Evaluation of the effectiveness of state aid as a policy instrument: The Railway Sector

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Abstract

This paper analyses the effectiveness of national state aid in increasing the efficiency of railways in the 15 member states of the European Union. This is carried out by estimating a stochastic frontier production function for the incumbent monopolists in the EU15 countries during the period 1988-2000. By incorporating technical inefficiency effects in the stochastic frontier estimation, as described in Battese and Coelli (1993), the impact of state aid on efficiency levels is estimated. We find that aid level has a positive impact on efficiency, but aid intensity – defined as aid divided by total operating cost – has a negative impact. This result suggests that aid must be complemented with other means of finance to be effective. Furthermore, we show evidence that in countries with lower aid intensity, aid triggers more investment than in countries with higher aid intensity – highlighting the linkage between aid, investment and efficiency. Simulations are carried out, estimating the impact of various policy targets for state aid on the efficiency of national railway firms. We find that the aid/aid intensity trade-off effect on efficiency varies depending on the aid policy scheme implemented.

JEL-classifikation: C23, D24, H54, L92, R42

Keywords: European railways, production function, state aid

I. Introduction

National state aid has come under increasing scrutiny in the wake of restricted national budgets and the European commitment to the European Union's Fiscal and Stability Pact. However, despite the recent trends towards privatization and deregulation in the railway sector, most European Railway Firms are still public enterprises in highly regulated markets that have a long history of being recipients of state aid. Subsidies to the railway sector amounts to roughly 40% of the total national state aid registered at the European Commission (excluding national state aid for agriculture and fishery) and this sums up to roughly € 25 Billion per year in the EU.[5] Hence, it is an important issue to evaluate the effectiveness of this policy instrument in the presence of recent changes in the regulatory environment in the railway sector.

Perelman and Pestieau (1988) provide the seminal study on this issue by estimating technical efficiencies from a translog stochastic production function for railway and postal companies in the EU15 countries, Norway, Japan, Turkey and Switzerland. They find that exogenous factors such as the percentage of electrified lines, track-kilometer per line-kilometer, and the average haul of one ton to have an effect on the efficiency rankings of the railway firms. However, the impact of state aid or regulatory changes is not addressed by their analysis.

The only study we are aware of which directly includes subsidy measures in its efficiency estimates is that of Oum and Yu (1994). Their paper analyzes the efficiency of 19 railway companies in the EU15, Norway, Switzerland, Turkey and Japan over the years 1978-89 by employing a data envelopment analysis (DEA). In the first step a DEA was estimated were "gross efficiencies" were obtained. In the second step a Tobit regression was carried out, taking the "gross efficiencies" as the

[5] See various state aid reports available on DG Competition's web side.

dependant variable and distinct factors as regressors. They find that a greater aid intensity (measured as the ratio of subsidy to the total operating expenses), has a significantly negative effect on efficiency. They also find that a higher level of managerial autonomy leads to higher efficiency levels, and like in the case of Perelman and Pestieau (1988), that the inclusion of exogenous factors has significant impacts on the efficiency rankings of the railway firms.

However, the two-step procedure applied by Oum and Yu (1994) exhibits an important drawback. The estimation of the inefficiency terms in the first stage are based on the assumption that the inefficiency terms are identically distributed. In the second stage, however the opposite is assumed since they are characterized as function of firm-specific factors.[6]

This paper will carry out the estimations using the production function approach as suggested by Perelman and Pestieau (1988).[7] The production function approach simply measures how input quantities relate to output quantities. This approach has the advantage of measuring the technical efficiencies of firms whether or not the firm is allocatively efficient. This is especially important in the European railway sector as many European railways are public enterprises; hence it is questionable whether these firms can freely substitute capital for labor, in order to be allocatively efficient. A second advantage is that this approach does not require the use of input price data (which is a necessity for the cost function approach), which is not readily obtainable. The output approach has one drawback though – an aggregation of the various multi-product output must first be calculated before the approach can be applied.

[6] See Coelli, Rao and Battese 2002, p 207.

[7] There are in general various methods to estimate the technical efficiencies of railway firms. These methods can be adopted either from a production function or a cost function approach. These functions will in most cases be estimated via COLS, Stochastic Frontier Analysis or Data Envelope Analysis. Refer to Appendix I for an overview of the methods and main results of various studies estimating efficiency of the European railway sector.

To estimate the individual technical efficiencies, we make use of a stochastic frontier production frontier which incorporates technical inefficiency effects, as described in Battese and Coelli (1993). This approach avoids the methodological problems of a two step procedure as applied in Oum and Yu (1994).

Beside these methodological issues, this paper adds to the current literature twofold. Firstly, as most railway firms embarked upon the deregulation process in the last decade our estimates of the technical efficiencies of the EU15 railway firms over the sample period 1988-2000 have the advantage of being able (to a certain extent) to reflect the effects of deregulation.[8] Secondly, it explicitly estimates the effectiveness of national state aid on the efficiency of railway firms.

With regard to the first issue, we can not identify a positive time trend in the period under consideration. Hence, the ongoing deregulation process has had no common, positive effect on EU railways firms' efficiency within our statistical model. Regarding state aid, we find that the aid level has a positive impact on efficiency, but aid intensity – defined as aid divided by total operating cost – has a negative impact. This result suggests that aid might have to be complemented with other means of finance to be effective.

[8] However, UK data are only included up to 1995. Therefore, success or failure of the British railway reform cannot be evaluated by our analysis.

II. Methodology and Data

The main goal of this paper is to analyze the effect of state aid on railway efficiency. For this we make use of a stochastic frontier production function, in which technical inefficiency effects are incorporated (Battese and Coelli (1993)). This procedure has the advantage that the effects of exogenous factors on technical efficiency are directly incorporated. In this section, the technical inefficiency frontier model will be briefly introduced followed by a detailed description of the data used in the estimation technique.

1. The Inefficiency Frontier Model for panel data

The model we will be using for our efficiency estimations is the stochastic frontier production function for panel data as proposed in Battese and Coelli (1993). The model can be written as:

$$Y_{it} = x_{it}\beta \exp(V_{it} - U_{it}) \tag{1}$$

where:

Y_{it} denotes a multilateral output-index for the *i*-th country (*i* = 1,2,..., 15) for the *t*-th period of observation (*t* = 1988, 1989,..., 2000);

x_{it} is a $(1 \times k)$ vector of production inputs associated with the *i*-th country at the *t*-th period;

β is a $(k \times 1)$ vector of unknown parameters to be estimated;

V_{it} are assumed to be iid $N(0, \sigma_v^2)$ random errors;

$U_{it} \overset{iid}{\sim} N^{+}(\mu, \sigma_U^2)$ truncated at zero ;

The mean, μ is conditional on a set of variables:

$$\mu = z_{it}\delta \tag{2}$$

z_{it} is a $(1 \times m)$ vector of country-specific variables which may vary over time;

δ is a $(m \times 1)$ vector of unknown coefficients of the country-specific inefficiency variables.

