Network Industries Economics. A Comparison of Rail Infrastructures Output in Key European Countries

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Abstract

Infrastructure is widely recognized as a key ingredient in a country's economic success. However many issues surrounding infrastructure management are not well analysed. This paper assesses the performance of rail infrastructures management. Focusing on key European countries this study monitors the factors directly related to the effective allocation of resources. Results suggest that the outperforming system is the Swedish, characterised by reduced cost, and the German, marked by significant scale economics. The Italian case follows these two. The expenses for running the Spanish infrastructure are relatively low but this advantage is outweighed by weak traffic. If on one hand the cost of the British network appears to be above the average, on the other hand it is compensated by the intensive use of the network. The French infrastructure presents an average production cost along with moderate productivity; a remarkable average loading makes up for this performance gap. Main limitations stem from the fact that the railway industries and their development greatly differ across European countries since the infrastructure were built on national bases. This study serves as an entry point to further assessments and evaluation of the efficacy of policies regarding the management of rail infrastructures in Europe.

Keywords: rail infrastructure, productivity, utilities regulation, transportation, network industries.

Jel Classification: L2, L92.

1. Introduction

In the early and mid-twentieth century, many countries, especially in the developing world, sought to provide utility services by forming state-owned monopolies. Restructuring the industry generally involves the separation of the potentially competitive portions of the sector from the non-competitive or natural monopoly portions and the guarantee that non-discriminatory access of rivals to the non-competitive portions, which should be considered essential facilities. This separation of competitive from non-competitive may be accomplished through structural separation, functional separation, or unbundling. Railway companies used to exercise both infrastructure and transport services in almost all of the European countries. This structurally rigid supply, exacerbated by a series of other factors, started at the same time of/as the development of the EU railways and lasted until the Swedish reform process through which the separation began, i.e. 1988. In such market conditions the output corresponded to levels of traffic. Although scholars have considered a variety of regional models relating to infrastructure productivity, in many cases these models are formulated without taking into consideration spatial interactions (Kelejian and Robinson 1997). Therefore, reliable and comparable information on the cost and output of the rail networks is essential. We develop this idea in detail in an effort to determine what kind of improvements are called for, to analyse how other infrastructure managers achieve their performance levels, and, to provide policy makers with consistent information.

More specifically this study reconstructs comparable industrial and economic data for measuring the productivity and cost of rail infrastructure networks over a five year period. The key industrial data used for this paper are: rail network length (tracks), distance (train-km) and the traffic unit transported, whether measured in terms of passenger-km or ton-km. The indicators stem from analysis focused on six key European rail infrastructure networks as per extension and traffic levels i.e. Germany (DE), France (FR), Great Britain (UK), Italy (IT), Spain (ES) and Sweden (SE). Despite significant regional variation both between and within different markets, most of the data are comparable. Our results suggest two outperforming networks: Sweden and Germany, the Italian case is ranked third. Figures coming from the Spanish, British and French cases show mixed results. Although this paper used different types of information to reach its conclusions and the terms of reference were adequate, major challenges, especially of data availability was faced. The foremost benefit of this analysis is to support decision making by providing facts and judgements about the efficiency, effectiveness, and thus sustainability of the rail infrastructure management in Europe. Such information is crucial for fine-tuning existing or planning new policies and for setting governmental priorities and allotting resources.

The remainder of the paper is organized as follows: In the first section, we discuss the output and productivity of rail infrastructure networks. We then discuss the methodology for calculating the unit costs of railway networks. This is followed by a survey of total cost, unit cost and productivity of rail infrastructure managers, our assessment follows, and we conclude with a discussion of implications.

2. Background and related works

Networks include a large number of sectors such as telecommunications, broadcasting, transport, energy, utilities. Prior research suggests that the growing importance that these sectors have in the modern economy has led to a significant development of the so-called network economics. A major feature of network industries is that they show competitive network externalities. One central objective of organisational reforms in many industries is to create a competitive environment, with a vertical separation policy viewed as one option for stimulating competition (Matsushima and Mizutani 2014). Traditionally, the regulation of network industries in Europe was based on sector-specific rules rooted in the theory of natural monopoly and justified the granting of exclusive rights. Several researchers have investigated how the structure of vertical organisations is determined in competitive environments (Lin 2006, Matsushima 2009). There is evidence in support of the relationship between competition and efficiency of firms. Regulations, or anti-competitive behaviour preventing entry and expansion, may therefore be particularly damaging for economic growth. Competition also improves the productive efficiency of firms (OECD 2014). Davies *et al.* (2004) provides some illustrative cases, particularly noting significant price effects from deregulations that had the effect of introducing competition (for example, low cost airlines within Europe). Step by step, the European Union has been pursuing a top-down reform process leading to the gradual reorganisation aimed at the creation of a truly integrated market across Member States (de Hauteclocque 2013). The roadmap toward a single transport area represents a thought-provoking topic in the field of European transport economy. The European Commission (2011) has offered, for example, a strategy to revitalise the European railways by creating a sound financial basis, ensuring freedom of access to all traffic and public services and promoting the integration of national systems and social aspects. Early EU legislation laid down the basic principles guiding the improvement of rail efficiency via progressive market opening, establishment of independent railway undertakings and infrastructure managers and separation of accounts between them. In 2012, parts of the legislation were simplified, consolidated and further reinforced by Directive 2012/34/EU. To mark the enforcement of regulations on railways, this study focuses on the key rail infrastructures. The estimates of degrees and path of economic impact of infrastructure by various macroeconomic models are different. Lakshmanan (2011) reviews recent theoretical developments to identify the multiple causal mechanisms which link transport and economic growth such as: market expansion, gains from trade, technological shifts, processes of spatial agglomeration and processes of innovation. Although several measures to promote railway development, in particular, those from the first package of measures formed by directive 91/440, the level of competition on European railroad markets is still considered unsatisfactory (Knieps 2012). Efficiency of railway companies has often been studied in terms of effects of the regulatory measures and reforms. Cantos and Maudos (2001) focus on the types of reforms on technical and revenue efficiency and conclude that the separation between infrastructure and services achieved the most beneficial impact. Friebel *et al.* (2003) measure the impact on efficiency of a series of reforms as being introduced either sequentially over time or all together and suggest a positive effect of deregulation on efficiency for countries where reforms were implemented sequentially. To this extent it must be considered that the producer’s endogenous effort depends on the constraints exerted by the regulatory environment that it faces (Laffort 1994). After the liberalisation process started, firms provided a significant effort level to reduce cost inefficiency (Urdánoz and Vibes 2013). They further this idea by testing the independence of infrastructure managers from operations and show that countries which decide on a clear separation face lower costs for providing an effort, allowing them to reduce inefficiency. Previous literature also proposes life cycle costing approaches for measuring rail infrastructure (Zoeteman 2001). As far as we know, few studies specifically analyse key industrial and economic information on the rail infrastructure and its management even if the information would serve the regulatory bodies. It is generally agreed in fact that among the approaches to regulating the overall price level, rate of return (or cost of service) regulation, price cap regulation, revenue cap regulation, and benchmarking, or yardstick regulation play a major role (King 1998). These approaches are widely used together worldwide, nevertheless their interaction, requires special attention.

