurement illustrated his idea in input/input space using an input-reducing focus. Hence the name input-orientated efficiency measures.

DEA models are non-parametric and deterministic. The choice between input or output orientation depends on which quantities (inputs or outputs) the firms have most control over. In most cases input orientation seems most appropriate (Coelli et al., 1998). DEA models that assume constant returns to scale (CRS) are insensitive to the specific orientation. However, when DEA analysis is extended to allow for variable returns to scale (VRS), efficiency scores can differ between the two orientations. The CRS assumption is only valid when all firms are operating at an optimal scale, defined as the region in which scale economies do not differ significantly from zero. In this region firms cannot take advantage of returns to scale by altering in size. If this is not the case, VRS are required to correct for scale efficiencies.

Coelli and Perelman (2000) estimate multi-output distance functions using corrected ordinary least squares. This approach is advocated because it avoids making unrealistic assumptions of firm behaviour, while at the same time it is able to handle the multi-output nature of railways. The distance function results are compared with those obtained from single-output production functions. They find that the results differ substantially between the two methods. As a result, the authors doubt the reliability of the single-output methods.

One of the major strengths of DEA is its ability to handle multiple input and output cases. Unlike parametric techniques, DEA has no difficulty in accommodating the multi-output structure of railways that commonly produce both passenger and freight services. It does not require the construction of an aggregated index measure of output. Furthermore, DEA does not require the specification of a particular functional form for the production function and distribution of the data. Therefore it avoids the potential bias from selecting an incorrect functional form, rendering it more flexible than parametric techniques in approximating the true production frontier (Oum and Yu, 1994).

A disadvantage of DEA is that it does not take data noise (random shocks and measurement error) into consideration, because it is a deterministic approach. As a result, the efficiency estimates may be biased if the production process is largely characterised by stochastic elements. For this reason, DEA can be very sensitive to outliers in the data set. Moreover, statistical hypothesis tests are not directly possible with this technique. Furthermore, DEA has no formal tests to assess the merits of including or excluding variables or the specific DEA model choice. Alternatively, one must rely upon the sensitivity of the results to the inclusion and exclusion of variables and judgement (McMillan and Datta, 1998). As a consequence, variable selection is a most critical part of DEA. The same holds for the selection of firms in the data set. Firms are expected to be relatively homogenous and employ a common technology to convert inputs into outputs.

Our analysis uses DEA to establish relative efficiency scores. The prime reason for choosing DEA is the fact that railways are a multi-product (i.e. passenger and cargo transport) industry and that the lack of consistent accounting data does not enable us to calculate comparable cost figures in an international context. Therefore, DEA's ability of taking into account multiple inputs and outputs is the decisive consideration in choosing our methodology.

4 Data

The characteristics of the production process of railways are complex, making measurement of the performance of railways also complicated. In particular, the multiplicity of inputs and outputs poses some problems. As to output, railways transport both passengers and freight. As a result, passenger-kilometres and tonne-kilometres are usually the starting point for measuring railway output. Although it would be simple to add these together to form a measure of output known as total traffic, this would be inappropriate, because the two outputs require different combinations of inputs and have a different unit of measurement (people vs. freight). They tend to have inherently different cost structures (Productivity Commission, 1999). Fortunately, DEA is able to deal with the multiplicity of inputs and outputs. Concerning inputs, railway companies essentially use labour and capital to produce output (Affuso et al., 2002). Capital consists of rolling stock, tracks and stations.

As no common accounting practise exists among the different railway systems, comparative international efficiency analysis is best based on physical measures rather than value measures (Cowie and Riddington, 1996). Therefore, we use physical measures such as the amount of kilometres and employees instead of monetary measures like revenues and costs.

Ultimately, the choice of variables is constrained by the availability of data. This study uses two outputs (passenger-kilometres and tonne-kilometres) and three inputs (staff, track, and total rolling stock). Several previous studies have used the same measures of output and input. Thus use of rolling stock as a measure for input may be troublesome, as the rail fleet mix is probably not homogenous over countries. Any alternative measure suffers from the same problem however. The most obvious alternative, number of locomotives, is even less comparable over the sample, because of the use of mixed cars in some, but not all, countries.