The technical efficiency of production of the *i*-th country for the *t*-th period of observation, TE_{it}, is defined by:

$$TE_{it} = \exp(-U_{it}) \qquad (3)$$

2. Data Description

The multilateral output-index (Y_{it})

A panel of 15 European railway firms was selected over the period 1981 to 2000. The data for both person-km and freight-km are obtained from the UIC database. The two output measures, person- and freight-km, are then aggregated into a single output measure using a *multilateral output-index*. This index weights the outputs by their revenue share and allows for a consistent comparison across countries and time.[9] The revenue share data are also calculated from revenue data from the UIC database.

Figure 1 plots the multilateral output-index (per capita[10]) for the EU15 countries over the years 1981-2000. The multilateral output-index is constructed relative to the average European output in 1981. As a result the average European output in 1981 is normalized to 100. There are two striking observations in Figure 1. Firstly, the EU trend has more or less stagnated over the past 20 years. Secondly, individual countries exhibit significantly different levels and trends. For example, Austria displays roughly 100% more output per inhabitant than the EU average, while Greece achieves 80% less than the average.

[9] For more details see Good, Nadiri and Sickles 1996
[10] Population data is obtained from EUROSTAT.

The inputs (x_{it})

Three conventional input factors are used, namely labor, capital and energy. The average number of employees is used as a measure of labor input; transportation stock for passenger and freight and the length of the lines network are used as separate measures of capital inputs. In addition, the total consumption of energy by diesel and electrical modes of traction are included in the stochastic frontier estimation. These five variables are obtained from the UIC database. All input variables are divided by the respective populations in each country to adjust for size.

The country-specific variables (z_{it})

National state aid data is obtained from DG Competition of the European Commission. Aid intensity, which is aid divided by total operating cost, was constructed using total operating cost data from the UIC database (see also Oum and Yu (1994)). Due to the lack of data, aid variables are only available from 1988 to 2000. The aid level variable used in this paper is adjusted for population size (i.e. per capita). Figure 2 and 3 plot the two aid variables that we use in our analysis.

With regard to the EU average one finds that national aid towards railways decreased over the past 12 years (from €91.67 million per inhabitant in 1988 to €80.75 million per inhabitant in 2000). The aid intensity runs between 60% and 40%, with a falling tendency over the last six years.

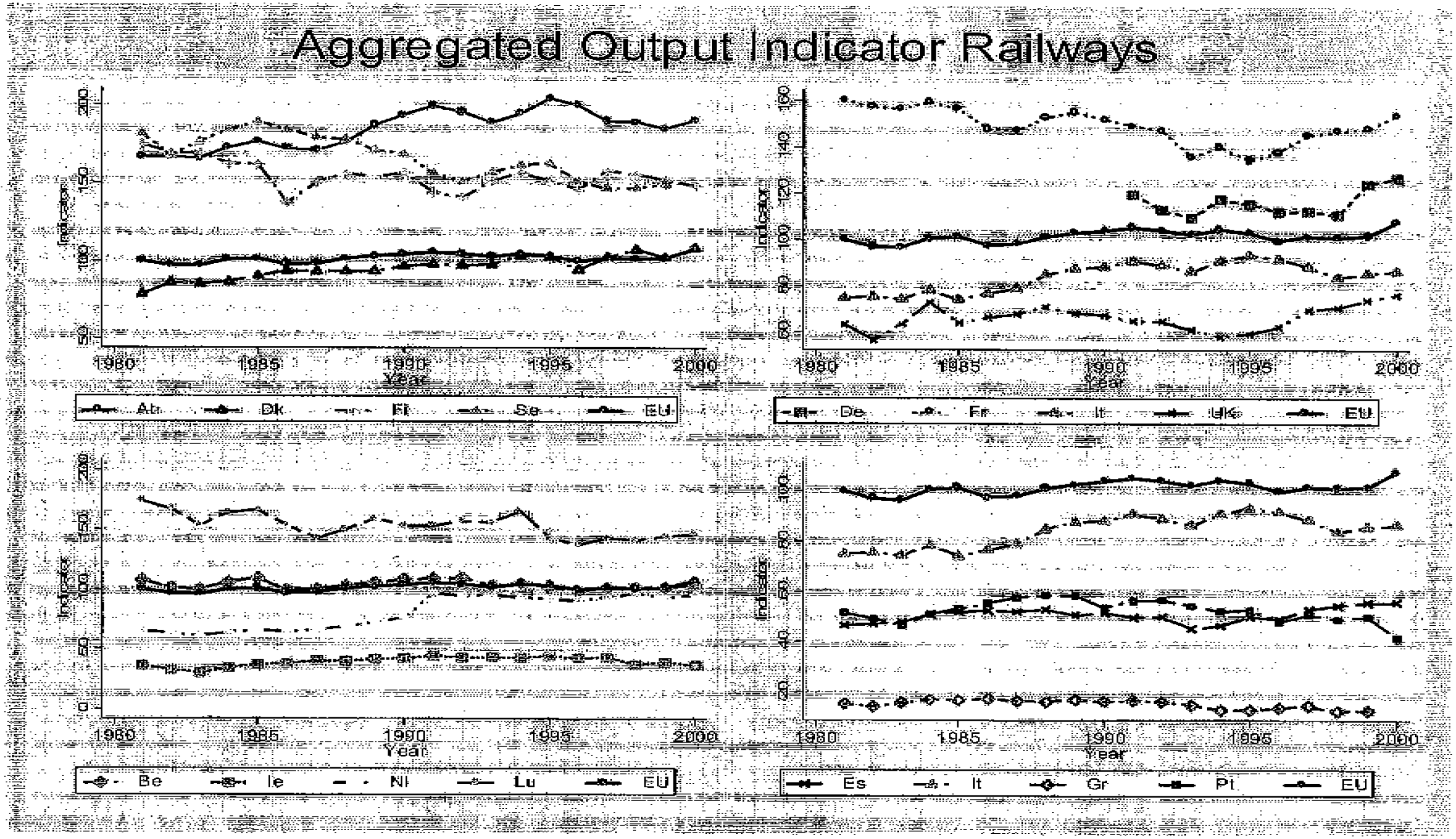
With regards to individual countries the figures show a very low level of aid per capita in Finland, United Kingdom, Ireland and the Mediterranean countries (with the exception of Italy). Interestingly, all of the Mediterranean countries (except Portugal) exhibit an above average aid intensity.[11] Ireland, a country with a relatively low aid level, is characterized with a below average aid intensity until 1996 followed by a sharp increase. Germany exhibits decreasing aid levels from 1994 onwards (the year Deutsche Bahn began reform), coupled with an increase in costs (what can be seen in the falling aid intensity). Italy displays a constant aid intensity, with decreasing aid levels over the period 1988-1995.

