THE ALLOCATIVE EFFICIENCY MEASURE BY MEANS OF A DISTANCE FUNCTION: THE CASE OF SPANISH PUBLIC RAILWAYS.

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1. INTRODUCTION

The aim of this paper is to verify whether there exists allocative efficiency in the Spanish public railways: RENFE. To do this, we analyse whether the proportion of productive factors chosen by the firm, with specific technology and given prices, is the most appropriate in order to minimise costs. The neo-classical model in production theory starts from the hypothesis of minimum cost production for firms; see for example McGeehan (1993) and Friedlaender *et al.* (1993) for railway systems. However, nowadays there are more and more studies which are sceptical of this hypothesis of cost minimising behaviour and study the problems of the allocative efficiency in companies, especially in the regulated sector and the public sector (Toda (1976), Atkinson and Halvorsen (1986), Domenech (1993), Grosskopf and Hayes (1993), Grosskopf *et al.* (1995) and Bosco (1996)).

In these latter three studies the allocative efficiency was investigated using a new methodology: a Shephard (1953) input distance function. This function has a series of advantages over the functions of production and cost. With reference to the first, the distance function is valid for various outputs, which justifies its usage in the case of a multioutput firm such as RENFE. Compared with the cost function, the distance function offers three advantages. Firstly, it does not imply cost minimisation. Secondly, it requires neither information on input prices nor the assumption of these being exogenous. This is of great relevance in the context of the public sector where there are often distinct control mechanisms on input prices. The third advantage is that the distance function allows us to directly obtain a measure of allocative inefficiency independent of the degree of technical inefficiency.[1]

Because of this, an input distance function is used with the objective being to check, taking into account the productivity and the relative prices of the distinct factors of production, whether the input allocation has been efficient in RENFE or, if this is not the case, what inputs are being relatively under or overutilised. Besides, in contrast with other studies which have calculated allocative inefficiency using an input distance function (Grosskopf and Hayes, 1993, Atkinson et al. 1998), we assume that the employment of an input in a proportion different from that which would minimise cost could be systematic, and incorporate this possibility into our empirical model. By doing this we can obtain not only a measure of relative allocative inefficiency but also a measure of absolute allocative inefficiency.

The sample period studied covers the years 1955-1995. During this period, railway transport in Spain was operated and managed by a single company, RENFE, which operates goods and passenger transport services in a quasi-monopoly regime.[2] There are reasons to question the fact that, in RENFE, resources are allocated in an efficient way. In 1984, a Government Commission carried out a report which highlighted the lack of competitiveness of the firm. In this report the relatively minor

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[1]Although the objective of our work is to study allocative efficiency, the methodology of the distance function also enables us to calculate technical efficiency (see for example Coelli, 1996 and Atkinson *et al.*, 1998). There are many studies in the literature on the railway sector which analyse the technical efficiency using production frontiers (for example, Perelman and Pestieau, 1988; Gathon and Pestieau, 1992 and Gathon and Pestieau, 1995).

[2]Although other railways companies exist in Spain (FEVE, FFCC, those of the Catalan Generalitat, the Autonomous Government of Valencia, the Basque Provinces, the Balearic Islands Autonomous Communities and private companies), RENFE accounted for 92% and 96% of total travellers and goods traffic respectively during 1995.

share of inter-city transport accounted for by the railway is shown: the average shares accounted for by RENFE were 8.5% in passengers and 8% in goods, in contrast to European averages of 10% and 24% respectively. These shares began to decline in the 1950s and this process continued until the late 1970s. Regulation made it practically impossible to reduce services and close lines and prevented the network size being adjusted to changes in the market (De Rus, 1989). On the other hand, transport service prices are fixed by the Administration, with the criterion that fares evolve in accordance with production costs and service quality. Moreover, it had been established as a general rule that operating revenues shall cover costs. This type of regulation could result in a lack of incentives in managerial activities to minimise costs.

Since the 1980s a series of measures have been observed which have tended to reduce capacity excess problems and the inefficiency the company was experiencing (Carbajo and De Rus, 1991). Several management contracts were agreed in which the State established objectives to be achieved by the company as a condition for the granting of subsidies, including a set of economic-fmancial objectives closely bound to a policy of adjustment which included staff reduction and the closing of lines which showed a high level of deficit. For example, the management contract in 1984-1986 provided an agreement to close 882 km of lines and to reduce the workforce by 15,000 in the space of four years. Subsequently, the 1988-1991 management contract designed a new fare system with the aim of achieving a financial clean-up. Finally, in 1994 another management contract was approved, which provided for cost-reduction, revenue increase and improvements in asset turnover. Furthermore, headway has been made towards the consolidation of business units as the basic instruments to manage the activity of RENFE, each being fixed with objectives and incentives.[3]

Our research provides empirical evidence on how these policies -reallocation of resources and management incentives- have affected company efficiency levels, favouring a better input allocation, given productivity and their relative price levels. Furthermore, the estimation carried out allowed us to calculate the Morishima elasticities of substitution.

The structure of the paper is as follows. In Section 2 the theoretical model is presented. In Sections 3 and 4 there is an explanation of the methodology used for the estimation of the shadow prices by means of the Shephard distance function. Section 5 concerns itself with the econometric model. In Section 6 we describe the data set that we used. Section 7 reports the empirical results. Finally, in Section 8 we present a brief summary and conclusions.