When studying transportation productivity, one can distinguish between the productivity of offering transport capacity (e.g seat kilometres) versus the productivity of actually transporting (e.g passenger kilometres). The first provides a technical interpretation of transport, whereas the second measure also takes allocation into account. As an extreme example, one might think of a rail company being very efficient in running empty trains on a track. Technically, this is very efficient, but from the viewpoint of allocation it is useless. There may be good reasons to look at the technical interpretation, as the allocation decisions may not all be in the hands of the rail company, for instance because of government obligations to serve very thin routes. Nevertheless, we decided to look at efficiency with allocation in mind, since we are mainly interested in the effect of competition design on welfare.

The primary data source of this study is International Union of Railways (2003). The data from this source covers the period 1990-2001 for the railway systems of 52 countries from over the world. At present, it is the key source of information from which most industry analysts and academics obtain their information on railways. It is especially made to ensure comparability and consistency through the use of common definitions. However, in the end it is dependent on the quality of data provided by the individual railways. Supplemental data is received from the Norwegian Office of Statistics and a railway magazine from the Netherlands.

Each railway system is represented by the main railway organisation in the specific country. When a railway system is made up of more than one organisation, we combine the operations to a single organisation.[4] Despite the extensiveness of the data set, considerable data gaps and inconsistencies exist, severely limiting the number of railway systems available for assessment. In particular, the railway systems of the United Kingdom and Ireland could not be included due to poor data. Nash and Shires (1999) find this issue a major source of concern. They argue that, due to institutional changes, railway operators are often reluctant to release details of their operations. This makes data collection difficult and reduces the scope for future research.

Given the focus of this study, namely the analysis of the effect of the design of competition on productive efficiency, and the fact that we use DEA, we need to ensure that the group of countries is rather homogenous. That is, the railways systems have to be comparable in their production characteristics. From the initial set of countries, sixteen countries are available that have enough observations; that is, at most two observations are missing. Within this group, Japan, the United States and Luxembourg exhibit characteristics that make them somewhat different from the others.

Luxembourg is the smallest country in the data set, with a network size of about one tenth of that of Denmark, the second smallest country. As a consequence, Luxembourg has a unique scale that will always make it a fully efficient country. Even applying VRS DEA does not solve this problem, because Luxembourg has no countries, or in DEA terms peers, to be compared with. Including Luxembourg would not only limit the discriminatory power of the DEA analysis, it would also distort the analysis of the variation in efficiency scores in the subsequent regression analysis. Similarly, including the United States would be detrimental to the discriminatory power of the empirical analysis. Compared to the second largest country in the data set (Germany), United States have a network that is approximately six times as long as Germany's. So, both Luxembourg and the United States are left out of the data set in order to create a set of countries that are comparable.

[4] Note that this influences our conclusions on scale and density. These conclusions are to be interpreted at the (national) system level rather than at the firm level.

Japan differs from the other countries because of the large output in terms of passenger kilometres, exceeding the largest European country by almost 150 percent. Furthermore, Japan's railway system is well known for its formidable efficiency. This may partly be related to market and system design, partly to cultural factors and partly by the socio-geographical outlay of the country. Japan's very densely populated urban areas are separated by distances ranging from 100 to 500 km, which is an ideal spatial environment for rail operations. The differences between Japan and the other countries in the sample are not as large as in the case of Luxembourg and the United States, so we see no reason to exclude Japan from our analysis. On the other hand, as we will see later on, Japan's special position influences our results considerably, urging us to treat Japan separately in our analysis.

Table 4.1 Descriptive statistics of the data

			Europe				Japan
Variable	Symbol	Unit of measurement	Mean	Min	Max	Standard deviation	Mean
Outputs							
Passengers kilometres	Pkm	Billions of passenger kilometres	19.5	2.1	74.0	21.6	182.5
Freight kilometres	Fkm	Billions of gross-hauled tonne-kilometres	13.6	1.4	100.0	18.8	24.3
Inputs							
Input of labour	L	Annual average number of staff (x1000)	70.4	6.6	482.3	87.8	182.5
Tracks	T	Track length at the end of the year (km x 1000)	11.2	2.0	41.7	11.4	20.2
Input of capital	C	Annual average number of rolling stock (x 1000)	55.1	3.0	43.8	81.1	48.9
Control variables							
Total area	AREA	1000 Square miles	89.7	11.7	210.7	70.1	152.4
GDP per capita	GDP	In constant prices (2000) 1000 US dollars PPPs	23.3	6.8	37.1	5.6	24.9
Population density	POPDEN	Population per square mile	396	36	1224	325	824
Traffic structure	TSTRUC	Passenger kilometres / total traffic in kilometres	0.58	0.23	0.90	0.20	0.91
Traffic density	TDEN	Total traffic in kilometres (in millions) / total length of lines in kilometres	3.0	1.2	7.1	1.4	13.3

Countries: Austria, Belgium, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland
Period: 1990 - 2001 (Denmark until 2000, Sweden until 1999)
Sources: UIC (2003), Alexandersson and Hultén (2005); Berne and Pogorel (2003); Farsi et al. (2005); IBM (2004); Mizutani and Nakamura (2004); Nilson (2002); OECD (1998) OECD (2005); Nash and Rivera-Trujillo (2004); Thompson (2003); United Nations (2003); Van de Velde (1999); various websites of rail companies and DG Transport of European Union.