3. Output and productivity of rail infrastructure networks

Competitiveness and performance of transport industries have been widely researched, however, several methodologies are available to address how they shall be evaluated (Di Foggia & Lazzarotti 2014). This paper takes into consideration six cases: RFI for Italy (I), RFF for France (FR), DBnetz for Germany (DE), Network rail for Great Britain (UK), Adif for Spain (ES), Trafikverket for Sweden (SE). To guarantee comparable information of financial statements, the analysis comprises five years: from 2009 to 2013. Since most of the EU's network were designed at country level to be a single network, rail infrastructure in the EU is likely to remain a natural monopoly in the medium term. Existing EU legislation therefore requires a degree of separation between infrastructure managers, which run the network, and services (railway undertakings, RUs) which run the train services on it, with the aim of ensuring fair and equal treatment of all RUs. Full independence of charging and capacity allocation is required, as these were seen as key to ensuring equal access, to this extent Gibson (2003) examines the nature of capacity on a railway network and identifies the key features of rail timetables and track access rights that need to be accommodated in any capacity allocation mechanism. Nevertheless as natural monopolies, IMs do not always react to the needs of the market. Information asymmetries lead to competitive advantages for incumbents and there is a persistent risk of cross-subsidisation due to the lack of complete financial transparency (European Commission 2013a). Rail network output and productivity have only recently emerged as critical in understanding the railway industry. Previously, this information appeared meaningless in the century and a half gap between the advent of the railways to the first separation of the network, which took place in Sweden in 1988. In fact, railway companies used to be vertically integrated, exercising both infrastructure and transport services. In such market conditions output corresponded to levels of traffic i.e. both passenger and freight. However, in the light of the current separation of infrastructure from operations, as required by the European Commission, such a quantity only represents the output of transport (passenger or freight) service operations. It is taken for granted that rail infrastructure networks produce transit capacity and that such capacity corresponds to a supply aimed at satisfying the demand of transport service companies. In this study, the main measure of network production is given in terms of the train-km circulating on the network over a given time period. However, alongside the stated variable, one should also consider as network output the passenger-km as per passenger services and the ton-km when considering freight services. The rail infrastructure networks thus produce train-km directly and passenger-km or ton-km indirectly, which can be conventionally merged to integrate an indicator of production defined as traffic unit (UT). The measurement of the network output using both train-km and traffic unit allows, through the interaction with measurements of network size, the calculation of productivity indicators. Subsequently the next step involves the calculation of the unit cost of the networks and requires both a preliminary and consistent total cost (TC) configuration with the scope of permitting yearly comparisons across companies after controlling for network amplitude and traffic. These indicators represent the premise for performance assessment.

4. Setting the unit costs

Quinet (1997) presents and discusses pertinent literature on the cost estimation of transport and the related scientific and political issues: especially the methodology of calculation as well as the impact of these transportation cost calculations on policies. As for other productive activity, the unit cost stems from the total cost of production over the level of production. Rail infrastructure networks principally produce train-km (therefore, a single-product). However, the product is not homogeneous since it includes freight trains and passenger trains (in turn, regional and long distance). However, this heterogeneity does not significantly impact upon the cost of the infrastructure manager having *UC* as the unit cost, *TC* the total cost, *UT* the traffic unit, *TKm* the train-km, *KoT* the km of tracks, a viable configuration of unit cost is formalised in Eq. (1) as the ratio between the total cost and train-km:

$$UC = \frac{TC}{\mathrm{TKm}} \tag{1}$$

However, it should be noted that this value is influenced by the productivity of the network, meant as the ratio of the train-km of the period and the extension of the network. The train-km measurement represents a variable that is weakly influenced by the choices of rail infrastructure managers and instead, depends largely on the level of demand for rail transport, goods and passengers. It is therefore preferable to decompose this configuration of unit cost in order to represent it as the cost per km of network times and as the inverse of the network productivity, so formalised in Eq. (2).

