RAILWAY (DE)REGULATION:

A EUROPEAN EFFICIENCY COMPARISON[1]

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Abstract

Many European countries have sought to increase the efficiency of national railroad companies through a range of reforms: separating infrastructure and operations, creating independent regulatory institutions and providing access to the network to third parties. To estimate the effects of reforms on railroad efficiency, we investigate a new panel data set, which covers many EU countries over a period of more than 20 years. Comparing the efficiency of national railroad companies by means of a production frontier model, we find that efficiency increases when reforms are implemented. However, this effect depends on sequencing: introduction of multiple reforms in a package has negative effects, while sequential reforms improve efficiency. We also show that our results are robust against potential problems of endogeneity.

Keywords: production frontier, network industries, panel data analysis, passenger and freight traffic, LISREL.

JEL codes: L51, L92, D24, C23

1. Introduction

By the end of the 20th century, railroads were in dire straits. Most national railways companies were heavily subsidized (Crozet et al., 2000, Friederiszick et al. 2003), but the shares of railroads in total (inter-modal) transportation were, at best, stable. In many European countries, rail market shares decreased throughout the nineties (European Commission, DG Energy and Transport, 2002). Moreover, surveys show low levels of customer satisfaction with railway services in many countries (INRA, 2000).

The European Commission, in its *White Paper* (EC, 2001), has declared the development of the European railway system a priority for achieving sustainable development in Europe with the explicit goals of promoting railways, increasing their market share, and reducing subsidies. Based on the experience in a number of countries throughout the 1980s and 1990s, the cornerstones of the EC reform model (EC, Directive 91/440) are: a) to unbundle infrastructure from operations, that is, to separate them fully or create separate organizations and accounts within one holding, b) to create independent regulatory institutions for railways, c) to open access to national railway markets for competitors ("third party access"). The so-called "Third Railway Package" (EC, 2004) builds on these pillars of deregulation and takes further steps to integrate the European railroad market, to increase competition and to strengthen passenger rights.

There is a firm belief among many policy-makers on both EU and national level that these reforms increase efficiency. However, while there is a substantial literature on efficiency in the railway industry (Cantos et al. 1999, Cantos et al. 2000, Coelli and Perelman, 1999, Cowie and Riddington, 1996, Gathon and Perelman, 1992, Oum and Yu, 1994), little is known about how regulatory reforms have affected railway efficiency. We are only aware of two papers. Cantos et al. (1999) analyze the impact of four types of reforms on different dimensions of railway efficiency. They look at separation between infrastructure and operations, changes in the legal constitution of companies, degree of regulation of prices, and degree of government influence over investment. They find that vertical separation appears to have had the strongest impact. However, the construction of their regulatory variables does not allow using variations over time, but only across countries. Gathon and Pestieau's (1995) cross-sectional study indicates that constraints on managerial autonomy may reduce the efficiency of railway firms. Conversely, deregulation would increase efficiency, as it provides managers with more autonomy and increases competitive pressure.

In this study, we investigate systematically to what extent third-party access, independent regulation, and separation of infrastructure have affected railway performance. Not only is this interesting to better understand the determinants of railroad performance, but also to learn more about the effect of deregulation on industry performance in more general terms. To our knowledge there exist no comparable studies for other network industries.

Indeed, it is rarely the case to have enough cross-country variation and variation over time to disentangle reform effects from other influences. For railroads, however, different countries have implemented the reforms proposed by the European Commission to different degrees and at different times, making it possible to identify the impact of regulatory regimes on railway performance. We apply the production frontier approach, pioneered by Farrell (1957). We use a new World Bank (2003) panel dataset that builds on data from the International Union of Railroads (UIC) and provides information about inputs and outputs for twelve European countries, over the period 1980-2003. We match this dataset with information about regulatory reforms in these countries and look at the impact of reforms on the efficiency in passenger traffic.

The main findings are as follows: First, our regressions show that reforms have positively affected railroad productivity. Deregulation improves the productivity trend of a country, an effect that corresponds to an average output increase of 0.5 percent per year. Second, higher reform intensity does not necessarily increase productivity. Rather it depends on sequencing of reforms. In countries in which reforms are implemented in a sequential way, productivity increases, while the opposite is true in countries that have implemented packages of reforms. Third, our regressions provide a measure of total productive efficiency. We find that in many countries, gains in total productive efficiency are highly correlated with staff cuts. Finally, on a methodological level, we are able to reject potential endogeneity of reforms and other explanatory variables by investigating the structure of the variance-covariance matrix using the LISREL technique.[5]

Section 2 discusses some methodological points. Section 3 presents the data. Section 4 introduces the econometric model and looks at endogeneity. Section 5 presents regression results and efficiency measures. Section 6 discusses why sequencing may matter and the relation of our results to the experience from other network industries. Section 7 concludes.

[5] This technique was introduced by Jöreskog (1973) and used in a similar context before by Ivaldi et al (1995).

2. Methodological remarks

A comment is in order here to better understand the rationale and methodological basis for our approach.[6] Railroads are multi-output firms: they produce short haul (regional) and long haul passenger service, various types of freight operations and infrastructure access. Since long, it has been recognized that aggregating several outputs into a single output involves methodological issues (see Klein, 1953). The question has received further attention in the literature, for instance, in the often-quoted articles by Mundlak (1963) and Caves, Christensen and Diewert (1982). Output distance functions have been advocated as a solution. Coelli and Perelman (1999), for instance, look at multi-output European railroads and compare different estimation methods for output distance functions (a parametric frontier using linear programming, data envelopment analysis, corrected ordinary least squares) to measure technical inefficiency. Interesting enough, the differences among estimation methods are smaller than expected, which suggests the use of a combination of different methods to further improve efficiency estimates. However, the discussion of stochastic distance functions of Khumbhakar and Lovell (2000) suggests that it is difficult to handle two conflicting goals by means of a production function: to deal with the problem of endogeneity and high correlation among outputs and inputs, while trying to obtain the best approximation of the production function. A cost function approach would be more appropriate, but a coherent database on railroads' costs is far from being available. Hence, we are left with the use of production frontier to estimate efficiency.