Descriptive statistics of the input and output variables are presented in the table below. Because of the special position of Japan discussed earlier, we present Japanese figures separately, giving only the mean over time, as the standard deviation over time is of less interest to our analysis.

In the second stage of our analysis, we will use several variables reflecting the institutional design of competition. The data for the these variables are constructed using a variety of sources. For the exact list of materials used to construct this set, the reader is referred to the bottom of Table 4.2. This table also provides an overview of changes in competition design in the various countries, including aspects of structural design that we do not assess empirically due to lack of variation in the data. The quality of these data is verified through a survey submitted to a number of experts of the different national railway systems considered in this study. Once more, note that there are certain limits concerning the extent to which one can interpret the results, because there are many reform specificities across countries that cannot be perfectly captured in an empirical analysis (see Friebel et al., 2003).

Table 4.2 Structural design of the railway industry in European countries and Japan, 1990 - 2001

Country	Characteristic in 1990	Changes during 1990 – 2001
Austria	vertically and horizontally integrated, no competition, state-owned, public agency	- accounting separation in 1992 - independent management in 1992
Belgium	vertically and horizontally integrated, no competition, state-owned, public agency	- accounting separation in 1993 - independent management in 1991
Denmark	vertically and horizontally integrated, no competition, state-owned, public agency	- institutional separation in 1997 - independent management in 1999
Finland	vertically and horizontally integrated, no competition, state-owned, public agency	- institutional separation in 1995
France	vertically and horizontally integrated, no competition, state-owned, public agency	- accounting separation in 1995 - institutional separation in 1997 - independent management in 1997
Germany	vertically and horizontally integrated, no competition, state-owned, public agency	- accounting separation in 1994 - free entry (freight) in 1994 - regional tendering in 1996 - independent management in 1993
Italy	vertically and horizontally integrated, no competition, state-owned, public agency	- accounting separation in 1998 - independent management in 1992
Japan	vertically integrated, horizontally separated, infrastructure competition, public agency	- yardstick competition in 1997
Netherlands	vertically and horizontally integrated, no competition, state-owned, public agency	- accounting separation in 1995 - horizontal separation in 2000 - free entry (freight) in 1998 - regional tendering in 1999 - independent management in 1995
Norway	vertically legally separated, horizontally integrated, no competition, state-owned, public agency	- independent management in 1997
Portugal	vertically and horizontally integrated, no competition, state-owned, public agency	- institutional separation in 1997 - independent management in 1997
Spain	vertically and horizontally integrated, no competition, state-owned, public agency	- accounting separation in 1997 - independent management in 1994
Sweden	vertically institutionally separated, horizontally integrated, regional tendering, state-owned, independent management	- free entry (freight) in 1996
Switzerland	vertically and horizontally integrated, no competition, state-owned, independent management	- accounting separation in 1999 - free entry (freight) in 1999

Sources: Alexandersson and Hultén (2005); Berne and Pogorel (2003); Farsi et al. (2005); IBM (2004); Mizutani and Nakamura (2004); Nilson (2002); OECD (1998) OECD (2005); Nash and Rivera-Trujillo (2004); Thompson (2003); UIC (2003); United Nations (2003); Van de Velde (1999); various websites of rail companies and DG Transport of European Union.

5 Efficiency analysis results

This section presents estimates of relative productive efficiency for the 14 countries in our data set. The productive efficiency indices are estimated by using the Efficiency Measurement System (EMS) program by Holger Steel.[5] As we stated earlier, we show the DEA results including and excluding Japan. We use *variable* returns to scale DEA as most of the railway systems in our analysis are not operating at the optimal scale (see Preston, 1994). The DEA-results are based the inputs (labour, track and capital) and outputs (passenger kilometres and freight kilometres) mentioned in table 4.1. All other variables are used in the second stage of our analysis.

