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EFFICIENCY IN EUROPEAN RAILWAYS: NOT AS INEFFICIENT AS ONE MIGHT THINK

DIMITRIS CHRISTOPOULOS
Department of Regional and Economic Development, Panteion University, Athens, Greece

JOHN LOIZIDES
Department of International and European Economic Studies, Athens University of Economics and Business, Athens, Greece

EFTHYMIOS G. TSIONAS *
Department of Economics, Athens University of Economics and Business, Athens, Greece

The paper studies technical inefficiency in the railway systems of ten countries of the European Union. A new approach is used which permits the disaggregation of inefficiency by factor of production to result in estimates of input-specific technical inefficiency. The cost structure is represented using a generalized McFadden flexible functional form. Policy implications and guidelines for rational decision making in the railway sector, are discussed in detail.

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* Address: Dr. E.G. Tsionas, Council of Economic Advisors, Ministry of National Economy, 5 Nikis Str., Syntagma Sq., 101 80 Athens, Greece. Tel.: *(301) 333-2558*, Fax: *(301) 333-2527*, Internet: soe3@compulink.gr

I. Introduction

The measurement of technical efficiency in railways and other public enterprises, especially in the transportation sector is still an area of active interest in applied economics.[1] Part of this active interest is the preoccupation of policy makers and managers with mounting subsidies and high (alleged) inefficiencies in the sector. Although many studies document the existence of overall technical inefficiency[2] and propose policies designed to improve efficiency and productivity growth, there have been no studies that examine the important issue of how technical inefficiency is decomposed into separate factor-specific components. Other researchers have obtained numerical estimates of total factor productivity growth or overall production inefficiency, used regression analysis to relate these measures to railway technical characteristics or policy variables (mainly subsidies and corporate autonomy regarding pricing) and provided policy recommendations based on their results.[3]

Such results, however, should be viewed with some caution. These studies do not identify the source of the problem as they are only able to provide measures of overall (or catch-all) technical inefficiency. If it were possible to identify the sources of inefficiency and decompose it by input, it would be possible to direct policy efforts towards more efficient use of the factors of

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[1] See Nolan (1996), Hensher *et al*. (1995), Friedlander et all. (1993), McGeehan (1993), Gathon and Perelman (1992), McMullen and Stanley (1988), and Perelman and Pestieau (1988).

[2] Cost structure in the transportation sector has been examined using a number of techniques, including data envelopment analysis (Oum and Yu, 1994 and Nolan, 1996), conventional measurement techniques (Nash, 1985, Thompson and Fraser, 1993) and econometric approaches (Caves *et.al.*, 1981, 1984 and the references cited in the text).

[3] See for example Caves, Christensen and Swnason (1981), Caves, Christensen and Tretherway (1984), De Borger (1984, 1993), Gillen and Oum (1984), McMullen and Stanley (1988), Obeng (1985), Viton (1981), Perelman and Pestieau (1988), Deprins and Simar (1989) and Gathon and Perelman (1992).

production that are more heavily under-utilized. Moroever, if for some reason employment of a subset of inputs can not be reduced, it is still possible to increase the effectiveness of other inputs. Identifying these factors and the extent of their under-performance is, therefore, an important policy issue.

From a methodological point of view the question of inefficiency was examined by previous studies using the Cobb-Douglas or the translog production (cost) function. However, it is well known that the Cobb-Douglas production function is too restrictive to represent the technology of production. Since one would expect the estimates of technical efficiency to be affected by the extent of restrictiveness of the functional form, it is desirable to use flexible functional forms. On the other hand, flexible functional forms such as the translog cost function are only an approximation of the true function and we cannot expect concavity in factor prices to be satisfied globally. Concavity may be verified by testing whether the bordered Hessian matrix of the second derivatives is negative definite at each observation. However, most empirical studies fail to satisfy the concavity condition, see Conrad and Jorgenson (1977), Field and Grebenstein (1980), and Rao and Preston (1984) for example. The violation of the concavity condition implies that the underlying input demand equations are unstable and non-flexible. However, the data must be generated by stable demand equations, see Field and Grebenstein (1980). In this case the observed data which do not satisfy the concavity condition are simply incompatible with the hypothesis of cost-minimization. Of course, one may argue that if curvature conditions are satisfied in all but “few” observations then we may proceed as if technology was concave (Eakin and Kniesner, 1988). Since a rigorous statistical measure of “few” is unavailable it would be preferable to have a cost function which allows for *global imposition* of curvature conditions while at the same time giving us indication that imposing such constraints is at odds with the data. The cost function we use -the symmetric generalized McFadden form- allows exactly that.