$$UC = \frac{TC}{TKm} = \frac{TC}{KoT} * \frac{KoT}{TKm} \quad (2)$$

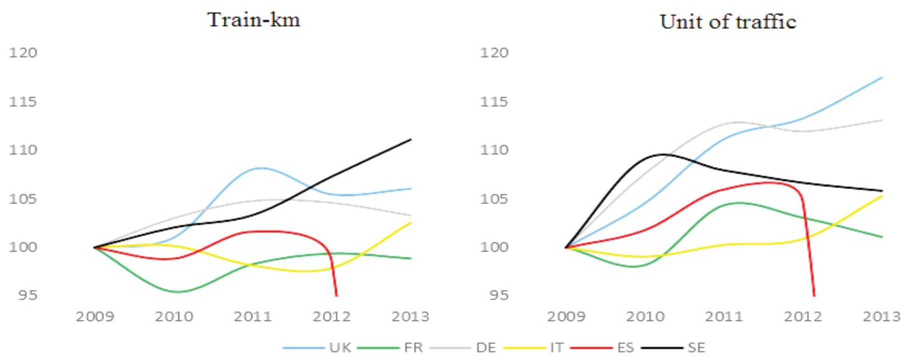
An additional configuration of unit cost is introduced in this way, one arising from the management cost per km of network, since we can reasonably expect to be, to a significant extent, under the control of the rail infrastructure managers. The manner in which this cost translates into cost for train-km depends on the productivity of the network, along with the intensity of its use. Moreover, it becomes useful to consider these differences, taking into account the load average. In this way, it is possible to consider one more definition of output – the total traffic unit – so calculating the unit cost of network per traffic unit as analytically represented in Eq. (3).

$$\frac{TC}{UT} = \frac{TC}{KoT} * \frac{KoT}{TKm} * \frac{TKm}{UT} \quad (3)$$

To improve the reliability of our analysis and make it consistent, the income statements of the infrastructure managers have been reclassified according to uniform criteria. Traffic data is then reconstructed accurately in the same manner. Nevertheless, we should take into consideration that: (i) unit costs higher than the average may be derived from the influence of unfavourable factors outside this economic model, whose effects should not be interpreted as inefficiency; and (ii) unit costs below the average may instead be influenced symmetrically by favourable exogenous environmental variables, which are not to be interpreted as greater efficiency. One could add that outside this economic model the price cap may automatically adjust for changes in specific prices that have strong implications for the profitability of the regulated firm.

Well-managed infrastructures enable economies of scale, shrink costs of trade, and are thus vital ingredient to economic growth and development. For railway infrastructure, benchmarking is an effective tool that can support the management in their pursuit of continuous improvement (Åhrén and Parida 2009). By focusing on maintenance performance indicators, the authors present case studies dealing with the application of benchmarking and maintenance performance indicators for the railway infrastructure. Similarly the International Union of Railways developed the Lasting Infrastructure Cost Benchmarking, an international benchmarking project (UIC 2008). More recently, the European Commission has started to benchmark the efficiency of infrastructure managers in terms of reliability and punctuality, capacity and availability), safety, asset management, maintenance and renewals (European Commission 2013b).

It is now possible to the productivity of the networks according to the indicators of train per km of rail track and traffic unit per km of rail track. Here, the German figure comes first, Italy and Great Britain follow, then the French network, Sweden comes later and the Spanish network is ranked lowest ranked. As previously mentioned, we should specify that the performance of a network depends on many factors. On one side, management decisions in conjunction with decisions concerning the planning, investment and financing of the infrastructure as well as the regulatory choices; on the other side, the presence of external factors which may or may not be favourable. The intensity of the network use, for example, increases with the population density of an area and the propensity of the demand for rail transport services. To this extent, those countries with low population density such as Sweden, Spain and France are disadvantaged in comparison to symmetrically advantaged countries with high population density such as Great Britain and Germany. These two measures are affected by the composition of demand for rail transport services. The higher the proportion of rail freight transport the higher the value of productivity that refers to traffic units, but at the same time, the lower the value for the productivity indicator referring to the train-km. In fact, freight transport usually concentrates many traffic units per train, more than passenger transport. Symmetrically a high proportion of the short-distance passenger service is, in turn, characterised by a lower number of traffic units per train, so thus influencing the productivity indicator relative to the train-km while penalising the indicator referring to traffic unit. With reference to cost indicators, the two most significant among those considered appear to be the costs per train-km and the cost per traffic unit. In this case, the countries with the best performances appear in the left corner. On the basis of these figures one can infer that a network outperforms in the presence of low values of both indicators or likewise lower values of an indicator in the presence of an identical value of the second indicator. According to the information contained in table 1 and table 2, it is possible to rank the productivity of the networks as per the cost per train-km and cost per traffic unit. First comes the Swedish rail network followed by Germany, Italy and Spain, then France and Great Britain. The French network appears at the tail group, along with Spain and Great Britain, even if no unique ordinal value applies with respect to Spain and Great Britain. This is because the French network outperforms Spain and Great Britain according to the traffic unit indicator but not in the case of the train-km indicator. It is also considered appropriate to monitor the evolution of the networks capacity over time. In fact the above analysis can be extended to five years.