Estimating a multi-output technology by means of a production frontier (as we do in this paper) is the outcome of a compromise between research objectives,

[6] We thank the referee for many helpful hints concerning these methodological considerations.

availability of data, flexibility of the parametric approximation, estimation method, and aggregation issues. In this respect it is important to note that our main goal is to provide a better understanding of the effect of regulatory reforms on the market for passenger transportation, rather than to provide the best global approximation of the full production possibility set (PPS) of railroads. When – as in our case - the objective is to identify and explain rather than to predict, a simple approximation (like a Cobb-Douglas production function) of the PPS performs well at the mean point (see for instance, Florens, et al. (1996)). Now, as in contrast to North America, the bulk of European rail traffic volumes consist in passenger transportation, we propose to estimate the efficiency of railroads conditional on realized freight activities.

To do this, we consider a Cobb-Douglas function, which implicitly assumes separability between outputs and inputs. We allow for the aggregation of outputs using a log linear relationship, whose main parameter is estimated together with the other parameters of the production function. We thus estimate the effect of reforms on passenger traffic by controlling for the congestion effect of freight traffic. In other words, the restricted output distance function we estimate does not entail all second-order terms to account for the most flexible representation of the technology, but the aggregation process is endogenously estimated. Coupled with the application of LISREL method, we believe that we reach a good compromise to produce meaningful and hopefully robust results.

3. The Data

The World Bank (2004) data set comprises coherent and complete input and output information on railway industries of twelve EU countries: Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden.

Data cover 1980 to 2003, the period in which all reforms in the railroad sector have occurred in Europe.

Unfortunately, data for United Kingdom are not complete. In particular, as a result of the reforms, there is no consistent information about staff of railroad firms for the period from 1995 to 2003. The reforms affected the national statistics; part of railroad staff has since then been accounted for in other industries like construction or consulting. Compared to other countries, the number of employees in the railway industry is hence substantially underestimated. This makes it hazardous to evaluate railroads efficiency in the most interesting period. We have thus have excluded UK from most of our regressions.

Table 1 provides an overview of the data. In terms of output we will look at *passenger kilometers* and *freight ton kilometers*. Table 1 reports means per country over the investigation period, showing that, in most countries, both outputs have increased in absolute values.

In the case of railroads, it is difficult to identify the correct input measures. Railroads are often integrated firms. The intermediate input "network" is produced by the inputs labor and land. This intermediate input network, additional labor, and rolling stock are then used in the production of the final outputs, *passenger-kilometers* and *freight-ton-kilometers*. The last column represents the measure for labor, *staff*, employed by railway carriers. In the regression this variable will be labelled L_{it}.

To find the right measure of capital input is not so easy a task. There are two problems: First, rolling stock can be interpreted both as input or output. At given labor and finance input, for instance, a company can decide to produce more passenger kilometers with old rolling stocks or higher quality traffic with new rolling stock. Similarly, a company can decide to build new faster or better tracks. In order to avoid this potential confusion between inputs and outputs, we focus on *route kilometers* as the second input besides *staff*. Route kilometers measure the total size of the network without taking into account whether a given connection has single, double or multiple tracks. They thus have the convenient feature to be clearly inputs, not outputs: In the mature networks of European countries, only few new routes are built. Actually, throughout the period we are interested in, route kilometers have decreased rather than increased in most countries. In the regressions, route kilometers are labelled K_{it}.

We have matched these physical data with information about reforms. Table 2 presents these deregulation data. It reports the year in which regulatory reforms were introduced and stems from a variety of documents: Erasmus University (1999), SORT-IT (1999), OECD (1998), Stoffaes et al (1995), Prognos (1998). We have updated these sources by our own research on the web. The data have the advantage of capturing the effects of regulatory changes both over time and across countries. They have the disadvantage that they report the state of national laws, and not the implementation of these laws. Moreover, there are many reform specificities across countries. There are thus certain limits concerning the extent to which one can interpret the results. We discuss these issues further in the next section.

4. Econometric specification and endogeneity

4.1 Specification

The frontier production function specifies which level of output can be achieved, if all decisions were taken according to “best practice”. As the frontier production function defines a theoretically achievable optimum, all empirical observations must lie below it. Consider the Cobb-Douglas function:

$$y = AK^{\alpha_K} L^{\alpha_L} .$$

In our regressions, output y is the weighted sum of passenger and freight kilometres.[7] Inputs are route kilometers (K) and staff (L). Expressed in logarithms, the production function becomes:

$$\ln y = A + \alpha_K \ln K + \alpha_L \ln L.$$

As we use a panel data set, we account for individual (country) fixed effects and time trends. For country i at time t, total factor productivity can be specified as:

$$A_{it} = \alpha + u_{it},$$

where u_{it} measures what we call *total productive efficiency*, which potentially varies across countries and over time. We further decompose total productive efficiency in order to learn about the effects of technological progress and institutional reforms. In particular, we assume that the term u_{it} can be decomposed as follows:

$$u_{it} = (\gamma_i + \theta_0 Deregulation_{it})t + \varepsilon_{it} \quad (1)$$

The term $(\gamma_i + \theta_0 Deregulation_{it})$ represents *technological progress*. Parameter γ_i represents a *country-specific* trend and captures the simple idea that for reasons exogenous to the model, some countries may engage in more technological innovations than others. The second term in the parentheses is supposed to capture the *effect of deregulation*, that is, we allow for technological progress to depend on whether or not a country has reformed its railroad industry. One could, alternatively, use a specification in which deregulation would enter in an additive way and not in a multiplicative way with time. However, our specification allows for more flexibility in estimating technological progress; reforms may affect the slope of the trend, rather than resulting in parallel shifts of a trend with a given slope.