The paper contributes to the following areas:

(i) Use is made of a symmetric generalized McFadden flexible form to

represent the cost structure of railway systems for ten countries of the European Union. One advantage of adopting this form is that neoclassical curvature conditions can be imposed globally. The overall, catch-all technical efficiency framework ia abandoned by adopting an input-specific inefficiency approach.

(ii) Quantitative evidence is provided on the magnitude of technical inefficiencies due to capital, labor and energy by country and over time, as well as estimates of the cost of such inefficiencies.

(iii) Numerical estimates are provided of cost savings that would be realized if policy makers reduced input-specific inefficiency to zero. Such estimates *may be of value* for rational decision making in this context.

The remaining of the paper is organized as follows. The theoretical model is developed in the next section. The data are presented in section 3. Section 4 contains our empirical results. Section 5 discusses the policy implications of the input-specific technical inefficiency model. The final section concludes the paper.

II. Theoretical Model

The specification of the adopted model starts with the assumption that the technology applied in the production process can be described by a twice differentiable production function which relates the flow of output with various inputs of production. In algebraic terms it can be expressed as

$$Y = F(\mathbf{X},T) \tag{1}$$

where Y denotes output, **X** is the vector of inputs, and T is an index of technological progress. It is assumed in (1) that F(**X**,T) is finite for every **X** and T, and continuous for all nonnegative Y and **X**. It is also assumed that monotonicity is valid for F(**X**,T), and the production function is strictly concave, see for example Diewert (1971) and Hall (1973).

Given the production function (1) and the associated assumptions, the cost function can be derived from standard duality principles (Samuelson, 1947, Uzawa 1964 and Shephard, 1970). Duality implies that there is a cost function equivalent to the production function that can represent the technology of production and vice versa.

To begin with, it is assumed that the cost function that corresponds to the production function can be written as

$$C(\mathbf{P},Y,T) = \min PX, \quad \text{s.t.} \quad Y \leq F(\mathbf{X},T),\ \mathbf{X} \geq 0 \tag{2}$$

where C stands for total cost and **P** is the vector of input prices. The cost function (2) is considered, similarly to (1), to be twice differentiable in **P** and T, finite for every **P**, $Y \geq 0$ and T, continuous in Y and **P**, linearly homogeneous in **P**, non- decreasing in $Y \geq 0$ and **P**, and concave in **P** .

Next, we specify the cost function (2) for European rail cost as

$$C = C\,(P_k,\ P_L,\ P_E,\ Y,\ T) \tag{3}$$

where Y is output, P_K is the price of capital, P_L is the price of labor, and P_E is the price of energy.

Taking into account that (3) is valid at each point in time (t = 1, 2, ...T) and each railway system (r = 1, 2, ...R), and assuming it can be represented by a Symmetric Generalized McFadden Cost Function (SGM), (see Diewert and Wales, 1987) it follows that

$$C^{*}(\cdot) = g(\mathbf{P})Y + \sum_i b_{ii} P_{irt} Y_{rt} + \sum_i b_i P_{irt} + \sum_i b_{iT} P_{irt}\, T\, Y_{rt} + \tag{4}$$

$$+ b_t \Big(\sum_i a_i P_{irt}\Big) T + b_{YY} \Big(\sum_i b_i P_{irt}\Big) Y_{rt}^{2} + b_{tt} \Big(\sum_i g_i P_{irt}\Big) T^{2} Y_{rt}$$

i, j = K, L, E,

where T stands for time trend (the customary proxy for technical change) and the g (.) function is defined by

$$g(\mathbf{P}) = \frac{1}{2} \cdot \frac{\mathbf{P}^T \mathbf{S}\,\mathbf{P}}{\Theta^T \mathbf{P}} \tag{5}$$

In (5), **S** is an 3 x 3 symmetric negative semidefinite matrix such that $\mathbf{S}^T\mathbf{P}^* = 0$ with $\mathbf{P}^* >> 0$ and $\Theta^{T*} = (\Theta_1, \Theta_2, ... \Theta_N)$ is a vector of nonnegative constants, not all equal to zero.