2. THE THEORETICAL MODEL

Neo-classical production theory starts from the hypothesis of minimum cost production by firms. According to this hypothesis, the existence of allocative efficiency implies that the firm hires inputs x_i and x_j in a combination such that their respective prices (w_i and w_j) equal their respective marginal revenue product (MRP_i and MRP_j). In

[3]The present management structure of RENFE is comprised of the following business units: Suburban, Regional, Long Distance and High Speed for passenger services, and Freight, Intermodal, Traction and Rolling Stock Maintenance for the remaining.

relative terms:

$$\frac{MRP_i}{MPR_j} = \frac{w_i}{w_j} \qquad (1)$$

However, this condition may not be satisfied if costs are not being minimised with respect to market prices, but with respect to others which are called *shadow prices.* Recently many empirical studies which question the above hypothesis have appeared: Eakin and Kniesner (1988), Grosskopf and Hayes (1993) or Grosskopf *et al.* (1995), are some examples. In our theoretical set-up we try to explain the existence of these shadow prices in a public company like RENFE, and their relationship with market prices.

2.1 Formalisation of the theoretical model

The theoretical model is based on the hypothesis of maximisation of management utility, as an alternative objective to the maximisation of profits (Williamson, 1963 and Niskanen, 1968). Under this hypothesis, and following Atkinson and Halvorsen (1986), the company management utility function can be formalised as a function of two variables, profit and the quantity of inputs. The maximisation problem is:

$$\max \ U = U(P, x) \qquad (2)$$

$$\text{s.t.} \quad P = R(x) - \sum_{i=1}^{n} w_i x_i \qquad (3)$$

where:

$U(.)$ = is a twice continuously differentiable quasi-concave utility function.

P = profits obtained by the firm

x = is the vector of inputs

R = firm revenue. It is assumed that revenue is a function of output, so $R = g(y)$, where y is the vector of outputs. Moreover, since $y = f(x)$, this can be written as $R = g\{f(x)\}$.

w_i = market price of i input.

x_i = quantity of i input ($i = 1 \ldots n$)

It is assumed that $\partial U/\partial P > 0$, and $\partial U/\partial x \geq$ or < 0 depending on the given input. That is to say, there will be inputs which yield a positive utility (i.e. "visible" inputs as staff, sophisticated machinery, etc.), others that yield negative utility (i.e. those which imply a bigger effort on the part of the manager) and others that are neutral.

The solution for the maximisation problem is expressed through the Lagrangian:

$$L(P, x, \lambda) = U(P, x) - \lambda\left[P - R(x) + \sum_i w_i x_i\right] \qquad (4)$$

From this, we find that marginal revenue value for the ith input is equal to:

$$\frac{\partial R}{\partial x_i} = w_i - \frac{\dfrac{\partial U}{\partial x_i}}{\dfrac{\partial U}{\partial P}} = w_i^s \qquad (5)$$

where w^s_i is the shadow price of *input i*. Hence, w^s_i differs from w_i by the effects of the manager's behaviour.

Dividing the marginal revenue product of input i by that of input j, we get:

$$\frac{\dfrac{\partial R}{\partial x_i}}{\dfrac{\partial R}{\partial x_j}} = \frac{\dfrac{\partial R}{\partial y_1}\dfrac{\partial y_1}{\partial x_i} + \ldots + \dfrac{\partial R}{\partial y_m}\dfrac{\partial y_m}{\partial x_i}}{\dfrac{\partial R}{\partial y_1}\dfrac{\partial y_1}{\partial x_j} + \ldots + \dfrac{\partial R}{\partial y_m}\dfrac{\partial y_m}{\partial x_j}} = \frac{MRP_i}{MRP_j} = \frac{w_i^s}{w_j^s} \qquad (6)$$

where y_r is the quantity of output r ($r = 1 \ldots m$).

Consequently:

$$\frac{MRP_i}{MRP_j} = \frac{w_i^s}{w_j^s} \qquad (7)$$

In contrast to equation (1), the necessary condition for cost minimisation can be satisfied with regard to shadow prices (w^s) which may differ from market prices.

2.2 Theoretical model conclusions.

Some interesting conclusions can be derived from the above analysis (see equation 5):

1. The difference between w and w^s will inversely depend on the magnitude of the marginal utility of profit, $\partial U/\partial P$. When $\partial U/\partial P$ is high (low), that is, when more (less) incentives exist to maximise profit, it will tend to be more (less) cost efficient.

2. The difference between w and w^s will also depend on the magnitude of the relationship between managers' utility and inputs $(\partial U/\partial x_i)$.

3. Moreover, relative comparisons of inputs can be obtained. For instance, if $w^s_i > w_i$ and $w^s_j < w_i$ then the i input will be underutilised relative to j input and viceversa .

The inconvenience of this model arises due to the fact that the shadow prices are not observable, and from equation (5) a difficult relationship between shadow prices and market prices is obtained, since the utility function is unknown. Therefore it is necessary to introduce a more simplified relationship between both. To achieve this objective a Shephard distance function is introduced (Färe and Grosskopf (1990)).

3. THE DISTANCE FUNCTION

Formally, given any two vectors x and y, the Shephard (1953) input distance function is defined as follows:

$$D_I(x, y) = \max_{\delta}(\delta \geq 1 : (x/\delta) \in L(y)) \qquad (8)$$

where:

$y\ (y_1 \ldots y_n)$ = is the vector of outputs

$x\ (x_1 \ldots x_n)$ = is the vector of inputs.

$L(y) = (x \in R_n^+ : x$ can produce $y \in R_m^+)$.