[7] See page 10 for a discussion of how to determine the weights.

We use different definitions and specifications for the dummy variables $Deregulation_{it}$. In the first step the dummy variable takes value 1 if a country has introduced (and maintained) at least one of three reforms we look at, and is nil otherwise. Other specifications will distinguish intensity and packaging of reforms.

We allow for technical progress to be country-specific while our specification assumes that deregulation variables affect countries in the same way. The term ε_{it} comprises all effects that are neither related to technological progress nor to deregulation.

The equation we estimate is then:

$$\ln y_{it} = \alpha + \alpha_K \ln K_{it} + \alpha_L \ln L_{it} + (\gamma_i + \theta_0 Deregulation_{it})t + \varepsilon_{it}. \qquad (2)$$

4.2 Output measures: total traffic versus passenger traffic

As discussed in the Introduction, we are mainly interested in the efficiency of passenger transport. That is, we will regress route-kilometers (*K*), labor input (*L*) and the deregulation variables further defined in section 4 on passengers-kilometers. As we have no information about how capital and labor are allocated for the production of passenger and freight traffic, we have to control econometrically for the effect of freight transportation on passenger traffic efficiency. In order to do so, we estimate Equation (2), using an aggregate (global) output measure defined as

$$\ln y_{it} = \ln passkm_{it} + \lambda \ln tonkm_{it} \qquad (3)$$

In what follows, we use $\hat{\lambda}$, the estimate of λ that provides the best fit of the model, that is to say estimate equation (2), introducing the variable ln*tonkm* on its right-hand side. For different specifications, $\hat{\lambda}$ lies between 0.22 and 0.33. That is, on average, if freight traffic increases by one percent, passenger traffic decreases by up to one third of a percent. The advantage of our method is that we receive an empirical measure for the congestive effects of freight on passenger traffic, rather than using *ad hoc* measures. Other studies have assumed, for instance, that each passenger equals a certain fixed weight of freight, specifically 80 kilograms. According to our estimate, the congestion effect owing to freight is higher.[8]

4.3 Endogeneity and LISREL estimates

With the specification we use, there is a potential problem of endogeneity. While we control for individual (country-level) effects, we can *a priori*, not exclude correlations of these individual effects with inputs (capital, labor). If there were such correlations, the regression results and the measure for efficiency, which is based on the error terms of the regression, would be biased.

We use the LISREL ("Linear Structural Relations")[9] method to verify whether or not this type of correlation is present in the data. LISREL has the convenient feature of estimating all possible correlations between inputs and individual effects and hence, for our case, between input quantities and individual technical efficiency levels. In Appendix 2, we briefly present the method.

Table 6 summarizes the results of the LISREL analysis. By looking at the co-variances of different variables and at their associated t-values, we conclude that correlations between variables are not significant. The results of our regressions are thus unbiased.

[8] It should, however, be noticed that this is lower than the estimate in Nash (1985).
[9] See Jöreskog (1973, 1996).

5. Regression results and efficiency comparison

In what follows we present and discuss the OLS regressions that provide us with estimates for the country-specific productivity trend γ_i, for the effects of deregulation θ. These, are then combined with the residuals to our measure of total productive efficiency.

5.1 Regression results

Table 3 presents the regression results when considering a simple dummy variable for deregulation events that takes value one if any of the three reforms has been implemented and zero otherwise. We have run the regression both including and excluding United Kingdom. The dependent variable is aggregated output as defined in equation (3).

The parameter estimates for labor and capital are in line with what could be expected for a network industry like railroads. As $\alpha_K + \alpha_L > 1$, there are increasing returns to scale. Note also that in all countries except Finland, the productivity trend is positive. The regression shows that, excluding United Kingdom, deregulation increases the productivity trend of a country at the 5%-level of statistical significance. This corresponds to an additional output of on average 0.5 percent per year after deregulation.[10]

These effects are statistically less significant when one includes United Kingdom. This points to the problem with United Kingdom data. With the beginning

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[10] To compute the magnitude, we first write output as $y = AK^{\alpha_K} L^{\alpha_L} e^{\theta Deregulation t} e^{\gamma_i t} e^{\varepsilon}$. To measure of the effect of deregulation dummy on output, we compute $E(y / Deregulation = 1, t + 1) - E(y / Deregulation = 1, t)$. Notice that as $\hat{\theta}_0$ is normally distributed with mean θ_0, $e^{\hat{\theta}_0}$ follows a lognormal distribution with mean: $E(e^{\hat{\theta}_0}) = \exp(\hat{\theta}_0 + \frac{1}{2}\hat{\sigma}_{\hat{\theta}_0}^2)$. As an example, the total technological progress term for Austria changes from 0.012 to 0.017, for Germany from 0.03 to 0.035, and for France from 0.048 to 0.053, after introduction of deregulation.

of reforms, data quality for United Kingdom has declined, and data for staff since 1995 are missing. In what follows we thus run our regressions without United Kingdom.