According to Diewert and Wales (1987) the cost function $C^*(.)$ is a flexible homogenous function in **P** and Y at the point ($\mathbf{P}^{*T}$, $\mathbf{Y}^{*T}$, $\mathbf{T}^*$) when the following restrictions hold

$$\Theta^T \cdot P^* > 0\,, \qquad \alpha_i^T P^* \neq 0, \qquad \beta_i^T P^* \neq 0 \quad \text{and} \quad \gamma_i^T P^* \neq 0 \tag{6}$$

Also, the cost function $C^*(.)$ defined in (4) is globally concave in input prices, **P**, if the estimated **S** matrix is negative semidefinite, (see theorem 11 of Diewert and Wales, 1987). If the estimated **S** matrix is not semidefinite negative then, negative semidefiniteness can be imposed without destroying flexibility of $C^*(.)$ by setting $\mathbf{S} = -\mathbf{B}\mathbf{B}^T$, where $\mathbf{B} = [b_{ij}]$ is a lower triangular matrix, $b_{ij} = 0$ for i < j and estimate **B** instead of **S**, see Diewert and Wales (1987) and Wiley, Schmidt and Bramble (1973). The parameters in Θ along with b_t, b_{YY} and b_{tt} are assumed to be exogenously given. The remaining parameters, b_{ii}, b_i, b_{iT} are to be estimated.

Differentiating (4) with respect to factor prices and applying Shephard's lemma gives the conditional demand functions

$$X_{irt} = \frac{\partial C}{\partial P_i} = Y_{rt}\left[\left(\frac{\mathbf{S}^i \mathbf{P}}{\Theta^T \mathbf{P}}\right) - \frac{\Theta_i}{2}\left(\frac{\mathbf{P}^T \mathbf{S}\mathbf{P}}{(\Theta^T \mathbf{P})^2}\right) \right] + b_{ii} Y_{rt} + b_i + b_{iT}\, T\, Y_{rt} + b_t \alpha_i T + \tag{7}$$

$$+ b_{YY} \beta_i Y_{rt}^2 + b_{tt} \gamma_i T^2 Y_{rt} + \varepsilon_{irt}$$

where $\mathbf{S}^T\mathbf{P}^* = 0$ since $\mathbf{P}^*$ is chosen to be the vector of ones and $X_i = K, L, E$ is the quantity demand of the production input, i = K, L, E. e_{irt} is the usual statistical noise.

Proceeding with model specification, the disturbance term e_{irt} in (7) is decomposed as

$$e_{irt} = V_{irt} + T^*_{irt} \tag{8}$$

We allow V_{irt} to be normally distributed to reflect the random variation of the cost function across railways systems, and to capture the effects of statistical noise, measurement error and exogenous shocks beyond the control of the production unit. The rationale behind normality is simply convenience at the estimation stage plus the fact that we lack information upon which to base alternative stochastic specification assumptions. T^*_{irt} represents technical inefficiency associated with input i = K, L, E for the r^{th} railway system. Further, T^*_{irt} can be interpreted as the amount by which the use of input i = K, L, E could be reduced using that amount of other inputs corresponding to a situation of full technical efficiency in the production process.

This concept of input-specific technical efficiency is based on the notion that the demand for any input, given all other inputs and output, may not increase equally because of technical inefficiency, see Kumbhakar (1989). This approach to the concept of technical efficiency is more general and is in contrast with approaches based on overall technical efficiency where the demand for each input, given output, increases equiproportionally, see for example Ali, Parikh and Shah (1996) and Dawson, Lingard and Woodford (1991).

The hypothesis that overall technical efficiency is a better description of the production process, can be tested against our more general input-specific technical efficiency specification, by considering that T^*_{irt} is the same for all inputs i = K, L, E. Of course the effectiveness of any input can never exceed 100%, $T^*_{irt} \geq 0$. If $T^*_{irt} = 0$ then it defines the stochastic production frontier or the best practice technology. In this case production lies on the stochastic frontier and the railway system is fully technical efficient. Following Kumbhakar (1989) input-specific technical efficiency for input X_i can be defined as

$$TE_{irt} = \frac{X^*_{irt}}{X_{irt}} = 1 - \frac{T^*_{irt}}{X_{irt}} \tag{9}$$

where X_{irt} is the minimum quantity of input i required to produce a given level of output keeping all other inputs unchanged. *One notable advantage of (9) over traditional inefficiency measures (DEA or frontier models) is that technical inefficiency, besides being specific to each factor of production, also depends on factor quantities*. If $T^*_{irt} > 0$ increasing use of input i implies more inefficiency. If $T^*_{irt} < 0$, increasing factor usage results in less inefficiency.