To control for technological specifications and other country-specific differences, we include the following three control variables in Equation (2): *share of electrified lines to total lines* - A measure of vintage of the infrastructure as well as the train stock. Electrified lines also allow for more energy efficient transportation; *area per capita* - A measure of the density of the population distribution; and *GDP per capita* – A measure of general economic performance. Share of electrified lines to total lines is obtained from the UIC database and area per inhabitant and GDP per inhabitant are obtained from the Eurostat database.

Refer to Appendix II for a summary of the data used in the estimations.

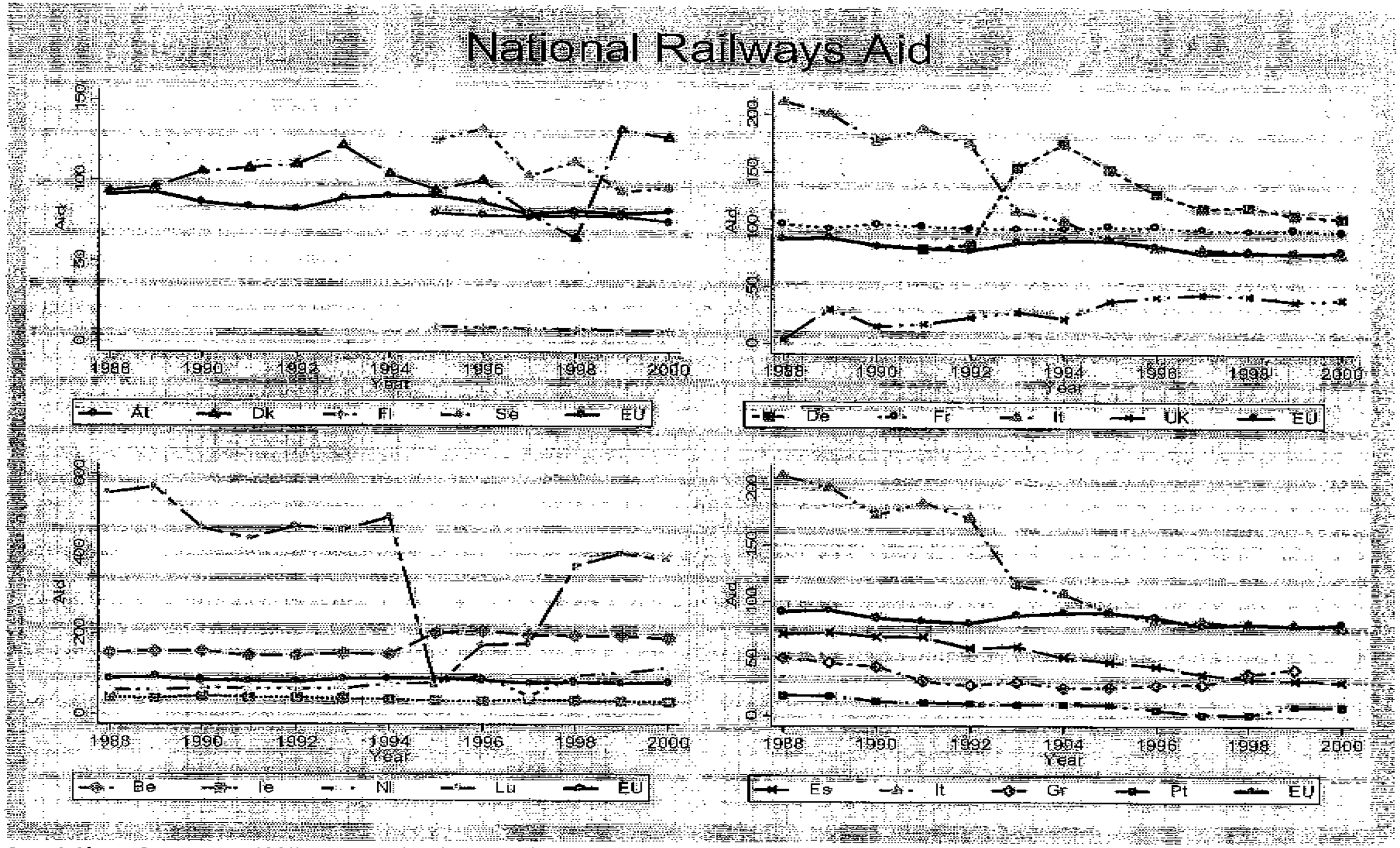
[11] The unexpected high aid intensity in Greek in the years 1998/99 is caused by a sharp increase of aid registered.

Figure 1:



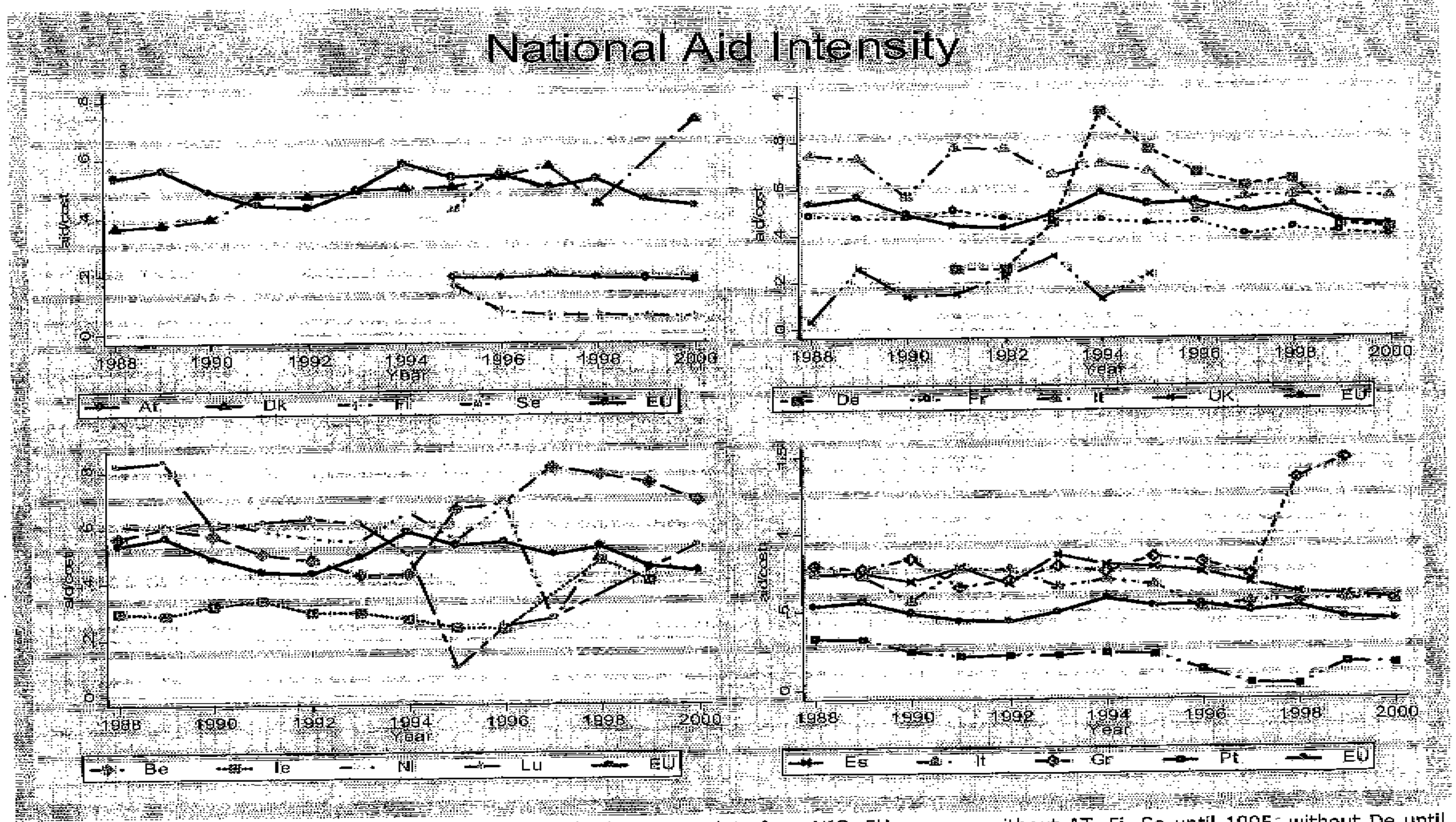
Annotations: Multilateral Output-Index based on output per capita. Missing data: passenger revenue Dk 1998 , Lu 1999 and Uk 1996 linear approximated. Constant share between freight and passenger revenue 1996-2000 for UK assumed. EU-average without De until 1991 and without Gr and Se 2000.