The first regression shows that reforms have affected railroad productivity in a positive way. In order to see whether more reforms are better than one reform, we have constructed a second set of reform variables: $DeregulationOneAspect_{it}$, which takes the value 1 when one and only one aspect of the deregulation is implemented, whatever happens later, and 0 otherwise. $DeregulationTwoAspects_{it}$ takes the value 1 when two or more aspects of the deregulation are implemented and 0 otherwise. Both interact multiplicatively with time, in the same way as for *Deregulation* before.

Table 4 shows that while both variables have positive effect on efficiency, the *t*-values decrease. It is important to notice that the group of countries with two reforms is very heterogeneous. In some countries (Austria, Finland, Italy, Spain, Sweden), the reforms (not necessarily the same across countries) were implemented sequentially. In other countries (France, Germany, Netherlands, Portugal), reforms were implemented at the same time, as a "package". To get some idea of whether sequencing matters, we define two variables that allow to distinguish the types of reform: $DeregulationSequential_{it}$ takes the value 1 if a reform is implemented, and is followed by further reforms, and 0 otherwise. $DeregulationPackage_{it}$, takes the value 1 if more than one reform are implemented by the same time, 0 otherwise.

The results in Table 5 show a statistically highly significant result: there is a clear difference in implementing a given number of reforms in one blow or gradually. While sequential reforms have a positive sign, the sign of package reforms is negative.

The results must nonetheless be taken with a grain of salt, as the variable *DeregulationPackage* entails countries that have quite different models of reforms and different railroad specificities. For instance, while both France and Germany introduced the same reforms into their law books (some unbundling of infrastructure and operations, third party access), the implementation of these reforms have differed largely. In Germany, the possibility of third-party access has led to entry of many new competitors, while no new competitors have entered the French market. To a similar extent, the implementation of infrastructure separation has been quite different in Germany from the one in France. While Germany chose an organizational solution in which infrastructure and operations remain in the holding of the largest railway firm, France decided to create a separate infrastructure company that is not under the purview of SNCF. However, track allocation and management have been contracted back to SNCF. This example illustrates how difficult it is to operationalize empirically different types of reform implementation.

We have hence tried to investigate the effect of different types of implementation of infrastructure separation, and have regressed output on these two different types of implementation. We use institutional work (Prognos, 1998) that classifies countries according to organizational or institutional types of infrastructure separation (see Table 9). Countries that have opted for organizational separation have created separate bodies and separate accounting, but retain them under the umbrella of one holding infrastructure. Other countries have created two (or more) independent institutions.

Running these regressions, we find no clear evidence about the impact of different types of separation on efficiency. In particular, and most importantly, the results are not robust against dropping a single country from the regressions.[11] We hence conclude that the evaluation of *reform implementation* is an important, but complicated issue, which with the available data is hardly achievable.

5.2 Total productive efficiency

We now look at the development of total productive efficiency as defined in equation (1). Note that the residuals capture all those effects we have not modeled, among others unexplained differences in implementation of reforms, and, in particular, different degrees of managerial efficiency. We rank the countries in each year and express total productive efficiency of all countries in relative terms to the most efficient country, using the regression results presented in Table 3. The efficiency measure takes the value 1 (or 100%) for the country with the highest performance in the year *t*. We look at two different types of total productive efficiency; for global traffic (the weighted sum of passenger and freight traffic as defined in eq. (3)) and for passenger traffic only. Here, total productive efficiency in passenger traffic is computed as follows:

$$PassEff_{it} \equiv \exp\Big((u_{it} - u^{\max}) + \hat{\lambda}(\ln tonkm_{it} - \ln tonkm^{\max})\Big)$$

The first term on the right hand side represents total traffic efficiency, and the second term represents the impact of freight transportation. As the value in the parenthesis is negative, we thus correct total efficiency by the relative level of freight efficiency of a country.

Tables 7a and 7b present the results for global traffic, for smaller and larger countries separately. Tables 8a and 8b do the same for the efficiency of passenger traffic only. The Tables show that the development of productive efficiency is

[11] For space constraints, we do not report the regression results. They are available on request.

correlated across countries, in particular since the 90s that have seen much efficiency improvement.[12]

6. Discussion

Our regressions results show that reforms have increased railroad efficiency. This is in line with what has been found in studies on other network industries, in particular airlines. Ng and Seabright (2001) find that in the period from 1990 to 1995, European airline costs could have dropped by as much as 26%, had European airlines been privately owned and subject to the same degree of competition as US carriers. Baltagi et al. (1998) report that airline deregulation in the US resulted in substantial cost savings and a shift towards more efficient technologies.

However, the result needs some qualification. In particular, the effect of reforms depends how they are packaged. When a number of reforms were introduced at the same time, efficiency did not increase. Sequential reforms, however, did improve efficiency. The literature on gradual versus shock reforms (see, for instance, Dewatripont and Roland, 1995) argues that gradual reforms allow a government to learn about the desirability of further reforms in intermediate stages. This is consistent with our finding that gradual reforms have a stronger and statistically more significant effect than partial reforms and that both are better than package (shock) reforms. This ranking is consistent with the theory, in which a government can learn in intermediate stages about appropriate reforms, an option that does not exist when several reforms are implemented in one blow.

[12] As the referee pointed out, by looking at the descriptive statistics in Table 1, it appears that staff reductions have been highly correlated with efficiency gains. This could be a concern if there were strong correlations between reforms and staff reductions, as estimations could then be biased. To exclude that this is the case, we have carried out the LISREL estimations in sections 3.2.