Source: own elaboration

Graph 1 – Evolution of train-km and UT

Graph 1 shows that both train-km and traffic unit have increased in the Swedish and Italian networks. Among other possible interpretations, one viable explanation for this is the liberalisation of the Swedish network, introduced in 2010, and the advent of competition in the Italian high-speed (HS) market segment in 2012. However, the traffic level or even traffic expressed through the train-km is not a reliable indicator to capture the dynamics of the levels of transportation that would otherwise be better expressed through the traffic units. In fact, the average load of trains could evolve over time and this has happened in Germany and Great Britain. Taking into consideration the total train-km, these two countries ended up with a weak increase (+5%). Instead, these two countries have registered stronger dynamics in terms of traffic unit. Graph 1 also confirms the steadiness of the Spanish and French networks. More recently, the good performance of the Italian network has been a consequence of the growth in supply followed by the increase in high-speed passenger service demand. The case of Sweden is less inspiring, where the increased supply in the passenger segment has not found a corresponding growth in demand; freight service traffic has also decreased. These foregoing considerations, connected to the production levels of the networks, can also be transposed to productivity levels, providing a picture of the substantial invariance of the infrastructures throughout the period considered. Instead, it is essential to observe the dynamics of the average cost, whether related to train-km or traffic unit. The mentioned facts may serve policy makers in different stages of the decision process, e.g. in the ex-ante evaluations, conducted prior to the implementation of a policy to contribute to its design and cost-effectiveness, and in interim evaluations, applied during implementation to improve the management of the policy. The same facts also play an important role in ex-post evaluations, which are made after the completion of a policy to assess the results achieved.

5. Costs and output

The process of comparing business processes and performance metrics to market bests or best practices within an industry has become vital in competitive markets. It is generally recognised that intra-industry comparisons allow those firms that operate in the sector to develop plans and it future allows policymakers to legislate better laws. The approach to making comparisons involves using more aggregate cost along with production information to identify strong and weak performing units. Using reliable and comparable data on cost and output Table 1 show industrial results mainly related to traffic intensity. In fact, as for vertical separation the effects change according to the traffic intensity. The situation that emerges from the analysis of the information collected shows a sector that is rooted in each of the six cases. First comes the length of the network. Table 1 indicates that only two out of the six networks exceed thirty thousand km; namely, the German rail network with thirty three thousand km and the French rail network with thirty one thousand km. Three networks are of similar length, ranking in the middle (the Spanish, the British and the Italian, which range from fifteen to seventeen thousand km) while the length of the Swedish network is roughly eleven thousand km. Second comes the length of track. Similarly, the networks of France and Germany are more extensive when compared with the remaining four networks; in these two, both infrastructure managers handle over fifty thousand km of tracks. The length of the other networks can then be ordered: 32 000 km in the case of UK, 24 000 km in Italy, 21 000 km in Spain, and 16 000 km in Sweden. Third comes the total train-km, representing the production network. One network exhibits an outstanding total level of traffic - the German network - hosting more than 1 billion train-km. Two networks (France and Great Britain) show an average traffic - which host more than 500 million train-km. Italy, with 330 million, ranks immediately after, while the Swedish and the Spanish networks host less traffic, both slightly below 200 million. Forth comes the yearly trains per km of rail track, as an indicator of network productivity. The average value of the six networks (as a simple mean) is 12700 yearly trains; or 35 daily trains per km of rail track. The Italian network ranks slightly above the mean value. Germany, with 47 trains and Great Britain, with 46 trains are above the average. The remaining three countries rank below average: France and Sweden with 27 trains, and Spain with 25 trains. Fifth becomes the average traffic unit per train. This represents the load of a train and here the average of the six networks combined is a little less than 200 units. The Italian data is identical to the medium, while the German figure slightly below. France and Sweden rank above average. France, due to of the effect of long-distance TGV trains, and Sweden, thanks to the substantial number of freight trains. Sweden and Great Britain lie below the average value due to the predominance of short distance passenger trains. Sixth becomes the traffic unit per km of rail track, representing a further indicator of productivity of the networks. The average value of the six networks is almost 2.5 million traffic units per km of rail track. Italy's figures are slightly above the average, as can be seen in Table 1 Sweden, France and Great Britain present data in line with the average. The Spanish network scores below, the average, while the German figures are much higher (over 3 million). Seventh becomes the row containing data referring to the average tracks per km of network. This data is aimed at transforming the cost per km of network to cost per km of rail track.

Table 1 – key industrial data

Variable	DE	FR	IT	UK	ES	SE
Length of network (Km)	33 300	30 600	16 800	15 800	15.100	11 000
Length of tracks (Km)	61 200	50 700	24 300	32 200	20 500	15 500
Total train-km (million)	1 042	500	332	541	185	151
Trains per km of rail track	17 000	10 000	14 000	17 000	9 000	10 000
Traffic unit per train	192	239	197	153	178	222
Traffic unit per km of rail track (million)	3 300	2 400	2 700	2 600	1 600	2 200
Tracks per km of network	1.8	1.7	1.5	2.0	1.4	1.4

Source: own elaboration; year 2012 – Adif; year 2013-14 – Network Rail; 2013 others.