Table 5.1 DEA estimates of productive efficiency, Europe, 1990 to 2001 (VRS efficiency scores)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Austria	0.80	0.80	0.77	0.76	0.80	0.83	0.83	0.87	0.90	0.91	1.00	1.00
Belgium	1.00	1.00	0.99	0.96	1.00	0.96	0.95	0.96	0.96	0.95	0.97	0.94
Denmark	0.87	0.87	0.89	0.89	0.87	0.87	0.87	0.92	0.91	1.00	1.00	.
Finland	0.77	0.74	0.76	0.84	0.90	0.91	0.89	0.96	0.97	0.97	1.00	1.00
France	0.77	0.74	0.70	0.72	0.75	0.72	0.80	0.84	0.89	0.93	0.98	1.00
Germany	0.80	0.82	0.75	0.72	0.77	0.76	0.76	0.88	0.92	0.93	1.00	1.00
Italy	0.93	0.94	0.93	0.89	0.93	0.97	0.97	0.97	0.93	0.94	1.00	1.00
Netherlands	0.89	0.96	0.97	0.97	0.95	1.00	0.97	0.96	0.99	0.98	1.00	1.00
Norway	0.76	0.81	0.80	0.81	0.81	0.83	0.89	0.87	0.94	1.00	0.95	1.00
Portugal	0.67	0.68	0.68	0.84	0.88	0.90	0.89	0.89	0.88	0.74	0.91	0.95
Spain	0.51	0.50	0.52	0.59	0.59	0.64	0.68	0.75	0.82	0.88	0.93	1.00
Sweden	0.86	0.85	0.96	0.96	1.00	1.00	1.00	0.92	0.98	1.00	.	.
Switzerland	0.59	0.61	0.58	0.58	0.63	0.65	0.64	0.71	0.74	0.81	0.87	0.93

. = data not available

Source: CPB estimates

[5] See EMS: Efficiency Measurement System User's Manual, available at www.wiso.uni-dortmund.de/lsfg/or/scheel/ems.

Table 5.2 DEA estimates of productive efficiency, Europe and Japan, 1990-2001 (VRS efficiency scores)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Austria	0.80	0.80	0.77	0.76	0.80	0.83	0.83	0.87	0.90	0.91	1.00	1.00
Belgium	1.00	0.99	0.99	0.96	1.00	0.96	0.95	0.96	0.96	0.95	0.97	0.94
Denmark	0.87	0.87	0.89	0.89	0.87	0.87	0.87	0.92	0.91	1.00	1.00	.
Finland	0.77	0.74	0.76	0.84	0.90	0.91	0.89	0.96	0.97	0.97	1.00	1.00
France	0.23	0.22	0.22	0.23	0.24	0.25	0.27	0.29	0.30	0.31	0.32	0.31
Germany	0.80	0.81	0.72	0.68	0.76	0.76	0.76	0.88	0.92	0.91	1.00	1.00
Italy	0,52	0.58	0.57	0.54	0.61	0.67	0.64	0.69	0.67	0.66	0.66	0.64
Japan	1,00	1.00	1.00	0.99	0.97	0.99	1.00	1.00	0.98	0.99	0.99	1.00
Netherlands	0,89	0.96	0.97	0.97	0.95	1.00	0.97	0.96	0.99	0.98	1.00	1.00
Norway	0,76	0.81	0.80	0.81	0.81	0.83	0.89	0.87	0.94	1.00	0.95	1.00
Portugal	0,67	0.68	0.68	0.82	0.88	0.89	0.89	0.89	0.88	0.74	0.91	0.94
Spain	0,33	0.33	0.33	0.36	0.36	0.39	0.40	0.42	0.45	0.47	0.49	0.51
Sweden	0,86	0.85	0.96	0.96	1.00	1.00	1.00	0.90	0.97	1.00	.	.
Switzerland	0,57	0.58	0.55	0.54	0.58	0.59	0.57	0.61	0.64	0.69	0.74	0.76