Hence, while our paper shows that the railroad sector seems to be quite sensitive to changes in the regulatory framework, building reform of the railroad industry on a one-size-fits-all model may not be a fruitful way to enhance efficiency. Anecdotically, the experience in Britain has shed further doubt on the extent to which experiences can be simply transferred from one sector or country to another. The separation of infrastructure from operations, for instance, was motivated on grounds of the experience in the energy industry, but in the meantime, there are doubts that experience can easily be transferred across sectors. As David Willett, the Conservative Party's policy chief put it in an interview with *The Daily Telegraph* (see Rail News and Vies, 2003): “I would not defend the way we carried out the railway privatisation. Rail privatisation was a classic example of taking a model that had worked for one industry and wrongly applying it to different circumstances.”

7. Concluding remarks

This paper has investigated a new panel data set, which we have enriched by information about changes in regulatory regimes over the last twenty years. We find that reforms have had positive impact on output. The efficiency development of European carriers has been quite heterogenous. The LISREL analysis of the variance/covariance structure shows that the results are *not* subject to endogeneity issues. An additional contribution lies in the fact that we have controlled for the effect of freight traffic on passenger traffic efficiency without relying on ad-hoc weights given to freight versus passenger traffic.

Some limitations of our study should be noted. First, owing to data problems, we have not been able to include UK data in most of the regressions. Second, we have to date only been able to look at reforms in the law book, and cannot control for different types and intensity of implementation. Better data are needed to come to a final conclusion about the effect of different policies solution for the deregulation of railways. Third, we have not taken into account that the degree of subsidization is quite different across European countries as Friederiszick et al (2003) and NERA (2004) have shown. This may have an important impact on our measure of efficiency. Finally, we have only used quantitative measures of output. Quality is an equally important issue and would allow taking into account the effects of reforms on a multi-dimensional set of outcomes.

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APPENDIX 1: Tables

Table 1: Summary statistics

	period	*pass-km (millions)*	*ton-km (millions)*	*route (km)*	*Number of employees*
Austria	1980-1991	7639	10998	5748	70043
	1992-2003	8702	14409	5651	55438
Belgium	1980-1991	6580	7716	3689	56351
	1992-2003	7285	7792	3443	41793
Denmark	1980-1991	4533	1679	2322	21715
	1992-2003	5079	1948	2241	13169
Finland	1980-1991	3201	7915	5954	25236
	1992-2003	3253	9549	5863	14474
France	1980-1991	59896	56114	34443	231180
	1992-2003	63989	50411	31425	180359
Germany	1980-1991	62553	111652	41770	522362
	1992-2002	64660	71378	38653	258262
Italy	1980-1991	41163	17896	16090	213653
	1992-2003	43892	21281	16038	124465
The Netherlands	1980-1991	9868	3122	2831	26981
	1992-2003	14502	3383	2783	25195
Portugal	1980-1991	5727	1304	3478	22516
	1992-2003	4467	2033	2854	13521
Spain	1980-1991	15096	10808	12968	63303
	1992-2003	17173	10713	12460	36944
Sweden	1980-1991	6288	16712	11208	34763
	1992-1999	6203	15774	9910	21119
United Kingdom	1980-1989	31948	17112	16970	180128
	1992-2003[13]	34813	16393	16574	n.a.

[13] Staff data are missing for UK during this period.

Table 2: Deregulation events (three main aspects)[14]

	separation infra-structure, operations	*third party access*	*independent regulatory entity*
Austria	1997	1995	2000
Belgium	1998		
Denmark	1997	2000	
Finland	1995	1999	
France	1997	1997	
Germany	1994	1994	
Italy	1998	1999	
The Netherlands	1995	1995	
Portugal	1997		1997
Spain	1996	1995	
Sweden	1988	1989	
United Kingdom	1993	1993	1993

Table 3: OLS regression estimates: global deregulation

	Without United Kingdom		*With United Kingdom*	
Variables	*Parameter estimate*	*t-value*	*Parameter estimate*	*t-value*
Intercept	-1.476***	-5.74	-0.655***	-2.58
Logarithm (Capital)	0.551***	10.32	0.564***	10.68
Logarithm (Labor)	0.779***	16.30	0.612***	13.73
Deregulation Productivity trend	0.005**	2.10	0.004*	1.78
Productivity trend Austria	0.012***	2.97	0.009**	2.07
Productivity trend Belgium	0.021***	4.99	0.019***	4.28
Productivity trend Denmark	0.042***	9.14	0.036***	7.73
Productivity trend Finland	0.006	1.19	-0.008	-1.47
Productivity trend France	0.048***	10.47	0.047***	9.97
Productivity trend Germany	0.030***	6.05	0.031***	6.03
Productivity trend Italy	0.045***	11.31	0.047***	11.51
Productivity trend The Netherlands	0.075***	16.98	0.073***	15.75
Productivity trend Portugal	0.024***	5.20	0.019***	4.09
Productivity trend Spain	0.040***	8.05	0.034***	6.69
Productivity trend Sweden	0.022***	3.30	0.006	0.85
Productivity trend United Kingdom	-	-	0.062***	11.33

Note: *: significant at 10% level, **: significant at 5% level, ***: significant at 1% level.
Without United Kingdom:
$\lambda = 0.32$
$R^2 = 0.9814$, Number of observations: 259
With United Kingdom:
$\lambda = 0.22$
$R^2 = 0.9755$, Number of observations: 277

[14] In some countries, separate divisions of the respective Ministry of Transport were established to regulate the industry. We do not consider these departments as independent regulatory entities.