Assuming that a reasonable set of data is available, it is important to measure performance from different perspectives, Table 2 contains key economic facts to be analysed along with industrial output. As one may expect, the total cost of the rail infrastructure appears to be correlated with its extension. The cost is higher in Germany at EUR 3.8 billion, stations considered, whereas in France the total cost amounts to EUR 2.9 billion and in Great Britain to EUR 3 billion. As can be seen in Table 2 the cost is not as much as in the residual countries. The average cost per km of network is EUR 102 000. Italy and France score in the middle at EUR 98 000 and EUR 95 000 respectively. Germany level is slightly above the average at EUR 115 000. The outliers are, on the one side, the British network with EUR 190 000 and, on the opposite side, the Swedish and Spanish with a cost approximately half of the average. The cost per km of rail track highlights an average value of EUR 60 000 over the six networks. Three networks come close to that value: the French with EUR 58 000, the German with EUR 62 000 and the Italian with EUR 67 000. The cost of the British rail network comes in at 50% higher than the average, EUR 93000. In terms of medium ranking value, the Spanish are at EUR 46 000, and the Swedish, EUR 35 000, correspondingly. The average cost per train-km is EUR 4.8. Amongst the networks selected, two countries present data close to the amount mentioned: Italy at EUR 4.9 and Spain with EUR 5.1. The higher values corresponds to Great Britain totalling up to EUR 5.5 (more expensive and more traffic than the median) and France with EUR 5.8 (more expensive and less traffic than the average). In contrast, Germany figures at EUR 3.7 (greater average cost and greater traffic than the median), while Sweden comes to EUR 3.6 (cheaper and less traffic than the average). The average cost per traffic unit amounts to EUR 0.25. The Italian (EUR 0.25) and the French (0.24) data are close to the arithmetic mean. Meanwhile, the cost per unit of the Spanish network (EUR 0.28) and the cost per unit of the British network (EUR 0.36) are above average. The average cost is higher than the German value (EUR 0.19) and the Swedish value (EUR 0.16) respectively.

Table 2 – Key Economic data (values in EUR)

Variable	DE	FR	IT	UK	ES	SE
Total cost of rail network managers (million EUR)	3 800	2 900	1 600	3 000	900	500
Cost per km of network	114 600	95 500	97 700	190 000	61 900	49 800
Cost per km of rail track	62 400	57 600	67 400	93 300	45 700	35 300
Cost per train-km	3.7	5.8	4.9	5.5	5.1	3.6
Cost per traffic unit	0.19	0.24	0.25	0.36	0.28	0.16

Source: own elaboration; year 2012 – Adif; year 2013-14 – Network Rail; 2013 others

From table 2 some interesting insights emerge; among others the good result of the Italian infrastructure both in terms of productivity and unit costs of the network. The cost of the British network results to be high but this disadvantage is partly offset by the intense traffic. The cost of the French network aligns itself in the middle, but, it is characterised by weak network productivity in terms of traffic density, which only a higher loading factor of the trains can rebalance. Two networks outperform: the German and the Swedish.

6. Average production cost and access charge

It is commonly recognized that network industries share some characteristics; nevertheless, each network industry has its own characteristics and specificities. On the one hand, the infrastructure segment displays features of natural monopoly and is thus usually subject to regulation on pricing and access to the network. This applies to the transmission and distribution networks in e-communications, energy, and transport infrastructures. On the other hand, as long as each operator gets a fair and transparent access to the infrastructure, competition can be ensured in service provision.

Among scholars of regulatory economics, the models for regulating optimal output, tariffs, and surplus subsidy schemes play a remarkable role which are aimed at regulating firms in a way that induces them to both produce and to price efficiently (Trail 1991). It is understood that a healthy regulatory environment will guarantee fair access to essential facilities, specifically in the presence of vertically related markets (Arrigo and Di Foggia 2014). Economic literature suggests a price-cap regulation is one of the most suitable forms to regulate access charges for essential monopolistic infrastructures (Carlton and Perloff 1994). Price cap regulation, as an alternative to traditional rate-of-return regulation, developed as a practical regulatory tool in the early 1980s, since then, price cap regulation has been adopted in a wide range of countries and industries. This tool of charge regulation defines ex-ante a price cap for a regulation period. Given a portfolio of products i, where i =1, ...,n products of quantity q and price p, by means of a measurement of current prices or quantities in relation to those of a selected base period i.e. the Laspeyres price index in the left-hand side of the formula, the price-cap formalisation becomes the following.

$$\frac{\sum_{i=1}^{n} q_{it-1} p_{it}}{\sum_{i=1}^{n} q_{it-1} p_{it-1}} \leq I_t - X_t \qquad (4)$$

According to Eq. (4) the increase of the regulated access charge is linked to the increase of inflation for the inputs It minus the increase of productivity Xt. The inflation for the input I and the increase in productivity X have to be chosen by the regulator. This regulatory scheme limits the infrastructure manager only as regards the price but not regarding the quantity of products and therefore revenues (Link 2013). The same author also advocates that within a price cap regulation, the regulatory body shall outline the inflation rate for the inputs It as well as the productivity growth X. By putting the government funding for rail infrastructure on the left-hand side of the price cap formula as part of the revenues as suggested by Mitusch *et al.* (2011), the regulated infrastructure manager shall limit the increase of its revenues by the differential between the inflation and productivity growth rate. Thus, as illustrated in Eq. (5) where S represents government funding for infrastructure.

$$\frac{\sum_{i=1}^{n} q_{it-1}(p_{it} - p_{it-1}) + S_t - S_{t-1}}{\sum_{i=1}^{n} q_{it-1} p_{it-1} + S_{t-1}} \leq I_t - X_t \qquad (5)$$

In case of no government funding, Eq. (5) collapses into Eq. (6) i.e. the standard formula. This also holds if government funding increases with the same growth rate $I_t – X_t$. this happens, for example if $S_t = S_t$-1 $(1 + I_t – X_t)$.