Since inefficiency increases cost, it is important to calculate the percentage increase in cost due to inefficiency in the use of capital, labor and energy. These indices can be calculated from the following formula, due to Kumbhakar (1989):

$$CTE_{irt} = 1 - \frac{P_{irt} \cdot T^*_{irt}}{C} \tag{10}$$

Finally, the term T^*_{irt} used to calculate TE_{irt} and CTE_{irt} can be estimated as:

$$T^*_{irt} = \hat{d}_{irt} - \min(\hat{d}_{irt}) \tag{11}$$

i = K, L, E r = 1, 2, 3, ... R

where $\hat{d}_{irt}$ is a dummy variable for each railway system introduced in the demand system defined in (7), see Kumbhakar (1989, 1990b). The *overall technical efficiency model (OTEM)* emerges as a special case when d_{irt}'s are the same for each i. From (9) and (10) is clear that *input-specific technical* *inefficiency as well as the cost of input-specific technical inefficiency are time varying.* Thus the model does *not* carry the unreasonable implication that inefficiency is constant over time. Moreover, in line with Hay and Liu (1997) the T_{irt}^{*}'s may be interpreted as structural or long-run input-specific inefficiency components. These are likely to reflect geographical factors, long-run government scope in the transportation sector, accepted arrangements with syndicates, etc.

Before proceeding we must point out that by adopting a generalized MacFadden cost function we are able to incorporate all neoclassical restrictions without sacrificing the fit of the model relative to a translog approximation. Indeed, from (7) input demand equations contain almost all terms that a translog would contain, except that prices enter quadratically. To the extent that prices have some persistence, it is expected that the generalized MacFadden cost function is not a bad approximation provided the translog is. Of course, the functional form of the cost function matters as far as efficiency measurement is concerned. The significance of using a generalized MacFadden cost function instead of other forms, for example the translog, is that once curvature restrictions are imposed on the translog it ceases to be flexible. Therefore there is a trade-off between consistency with the neoclassical restrictions and flexibility which we are able to bypass by using the generalized MacFadden form.

III. Data Description and Sources

The data used in this study covers the period 1969-1992[4] for the railway systems of ten countries of the European Union, namely Belgium, Denmark, France, Germany, Greece, Italy, Luxembourg, Netherlands, Portugal and the United Kingdom. The data set includes output, cost, price and quantities of capital, labor and energy. The cost of capital is user's cost defined as the sum

[4] According to UIC, data after 1992 are not comparable with data before 1992.

of interest and depreciation costs. Capital prices were obtained by dividing user costs by the capital stock. Capital stock includes land and fixed installations, transport stock and other equipment. The source of data is the International Union of Railways (UIC,1960-1993). For Belgium, France, Greece and the United Kingdom, we have used the price deflator of transport equipment (obtained from the National Accounts of O.E.C.D) as the price of capital, because frequent re-evaluations of the capital stock distorted capital prices.

The quantity of labor is the number of employees. Labor costs have been obtained as the sum of total wages and salaries paid, including benefits and pensions. Labor costs divided by the number of employees gives the price of labor.

Electricity, diesel oil and lubricants expressed in equivalent thermal units consumed, give the energy input. The price of energy is defined as the ratio of energy cost divided by equivalent thermal units. Since the International Union of Railways Statistics does not report energy values for 1990-1992, these were taken from O.E.C.D (1995) adjusted for conformity to those used for the period 1969-1990.

The definition of output is dictated, to a large extent, by the availability of data. We use as output total traffic units as reported by the International Union of Railways (UIC,1960-1993). See also Nash (1985). Several previous studies have used the same measure of output, see Perelman and Pestieau (1988), Gathon and Pestieau (1992), Gathon and Perelman (1992) and Oum and Yu (1994). We have also experimented with alternative definition of output defined as a revenue-weighted sum of kilometric passengers and kilometric freight, however our results were robust to this choice. Finally, value and price data have been converted to U.S dollars using exchange rate data obtained from the International Monetary Fund (1997).

It must be mentioned that measuring passenger train service output in terms of train kilometers may work to the disadvantage of those railways -notably France an Italy- that operate a large proportion of long, heavily loaded trains. In this respect we have followed Andrikopoulos and Loizides (1998) who have used a translog cost function with the same definition of output. It would be worthwhile to compare results with a multi-output cost function specification, a topic that we leave for future research. The chances that multi-output specifications will be successful are, however, slim. The reason is that the symmetric generalized McFadden has not been generalized to allow for multi-output production, and important technical problems remain before a solution to the problem can be suggested. For this reason, we stick with a single-output, symmetric, generalized McFadden specification.

Another point is that quality aspects related to timetable, frequency, punctuality, reliability, security, response to complaints, etc., are ignored in our definition of output. These considerations are important because they are related to the public's perception about the "efficiency" of a railway system. Therefore, a quality adjusted measure of output could show different results. The problem, however, is that we do not have the necessary data to construct this quality adjusted output index.