Table 4: OLS regression estimates, intensity of reforms

Variables	*Parameter estimate*	*t-value*
Intercept	-1.435***	-5.56
Logarithm (Capital)	0.539***	10.02
Logarithm (Labor)	0.777***	16.17
DeregulationOneAspect Productivity trend	0.006*	1.70
DeregulationTwoAspects Productivity trend[15]	0.004*	1.82
Productivity trend Austria	0.012**	2.87
Productivity trend Belgium	0.020***	4.51
Productivity trend Denmark	0.042***	9.09
Productivity trend Finland	0.006	1.10
Productivity trend France	0.048***	10.29
Productivity trend Germany	0.030***	5.96
Productivity trend Italy	0.045***	11.26
Productivity trend The Netherlands	0.075***	16.80
Productivity trend Portugal	0.024***	5.20
Productivity trend Spain	0.040***	7.98
Productivity trend Sweden	0.022***	3.23

Note: *: significant at 10% level, **: significant at 5% level, ***: significant at 1% level.
$\lambda = 0.31$
$R^2 = 0.9811$
Number of observations: 259.
Note: In some countries, separate divisions of the respective Ministry of Transport were established to regulate the industry. We do not consider these departments as independent regulatory entities.

[15] Includes Austria, the only country (besides UK, which is not included in this reression) that has introduced three reforms.

Table 5: OLS regression estimates, sequencing of reforms

Variables	*Parameter estimate*	*t-value*
Intercept	-1.157***	-4.72
Logarithm (Capital)	0.493***	9.76
Logarithm (Labor)	0.765***	16.92
Deregulation Sequential Productivity trend	0.012***	4.78
Deregulation Package Productivity trend	-0.008**	-2.59
Productivity trend Austria	0.004	1.06
Productivity trend Belgium	0.014***	3.35
Productivity trend Denmark	0.035***	7.80
Productivity trend Finland	-0.002	-0.35
Productivity trend France	0.057***	12.36
Productivity trend Germany	0.041***	8.07
Productivity trend Italy	0.042***	10.95
Productivity trend The Netherlands	0.083***	18.64
Productivity trend Portugal	0.031***	6.87
Productivity trend Spain	0.035***	7.32
Productivity trend Sweden	0.013**	2.07

Note: *: significant at 10% level, **: significant at 5% level, ***: significant at 1% level.
$\lambda = 0.28$
$R^2 = 0.9824$
Number of observations: 259

Table 6: LISREL estimates

	Estimates	***t-values***
Logarithm (Capital)	0.5437***	8.299
Logarithm (Labor)	0.8261***	12.665
Cov(γ_i,LogCapital)	-0.0003	-0.108
Cov(γ_i,LogLabor)	-0.0010	-0.342
Var(γ_i)	0.0004**	1.962
σ^2	0.0411***	9.592
Ridge constant	0.001	

Note: *: significant at 10% level, **: significant at 5% level, ***: significant at 1% level.

The endogenous variable here is aggregate output. We report here an experiment with global individual effects, not controlling for deregulation. Covariances between capital and individual effects and between labor and individual effects are constrained to be constant over time. To avoid "near multi-collinearity" among predictors, LISREL automatically applies a ridge estimation (Jöreskog, 1996).

We have also run a model with $\delta_{it} = \gamma_i + \theta_0 Deregulation_{it}$. Because of their time pattern and structure, the deregulation dummies creates a problem because the matrix is not invertible. This imposes to restrict the panel to the period 1995 to 1999. In this regression we find similar results: covariances between individual effects and inputs are not significant.

Table 7a: Relative efficiency measures, total traffic, smaller countries

	Austria	*Belgium*	*Denmark*	*Finland*	*The Netherlands*	*Portugal*
1980	0.37	0.43	0.47	0.30	1.00	0.43
1981	0.35	0.42	0.50	0.31	1.00	0.43
1982	0.37	0.41	0.57	0.32	1.00	0.42
1983	0.38	0.43	0.53	0.34	1.00	0.42
1984	0.38	0.44	0.51	0.33	1.00	0.46
1985	0.38	0.47	0.53	0.32	1.00	0.47
1986	0.39	0.46	0.58	0.27	1.00	0.53
1987	0.38	0.47	0.54	0.32	1.00	0.53
1988	0.39	0.47	0.50	0.33	1.00	0.51
1989	0.41	0.48	0.49	0.33	1.00	0.51
1990	0.39	0.47	0.49	0.34	1.00	0.44
1991	0.32	0.37	0.37	0.24	1.00	0.34
1992	0.35	0.40	0.38	0.25	1.00	0.39
1993	0.34	0.40	0.40	0.27	1.00	0.43
1994	0.35	0.40	0.41	0.29	1.00	0.49
1995	0.38	0.40	0.49	0.33	1.00	0.51
1996	0.39	0.39	0.45	0.33	1.00	0.45
1997	0.31	0.37	0.58	0.32	1.00	0.43
1998	0.30	0.35	0.61	0.31	1.00	0.41
1999	0.33	0.38	0.64	0.35	1.00	0.42
2000	0.34	0.39	0.74	0.35	1.00	0.33
2001	0.37	0.40	0.87	0.36	1.00	0.38
2002	0.37	0.41	0.84	0.36	1.00	0.42
2003	0.38	0.42	0.75	0.38	1.00	0.41
Mean	0.36	0.42	0.55	0.32	1.00	0.44