Previous literature suggests that the control of governments funding has become a prominent topic to protect fair competition in Europe. State aid control should more effectively target sustainable growth enhancing policies while encouraging budgetary consolidation, limiting distortions of competition and keeping the single market open (Arrigo and Di Foggia 2013). Finally, if public expenditure remains constant in nominal terms, e.g., if S_t=S_t-1= S, the price-cap formula converges in the Eq. (6).

$$\frac{\sum_{i=1}^{n} q_{it-1}\,(p_{it}-p_{it-1})}{\sum_{i=1}^{n} q_{it-1}\,p_{it-1}+S} \leq I_t - X_t \qquad (6)$$

This analysis of unit cost concludes with a comparison with the average revenues from access charges. As shown in Table 3, the access charge varies according to the adoption of different charging models in different countries. Sweden, for example, has opted for a marginal cost charging model, hence applying low charges – EUR 0.5 per train-km in 2013 – that are integrated by transfers from the public sector up to the complete coverage of the cost. In the same token, the Spanish case is relatively close to the Swedish one, with relatively low access charge for the use of the conventional network and the cost coverage ratio through access charges at about 40%. Italy represents an intermediate case given that the average access charge for use of the infrastructure, EUR 3.3 per train-km, is aimed at covering approximately two-thirds (67%) of the average cost, and is supplemented by EUR 1.6 of government subsidy to cover the cost. In Great Britain, 90% of the average cost per train-km is covered by the access charge. In Germany, the average access charge, EUR 4.4 per train-km, ends up being higher than the average cost per train-km that amounts to EUR 3.7, since it is aimed at covering investment and depreciation costs. Finally, the French case is not fully comparable with the others as per access charges; in fact, those charges for regional services are borne by the public sector, therefore, represent transfers rather than access charges from the market.

Table 3 – Cost and access charge

	DE	FR	IT	UK	ES	SE
Cost per train-km (EUR)	3.7	5.8	4.9	5.5	5.1	3.6
Access charge (EUR)	4.4	6.6	3.3	4.9	2.1	0.5

Source: own elaboration

7. Breakdown output of the rail infrastructure networks

Table 4 – Facts of the British rail infrastructure

Great Britain	2009	2010	2011	2012	2013
NETWORK	*(Thousand km)*				
Length of network	15.8	15.8	15.8	15.8	15.8
Length of tracks	32.2	32.2	32.2	32.2	32.2
Tracks per km of network	2.0	2.0	2.0	2.0	2.0
TRAFFIC	*(million)*				
Passenger train-km	470.6	476.8	510.4	497.9	500.6
Freight train-km	39.6	38.7	40.8	40.2	40.4
Total train-kilometre	510.2	515.5	551.2	538.1	541.0
TRANSPORTED QUANTITY	*(billion)*				
Passenger-km	51.4	54.5	57.3	58.4	60.1
Ton-km of goods	19.1	19.2	21.1	21.5	22.7
Traffic unit (passenger-km + tons-km)	70.5	73.7	78.4	79.9	82.9
PRODUCTIVITY OF TRAINS	*(unit)*				
Average passenger per passenger train	109	114	112	117	*120*
Average tons per freight train	481	497	517	534	*561*

Average traffic unit per train	138		143	142	148	*153*
PRODUCTIVITY OF NETWORK			*(thousand)*			
Yearly trains per km of network	32.3		32.6	34.9	34.1	*34.2*
Yearly trains per km of rail track	15.9		16.0	17.1	16.7	*16.8*
			(million)			
Yearly traffic unit per km of network	4.5		4.7	5.0	5.1	5.2
Yearly traffic unit per km of rail track	2.2		2.3	2.4	2.5	2.6

Source: own elaboration on data ORR. Office of Rail Regulation. Latest available year provisory

Table 5 – Facts of the French rail infrastructure

France	2009	2010	2011	2012	2013
NETWORK			*(Thousand km)*		
Length of network	30.9	30.3	30.4	30.6	30.6
Length of tracks	51.3	50.3	50.4	50.7	50.7
Tracks per km of network	1.7	1.7	1.7	1.7	1.7
TRAFFIC			*(million)*		
Passenger train-km	422.8	407.4	425.1	426.9	430
Freight train-km	82.9	75.4	72.0	75.7	70
Total train-km	505.7	482.8	497.1	502.6	500
TRANSPORTED QUANTITY			(billion)		
Passenger-km	85.9	85.9	89.0	89.1	87.3
Ton-km of goods	32.1	30.0	34.2	32.6	32.0
Traffic unit (passenger-km + tons-km)	118.0	115.9	123.2	121.7	119.3
PRODUCTIVITY OF TRAINS			(unit)		
Average passenger per passenger train	203	211	209	209	203
Average tons per freight train	388	397	475	430	457
Average traffic unit per train	233	240	248	242	239
PRODUCTIVITY OF NETWORK			(thousand)		
Yearly trains per km of network	16.3	15.9	16.3	16.4	16.4
Yearly trains per km of rail track	9.9	9.6	9.9	9.9	9.9
			(million)		
Yearly traffic unit per km of network	3.8	3.8	4.1	4.0	3.9
Yearly traffic unit per km of rail track	2.3	2.3	2.4	2.4	2.4

Source: own elaboration on data RFF, *Comptes des Transports* and Eurostat.