Figure 2:



Annotations: In constant 1995 Euros. National State Aid per capita per year. EU average without At, Fi, Se until 1995 and without De until 1991.

Figure 3:



Annotations: Aid and cost in constant 1995 Euros, yearly data. Cost data from UIC. EU average without AT, Fi, Se until 1995, without De until 1991, without Dk 1999, without Gr 2000, without Ie 1997 and 2000, without Lu 1998/99, without Nl 1999/00, without Se 1998-2000, without UK 1996-2000.

III. Efficiency Estimation

The logarithmic form of Equation (1) of the inefficiency production frontier model as depicted in Equation (4), together with the inefficiency equation as depicted in Equation (5) were then estimated using STATA 8.

$$\begin{aligned}\ln Y_{it} &= \beta_0 + \beta_1 \ln(\text{Labor}_{it}) + \beta_2 \ln(\text{Length of lines}_{it}) \\ &+ \beta_3 \ln(\text{Passenger stock}_{it}) + \beta_4 \ln(\text{Freight stock}_{it}) \\ &+ \beta_5 \ln(\text{Energy}) + V_{it} - U_{it} \qquad (4)\end{aligned}$$

$$\begin{aligned}\mu_{it} &= \delta_0 + \delta_1(\text{Aid}_{it}) + \delta_2(\text{Aid intensity}_{it}) + \delta_3(\text{Electrified lines}_{it}) \\ &+ \delta_4(\text{Area per capita}_{it}) + \delta_5(\text{GDP per capita}_{it}) + \delta_6\text{Trend}_t \qquad (5)\end{aligned}$$

The results are displayed in Table 1. We present here the estimated model for the panel from 1988 to 2000. The signs of the coefficients of the stochastic frontier are as expected, with the exception of the negative coefficient of the freight stock variable. Its negative sign may be a result of the aggregated Tornqvist (multilateral) output which we used as the dependent variable.

Of particular interest in this study are the coefficients of the explanatory variables in the inefficiency model (5). With regards to the impact of the country-specific variables on technical inefficiency, one finds that the share of electrified lines has a positive significant impact on efficiency while area per inhabitant has no impact. Most importantly, however, are the coefficients for aid, aid intensity and time trend. The time trend variable allows for inefficiency effects to change linearly with respect to time.[12]

[12] Estimations with a time trend in the stochastic frontier production function were also carried out, but its coefficient was not significant.

Table 1: Estimation Results of the Inefficiency Frontier Model

Variables	Parameter	Coefficient	Standard error
Stochastic production frontier			
Constant	β_0	-4.278***	0.391
Ln(Labor)	β_1	0.039	0.054
Ln(Length of lines)	β_2	0.442***	0.064
Ln(Passenger stock)	β_3	0.329***	0.078
Ln(Freight stock)	β_4	-0.171***	0.031
Ln(Energy)	β_5	0.142*	0.073
Technical inefficiency model			
Constant	δ_0	0.849***	0.155
Aid level	δ_1	-0.004***	0.001
Aid intensity	δ_2	0.636***	0.094
Electrified lines	δ_3	-1.482***	0.134
Area per capita	δ_4	-0.000*	0.000
GDP per capita	δ_5	-0.007	0.010
Time trend	δ_6	0.010*	0.005
Variance parameter			
γ		0.239	
σ^2		0.017	
Log(likelihood)		98.439	
Observations:		141	
Countries:		15	

Note: Estimated standard errors are given in parentheses.
*** Significant at 1%
** Significant at 5%
* Significant at 10%

Before discussing the individual coefficients, some remarks to the overall significance of the technical inefficiency model. The γ-parameter[13] associated with the variances in the inefficiency parameter was relatively small (0.239) and insignificant as estimated by STATA [14]. Hence it was important to carry out hypotheses testing involving restrictions on the γ-

[13] γ is defined as $\sigma_U^2 / (\sigma_V^2 + \sigma_U^2)$.

[14] The model was estimated again using the program FRONTIER version 4.1 Coelli 1996. Similar results were obtained. However, the estimated gamma was much higher (0.856) and was significant at the 1% level.

and δ-parameters, as these parameters are important indicators as to whether technical inefficiency effects make a significant contribution to railway output.

We performed 3 generalized likelihood-ratio tests of various null hypotheses as depicted in Table 2. The first hypothesis tests if technical inefficiency effects are stochastic. The second tests if technical inefficiency effects are present. The third hypothesis tests if the technical inefficiency effects have a traditional half-normal distribution with 0 mean.

The generalized likelihood-ratio statistic, λ is given by:

$$\lambda = -2[\ln\{L(H_0)\} - \ln\{L(H_1)\}] \quad (6)$$

where $L(H_0)$ and $L(H_1)$ denote the values of the likelihood function under the null H_0 and alternative H_1 hypothesis, respectively. If the null hypothesis is true, λ has an approximate χ^2-distribution (Battese and Coelli (1993)).