To explain the distance function graphically, we consider the case (Figure 1) where a firm which produces a single output (y) that uses two production factors (x_1 and x_2).

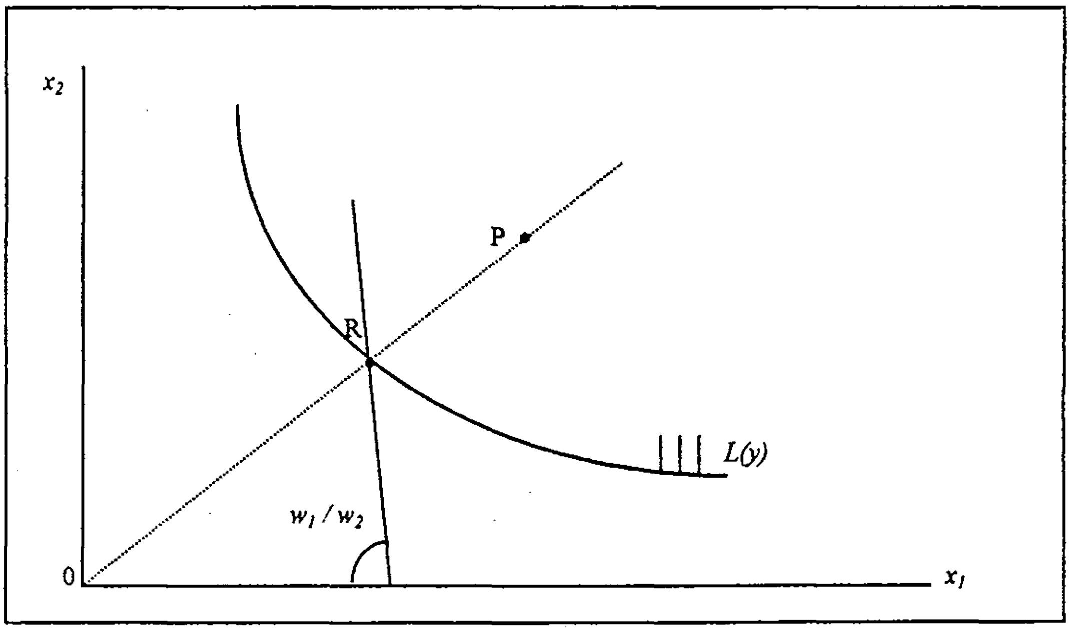

Figure 1

The ratio OR/OP is the Farrell (1957) radial measure of technical efficiency (TE) for the point P. It signifies the maximum proportional reduction that can be achieved in the utilised inputs which still allows production of the same amount of output. Formally:

$$TE(x, y) = \min_{\lambda} (\lambda \in (0,1) : \lambda x \in L(y)) \qquad (9)$$

The maximum value of this index is one, which means that the firm is operating on the isoquant and thus technically efficient. A value lower than one (as can be seen in Figure 1) informs us about of degree the technical efficiency achieved by the firm. It can be seen that from reciprocal of the index we obtain the definition of the distance function, that is, OP/OR represents the largest scalar by which all factors can be divided proportionally and continue producing the same output level.

Evidently $x \in L(y)$, *if and only if* $D_I(x,y) \geq 1$. If D_I equals one, it means that production is technically efficient. A higher value than one informs us about the degree of efficiency achieved.[4]

The Shephard input distance function satisfies the following properties:[5]

(1) $D_I(x, y)$ is dual of the cost function

(2) $D_I(x, y)$ is decreasing in each output level

(3) $D_I(x, y)$ is increasing in each input level

[4] We could also define an output distance function which is the maximum possible proportional increment in the output vector, with the given inputs vector and technology. Applications of this type of function can be found in English *et al.* (1993) and Grosskopf *et al.* (1995b).

[5] Proofs of these properties can be found in Cornes (1992).

(4) $D_I(x, y)$ is homogeneous of degree 1 in x

(5) $D_I(x, y)$ is concave in x

4. ESTIMATION OF SHADOW PRICES BY MEANS OF A SHEPHARD DISTANCE FUNCTION

Initially, studies using shadow prices to obtain a measure of allocative efficiency were based on the estimation of a system of equations formed by a shadow cost function and the set of cost share equations (Atkinson and Halvorsen (1986), Eakin and Kniesner (1988), Domenech (1993)). This equations system had the property of establishing a relationship between shadow prices and market prices using the appropriate parametric corrections in input prices, to satisfy the cost minimisation condition.

Färe and Grosskopf (1990) study an alternative method to get shadow prices out of inputs using Shephard's distance function, providing themselves thereby with analysis of firm cost efficiency. Distance function has the advantage over the first method that in order to estimate distance function, data about factors prices are not necessary.

Färe and Grosskopf (1990) assume that the firm minimises costs with respect to certain shadow prices that may differ from market prices. Therefore, the cost function can be defined as:

$$C(y, w^s) = \min_x (w^s x : x \in L(y)) = w^s x(y, w^s) \qquad (10)$$

where w_i^s is *shadow price* of factor i for which the cost minimisation condition would be satisfied.