. = data not available
Source: CPB estimates

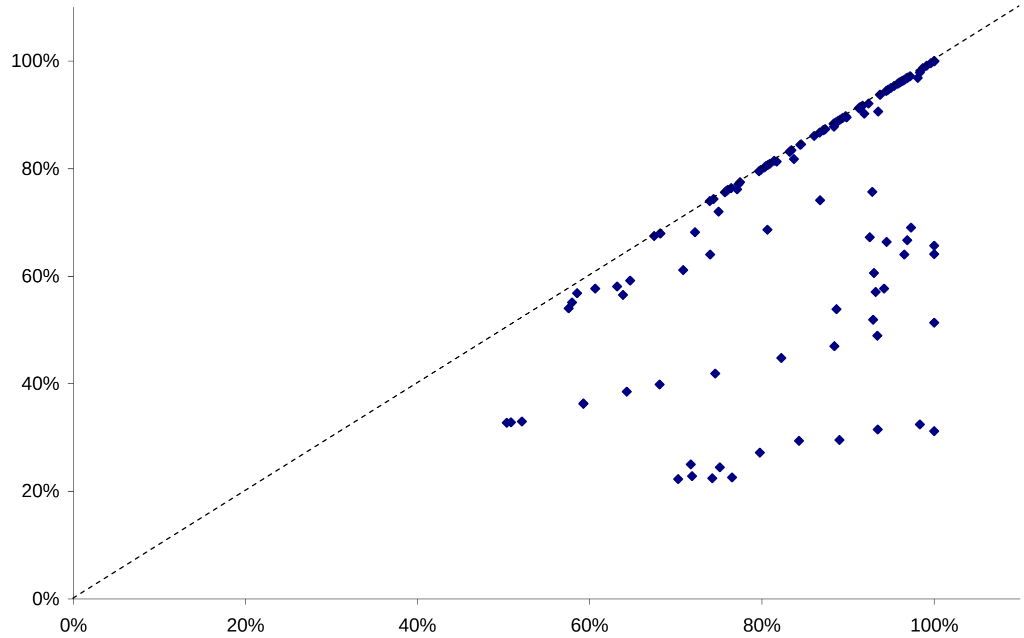
Tables 5.1 and 5.2 present the results. Several noteworthy aspects emerge from these results. First of all, most countries evolve over time towards a DEA index of 100%. This suggests that, in final years of the data set, the countries form a relatively homogenous group as their relative efficiency scores are identical. However, in the beginning of the nineties, significant differences were present between the countries.

It seems likely that the railway systems have grown towards each other in terms of relative productive efficiency. Second, some countries, notably, Belgium, Netherlands, Japan, and Sweden, have the most efficient railway systems over the whole period.

Third, several countries experience a big drop in their relative efficiency levels when Japan is added to the analysis. Looking at the two tables, it seems that especially countries such as France, Spain and Italy are affected by including Japan to the data set. Switzerland's results are also influenced to some extent. Japan is the efficient peer for these countries, meaning that Japan's input-output mix is comparable to these countries. Including Japan's very efficient railway system in the analysis implies that all countries that are compared to Japan have lower efficiency scores.

We have plotted the DEA results of both tables against each other in Figure 5.1. Every country-year combination is represented by a point. From this figure, it appears that most countries have (nearly) equal efficiency levels in two models as most dots are on the 45 degree line. However, the countries mentioned above have very different efficiency levels between the two models. These countries are represented by the points below the 45 degree line. .

Figure 5.1 Correlation between DEA results excluding and including Japan



It is clear from the figure that the inclusion or inclusion of Japan makes quite a difference to the DEA results. A drawback of the use of a non-parametric method like DEA is that we can use neither parameters nor test statistics to assess the reason behind the high efficiency score. As there is no clear theoretical argument to either include or exclude Japan, we will further investigate the sensitivity of the results to the inclusion of Japan in the following chapter.

6 Relationship between competition design and relative productive efficiency

We use a limited dependent variable model to estimate the effects of the design of competition on productive efficiency. Applying the usual least-squares estimator in this case would result in biased results, since it fails in treating censored observations properly (Hill et al., 2001). The regression function to be estimated is expressed as follows:

$$DEA_{it} = CONSTANT + \beta_1 VERT1_{it} + \beta_2 VERT2_{it} + \beta_3 THIRD_{it} + \beta_4 TEND_{it} + \beta_5 INDP_{it} + \beta_6 TIME_t + \beta_7 AREA_{it} + \beta_8 POPDEN_{it} + \beta_9 GDP_{it} + \beta_{10} TDENS_{it} + \beta_{11} TSTRUC_{it} + \beta_{12}(DUMJAP_i) + \varepsilon_{it}$$

where DEA is the dependent variable derived from the efficiency analysis and ε is a random term, which is assumed to be symmetrically distributed with zero mean and constant variance. All other variables are introduced below. Most terms differ across countries and time and are thus indexed by *it*. We include a time trend, $TIME_t$, to represent technological progress.