IV. Statistical Estimation and Results

Since the cost function (6) contains no additional statistical information, only the demand functions (7) are used for estimation. The system of conditional demand functions contains all the parameters in the cost function. However, not all the parameters in (7) can be identified and therefore estimated. For estimation purposes, $_{i}$ was set equal to the mean quantity of the corresponding input X_i over the whole sample. Also, we set b_t, b_{YY} and b_{tt} equal to unity. It has been mentioned before in the literature that by adopting these assumptions, the estimated system (7) is made more flexible. System (7) was estimated by Iterative Zellner's Efficient Method (IZEF). The IZEF method yields estimates asymptotically equivalent to those of full information maximum likelihood, see Kmenta and Gilbert (1968). It should be noted that there are three equations to estimate (demands for capital and labor, and energy) but this has to be done using the entire panel, *not* each country separately, in order to exploit information and get more efficient parameter estimates. The resulting system is of course highly nonlinear for two reasons. First, because of the nature of the McFadden form and, second, because of the presence of cross-equation restrictions in the panel.

An additional complication was that regressions of estimated residuals on their lagged values indicated the presence of autocorrelation. To cope with the problem, we used a first order autoregressive process (AR(1)) specification to remove autocorrelation. The overall technical efficiency specification (OTEM) was estimated and tested against the more general specification in (7). The statistical comparison between the input specific technical efficiency specification (ISTEM) and the overall technical efficiency specification (OTEM) reveals that *the ISTEM is superior to its corresponding OTEM* (the relevant likelihood ratio test -asymptotically distributed as χ^2 (10)- is 113.52 with a 5% critical value equal to 18.31).

Therefore, in view of the testing procedure the ISTEM is adopted to estimate and analyze technical efficiency in European railways. One may, however, argue that imposing global concavity in the McFadden form is undesirable, because such restrictions may be incorrect in the light of the data. Therefore, we have estimated the system *without* imposing curvature conditions. Next, we have estimated the Hessian of the system. If the Hessian is not negative definite we know that either we have used the wrong functional form, or that (given the functional form is correct) neoclassical production theory is rejected by the data. However, the estimated **S** matrix turned out to be negative definite, which implies that the estimated cost function is globally concave.

Turning now to regression results of the ISTEM reported in Table 1, we notice that R^2 values for model (7) are very high. They are 0.79, 0.97 and 0.94 for the capital, labor and energy equations respectively. The system R^2 was 0.997. Since we have performed an autocorrelation correction these high values are not necessarily attractive features. On the other hand, the majority of coefficients are statistically different from zero at the conventional 5% level of significance. These results show that the ISTEM provides an acceptable fit to the data.

Table 1. Parameter Estimates for the Symmetric Generalized McFadden Cost Function

Parameter	*Capital equation*	*Parameter*	*Labor equation*	*Parameter*	*Energy equation*
S_{KK}	$-1.76x10^2$*				
	[-2.367]				
S_{KL}	3.13*				
	[2.527]				
S_{LL}	-7.39				
	[-0.524]				
B_{KK}	-.330460	b_{LL}	.564894*	b_{EE}	-7.234931*
	[-0.196]		[5.034]		[-6.986]
B_{KT}	-.181212	b_{LT}	-.047556*	b_{ET}	.037848
	[-1.369]		[-5.422]		[1.102]
α_T	-.045372	α_T	-.030994*	α_T	1.274656*
	[-0.346]		[-3.582]		[3.957]
β_K	.125883	β_L	-.044595*	β_E	1.070314*
	[0.388]		[2.102]		[5.316]
γ_K	.10559*	γ_L	.001615*	γ_E	-.002387**
	[2.266]		[5.184]		[-1.7111]
R^2	0.794	R^2	0.972	R^2	0.946
D.W.	1.694	D.W.	1.899	D.W.	2.020

Notes: K stands for capital, L for labor and E for energy. t-statistics are reported in parentheses beneath parameter estimates. D.W stands for the Durbin-Watson statistic. System R^2 was 0.997. *, ** indicates statistical significance at 1% and 10% level respectively. Parameter estimates for the generalized McFadden form cannot be given a structural interpretation, and therefore, evaluation of parameters based upon the signs of parameter estimates is not possible. The fit of the model can, however, be evaluated on the basis of statistical significance and equation or system values of R^2's.

All parameter estimates have been divided by 10^6 (save for elements of **S** where the scale factor is 10^{10}) which amounts to a re-scaling of the data. This does not affect the signs or relative magnitudes of estimates. The large values of coefficient estimates are due to the fact that (in original units) the dependent variable assumes large values while prices assume small values. Such large values of coefficients are not unusual in the McFadden functional form literature, see Kumbhakar (1989) for additional details.
Fixed effect coefficients are not reported to save space, but are available from the authors on request. Fixed effect coefficients can be identified with "structural input-specific inefficiency" as mentioned in the main text.