Applying duality theory to the cost function and distance function[6], Färe and Primont (1990) derive the dual Shephard's lemma:

$$\frac{\partial D_I(x,y)}{\partial x} = \frac{w^S}{C(y,w^S)} \qquad (11)$$

That is, the derivative of the distance function with respect to an input is the normalised shadow price. From (11), with any two given inputs i, j = 1,2,...,n, the shadow price ratio is obtained:

$$\frac{\dfrac{\partial D_I(x,y)}{\partial x_i}}{\dfrac{\partial D_I(x,y)}{\partial x_j}} = \frac{w_i^S(y,x)}{w_j^S(y,x)} \qquad (12)$$

Now, if the cost-minimisation assumption is satisfied, this normalised shadow price ratio should be the same as the input market price ratio. However, if inputs are not selected in the appropriate proportion, that is to say, if allocative inefficiency occurs, the aforementioned price ratios will differ.

To study the quantity and direction of such a deviation, a relationship between the normalised shadow prices obtained through the distance function and the input market prices is introduced by means of a parametric price correction (Eakin and Kniesner (1988) and Färe and Grosskopf (1990)):

$$w^s{}_i(x, y) = k_i\, w_i \qquad (13)$$

Dividing this expression (13) by that corresponding to input j we obtain:

$$\frac{w_i^S(x,y)}{w_j^S(x,y)} = k_{ij}\frac{w_i}{w_j} \qquad (14)$$

[6]The duality between the distance function and cost function is explain in Färe and Primont (1995).

where:

$$k_{ij}=\frac{k_i}{k_j} \qquad (15)$$

Thus, from (14) the degree to which the shadow prices differ from the market prices is calculated. Moreover, we can obtain the direction of such inefficiency as follows:

(a) If $k_{ij} = 1$, there is allocative efficiency in *relative terms.*

(b) If $k_{ij} > 1$, the factor i is being underutilised relative to the j factor.

(c) If $k_{ij} < 1$, the factor i is being overutilised relative to the j factor.

As can be observed in Figure 2, the normalised shadow price ratio would indicate the isocost slope if costs were actually minimised with the chosen input proportion. That is to say, the isocost with slope $\frac{w_1^s(x,y)}{w_2^s(x,y)}$ tells us what prices (shadow prices) would minimise costs to produce output y, with the observed input bundle and given technology.

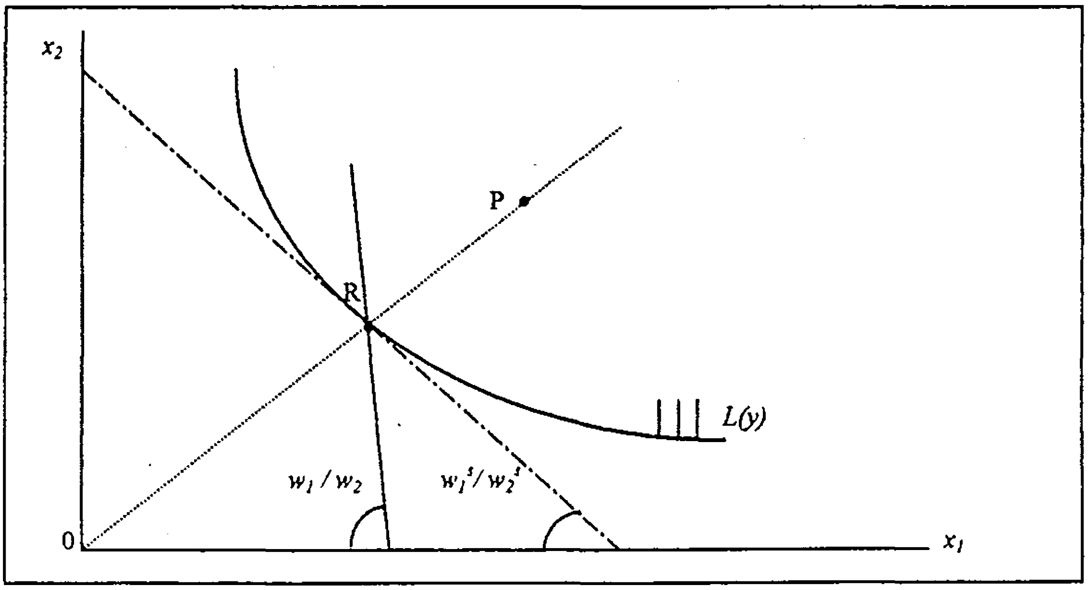

Figure 2

Starting with Färe and Grosskopf (1990), there have been numerous studies in which the distance function has been used as a means to check allocative efficiency in production: Grosskopf and Hayes (1993) and Grosskopf *et al.* (1995) are some examples.

Next, we turn to applying this methodology to RENFE. For this we begin by proposing the econometric model. In our study, we also obtain a measure of *absolute allocative inefficiency*. We discuss this in detail in the empirical results section.

5. THE ECONOMETRIC MODEL

To obtain the shadow prices of productive factors, we propose estimating an translog input distance function. To improve the efficiency of the estimation process, the input distance function will be estimated jointly with the cost share equations, which we can obtain by differentiating the translog distance function with respect to $ln\ x_i$.

One of the difficulties in estimating this model is that the distance function value $D_I(x,y)$ is not known. To solve this problem, we assume that its value is, for instance, equal to one which implies the assumption of technical efficiency. Of course, this is not necessary, since the distance function is homogeneous of degree one in inputs and the cost share equations are homogeneous of degree zero in productive factors. That is, the measure of allocative inefficiency that it is obtained by means of a translog input distance function is independent of the degree of technical inefficiency.[7]

[7] Technical efficiency affects only the intercept of the translog distance function. Consequently, the derivatives of the distance function with respect to inputs are independent of the degree of technical inefficiency.