To estimate the likelihood functions of the models under the null hypothesis, the following models were estimated. A traditional average function stochastic frontier production function in which the explanatory variables in the technical inefficiency model are included in the production function was estimated for the first null hypothesis. A traditional average function stochastic frontier production function in which the explanatory variables in the technical inefficiency model are *not* included in the production function was estimated for the second null hypothesis. And a stochastic frontier production function with technical inefficiency effects that have a traditional half-normal distribution with 0 mean was estimated for the third null hypothesis.

Table 2: Tests of Hypotheses for Parameters of the Inefficiency Frontier Model

Null Hypotheses	Log-likelihood value	Test Statistic (λ)	Critical Value ($\chi^2_{0.995}$)	Decision
$H_0 : \gamma$	48.260	100.358	7.87944	Reject H_0
$H_0 : \gamma = \delta_0 = ... = \delta_6$	-0.210	197.298	21.9550	Reject H_0
$H_0 : \delta_0 = ... = \delta_6$	-0.028	196.934	20.2777	Reject H_0

Table 2 shows that all null hypotheses can be rejected at 1% level of significance. The large test statistics could be accounted to the high significance of the explanatory variables in the technical inefficiency model. The results of these tests indicate that technical inefficiency effects are significant in explaining the variation in the productive performance of European railway firms.

Let us return to the interpretation of the individual coefficients incorporated in the technical inefficiency model. Aid has a negative effect and aid intensity a positive effect on the inefficiency of railway firms. In other words, aid has a positive effect and aid intensity a negative effect on the performance of railway firms.

One explanation – and we think the most plausible one – for the positive effect of aid on efficiency (the 'direct effect' of aid) is the effect of aid on investment. If aid triggers additional investment, an increase in the aid level will positively affect the technical efficiency of railway firms.

The negative effect of aid intensity points to the fact that an upper bound exists (defined relative to costs) which limits the positive effect. One explanation of this upper limit is that firms with higher aid intensity spend less money on additional investment due to state aid than those firms with low aid intensity.[15] Hence, we will label this effect as a negative 'incentive effect' as it indicates limited incentives of firms to invest.

The presented estimation results are consistent with the outlined relations between aid, aid intensity and investment. However, a more direct inclusion of investment data is necessary to proof this relationship. We will return to this issue in a later section.

Efficiency change over time is an issue often addressed in the literature. There has been in particular major restructuring and deregulation with regard to inter-modal competition in the railway sector in Europe in the past decade. Some studies find a positive time trend and concluded that this was due to the positive change in the competitive environment and market liberalization. By contrast, we find a negative common time trend. One reason could be that the positive effects of the restructuring and deregulation processes have different lag effects on efficiency, and hence would not be visible until much later.

Let us now turn our attention to the estimated efficiency levels. Figure 4 plots the estimated technical efficiency of the individual EU15 countries as well as the population weighted EU average. Several interesting points can be noted. First of all, one finds that Austria, Sweden, Belgium, the Netherlands and Luxembourg outperform the other countries over the whole period with an efficiency level close to one. Furthermore, one finds that from the large European countries, Italy, Germany and France exhibit a comparable efficiency level from 1995 on, reaching a value of around 98% in 2000. However, France and Germany hold a positive time

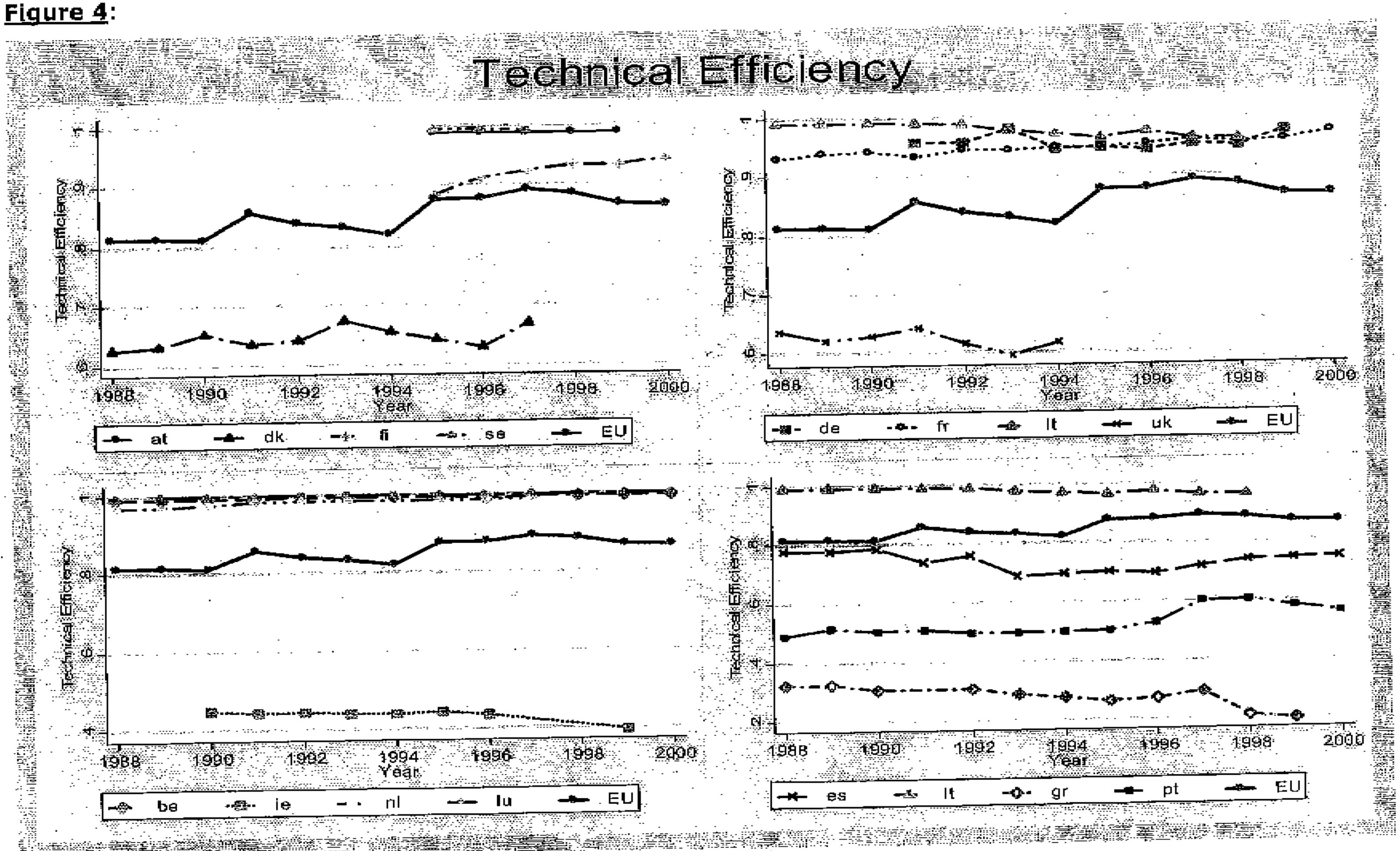
[15] Such a relationship could be derived for example by assuming a moral hazard problem which arises due to asymmetric information between railway firms and the government. This results in weak regulation of the railway firm and reduced investment incentives. Hence, some degree of internal (revenue-based) or external financing is necessary (measured by aid intensity) to overcome underinvestment due to this moral hazard problem.

trend while Italy's efficiency slightly decreases. The United Kingdom does not follow this picture with an efficiency level of below 65% until 1994 (later estimates are not available). Denmark, Finland, Spain and Portugal are in the lower midfield with regard to their efficiency level in 2000. Spain and Portugal show a more or less stagnating time trend. Finland and Denmark could improve efficiency levels sharply. An important result given the accelerated liberalization process imposed on their railway firms in the late nineties. Ireland and Greece characterize the bottom line in Europe. Both countries also display a negative time trend.