Table 6 – Facts of the German rail infrastructure

Germany	2009	2010	2011	2012	2013
NETWORK			*(Thousand km)*		
Length of network	33.7	33.7	33.6	33.5	33.3
Length of tracks	62.0	62.0	61.8	61.6	61.2
Tracks per km of network	1.8	1.8	1.8	1.8	1.8
TRAFFIC (estimated)			*(million)*		
Passenger train-km	780	783	794	788	782
- Long distance	151	149	152	144	140
- Local (regional)	629	634	642	644	642
Freight train-km	229	256	263	267	260
Total train-km	1.008	1.039	1.057	1.055	1.042
TRANSPORTED QUANTITY			(billion)		
Passenger-km	81	83	86	88	*89*
- Long distance	35	36	37	37	*37*
- Local (regional)	47	48	50	51	*52*
Tons-km of goods	96	107	113	110	*112*

Traffic unit (passenger-km + tons-km)	177	190	199	198	*200*
PRODUCTIVITY OF TRAINS			(unit)		
Average passenger per passenger train	104	106	108	112	*114*
- Long distance	232	242	244	257	*265*
- Local (regional)	75	76	77	79	*81*
Average tons per freight train	420	419	430	412	*430*
Average traffic unit per train	175	183	189	188	*192*
PRODUCTIVITY OF NETWORK			(thousand)		
Yearly trains per km of network	29.9	30.8	31.5	31.5	31.3
Yearly trains per km of rail track	16.3	16.8	17.1	17.1	17.0
			(million)		
Yearly traffic unit per km of network	5.2	5.6	5.9	5.9	*6.0*
Yearly traffic unit per km of rail track	2.9	3.1	3.2	3.2	*3.3*

Source: own elaboration on data BnetzA, DB Competition Report, Eurostat.

Table 7 – Facts of the Italian rail infrastructure

Italy	2009	2010	2011	2012	2013
NETWORK			*(Thousand km)*		
Length of network	16.7	16.7	16.7	16.7	16.8
Length of tracks	24.2	24.2	24.2	24.3	24.3
Tracks per km of network	1.4	1.4	1.4	1.5	1.5
TRAFFIC			*(million)*		
Trenitalia's Train-km on the network managed by RFI	307.2	301.8	275.5	259.3	266.1
M - Medium-long distance passenger	*80.1*	*78.1*	*76.6*	*71.1*	77.5
- Local (regional) passenger	*187.1*	*189.2*	*157.7*	*154.8*	154.5
- Total passenger	*267.2*	*267.3*	*234.4*	*225.8*	*232.1*
- Goods	*36.1*	*30.8*	*28.9*	*28.7*	27.8
Train-km generated by other railway undertakings on the network managed by RFI	16.3	22.1	41.8	57.1	65.6
Total train-km	323.4	323.9	317.4	316.4	331.6
TRANSPORTED QUANTITY			(billion)		
Trenitalia					
- Passenger-km Trenitalia medium-long distance	*22.2*	*20.6*	*20.2*	*18.4*	*18.9*
- Passenger-km Trenitalia local (regional)	*22.2*	*22.7*	*19.2*	*19.0*	*18.9*
Total passenger-km Trenitalia	*44.4*	*43.3*	*39.4*	*37.5*	*37.8*
Tons-km of goods Trenitalia	*15.2*	*13.4*	*13.0*	*12.8*	*11.9*
Total traffic unit Trenitalia	59.6	56.8	52.3	50.2	49.7
Other railway undertakings (estimated)					
- Passenger-km other railway undertakings	*0.0*	*0.0*	*3.7*	*5.5*	*8.2*
- Tons-km of goods other railway undertakings	*2.5*	*4.8*	*6.3*	*7.0*	*7.6*
Total traffic unit other railway undertakings	*2.5*	*4.8*	*10.0*	*12.5*	*15.7*
Total traffic unit	62.2	61.6	62.3	62.7	65.4
PRODUCTIVITY OF TRAINS (only Trenitalia)			(unit)		
Average passenger per passenger train	166	162	168	166	163
- Long distance	278	264	263	260	243
- Local (regional)	118	120	122	123	122
Average tons per freight train	422	436	448	445	429
Average traffic unit per train	197	190	199	197	191

PRODUCTIVITY OF NETWORK			**(thousand)**		
Yearly trains per km of network	19.4	19.4	19.0	18.9	19.8
Yearly trains per km of rail track	13.4	13.4	13.1	13.0	13.6
			(million)		
Yearly traffic unit per km of network	3.7	3.7	3.7	3.7	3.9
Yearly traffic unit per km of rail track	2.6	2.5	2.6	2.6	2.7

Source: Own elaboration on data RFI, Trenitalia and Conto Nazionale dei Trasporti.