Thus, the set up model is as follows:

$$ln\ 1 = ln\ D_I\ (x, y) \qquad (16)$$

$$\frac{\partial \ln D_I(x,y)}{\partial \ln x_i} = \frac{\partial D_I(x,y)}{\partial x_i}\frac{x_i}{D_I(x,y)} = \frac{w^s}{C(y,w^s)}x_i = W_i^s x_i \qquad (i=1,\ldots,n) \qquad (17)$$

To estimate the distance function it is necessary to select a determined functional form. In doing so, a series of characteristics are being imposed on the technology without exact knowledge as to whether or not such properties are true or false. For this reason it is especially advantageous to use flexible functional forms that impose the least possible restrictions on the technology that one is trying to describe. Due to this we have used a Translog multiproduct function.

In short, the Shephard input distance function is defined as:

$$Ln1 = \alpha_0 + \sum_{r=1}^{m}\alpha_r \ln y_r + \frac{1}{2}\sum_{r=1}^{m}\sum_{s=1}^{m}\alpha_{rs}\ln y_r \ln y_s + \sum_{i=1}^{n}\beta_i \ln x_i +$$

$$+\frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\beta_{ij}\ln x_i \ln x_j + \sum_{r=1}^{m}\sum_{i=1}^{n}\rho_{ri}\ln y_r \ln x_i + \varepsilon \qquad (18)$$

The cost share equations of each input i are given as :

$$\frac{x_i w_i}{C} = \beta_i + \sum_{j=1}^{n}\beta_{ij}\ln x_j + \sum_{r=1}^{m}\rho_{ri}\ln y_r + u_i \qquad (19)$$

for r, s = 1,...,m outputs; i, j = 1, ...,n inputs, and where ε is the random disturbance term and C represents total cost. The dependent variable in (19) is $\frac{x_i w_i}{C}$, so errors in the share equations system indicate the cost of allocative inefficiency.

Given that the dependent variable in the distance function equation is $ln1 = 0$, estimation can be carried out if a nonzero linearity of the parameters is imposed.

Therefore, the conditions required by the theory (see section 3.1) have been imposed:

a) homogeneity of degree one:

$$\sum_{i=1}^{n} \beta_i = 1 \qquad \sum_{j=1}^{n} \beta_{ij} = 0 \qquad \sum_{r=1}^{m} \rho_{ri} = 0$$

b) and symmetry: $\beta_{ij} = \beta_{ji}$

According to our model, the proportionality factors (k_{ij}) can be derived from equations (14) and (12):

$$k_{ij} = \frac{\dfrac{w_i^s(x,y)}{w_j^s(x,y)}}{\dfrac{w_i}{w_j}} = \frac{\dfrac{\dfrac{\partial D_I(x,y)}{\partial x_i}}{\dfrac{\partial D_I(x,y)}{\partial x_j}}}{\dfrac{w_i}{w_j}} \tag{20}$$

Taking into account that we specified the distance function in terms of logarithms, from (17) we get:

$$\frac{\partial D_I(x,y)}{\partial x_i} = \frac{\partial \ln D_I(x,y)}{\partial \ln x_i}\frac{D_I(x,y)}{x_i} = \left[as\ \ D_I(x,y) = 1\right] = \frac{\partial \ln D_I(x,y)}{\partial \ln x_i}\frac{1}{x_i} \tag{21}$$

Substituting (21) into (20) and using (19) we get that:

$$k_{ij} = \frac{\dfrac{\dfrac{\partial \ln D_I(x,y)}{\partial \ln x_i}\dfrac{1}{x_i}}{\dfrac{\partial \ln D_I(x,y)}{\partial \ln x_j}\dfrac{1}{x_j}}}{\dfrac{w_i}{w_j}} = \frac{\dfrac{w_j}{x_i}\left[\widehat{\beta}_i + \sum_{j=1}^{n}\widehat{\beta}_{ij}\ln x_j + \sum_{r=1}^{m}\widehat{\rho}_{ri}\ln y_r\right]}{\dfrac{w_i}{x_j}\left[\widehat{\beta}_j + \sum_{i=1}^{n}\widehat{\beta}_{ij}\ln x_i + \sum_{r=1}^{m}\widehat{\rho}_{ri}\ln y_r\right]} \tag{22}$$

6. DATA

The railway activity is a multiproduct one, since not only can we distinguish between passenger and freight transport, but also such other products as origins-destinations which exist in the railroad network. However, the lack of data has led us to consider only two outputs: kilometres covered by travellers (millions of travellers-km transported) and kilometres covered by goods. With respect to the latter, only the pure traffic which includes tons (in millions) of commercial goods per kilometre has been considered.[8] Thus, our variables Fkm and Pkm measure the outputs freight-tonnage per kilometre and passengers per kilometre, respectively.

Three inputs have been considered: Labour (L), Capital (K), and Energy (E). Labour includes both permanent and temporary personnel. The labour cost is the personnel expense in millions of current pesetas. For the energy variable, motor equipment energy consumption has been used, in thousand million kilocalories.[9] The energy cost is the energy and fuels expenditure in millions of current pesetas each year.

As for the capital series, we have considered physical units of motor equipment which includes, during the sample period, electric, diesel, and steam locomotives, as well as electric and diesel trains. Starting from the data provided in Muñoz Rubio (1995) and from RENFE reports, we have constructed, firstly, the age structure of each type of haulage unit which was in service in each year. Then, these have been

[8] The post is included while the suppliers traffic and the interior service are excluded.