Aside from their signs, the coefficients of Tobit models are not easy to interpret directly. One way to interpret the parameters is to consider the marginal effect of a change in x_{ik} upon the expected DEA outcome. According to Verbeek (2004), this is simply given by the model's coefficient multiplied by the probability of having a non-censored outcome. The latter is equal to the standard normal density function. Formally, this can be written as:

$$\frac{\partial E\{DEA_i\}}{\partial x_{ik}} = \beta_k \Phi\left(x_i^{'}\beta / \sigma\right).$$

Table 6.1 provides an overview of the dummy variables we use. Two dummy variables are designed to reflect the vertical structure of the railway system in a country. We distinguish between institutional (full), *VERT1*, and accounting (partial) separation, *VERT2*, to investigate whether there is a difference between the two options.

Competition 'in' and 'for' the market are represented by free entry, *ENTRY*, and competitive tendering, *TEND*, respectively. Further, managerial independence from the government of the railway company is captured by a specific dummy variable, *INDP*. Finally, to identify the unique characteristics of the Japanese railway system, we use a special dummy variable for this country, *DUMJAP*. Note however that this dummy does not affect countries that are in Japan's peer group.

Unfortunately, features such as horizontal structure (freight and passenger integrated/separated), ownership (private or public), infrastructure competition and yardstick competition, could not be included as a dummy variable, because of too little variance in these features in our data set.[6] As a consequence, it is not (yet) possible to investigate the influence of these variables on productive efficiency in this research. With the help of better data sets, which encompass a larger set of countries and more recent data, further research should be aimed at investigating these aspects empirically.

Table 6.1 Description of regression variables

Variable	Symbol	Description
Dummy variables		
Institutional (or full) separation	VERT1	If variable is 1, then infrastructure and services are institutionally separated; 0 if this is not the case.
Accounting (or partial) separation	VERT2	If variable is 1, then infrastructure and services are separated on an accounting basis; 0 if this is not the case
Free entry	ENTRY	If variable is 1, then legislation is transposed that allows free entry to competitors (either freight or passenger) and competition has evolved to a significant extent; 0 if this is not the case.[a]
Competitive tendering	TEND	If variable is 1, then competitive tendering is used to procure regional railway franchises; 0 if this is not the case.
Managerial independence from the government	INDP	If variable is 1, then legislation is transposed that assures independent management from the government of railway companies; 0, if this is not the case.[b]
Japan dummy	DUMJAP	If variable is 1, then country is Japan; 0, if this is not the case
Control variables		
Total area	AREA	Measured in 1000 square miles
Gross Domestic Product per capita	GDP	Measured in constant prices (2000) 1000 US dollars PPPs
Population density	POPDEN	Measured in population per square mile
Traffic structure	TSTRUC	measured by passenger kilometres / total traffic in kilometres
Traffic density	TDEN	Total traffic in kilometres (in millions) / total length of lines in kilometres

[a] Significant evolution of competition implies that competitors of the incumbent obtain sufficient and nontrivial large market shares. We use a threshold value of 1%. Admittedly, this value is rather arbitrary, but required for this analysis.

[b] Managerial independence as it is prescribed by the European Union by directive 91/440/EEC.

In order to arrive at accurate results of the effects of the designs of competition, we need to correct for particular environmental variables outside the control of the management of the railway firm. The control variables included in this analysis and their definitions are also listed in table 6.1. The first factor we control for is the influence of population density, *POPDEN*. High population density might facilitate (in terms of efficiency) a more intense use of inputs than would otherwise be the case. The second control variable is GDP per capita, *GDP*. Higher

[6] Estimations including these variables did not deliver any meaningful results and are therefore not published in this study.

purchasing power, through income effects, could result in a higher mobility level of the customers of a railway system.

Besides these two factors, we also control for the effects of country size, *AREA* (facilitates economies of size), traffic structure, *TSTRUC* (to correct for the cost difference between producing freight and passenger services), and traffic density, *TDEN* (facilitates economies of density, in so far this is not captured by population density and income per capita). Note that traffic density is not fully beyond the control of management, since firms can influence the density of traffic by changing their prices or supply of services. Nevertheless, social and regulatory objectives affect to a large extent whether and how often certain lines are to be operated, thereby influencing traffic density.