The EU average efficiency level was relatively constant throughout the period 1988-2000. A slight increase of the level in 1995 could have been due to the inclusion of the highly efficient Swedish SJ and the exclusion of the inefficient British Rail.

Given the heterogeneity of the estimated efficiency levels and their trends, the impact of the various country-specific variables on the efficiency parameters is an important issue. Let us illustrate this issue with an example. From the results in Table 1, we know that an increase in the aid level, assuming aid intensity remains unchanged, results in higher efficiency (the direct effect). Taking this direct effect of aid, a € 1 million increase in state aid per Million inhabitants results in a higher average efficiency of approximately 0.4 index points. Using the numbers in Figure 2, we find that on average €80 million per inhabitant state aid was granted in 2000. Simulated results show that a 10% increase of aid will result in roughly 0.5% more output due to efficiency gains. More simulation schemes will be elaborated on the following section.

Figure 4:



Annotations: Note different scaling.

IV. Policy Simulations

We simulated three different policy aid schemes to analyze the interplay of the two effects of aid on the efficiency of railways. Scheme 1 consists of an increase in each country's aid level by 10%. Scheme 2 consists of giving every EU member country the EU average aid weighted by population. Scheme 3 consists of giving each EU member country the EU average aid per GDP, weighted by GDP. For each scheme, simulations were carried out keeping aid intensity constant (direct effect model) as well as an adjusted aid intensity level calculated by assuming constant costs (direct and incentive effect model).

Table 3 depicts the differences in the EU average technical efficiencies in year 2000 under the various schemes. For all schemes the compound effect (direct and incentive effect) is negative. That is, the negative incentive effect dominates the EU average. For example, Scheme 1 would result in an efficiency increase of 0.50 percent points in the direct effect model and -0.34 percent points in the compound effect model. However, note that for individual countries the compound effect may be positive (in fact, it is in 2000 positive under Scheme 1 for At, Be, De, Fr, Lu, Se).

If one accepts the compound effect, Scheme 1 suggests aid reductions as efficiency enhancing. That is, a reduction of EU wide railway aid by 10% (roughly €2.5 Bill.) would result in an increase in efficiency by 0.34 percent points.

Scheme 2 and Scheme 3 are redistribution schemes. Some firm receive more, other less aid compared to the factual distribution of aid. In scheme 2 a country with below average aid per capita (per GDP in scheme 3) will receive aid and a country with above average aid per capita (per GDP) has to reduce aid. Both schemes result in a loss of average EU efficiency. Hence, gains from simple redistribution schemes are negative.

Table 3: Changes in technical efficiencies, EU average (2000)

Model	▲TE EU Average
Scheme 1 direct effect	0.0050
Scheme 2 direct + incentive effect	-0.0034
Scheme 2 direct effect	0.0353
Scheme 2 direct + incentive effect	-0.0724
Scheme 3 direct effect	0.0195
Scheme 3 direct + incentive effect	-0.0383

It is interesting to note that Scheme 2 seems to be more "risky" as compared to Scheme 3. In the case where only aid level is increased, keeping aid intensity constant, efficiency gains are roughly 2 percent under Scheme 3 and roughly twice as much under Scheme 2. And when both the direct and incentive effects are taken into consideration, efficiency losses are roughly 3.8 percent under Scheme 3 and roughly twice as much under Scheme 2 and. This suggests that railways firms can either gain or lose roughly twice as much in efficiency under Scheme 2 as compared to Scheme 3.

These results suggest that the effectiveness of aid crucially depends on the specific form of the aid scheme and on the individual country. An aid scheme that does not raise aid intensity is clearly more effective, since the negative incentive effect is minimized and the positive direct effect maximized. However, the compound effect hints to the fact that significant aid reductions are possible without affecting technical efficiency negatively (or even positively).

The Incentive Effect and Investment

In order to check if state aid triggers investment in the presence of low aid intensity, we carried out a further estimation built upon investment data obtained from Eurostat. This data allowed us to measure directly if state aid is complementary to investment when aid intensity is low. Table 4 presents the results of the analysis for the panel from 1988 to 2000.

Table 4:

Dependant variable:		**investment of railway firms**	
Explanatory variables		**Coefficient**	
		Estimation I	**Estimation II**
GDP per capita		1.55	2.31
Railway Aid		0.61**	.
	if aid intensity is high	.	0.26*
	if aid intensity is low	.	0.75**
Aid intensity		-92.79**	.
Constant		28.36**	-16.6**
R^2:		0.56	0.53
Observations:		50	50
Countries:		11	11

Annotations: Due to missing data At, Dk, Lu and Nl are not included. UK only one observation.

We carried out two panel data estimations. In both estimations, investment expenditures of the main railway firms are used as the endogenous variable. In estimation I we included the aid level as well as the aid intensity variable (and GDP per capita). The estimated coefficient shows a positive sign with regard to aid level and a negative sign for aid intensity. Hence there seems to be a comparable relationship between aid and investment as between aid and efficiency. This result supports the interpretation that the various effects of aid on efficiency are driven by the impact of aid on investment. To further elaborate this point we divided the sample into two groups. Group one has a value of aid intensity above the median value for the year 2000 and group 2 below the median aid intensity. The results of Estimation II show that aid is much more efficient in triggering new investment in countries which exhibit a below median aid intensity (the point estimates suggest a value of 3 times more efficient). Note that a test that the two coefficients are equal can be significantly rejected.

V. Comparison to other studies

We compare here the technical efficiency results of our paper with that of other papers. We chose papers that used a similar estimation method, i.e. papers that applied a production function (output) approach. Comparisons are displayed in Table 5.

Coelli and Perelman (2000) utilize a multi-product distance function and estimate technical efficiencies for the 15EU countries over the period 1988-1993. The technical efficiency estimate from the multilateral Tornqvist index is displayed in Table 3. When Austria, Finland and Sweden are omitted due to lack of data before 1995, the correlation coefficient is 0.6579 and the Spearman's correlation coefficient is 0.6853. The null hypothesis under the Spearman's test that the 2 variables are independent can be rejected at the 5 % level of significance.