[9] In energy-equivalent terms.

depreciated according to their years of service, using a method of constant shares and allowing for an average serviceable lifetime of 30 years. Finally, due to diversity of haulage equipment, we have homogenised, it based on energy performance, average traction power and productive routes. Thus, each unit of capital would represent a machine with the same energy performance, average traction power and productive routes as an electric locomotive in 1980. In doing this, the intention is to capture the modernisation process experienced by motor equipment over the period studied.

With regard to the total capital cost, we have used investments made by RENFE in mobile equipment, divided by the average number of years of serviceable life of said equipment material, plus the expenses in repayments, all in millions of current pesetas.

As it would also be desirable to incorporate a variable which could capture the modernisation process on the railway network structure, we have taken traffic density (MODER) as a proxy of efforts made to improve the quality of the network. However, given the complexity of railway transport technology, it would be naive to think that in a distance function estimation we could encompass all the elements that could affect it.

Finally, we have incorporated another time trend variable (PROGC) from 1984 with the idea of capturing the influence of management contract established in RENFE from this date.

The series of annual data used comes from the Communications and Transport Annual Report, prepared by the Institute of Transport and Communications Studies, RENFE memorandums, Spain's National Accounts and Muñoz Rubio (1995).

7. EMPIRICAL RESULTS

We jointly estimate the system of equations for the input distance function and the share equations given by expressions (18)-(19), imposing homogeneity and symmetry restrictions, for the period 1955-1995.

In accordance with the theoretical model presented in section 2, the outputs (Fkm and Pkm) would be exogenous and the inputs (E, L and K) endogenous. As a result of this, in equations (18)-(19), we have the problem that the inputs and the errors are correlated.[10] To resolve this, the system has been estimated using instrumental variables. As instruments, the following Spanish macro measures have been used: fixed capital, number of employees in the agricultural sector and consumption of automobile gasoline.

Moreover, the theoretical model captures the idea that allocative inefficiency can be systematic and continuous in time. In contrast to Grosskopf and Hayes (1993) this fact is taken into account in our estimation. For this reason, in the error term μ_i of the share equations we consider two components with distinct characteristics. We assume that the error term has an additive structure of the form:

$$\mu_i = \eta_i + A_i \qquad i = 1,\ldots,n.$$

[10]For a discussion on this point, see Coelli and Perelman (1996) and Akinson *et al.* (1998).

η_i being a random disturbance term with the usual characteristics (iid, N(0, σ^2)) which captures random factors and A_i representing the deviation (positive or negative) of the observed proportion of expenditure with respect to the optimum. This deviation could arise from the systematic utilisation of the input in a proportion different from that which would minimise costs. We assume therefore that A_i is a variable which is iid with mean a_i and variance $\sigma^2_{a_i}$. That is, a_i indicates the average value of the *cost of absolute allocative inefficiency*. Thus, equation (19) should be rewritten as

$$\frac{x_i w_i}{C} = (\beta_i + a_i) + \sum_{j=1}^{n} \beta_{ij} \ln x_j + \sum_{r=1}^{m} \rho_{ri} \ln y_r + (A_i - a_i) + \eta_i \qquad (19')$$

where the new error has mean zero.

The *relative allocative inefficiency* is given by the expression k_{ij} (see equation 22) and is obtained from the parameters estimated from the system of equations. It is important to point out that if we did not take into account the correction of the error term proposed in equation (19′) and the a_i parameters were significantly different from zero, the k_{ij} coefficients would be biased; moreover, at the sample mean the k_{ij} values would not be significantly different from one.

The estimation of the system (18)-(19') has been carried out by means of iterative seemingly unrelated regressions (ITSUR), which is equivalent to maximum likelihood estimation and invariant to the omitted share equation.

Before commenting on the results, two final considerations should be made. Firstly, we take into account that the errors of the system (18)-(19') display first-order autocorrelation. A first-order autoregressive parameter has therefore been introduced into the distance function and the cost share equations. Following Friendlaender *et al.* (1993) and Berndt *et al* (1993), the coefficient of the autoregressive term has been fixed at the same value across the different share equations in order to maintain the property that the model be invariant to the elimination of any share equation. Secondly, attention should be drawn to the fact that the variables are in the form of deviations with respect to their geometric means. That is, the first-order coefficients of the distance function can be interpreted as elasticities at the sample mean.[11]

The parameters obtained from the estimation of the system (18)-(19') are presented in Table 1. It is verified that the distance function, at the sample mean, fulfils the properties of being increasing and concave in inputs and decreasing in outputs (see section 3.1), and is also homothetic.[12] Moreover, the results show the greater weight that the passenger output has over freight in the distance function, as well as the greater weight that the labour input has over the other inputs. Also, the dummy variable which captures the introduction of the management contracts (PROGC) turns out to be significant and to have a negative sign, reflecting a reduction in the inputs, ceteris paribus. On the other hand, the coefficient of the variable which measures the process of modernisation of the network is positive and significant. This positive sign indicates that if in the presence of technological progress the firm maintains the same combination of inputs to produce a given quantity of output, the distance value will increase.[13]

The estimated parameters a_L, a_K and a_E show, as we have mentioned, the average

[11]Except for the dummy variables which are not expressed in logs.

[12] Homotheticity requires that $\rho_{ri} = 0, \forall\ r,i$. The test statistic has a value of 4.69 and given that it has a χ^2 with 4 degrees of freedom, we cannot reject the hypothesis of homotheticity.