Table 8 - Facts of the Spanish rail infrastructure

SPAIN	2009	2010	2011	2012	2013
NETWORK			*(Thousand km)*		
Length of network	13.5	14.0	14.1	14.1	15.1
Length of tracks	18.1	19.2	19.4	19.4	20.5
Tracks per km of network	1.3	1.4	1.4	1.4	1.4
TRAFFIC			*(million)*		
Passenger train-km	161.2	159.4	164.1	160.7	168.8
- Cercanias (local)	*59.8*	*59.2*	*60.1*	*103.1*	*108.4*
- Medium distance	*41.7*	*41.4*	*44.2*		
- Long distance	*59.7*	*58.8*	*59.7*	57.6	60.3
Freight train-km	26.1	25.8	26.3	24.1	23.9
Total train-km	187.3	185.2	190.4	184.9	192.7
TRANSPORTED QUANTITY			*(billion)*		
Passenger-km	21.8	21.0	21.5	21.1	22.6
- Cercanias (local)	7.6	7.3	7.5	10.7	10.6
- Medium distance	3.4	3.3	3.4		
- Long distance	10.8	10.4	10.6	10.4	11.9
Tons-km	7.9	9.2	9.9	10.0	10.4
Traffic unit (passenger-km + tons-km)	29.7	30.2	31.5	31.1	33.0
PRODUCTIVITY OF TRAINS			*(unit)*		
Average passenger per passenger train	135	132	131	132	134
- Cercanias (local)	126	123	125	104	98
- Medium distance	81	80	78		
- Long distance	181	177	177	181	198
Average tons per freight train	304	357	378	412	435
Average traffic unit per train	158	163	165	168	171
PRODUCTIVITY OF NETWORK			*(thousand)*		
Yearly trains per km of network	13.9	13.2	13.5	13.1	12.7
Yearly trains per km of rail track	10.3	9.6	9.8	9.5	9.4
			(million)		
Yearly traffic unit per km of network	2.2	2.2	2.2	2.2	2.2
Yearly traffic unit per km of rail track	1.6	1.6	1.6	1.6	1.6

Source: own elaboration on data *Observatorio del Ferrocarril, Adif, Renfe Operadora* and Eurostat.

Table 9 – Facts of the Swedish rail infrastructure

SWEDEN	2009	2010	2011	2012	2013
NETWORK			*(Thousand km)*		
Length of network	11.1	11.2	11.2	11.1	11.0
Length of tracks	15.5	15.5	15.6	15.6	15.5
Tracks per km of network	1.4	1.4	1.4	1.4	1.4
TRAFFIC			*(million)*		
Passenger train-km	95.4	98.0	97.0	106.0	113.0

Freight train-km	40.4	40.6	43.4	39.7	37.9
Total train-km	135.8	138.6	140.3	145.7	150.9
TRANSPORTED QUANTITY			(billion)		
Passenger-km	11.3	11.2	11.4	11.8	11.8
Tons-km	20.4	23.5	22.9	22.0	21.7
Traffic unit (passenger-km + tons-km)	31.7	34.6	34.2	33.8	33.6
PRODUCTIVITY OF TRAINS			(unit)		
Average passenger per passenger train	119	114	117	111	105
Average tons per freight train	504	577	527	555	574
Average traffic unit per train	233	250	244	232	222
PRODUCTIVITY OF NETWORK			(thousand)		
Yearly trains per km of network	12.2	12.4	12.5	13.1	13.8
Yearly trains per km of rail track	8.8	8.9	9.0	9.3	9.8
			(million)		
Yearly traffic unit per km of network	2.8	3.1	3.1	3.0	3.1
Yearly traffic unit per km of rail track	2.0	2.2	2.2	2.2	2.2

Source: own elaboration on data Trafa – Trafik analys, *Bantrafik 2013*.

Concluding remarks

The last decade has seen significant developments in the liberalisation and deregulation of the railway industry in Europe. One characteristic has been vertical disintegration and the separate regulation of previously state-owned companies.

This study has focused on the measurement of the quality of rail infrastructure managers' policies, infrastructure output and productivity. The objectives of the benchmarking have been targeted to determine what and where improvements are called for and to analyse the determinants of high performance levels in those organisations that have been shown to maintain high quality standards in their service delivery. That is why this paper has founded worthwhile to reclassify, using homogeneous criteria, the income statements of six European rail infrastructure managers. In an effort to fine-tune the analysis the paper has also rebuilt the traffic data in these countries in order to compute productivity and cost indicators for the rail infrastructure networks.

The results, based on indicators of unit cost, suggest that the two most productive rail network is in Sweden, with a network that is efficiently managed leading to reduced cost, and Germany, which has a network characterised by significant rail traffic, which is then able to improve productivity and to bring down the unit cost.

The Italian case is ranked third among the six networks and is also to be considered the only rail infrastructure in which traffic and productivity have increased while the production cost has decreased. The remaining three networks show mixed results. The cost of the Spanish rail network is relatively low but this advantage is eroded by weak traffic. Great Britain has a rail infrastructure that is fairly expensive in terms of production cost and this factor is only partially offset by an intense circulation.

The French network, finally, has a production cost in line with the average, along with aproductivity below the average in terms of trains per km of rail track and where only a higher average train load can rebalance this situation. Sweden deserves some additional considerations being that it has been shown to be the most sustainable in this study, and is therefore considered the benchmark for all the others. Being that the low Swedish network cost is only partly offset by the productivity of the network, one lower than the European average, Sweden is a case of high interest that should be investigated in depth to verify how the mentioned performance stems from an organisational model unique in Europe.

The Swedish model is characterised by (i) public management that is integrated with the management of the road network by the public agency named Trafikverket; (ii) outsourcing of line maintenance where maintenance services are assigned via an efficient system of tenders; and iii) flexible organizational structure. The strong performance of the Italian infrastructure was made possible both by the reduction of production cost and through an increase in traffic, particularly in the liberalised segments. The above statements also provide support for policy. The incentive for managers to pursue activities that reduce costs will depend on the rewards that they receive from any cost reduction. The higher benefit of any cost reduction the higher (and socially desirable) the incentives to pursue activities that reduce costs, and vice versa. This paper has political implications for regulatory bodies since it has provided pieces of information to serve them in issues such as the regulation according to objective criteria to improve performance. On the basis of the results obtained, regulatory bodies are supported in establishing clear and consistent objectives through a strategy of growth, investment and repercussion that the services provided generate on the general wellbeing.

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