Cantos, Pastor et al. (2000) estimate the technical efficiency levels using a Data Envelope Analysis. We compare their technical efficiencies estimated from the model that uses passenger-kilometers and ton-kilometers as output measurements. Although their efficiency measurements are from 1970 to 1995, their mean technical efficiency is correlated at the 5% level of significance (the correlation coefficient is 0.7831 and the Spearman's correlation coefficient is 0.6272) with our estimates from 1988-1995.

Thus our efficiency estimates are comparable to other similar studies and represent a sensible up-date of former results high lightening the importance of state aid in explaining Railway firms' efficiency.

Table 5: Comparison of Mean Technical Efficiency Levels

Country	Röller et al. (1988-1993)	Coelli & Perelman (Tornqvist, 1988-1993)	Röller et al. (1988-1995)	Cantos, Pastor et al. (2-INEF, 1970-1995)
At	-	0.723 [13]	0.989 [4]*	0.980 [6]
Be	0.991 [2]	0.807 [3]	0.992 [3]	0.893 [11]
De	0.964 [5]	0.800 [4]	0.957 [7]	0.973 [8]
Dk	0.644 [8]	0.751 [10]	0.645 [11]	0.731 [12]
Es	0.752 [7]	0.738 [12]	0.738 [10]	0.955 [10]
Fi	-	0.926 [2]	0.883 [9]*	1.000 [1]
Fr	0.938 [6]	0.777 [8]	0.941 [8]	0.986 [5]
Gr	0.308 [12]	0.653 [15]	0.296 [15]	0.525 [14]
Ie	0.444 [11]	0.749 [11]	0.443 [14]	0.297 [15]
It	0.988 [3]	0.790 [6]	0.983 [5]	0.971 [9]
Lu	0.998 [1]	0.789 [7]	0.998 [1]	0.996 [4]
Nl	0.977 [4]	0.942 [1]	0.978 [6]	1.000 [1]
Pt	0.502 [10]	0.776 [9]	0.502 [13]	0.978 [7]
Se	-	0.682 [14]	0.994 [2]*	1.000 [1]
UK	0.623 [9]	0.798 [5]	0.622 [12]	0.648 [13]
Correlation coefficient		0.6579 a) (0.0200)		0.7831 (0.0006)
Spearman's correlation coefficient		0.6853 a) (0.0139) 0.8000 b) (0.0031)		0.6272 (0.0123)

Note: Rankings according to the most productive firm are indicated in brackets [].
. data unavailability
*** 1995 values due to data unavailability**
() represent the level of significance of the correlation
a) Spearman's correlation without At, Fi and Se
b) Spearman's correlation without At, Fi, Se and UK

VI. Summary and Conclusion

This paper provides a first step attempt towards a rigorous empirical evaluation of state aid for railway firms. It leads to some important policy relevant results with regard to the railway sector:

- efficiency depends on state aid
- it is positively correlated with the level of aid and negatively with aid intensity
- hence, aid schemes which increase aid, will only become effective if aid intensity is not to high
- significant EU wide aid reductions are possible without loss of technical efficiency
- the potential of state aid to trigger investment is crucial for effectiveness of an aid scheme
- simple EU wide aid redistribution schemes do not allow efficiency gains

However, many important questions are left open by our study as well as by the existing literature regarding the optimal provision of aid to the Railway sector. This is particularly true for the question for further criteria (beside aid intensity, like the degree of external/ revenue based financing, complementarity with other regulatory factors, etc.) which allow to distinct between efficiency enhancing and efficiency tempering state aid. However, data on these specifications have become only recently available. One of the major future research steps is to incorporate those factors into the empirical analysis.

Literature

Andrikopoulos, A. A. and J. Loizides (1998). "Cost Structure and Productivity Growth in European Railway Systems." Applied Economics **30**(12): 1625-39.

Battese, G. E. and T. Coelli (1993). A Stochastic Frontier Production Function incorporating a Model for Technical Inefficiency Effects. Working Papers in Econometrics and Applied Statistics. Armidale, NSW.

Cantos, P. and J. Maudos (2000). "Efficiency, Technical Change and Productivity in the European Rail Sector: A Stochastic Frontier Approach." International Journal of Transport Economics **27**(1): 55-75.

Cantos, P. and J. Maudos (2001). "Regulation and Efficiency: The Case of European Railways." Transportation Research: Part A: Policy and Practice **35**(5): 459-72.

Cantos, P., J. M. Pastor, et al. (2000). "Efficiency Measures and Output Specification: The Case of European Railways." Journal of Transportation and Statistics **3**(3): 61-68.

Christopoulos, D. K., J. Loizides, et al. (2000). "Measuring Input-Specific Technical Efficiency in European Railways: A Panel Data Approach." International Journal of Transport Economics **27**(2): 147-71.

Coelli, T. (1996). A guide to FRONTIER version 4.1: a computer program for stochastic frontier production and cost funciton estimation. CEPA Working Paper 96/07. Armidale.

Coelli, T. and S. Perelman (2000). "Technical Efficiency of European Railways: A Distance Function Approach." Applied Economics **32**(15): 1967-76.

Coelli, T., D. S. P. Rao, et al. (2002). An Introduction to Efficiency and Productivity Analysis. Massachusetts, USA, Kluwer Academic Publishers.

Cowie, J. and G. Riddington (1996). "Measuring the Efficiency of European Railways." Applied Economics **28**(8): 1027-35.

Good, D. H., M. I. Nadiri, et al. (1996). Index Number and Factor Demand Approaches to the Estimation of Productivity. NBER Working Paper Series. Cambridge: 1-88.

Loizides, J. and E. G. Tsionas (2002). "Productivity Growth in European Railways: A New Approach." Transportation Research: Part A: Policy and Practice **36**(7): 633-44.

Oum, T. H. and C. Yu (1994). "Economic Efficiency of Railways and Implications for Public Policy: A Comparative Study of the OECD Countries' Railways." Journal of Transport Economics and Policy **28**(2): 121-38.

Perelman, S. and P. Pestieau (1988). "Technical Performance in Public Enterprises: A Comparative Study of Railways and Postal Services." European Economic Review **32**(2-3): 432-41.