Turning now to results concerning *input-specific inefficiency*, although, in some countries, there has been substantial progress in improving efficiency (for example France, Denmark and Italy) in Greece, and Portugal the inefficiency problem proves to be structural. In the beginning of 1990 there has been a large drop in capital efficiency in both Greece and Portugal. Before that date, Greece has made substantial progress in improving its capital efficiency. Portugal has been improving on a slower but constant rate. With the exception of the U.K. (notice the large drop in energy efficiency in 1984[5]) and subject to the above exceptions and qualifications, the inter-temporal variation in input-specific efficiencies in the majority of E.U railways, has been minor.

Next we derive estimates of input specific technical efficiency (TE_{irt}) and cost of inefficiency due to inputs (CTE_{irt}), we substitute T_{irt} from (11) in formulas (9) and (10) and evaluate X_i and C at their sample means to provide an *overall measure of input-specific inefficiency* in order to be able to discuss in some detail the policy implications of our model.

The results are presented in Table 2, and can be summarized as follows:

[5] This can be attributed to the structural reforms applied by the Thatcher government. Several workers lost their jobs, and several lines have been closed in that period. For a more detailed analysis see for example Pitfield and Whiteing (1985).

1. The efficiency measures of capital indicate that Greek, Portuguese and Italian railway systems are the least efficient in the use of capital compared to all systems in the sample. More specifically, Portugal's railway system could employ 29.34% less capital, Greek 25.8% and Italian 13.78% compared to the French railway system which is the most efficient -and defines the frontier.

2. Portuguese, Danish and Greek railway systems are the least efficient in the use of labor. They may save 19.45%, 6.34% and 4.52% labor respectively, to move to the frontier defined by France which employs labor 100% efficient. Equivalently, Portuguese, Danish and Greek railways are 19.45%, 6.34% and 4.52% technically inefficient relative to France's use of labor.

3. High technical inefficiency in the use of energy is observed in the case of Denmark (21.41%), Portugal (16.14%) and Belgium (7.95) while the highest technical efficiency is observed in the case of Dutch railways (100%).

4. Capital-specific technical inefficiency increases the cost substantially in the case of Greek and Portuguese railways. It is found that the cost increases due to inefficiencies in the use of capital of order 11.51% and 10.15% for Greek and Portuguese railways respectively.

5. The inefficiencies associated with labor and energy are very close to each other and imply nearly 5% cost increases for Portuguese and Belgian railways. In Denmark, the presence of energy specific-technical inefficiency which is rather high, implies cost increases -associated with energy technical inefficiency- equal to 8.32%.

Table 2. Overall Measures of Input-specific Railway Efficiency and its Cost by Country

Railway System	*Efficiency of Capital*	*Efficiency of Labor*	*Efficiency of Energy*	*Cost of Inefficiency due to Capital*	*Cost of Inefficiency due to Labor*	*Cost of Inefficiency due to Energy*
Greece	74.22%	95.48%	95.81%	11.51%	1.36%	1.23%
Portugal	70.66%	80.55%	83.86%	10.15%	5.24%	5.08%
Italy	86.22%	98.59%	98.35%	1.63%	0.63%	0.71%
Denmark	97.73%	93.66%	78.59%	0.55%	1.96%	8.32%
Belgium	96.17%	96.36%	92.09%	1.33%	5.25%	4.50%
Netherlands	96.52%	98.71%	100.00%	1.74%	0.31%	0.00%
France	100.00%	100.00%	98.99%	0.00%	0.00%	0.23%
U.K	99.87%	99.90%	97.75%	0.05%	0.03%	0.73%
Germany	99.54%	99.92%	99.98%	0.23%	0.02%	0.32%
Luxembourg	99.74%	99.96%	94.15%	0.08%	0.02%	0.92%

Notes: Computed from (9) and (10) when evaluated at sample means.

V. Policy Implications

Our results have implications for policy design and strategic planning in European railways. First of all, we have provided quantitative information on the magnitude of input-specific inefficiencies. This information can be used, first of all, to identify the sources of problematic performance. The inefficient use of capital seems to be a problem in Greece, Portugal and Italy. Labor inefficiencies are quantitatively important only in Portugal. Energy use is comparatively less efficient in Portugal and Denmark. Based on these results one would be tempted to conclude that Greece, Portugal and Italy should try to use capital resources in railways more efficiently, Portugal should reduce labor inefficiency and Portugal and Denmark should make attempts to make energy use more efficient. What makes our approach more powerful compared to traditional approaches that provide measures of overall efficiency, is that our approach can identify the sources of inefficiency and provide guidelines as to which inputs are responsible for the inefficiency problem.