Table 6.2 Tobit regression results

Model	(1) Europe				(2) Europe + Japan			
Dependent variable								
DEA efficiency indices								
Independent variables	Coefficient estimate	(Standard error)		Marginal effect	Coefficient estimate	(Standard error)		Marginal effect
CONSTANT	0.5827	(0.0493)	***	0.4643	1.0987	(0.0651)	***	0.8746
VERT1	0.0447	(0.0231)	*	0.0356	− 0.0005	(0.0301)		− 0.0004
VERT2	0.0225	(0.0213)		0.0179	0.0854	(0.0282)	***	0.0680
ENTRY	− 0.0812	(0.0311)	***	− 0.0647	− 0.0773	(0.0417)	*	− 0.0615
TEND	0.0826	(0.0346)	**	0.0658	0.2641	(0.0461)	***	0.2102
INDP	− 0.0691	(0.0181)	***	− 0.0551	− 0.1495	(0.0239)	***	− 0.1190
TIME	0.0211	(0.0033)	***	0.0168	0.0162	(0.0040)	***	0.01290
AREA	0.0002	(0.0001)		0.0002	− 0.0018	(0.0002)	***	− 0.0014
POPDEN	-7.75×10^{-5}	(5.45×10^{-5})		-6.18×10^{-5}	5.39×10^{-5}	(7.22×10^{-5})		4.30×10^{-5}
GDP	0.0016	(0.0014)		0.0013	− 0.0012	(0.0018)		− 0.0010
TDEN	0.0776	(0.0118)	***	0.0618	0.0261	(0.0154)	*	0.0208
TSTRUC	− 0.1331	(0.0481)	***	− 0.1061	− 0.5422	(0.0636)	***	− 0.4316
DUMJAP					0.3929	(0.1477)	***	0.3131
Log likelihood		127.13				93.1		
Adjusted R-squared		0.67				0.82		
Number of observations		153				165		

Note: Asterisks (*), (**), (***) represents statistical significance from zero at the 10%, 5%, and 1% level respectively.

Table 6.2 presents the regression results of two Tobit models. The difference between the first and the second model is the inclusion of Japan. In order to account for the possible particularities of this country a dummy variable is included in the second regression. Note, however, that even with a dummy variable, differences can be substantial between the results of the two models, because the inclusion of Japan also affects the efficiency scores of some other countries as we have seen in the previous section. Both the regression coefficient and the marginal effect of each variable are reported in the table.

The adjusted R-squared statistics indicate that both models perform well in explaining the variation of efficiency scores. The majority of coefficients are statistically different from zero at the 5% level of significance. In addition, multi-collinearity does not pose a problem, because the correlation among the explanatory variables is reasonably low. As we use a censored limited dependent variable, heteroskedasticity cannot be a problem. That is, the size of the variation in the residuals of the DEA indices is on average the same across countries.

Looking at the control variables, we find that the effect of both population density and income per capita are insignificantly different from zero. Furthermore, our results suggest that traffic density is important for productive efficiency. This is in line with the results found by Cowie and Riddington (1996). High utilisation of the track network is important for productive efficiency, due to economies of density. We also establish that railways systems that concentrate on passenger transport have lower levels of productive efficiency than freight oriented systems. This is also consistent with the literature. As aforementioned, one passenger-kilometre of output costs much more than one tonne-kilometre of output. Even though DEA corrects this somewhat, our results suggest that a control variable is necessary to correct for differences within peer groups. Further, when economies of density are accounted for by a traffic density variable, both population density and income effects do not matter for productive efficiency.

The main results of our analysis are those regarding the design of competition. First of all, we find that competitive tendering improves productive efficiency, which is in line with economic intuition as well as with expectations on the design of competition. Our second finding -free entry lowers productive efficiency- is much less in line with intuition. The effect of free entry is to lower productive efficiency of the incumbent railway company. A possible explanation for this result could be that free entry may disable firms to reap economies of density. For instance, sharing terminal space and traffic may reduce the efficiency of railway operations. In addition, train scheduling can become less flexible due to competition on the tracks (BRTE, 2003). These problems may be overcome by efficient coordination, but it should be noted that coordination comes at a cost.

Perhaps even more surprising is the third finding that more autonomy of management lowers productive efficiency.[7] However, if one looks at the national railway markets in Europe this effect might not come as a bolt from the blue. Most of the incumbent railway companies are state owned and do not face any competitive pressure. Increased independence may give rise to principal-agent problems, as more autonomy increases the information asymmetry between government and management. Without sufficient competition or adequate regulation, this may deteriorate incentives for productive efficiency. This is point is also proposed by Vickers and Yarrow (1991), De Fraja (1991), and Caves and Christensen (1980).