Appendix I:

Studies analyzing efficiency of European railway firms by production/ cost function estimation

Study	Covered years	Covered countries	Method applied	LHS Variable	RHS Variables	Main estimation results	Others results/ remarks
Loizides and Tsionas (2002)	1969-1992	10 EU countries	SUR panel model method using a Cobb-Douglas cost function, allowing for distinct technical coefficients for each country	Total cost	Output: passenger- and tons- km; input: Capital; labor prices; energy prices; dummy for common technological change interacted with all other variables	Total factor productivity is falling for all countries over time except in Germany and UK. Ranking (highest productivity first): De, UK, Be, Fr, It, Nl, Gr, Dk, Lu, Pt.	Results differ significantly from the results of other studies
Cantos and Maudos (2001)	1970-1990	16 firms in EU15 and Switzerland	Stochastic frontier analysis (SFA) using a Translog cost function and a revenue function	Total cost and revenue (from traffic and freight)	output: passenger-km and ton-km; output and input prices. Costs: Labor costs, fuel and energy, consumption of materials and purchases and external services.	Average cost efficiency: 87%, constant over time. Ranking (highest first): Es, Fr, NL,Se, Sw, Pt, Lu, No, Dk, It, At, Fi, Gr, De, Be, Uk Av. revenue efficiency:80%, decreasing over time. Ranking (highest first): UK, Sw, At, Lu, De, No, Dk, Fi, Be, Gr, It, Nl, Pt, Fr, Se, Es	Data from International Railway Statistics (UIC); Physical capital cost not included because of accounting problems
Cantos and Maudos (2000)	1970-1990	16 firms in EU15 and Switzerland	Stochastic frontier analysis (SFA) using a translog cost function	Total cost	Output: passenger-km and ton-km; output and input prices. Costs: Labor costs, fuel and energy, consumption of materials and purchases and external services	Decompose effect which drive growth in total factor productivity (most important first): 1. technical progress 2. technical efficiency 3. efficiencies of scale	
Cantos, Pastor et al. (2000)	1970-1995	17 firms in EU15 and Norway, Switzerland	DEA method	Two estimations 1) passenger- and tons-km 2) passenger- and freight-train-km	input: number of workers, consumption of energy and materials, number of locomotives, number of passenger carriages, number of freight cars, number of track-km	Analyze the effect of distinct output variables. Find high differences with regard to efficiency indicators. Results become closer if a loading factor is included.	
Christopoulos, Loizides et al. (2000)	1969-92	10 EU countries	Zellner's iterative estimation method using a symmetric generalized McFadden cost function	Total cost	Output: total train km Input : capital, labor, energy	Decompose technical efficiency into capital, labor or energy driven effects. Least efficient with regard to capital utilization: Gr, Pt, It. labor utilization: Pt, Dk, Gr. Energy utilization: Dk, Pt, Be.	Data from International Railway Statistics (UIC)
Coelli and Perelman (2000)	1988-1993 and 1978-83	17 firms in EU15 and Norway, Switzerland	COLS method using Multi-input distance functions	Passenger-km and ton-km	Input: labor, rolling stocks and lines.	Mean technical efficiency for the period 1988-93 of 86% ranging from 78%(It) to 98%(Nl). Ranking (highest first): Nl, Sw, Fr, Ie, UK, No, Fi, De, At, Lu, Gr, Be, Es, Se, Dk, Pt, It. Find a rise in average TFP of 16.7% between the two periods.	Data from International Railway Statistics (UIC) Energy data missing

Studies analyzing efficiency of European railway firms by production/ cost function estimation (continued)

Study	Covered years	Covered countries	Method applied	LHS Variable	RHS Variables	Main estimation results	Others results/ remarks
Andrikopoulos and Loizides (1998)	1969-1993	10 EU firms	Zellner's iterative estimation method using a Translog cost function	Total cost	Output: sum of passenger-kilometer and freight-kilometer Input: labor, capital, energy	Total factor productivity is falling for all countries over time except in Germany, France and UK. Least efficient with regard to capital utilization: Fr, Dk, It. labor utilization: Lu,Fr, Dk. energy utilization: Pt, Fr, De.	Data from International Railway Statistics (UIC)
Cowie and Riddington (1996)	1992	11 EU countries, Switzerland and Norway	various estimations methods	Two estimations a) Passenger-km b) Service Indicator	Input: population density, labor, capital	Average efficiency in provision of Passenger-km: 83%, lowest ranking: Be, Fr, Ie in provision of services: 87%,lowest ranking: AT, Sw, Be (overall methods)	Includes comparison of five studies on the provision of train kilometers.
Oum and Yu (1994)	1978-1989	19 railways in EU15, Norway Switzerland, Turkey and Japan	DEA method and Tobit-regression	Two estimations 1) passenger- and tons- km 2) passenger and freight train-km	Input: number of employees, energy consumption, ways and structures, materials, number of passenger cars, number of freight wagons, number of locomotives	Ranking (passenger-km/ tonne-km as output variable 1989): Ie, Nl, UK, DK, Fi, Se, Pt, Lu, Es, No, It, Be, At, Fr, Gr, De. Subsidies negative effect; managerial autonomy positive effect on efficiency	Data from International Railway Statistics (UIC), railways annual reports and national statistical yearbooks.
Perelman and Pestieau (1988)	1970-1983	EU-15 plus Norwegian, Japan, Turkey, Switzerland	COLS method using a deterministic frontier translog production function	Passenger- and freight-trains-km (aggregated index of both)	Labor, energy, rolling and fixed stock, index of relative importance of the two outputs and so called exogenous factors representing the regulatory and institutional environment.	Total factor productivity is rising in most EU-countries.. Exception: Ie, It, Lu. Ranking technical efficiency for EU countries in 1981-83 (highest productivity first): Ie, Nl, Dk, Pt, Fr, Se, Fi, Es, UK, De, At, Lu, Be, It, Gr. For all countries: Average TFP change = 1.03%; Technical Progress = 0.9% and Efficiency change =0.13%.	See efficiency change as main policy variable (not total factor productivity, which includes technological progress in addition)

Appendix II: Summary of data

Variable		Mean	Min	Max	Obs.	Definition
Ouput	Aggregated Output	1.00	0.12	2.04	288	Revenue weighted, multilateral output index
	Freight output	737	27	2155	289	Total ton-kilometers for revenue-earning rail freight traffic in millions
	Passenger output	668	147	1208	289	Number of passenger-kilometers for revenue-earning rail passenger traffic in millions
Labor		3807	845	11384	282	Annual mean staff strength in persons per capita
Capital	Length of lines	532	176	1411	289	Length of lines worked in km per capita
	Passenger stock	225	43	538	285	Passenger transportation stock in number per capita
	Freight stock	2229	209	8729	282	Freight transportation stock in number per capita
Energy	energy consumption	619	119	1369	176	diesel und electrical energy consumed in Terra Joule (TJ) per capita
Control variables	Electrified lines	0.45	0.02	0.95	289	Share of electrified lines to total lines worked
	Area per inhabitant	1480	213	6346	289	Area per capita in 1000 ha per capita
	GDP per inhabitant	17.71	6.88	42.9	265	GDP in constant 1995 € billion per capita
Railways aid	Aid level	100.8	1.81	566	170	Aid towards Railways All instruments
	Aid intens	0.49	0.03	1.5	155	Railways Aid/ Total operating cost

Annotations: GDP data in billion, all other monetary variables in constant 1995 million Euro. All variables, which are no percentages, are divided by million inhabitants. Mean and minimum value without zero observations.