Table 7b: Relative efficiency measures, total traffic, larger countries

	France	*Germany*	*Italy*	*Spain*	*Sweden*
1980	0.70	0.47	0.57	0.43	0.45
1981	0.71	0.48	0.56	0.45	0.44
1982	0.73	0.47	0.57	0.47	0.40
1983	0.77	0.48	0.57	0.49	0.44
1984	0.77	0.48	0.57	0.52	0.45
1985	0.77	0.51	0.53	0.57	0.46
1986	0.78	0.53	0.60	0.58	0.45
1987	0.77	0.49	0.60	0.59	0.43
1988	0.79	0.48	0.59	0.63	0.43
1989	0.79	0.47	0.60	0.58	0.42
1990	0.73	0.40	0.57	0.55	0.45
1991	0.54	0.27	0.47	0.40	0.31
1992	0.54	0.29	0.51	0.44	0.34
1993	0.54	0.31	0.51	0.44	0.42
1994	0.57	0.38	0.59	0.45	0.44
1995	0.55	0.40	0.64	0.52	0.46
1996	0.59	0.43	0.65	0.52	0.43
1997	0.57	0.43	0.59	0.53	0.42
1998	0.56	0.45	0.54	0.54	0.43
1999	0.62	0.63	0.58	0.61	0.51
2000	0.62	0.68	0.63	0.62	n.a.
2001	0.67	0.69	0.71	0.67	n.a.
2002	0.66	0.67	0.69	0.71	n.a.
2003	0.65	n.a.	0.66	0.71	n.a.
Mean	0.67	0.47	0.59	0.54	0.43

Table 8a: Relative efficiency measures, passenger traffic, smaller countries

	Austria	*Belgium*	*Denmark*	*Finland*	*The Netherlands*	*Portugal*
1980	0.17	0.18	0.12	0.13	0.32	0.09
1981	0.16	0.18	0.12	0.13	0.32	0.09
1982	0.17	0.17	0.15	0.14	0.31	0.10
1983	0.18	0.18	0.14	0.15	0.31	0.09
1984	0.18	0.19	0.13	0.14	0.32	0.11
1985	0.18	0.20	0.14	0.14	0.32	0.11
1986	0.18	0.19	0.15	0.11	0.31	0.13
1987	0.18	0.19	0.14	0.13	0.31	0.13
1988	0.18	0.20	0.13	0.14	0.31	0.13
1989	0.19	0.20	0.13	0.14	0.31	0.13
1990	0.20	0.21	0.13	0.15	0.33	0.11
1991	0.18	0.18	0.11	0.11	0.35	0.10
1992	0.19	0.20	0.12	0.12	0.36	0.12
1993	0.20	0.21	0.13	0.15	0.36	0.13
1994	0.20	0.20	0.13	0.15	0.36	0.15
1995	0.22	0.19	0.16	0.18	0.37	0.16
1996	0.23	0.19	0.14	0.17	0.37	0.14
1997	0.18	0.18	0.18	0.17	0.38	0.14
1998	0.18	0.17	0.20	0.16	0.39	0.13
1999	0.20	0.19	0.21	0.18	0.38	0.14
2000	0.21	0.19	0.23	0.18	0.38	0.11
2001	0.23	0.19	0.28	0.19	0.39	0.12
2002	0.24	0.21	0.26	0.19	0.39	0.15
2003	0.24	0.21	0.23	0.20	0.39	0.13
Mean	0.19	0.19	0.16	0.15	0.35	0.12

Table 8b: Relative efficiency measures, passenger traffic, larger countries

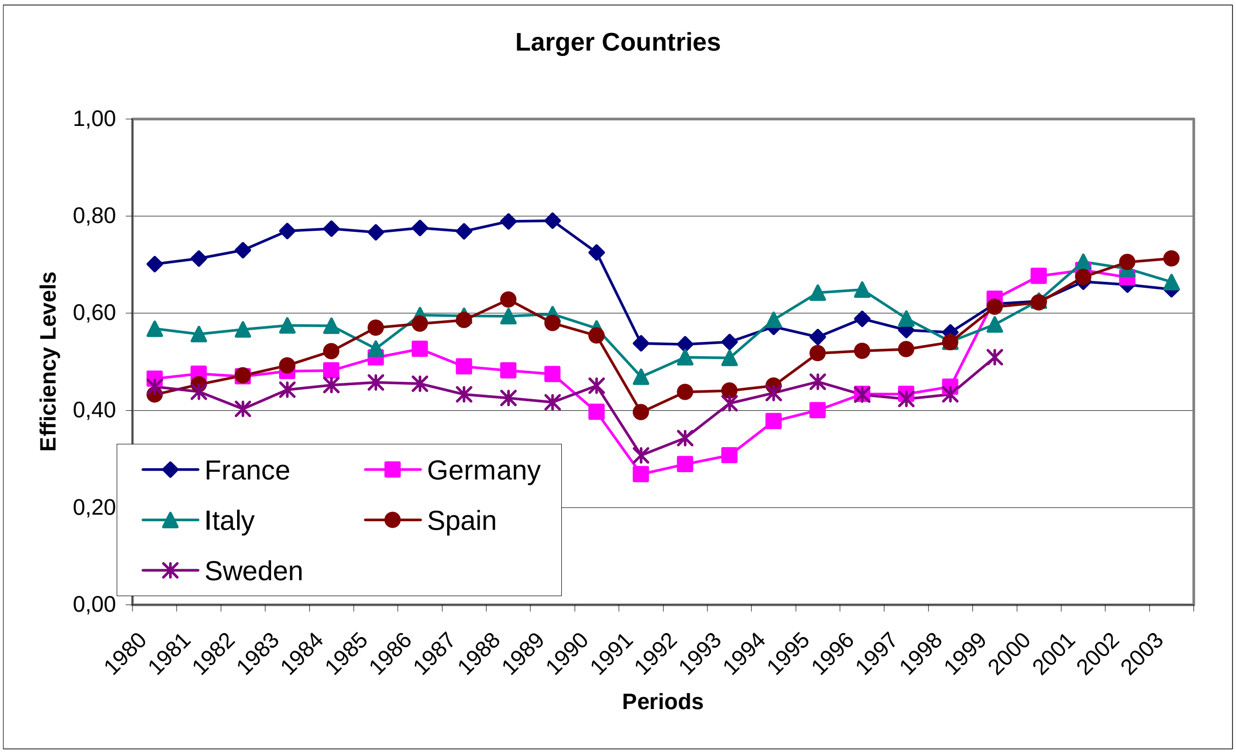
	France	*Germany*	*Italy*	*Spain*	*Sweden*
1980	0.59	0.47	0.31	0.20	0.24
1981	0.59	0.48	0.30	0.21	0.23
1982	0.60	0.47	0.31	0.22	0.21
1983	0.63	0.48	0.32	0.23	0.23
1984	0.63	0.48	0.32	0.25	0.25
1985	0.60	0.51	0.28	0.27	0.25
1986	0.59	0.53	0.32	0.27	0.25
1987	0.59	0.49	0.32	0.28	0.24
1988	0.61	0.48	0.33	0.30	0.23
1989	0.61	0.47	0.33	0.27	0.23
1990	0.58	0.40	0.34	0.27	0.26
1991	0.47	0.27	0.30	0.20	0.19
1992	0.48	0.29	0.34	0.23	0.22
1993	0.48	0.31	0.34	0.22	0.28
1994	0.51	0.38	0.39	0.23	0.28
1995	0.49	0.40	0.44	0.28	0.30
1996	0.53	0.43	0.45	0.28	0.28
1997	0.51	0.43	0.41	0.29	0.25
1998	0.51	0.45	0.37	0.30	0.26
1999	0.57	0.63	0.39	0.34	0.31
2000	0.56	0.68	0.42	0.34	n.a.
2001	0.59	0.69	0.48	0.37	n.a.
2002	0.59	0.67	0.48	0.41	n.a.
2003	0.56	n.a.	0.44	0.42	n.a.
Mean	0.56	0.47	0.36	0.28	0.25