However, such conclusions are not always relevant for policy making because the presence of large inefficiencies does not necessarily imply that their drastic reduction will result in equally drastic cost reductions. A host of historical, geographical, commercial and social factors play significant role. Firm-specific technology variables influence its production costs relative to other firms. Examples might include terrain, demand and network conditions such as highly seasonal traffic and empty backhauls, for imposed public duties such as serving low density routes. Even service frequency is often an important part of the social obligation laid on European railways by their governments and mean train loads are also influence by constraints on the complete closure of lightly used routes. Therefore, cost differences would partly explained by changes in these factors, rather than in the underlying efficiency of the railways concerned. Moreover, our approach is capable of providing measures of cost reductions associated with complete elimination of input-specific inefficiencies, which is what is really relevant for policy makers. Based upon the quantitative evidence in the last three columns of Table 2, main conclusions can be summarized as follows:

1. Two railways, Greek and Portuguese stand out from the rest on capital inefficiency grounds. In Greece and Portugal total cost can be reduced by 11.51%, 10.15% and 1.63% respectively provided capital use becomes 100% efficient: Greece wastes 25.18% of its capital resources, yet reducing the magnitude of the inefficiency will reduce cost by only 11.51%. Portugal's 30% inefficiency corresponds to a 10.15% cost reduction. Interestingly, Greek and Portuguese railways are quite similar in operating characteristics. On the other hand, in Italy, the capital efficiency problem

is highly structural, since Italy's complete elimination of 14% waste of capital resources will reduce cost by only a minor 1.6%. One explanation might be sought in terms of capital stock. In Italy a significant proportion of investment spending during the period under consideration is on completely new routes, rather than increased capitalisation of existing routes, whilst in Portugal and Greece (and Belgium) the higher spending is concentrated on track, signalling and electrification (only in Belgium and Portugal) rather than on rolling stock. In Greece and Portugal the railway network consists of approximately 2.600 kilometres of running track. A large proportion of this running track, however, (about 90%) is a low-quality single line track which rarely handle more than two trains each way per hour; whereas an appropriately signalled double-track may handle up to 20-30, provided that they are operating at similar speeds. On the other hand, the type of traction and rolling stock used is usually confined to low powered rail cars. Greek and Portugal are good examples (but by no means isolated) with regards to inter alia, their aged diesel multiple unit fleet. These aged units (more than 90%) make up the majority of services provided by both networks. Given that the units were built with a life span of 15-20 years, the inference should be clear. The financial burden of this particular obsolescence is such that, according to the Greek railway officials, unit costs operation increased eightfold during the 80's due to escalating maintenance requirements. The existence of a fixed track and associated works creates a considerable potential carrying capacity and the objective of any railway system is usually seen in terms of maximising utilisation of that capacity. (the marginal cost of achieving such a situation can be very low indeed. Bleasdale(1983) shows that the long-run marginal cost of operating an extra railway coach (72 seats) can be as low as 0.4 pence per seat mile). There are, however, two broad reasons why Greek and Portuguese railways find it difficult to maximize this potential. Firstly, the original construction of the single running track we mentioned above imposes limitations due to track layout, curvature, gradients, strength of bridges, etc. Secondly, the type of traction and rolling stock used is usually confined to low powered diesel rail cars. In Greece and Portugal the generalised time taken to complete a journey is normally compounded by the limited frequency of service offered, poor interchange, and lengthly travel time. Even then, the precise location of the railway station is often sub-optimal of the majority of the populace served. Thus service quality tends to stagnate or, at times decline. Furthermore, the changing nature of industrial production (i.e. the decline of the traditional bulk industries such as coal-minining and steel which made extensive use of rail transport coupled with the rise of manufucturing industry with somewhat different transport needs and often located away from the main railway atreries) combined with increased competition from road transport meant that these railways were hit rather more than many other sectors after the second half of the 80's. Finally, Greek railways enjoying high density operation over long distances in both the passenger and freight sector and Portuguese a slightly higher density operation over long distances only in the freight sector.

2. Labor's efficient use is a major problem only in Portugal: Portugal's 20% waste of labor resources, if eliminated, would result in a 5.24% reduction in total cost -indicating again the resistance of cost to inefficiency reduction. It should also be noted how different systems differ in their cost effectiveness: Both Belgian and Greek railways are about 4-5% inefficient. Yet in Belgium, total cost will decline by 5.25% and in Greece by only 1.36% if managers act to eliminate the inefficiency! Why do such differences occur? Much, again, would seem to depend on the regime under which the railways operate. For instance, there is some evidence of a relationship between mean train load and average trip length or average length of haul, reflecting the fact that on longer distance services it is more worth accumulating traffic over time and for a variety of origin-destination pairs than in the case of short distances. However, in Belgium