[13] Graphically, in Figure 1, taking P as our point of reference a technological improvement will lead to a shift of the isoquant to the left. See Fare and Grosskopf (1995) to construct a test of technical change.

cost of absolute allocative inefficiency of the factors labour, capital and energy respectively. The results show that a_L and a_K are significantly different from zero which implies that, at the sample mean, labour and capital have been employed inefficiently. In absolute terms, labour has been used in a quantity greater than the optimum while capital has been underutilized. The parameter a_E has been restricted to zero because in a earlier estimation its value was found not to be significantly different from zero.[14]

From the system (18)-(19′) we have calculate the mean values and evolution over time of the allocative inefficiency, *in relative terms*, in accordance with what has been set out in section four. Moreover, from the estimated parameters we could only obtain a single value of k_{ij} for each observation. In order to get a distribution for these k_{ij}, we have used a standard bootstrap technique, consisting of selecting a random sample of residuals from the estimation of the system (18)-(19'). Subsequently, "new" dependent variables were generated for each of the equations of the system, equal to the residuals selected randomly plus the value of the prediction of the corresponding equations. The reestimation of the system (18)-(19') with the pseudodata generated in this manner was repeated 100 times.[15] To obtain the confidence intervals for the k_{ij} we used the percentile method (Efron and Tibshirani, 1986).

Table 2 shows the results for the proportionality factors evaluated at the sample mean, together with their confidence intervals. Values of k_{ij} less than one indicate, given the factor prices, that input i is being overutilised with respect to input j and vice versa.

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[14] The estimated a_E was 0.01 with a t-statistic of 0.24.

[15] Taking into account in each case the correction for autocorrelation.

The results show that the capital and energy inputs are being relatively underutilised with respect to labour ($k_{LABOUR,\ ENERGY}$ = 0.82 and $k_{LABOUR,\ CAPITAL}$ = 0.39). Moreover, energy is overutilised with respect to capital ($k_{ENERGY,\ CAPITAL}$ = 0.71).

Figure 3 illustrates the evolution over time of these coefficients. It can be observed that the values of $k_{LABOUR,CAPITAL}$ are below one during the period analysed, implying that the relative overutilisation of labour with respect to capital has been maintained over the 41 years studied. Certain parallels are also revealed in the behaviour of $k_{LABOUR,CAPITAL}$ and $k_{ENERGY,\ CAPITAL}$: allocative inefficiency has tended to be corrected over the period 1963-73. In this period RENFE experienced the highest levels of capital investment in its history due to the *Plan Decenal de Modernización* (Ten-Year Modernization Plan). An improvement can also be appreciated as a consequence of the introduction of the management contracts in 1984.

With regard to the evolution over time of the coefficient $k_{LABOUR,ENERGY}$, we can see that over the earlier years of the period studied there was an overutilisation of energy, with the opposite occurring from 1966 on, i.e. the overutilisation of labour with respect to energy, a situation gradually accentuated over the remainder of the period.

Moreover, as a byproduct of the analysis, we have measured of returns to scale in RENFE. Its mean value turns out to be 1.37, which is consistent with the majority of the values presented in the literature on rail transport.[16]

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[16]The returns to scale associated with an increase in outputs is defined as: $RST = -\frac{1}{\frac{\partial D_I}{\partial y}}$ where y is the vector of outputs.

8. SUMMARY AND CONCLUSIONS

This paper is an empirical application of the distance function to study the allocative efficiency of a regulated railway firm, RENFE, where the cost minimising hypothesis may be questioned. The distance function, which is the dual of the cost function, completely describes the technology and, like the cost function, it allows a multiproduct analysis. However, unlike the cost function, the input prices are not needed for its calculation and it does not imply cost minimisation.

By means of this technique we have obtained the shadow prices of the productive factors, which satisfy the condition of minimum cost. These shadow prices are used to calculate the degree of allocative inefficiency of the firm and the origin of this inefficiency by using a parametric correction of prices (k_{ij}). The procedure followed has consisted of estimating a system of equations for the input distance function and cost share equations, employing the iterative seemingly unrelated regressions method (ITSUR). Moreover, in contrast with other studies which have used this method, we assume that the employment of an input in a proportion different from that which would minimise cost could be systematic, and incorporate this possibility into our empirical model. The model was estimated using annual data over the period 1955-95. In order to achieve a distribution and the confidence intervals of the proportionality terms estimated, k_{ij}, we have used a standard bootstrap technique.

The results of this study indicate that there is no allocative efficiency, since the calculated shadow prices are different to those of the market. To be precise, we have observed an overutilisation of labour relative to capital and energy.

This overutilisation could be due in a some way to the difficulty of adjusting the optimal labour quantity in a regulated environment such as that in which RENFE operates. Moreover, and in accordance with our theoretical model, we also consider that the overutilisation of labour has been due in part to the lack of incentives at managerial to achieve cost minimisation.