Table 9: Types of separation of infrastructure from operations

	Organisational	*Institutional or Full*
Austria	From 1997	
Belgium	From 1998	
Denmark		From 1997
Finland		From 1995
France		From 1997
Germany	From 1994	
Italy	From 1998	
The Netherlands	From 1995	
Portugal		From 1997
Spain	From 1996	
Sweden		From 1988
United Kingdom		From 1993

APPENDIX 2: Figures

Figure 1: Efficiency development over time by country, global traffic



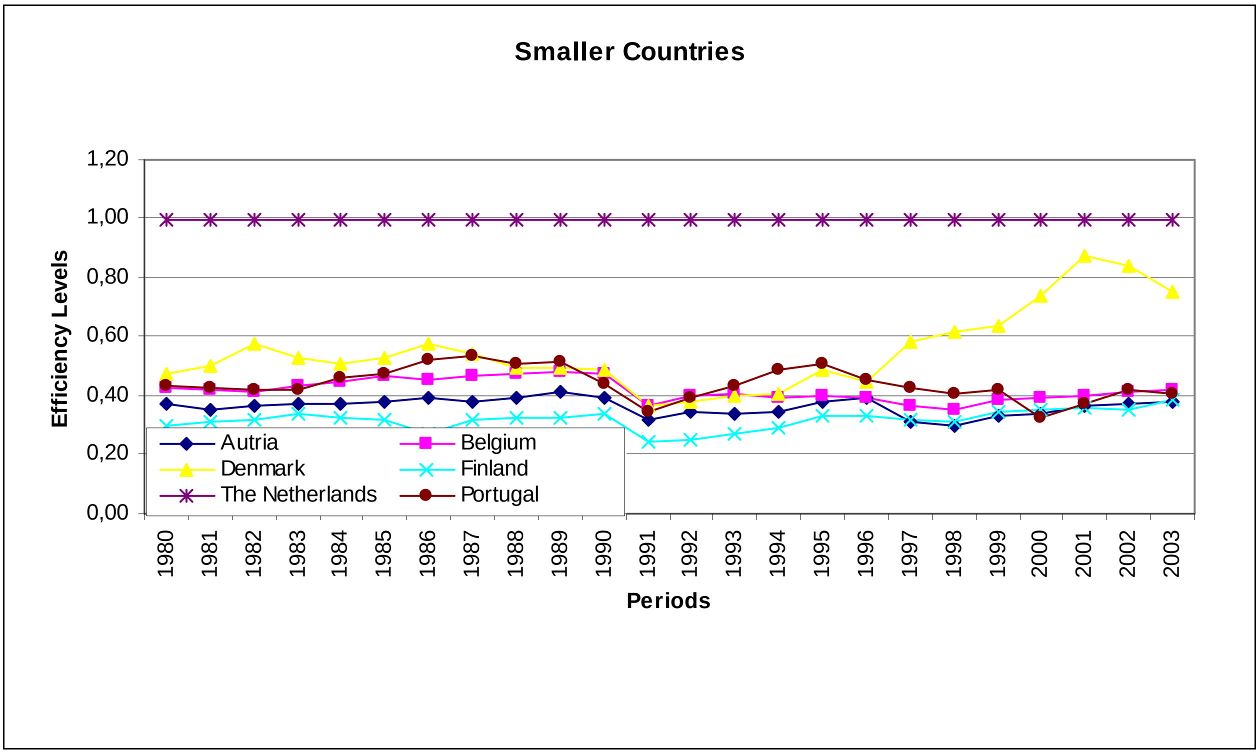


Figure 2: Efficiency development over time by country, passenger traffic