The second and third result are in conflict with previous studies. Others found that free entry (Friebel et al., 2003) and more independence (e.g., Gathon and Pestieau, 1995) are efficiency improving. The different definitions of free entry and managerial independence between those studies and the present study could possibly explain the divergence in the results. For instance, Gathon and Pestieau use an autonomy index based on a questionnaire created in 1990 for their managerial independence variable, whereas we use a dummy variable to represent whether a country has implemented legislation to create more managerial independence. In contrast to the paper by Gathon and Pestieau, our dummy variable is year specific. Moreover, we use different data and estimation method to measure productive efficiency. For example, Friebel et al. (2003) use SFA, while we use DEA. Lastly, the period under investigation by Gathon and Pestieau (1986 to 1988) is different from ours (1990 to 2001).

The results regarding vertical separation are not consistent between the two models. Whereas in the first model institutional separation is needed to get a positive effect on productive efficiency, the second model tells that accounting separation is sufficient. So, while the results suggest that separation could be beneficial for productive efficiency, the results disagree on which form of separation is preferred from a productive efficiency point of view. An alternative explanation would be that the positive effects of more transparency are offset by losses in economies of scope or by duplicating facilities in the case of full separation.

Although the signs of the coefficients are mostly robust across the two models, the order of magnitude of the coefficients alters considerably when Japan is included. This effect is caused by the drop in the DEA scores of some European countries explained in the previous section. For this reason, the results regarding the order of magnitude of the coefficients in the second model are disturbed and therefore to be interpreted with due caution.

[7] Note that our definition of autonomy does not rule out that governments set equity-related goals for rail companies.

7 Conclusion

We used a two stage approach to identify the effects of different designs of competition on relative productive efficiency of railways. The first stage, using DEA, measures relative productive efficiency of the railways of a number of European countries and Japan. The results show a large variation in the efficiency scores across countries which is decreasing over time. In the second stage of the empirical analysis, we applied Tobit regression to investigate the effects of various designs of competition on the efficiency results derived in the first stage. We find no unambiguous results for the effect of vertical separation on productive efficiency. The main results are that competitive tendering encourages productive efficiency, whereas free entry and increased managerial independence may deliver the opposite. Noticeably, both latter results are in contradiction with economic intuition, as well as with earlier results, as found by Friebel *et al*. (2003) and Gathon and Pestieau (1995) .

The difference between our results and those found by others may either be caused by differences in the actual situation reflected by the data, by differences in the definition of variables, or by differences in estimation methods used. Further research may be aimed at taking a closer look at these effects, especially as -over time- more data on reformed rail systems will become available.

We also find that both economies of density and the composition of output are important in explaining variation in productive efficiency. On the contrary, the impact of population density and income per capita is insignificantly different from zero.

What can be deduced from these results for policy purposes? First of all, the results indicate that competitive tendering seems to improve productive efficiency. In addition, the results suggest that introduction of competition on the tracks may not under all conditions improve productive efficiency. Further research may shed light on the background of this finding. Our analysis also suggests that providing the management of an incumbent railway company more autonomy should be done with care. One should keep in mind that greater autonomy without either competitive or regulatory pressure is at least vulnerable to inverted incentives for productive efficiency.

Due to limitations to the data, we were not able to include an interesting country such as the United Kingdom. Furthermore, our analysis is constrained to the period 1990-2001. Consequently, the effects of recent structural measures may not be fully materialised. For instance, full separation of infrastructure and train services in the Netherlands did not occur until 2002. Another important issue is that we only investigate performance in terms of input and output quantities and therefore disregard important facets such as the quality of service and financial affairs. These are recommended avenues for future research.

Apart from using better and more recent data, further research may also be aimed at looking more in detail to the design of competitive mechanisms. We mentioned the issue of coordination between operators in markets with free entry. The use of a more precise definition of which activities are to be tendered, would also yield interesting information. Similarly, further research into the question under which conditions management autonomy will lead to higher or lower productive efficiency would be fruitful. On the technical side, further research may be aimed at finding a specification that allows us to estimate a stochastic frontier on the same data, or to apply the technique of canonical correlations (Bowden and Turkington, 1984) with the DEA methodology.. Finally, diving deeper into the reasons behind Japan's high efficiency scores may yield interesting results. Multidisciplinary research seems to be in place here, as these reasons might be partly cultural and geographical.

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