TABLE 1

Distance Function Estimated
(sample 1955-1995)

Variable	Coefficient	t-statistic
Constant	1.9324	1.1134
Log(Fkm)	-0.4001	-6.8821
Log(Pkm)	-0.9624	-9.3511
Log(L)	0.6262	18.9441
Log(E)	0.0950	5.2396
Log(K)	0.2786	8.4083
Log(Fkm) · Log(Fkm)	-4.0454	-1.9820
Log(Pkm) · Log(Pkm)	5.3174	3.0681
Log(Fkm) · Log(Pkm)	-0.9593	-0.7645
Log(L) · Log(L)	0.0141	0.3619
Log(L) · Log(K)	0.0198	0.7413
Log(L) · Log(E)	-0.0339	-1.6192
Log(E) · Log(K)	-0.0111	-0.7286
Log(E) · Log(E)	0.0451	2.6332
Log(K) · Log(K)	-0.0086	-0.3527
Log(Fkm) · Log(L)	0.0676	1.2265
Log(Fkm) · Log(K)	0.0178	0.4183
Log(Fkm) · Log(E)	-0.0855	-1.9253
Log(Pkm) · Log(L)	-0.0075	-0.1274
Log(Pkm) · Log(E)	-0.0410	-0.8223
Log(Pkm) · Log(K)	0.0485	1.0462
Log(Pkm) · PROGC	0.0158	0.6840
Log(Fkm) · PROGC	-0.0087	-0.2344
PROGC · PROGC	-0.0001	-0.1484
PROGC	-0.0229	-2.9255
Log(E) · PROGC	-0.0018	-0.6578
Log(L) · PROGC	-0.0135	-3.4299
Log(K) · PROGC	0.0154	5.0068
PROGC · MODER	-0.0123	-0.3957
MODER	0.9065	9.1480
MODER · MODER	0.2542	0.1318
MODER · Log (Pkm)	-2.5724	-1.5142
MODER · Log (Fkm)	1.6300	0.8752
MODER · Log (L)	-0.0667	-1.0293
MODER · Log (K)	-0.0383	-0.7593
MODER · Log (E)	0.1051	1.9283
a_L	0.1371	3.4059
a_K	-0.1371	-3.4059

TABLE 1 (cont.)
Statistics of Model

Equation	R-squared	DW	S.E. regression
Distance function	--	1.98	0.016
Labour cost share	0.97	2.09	0.017
Capital cost share	0.96	1.70	0.013
Energy cost share	0.99	2.15	0.015

TABLE 2
PROPORTIONALITY FACTORS
K_{ij} VALUES

	Average value(*)
$K_{ENERGY, CAPITAL}$	**0.7142** (0.61 , 0.81)
$K_{LABOUR, CAPITAL}$	**0.3877** (0.32 , 0.47)
$K_{LABOUR, ENERGY}$	**0.8242** (0.75 , 0.88)

(*) Evaluated at the means of the data using parameter estimates of (18)-(19′).
Note: confidence intervals at 95% of k_{ij} figures are in parentheses.

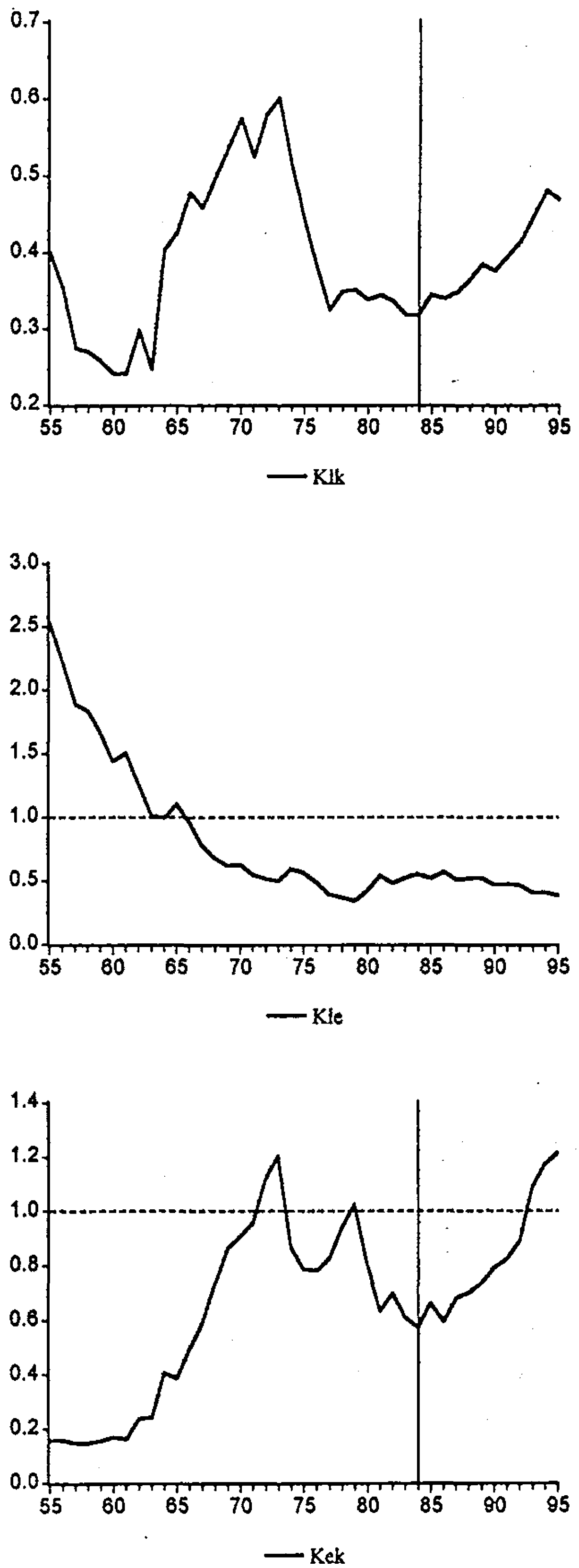

FIGURE 3

Time path of the coefficient k_{ij}

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