a 40 per cent rise in passenger train km during the time period under consideration has been accompanied by a 12 per cent lost of traffic. Within the freight sector there has been a modest decrease (5 percent) in both train kilometres and the number of tonnes carried probably because smaller yards and depots are closed. The point, however, is that where trains are on average more heavily loaded (and in Belgium railways have by far the largest mean freight load and the shortest mean length of haul) there the amount of rolling stock and terminal capacity and thus staff and costs, will be higher. One would not expect length of trip of length of haul to be all that important in determining efficiency. It may be argued that a high density regular interval service as it is in Belgium lends itself to high productivity operation. Important economies of scale in staff per train km are likely to arise from the density of train services over the route system. In comparing, however, passenger and freight train km in Belgium there is a fair degree of consistency with freight train kilometres requiring 2.6 times as many staff as passenger. Thus, Belgian railways lagged seriously behind other railways in train crew productivity, and that the principle reason for this is that it employs a minimum of two -and usually three- staff on the freight train, when elsewhere single-manning is common. British and the Netherlands railways had succeeded in rationalising their freight and parcels operations to the extent that marshalling their terminals staff requirements had been reduced substantially below those of other railways. Finally, labour protection legislation often prevents realization of another class of potential benefits, improving the productivity of employees, by reducing reduntancy and taking advantage of economies of scale and traffic density. Some of these measures have been implemented, although some more contentious aspects of the plan (including one-person operation of trains) have been blocked by union opposition.

3. Portugal and Denmark are both energy inefficient to a significant degree (about 16% and 21% respectively). Reducing these inefficiencies will result

in 5.08% and 8.32% cost savings respectively. An explanation might be sought it terms of differences in the levels of electification . There is some evidence that traction and rolling stock maintenance requirements are reduced by at least 50 per cent by the use of electric traction, and this is a very significant part of total operating cost. Portugal, Denmark and to a lesser extent Berlgium, suffer the disadvantage of low levels of electrification. Thus it makes a great deal of sense these railways to extent the electrification of their lines and especially in Greece, where no electrified lines are available.

4. Although Belgian railways are about 92% energy-efficient (which can be considered satisfactory) trying to use energy 100% efficiently will result in a drastic 4.5% cost reduction, which is about the cost savings we would expect in Portugal as a result of reducing its 16% energy use waste! It is thus very meaningful for Belgium to use energy and labor even more efficiently in order to experience a drastic 10% cost reduction. It must be mentioned that here we have focused on cost reductions associated with total elimination of factor inefficiencies, although it is clear that managers may find it optimal to reduce inefficiencies only to some extent. Primarily because there is no motivation from within the organisations, nor is there any external demand pressure on the managers of the system to function more efficiently. Setting up standards of performance at each level and providing adequate incentives to function efficiently has not been attempted in a systematic basis (see Allen and Williams (1985)). However, our estimates can be thought of as upper bounds to actual cost reductions corresponding to partial elimination of inefficiencies. Some european railways (i.e. British Rail, the Netherlands rail) have made significant economies in certain areas; examples have been the removal of station staff and the introduction of the conductory-guard joint function. The key deficiency, however, of some other railways, i.e. Greek and Portuguese, has been an inability to invest in order to minimize losses. With regard to

cost reductions (the major area of potential) there are two areas of justification for such investment. These are, firstly, to simplify the method of operation and secondly to replace obsolescence. It is only at the mid 80's when faced with an acute problem relating to the latter these governments are now agreeing to a significant investment programme. The first priority is the gradual replacement of the aged diesel multiple unit fleet. The new railway plan also includes the construction of locally based maintenance depot; erosion of traditional areas of labour demarcation, resignalling of two lines etc.

VI. Conclusions

The present paper used the symmetric generalized McFadden flexible functional form to represent the cost structure of railway systems in ten countries of the European Union. Contrary to popular overall technical efficiency models, we have used an input-specific inefficiency approach that allows us to decompose inefficiency by factor of production and nail down more accurately the sources of technical inefficiency. We have also provided quantitative estimates of cost reductions that would be realized if it were possible to increase a given input's efficiency to 100%. This information is highly relevant for policy recommendations and rational decision making in European railways. The results indicate that Greece, Italy, Portugal and Denmark experience technical efficiency problems. Reducing sizable factor-related inefficiencies is not found to result always in drastic cost reductions. In countries with trivial efficiency problems (for example Belgium) it is found that relatively small inefficiency reductions will result in rather drastic cost savings. Based on these results it would be safe to conclude that the input-specific technical inefficiency model should be given more attention by applied workers in the transportation sector and its implications should be considered by managers and policy makers in the sector in general, and railways in particular.

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