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Tracking the stepwise effects of regulatory reforms over time: a "back-door" approach

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Abstract

This paper describes a simple data treatment which can be used in econometric studies dealing with production efficiency measurement to identify the impact associated with regulatory reforms taken place gradually over time. The methodological proposal can be easily implemented by regulators using standard stochastic frontier software programs. The approach is illustrated with data on the Spanish port system which enjoyed a two-stage reform during the 1990s.

Tracking the stepwise effects of regulatory reforms over time: a “back-door” approach

1. Introduction

The 1990s were characterized by widespread efforts to liberalize public services in the hope of increasing their efficiency. In most instances, reformers were aware of the need for a residual regulatory role for the public sector to ensure a fair distribution of the efficiency gains between the users and the natural monopolies (transport and distribution service in water and energy or the supply of infrastructure in port services). Sector differences and differences in the complexity of the political context have however resulted in different strategies to get to the regulatory role. In many instances, the reformers have had to adopt a gradual and slow distancing from self regulated monopolies rather than a shock approach to reform.

The different stages of the gradual approaches all contribute in different ways in determining the total efficiency gains achieved by reform packages. Getting a “broad” sense of where the biggest bang for the buck can be achieved can come in handy in designing new reform packages. Data limitations are however typically so strong that it is difficult to get much more than anecdotal evidence on the relative impact of the various reform stages.

This paper proposes a simple “back door” method to address the problem. It allows an unbundling of the total gains achieved by a reform package and to assign credit for the relative contribution to each stage of the reforms. Several software programs allow to apply the method proposed. The approach is illustrated with an assessment of the impact of the gradual regulatory reforms adopted in the Spanish port sector during the 1990s.

This paper is structured as follows: section 2 offers a survey of the literature analyzing the evolution of the efficiency over time. Section 3 describes our proposal. Section 4 discusses the distance function we rely on to get to the total efficiency gains. Section 5 shows how we can unbundle the sources of efficiency gains with an application to the Spanish port reform experience. The discussion includes a description of the data, the model and the most important results. Section 6 concludes.

2. A brief survey of the literature

The first models designed to assess the temporal variation of efficiency emerged in the early 1990s. They were based on the traditional models of panel data. These models estimate the frontier by means of corrections of the least square method, and therefore the definition of the temporal structure of efficiency is made using the independent term (through the individual effects).

The pioneering work in this field was that of Cornwell, Schmidt and Sickles (1990). They suggested that the evolution of efficiency should follow a quadratic function of time, making it possible for efficiency to also vary between firms. This made the model highly flexible, although the price to be paid was that it required a lot of data. This is a major inconvenience in regulated sectors, where lack of data is a common problem, both in the cross-section and longitudinal dimensions. Lee and Schmidt (1993) propose another type of panel data model in which efficiency varies in the same way between firms. Although this model is more flexible than the previous one, it imposes that the efficiency varies in the same way for all the firms. These models do not allow for any distinction between the effects of a change in efficiency and the effects of neutral technical progress. This is an important issue in processes of regulatory changes; as such changes can be the result of variations in productivity due to an apparent technological change rather than the result of improvements in efficiency.

A second type of model often used in this context is stochastic frontier models in which the pattern of variance in efficiency is modeled using the error term, assuming a distributional assumption. In stochastic frontier models, also a distinction can be made between those that specify a common pattern of variance of efficiency between firms and those that allow the efficiency to vary in a differentiated way for each firm. The formers include the proposal suggested by Kumbhakar (1990) in which the inefficiency term is specified as an exponential function of time and the Battese and Coelli (1992) model, who made an attempt to come up with a simpler proposal that implies an unique time parameter to catch efficiency variability over time for all firms.

The main difficulty for the practical implementation of these proposals is the restriction that efficiency follows similar pattern overtime - for all firms, which is not a very plausible supposition in most cases, as less inefficient firms have a greater margin for improvement than more efficient ones.

To overcome the inconveniences of the previous models, new proposals have been developed that make it possible to vary the differentiated efficiency for each firm (Kumbhakar, 1991; Heshmati and Kumbhakar, 1994; Cuesta, 2000[1]). In addition to major theoretical econometric problems, from the applied work point of view, the fundamental issue with these models is that they require a large quantity of data, as the number of parameters to be estimated increases with the number of firms.

A more general solution to the problems of the above models could be offered however by the Battese and Coelli (1988) proposal. This is a model with time invariant efficiency. Therefore, although it is applied to panel data, it evaluates the efficiency of each firm at a single moment in time and does not resolve the question of measuring regulatory changes as a temporal evolution of the efficiency of each firm. However, this

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[1] For a more detailed survey about temporal variation in inefficiency see Cuesta (2001).

model can be made to be even more general than their authors suggested through a simple data transformation, as discussed in the next section.

3. The model transformation

None of the models surveyed in Section 2 allows a diagnostic of the relative reaction of firm specific performance to the various components of a reform package. There is thus a need to transform time invariant models into models that are time "variant" over chunks of periods. This is a major limitation for a wide range of policy applications.

It turns out that a simple transformation of the data samples is enough to make Battese and Coelli's model (1988) capable of measuring the efficiency of firms in different time periods. This is achieved simply by creating groups of firms by periods. These groups, despite actually containing the same firms, are tabulated in a different way for each period, so that what are simulated are different firms. In this way, the model, on recognizing "new firms", evaluates the corresponding efficiency of each group of firms which simply correspond to the same set of firms at different observation periods (i.e. the impact of a sequence of reforms can then be tracked over time).

For example, assume that there is a panel of data made up of 3 firms (called F_1, F_2 and $F_{3)}$, for which we have information for four years (T_1, T_2, T_3 and T_4). These firms produce product Y_{ij} by means of input X_{ij} (i refers to the firm and j to the time period). The usual way of incorporating the information into the software program is shown in la Table 1.[2]

Table 1. Original sample presentation

It is also supposed that in year 3, a change of regulation occurs, whose effects carry over into the next year, so we have to consider that the firms in years 3 and 4 are

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[2] At least three software programs allow the estimation of the Battese and Coelli's model (1988): FRONTIER (Coelli, 1996), LIMDEP and STATA.

independent of the firms in the first two years. This is done by naming the firms F_4, F_5 and F_6, respectively. Thus, the information should be incorporated as shown in Table 2.

Table 2. Restructured sample

It should be observed that, as the firms are really the same, despite being assigned different codes, the data referring to the variables is entered in the same order. This means that the result is an incomplete panel of data that is expressed as in Table 3, where T_1 to T_4 refer to the time period and F_1 to F_6 to the firms.

This way, the end result is the time invariant efficiency of firms F_1, F_2, F_3, F_4, F_5 and F_6. As firms E_4, E_5 and E_6, are in fact E_1, E_2 and E_3, in another period, the change in efficiency obtained is really the time variation of the efficiency of firms F_1, F_2 and F_3. The main assumption justifying the new sample organization is that regulatory reforms have had a major impact on firms' operations, such as that the same firm must be considered as a different and independent entity (decision making unit) before and after the reform.

Table 3. Structure of the panel of data

4. Empirical application

In order to demonstrate the suitability of the proposed transformation, we model Spain's two stage approach to port reform during the 1990s. The specific of these reforms are not of interest here.[3] The fact that it involves two main stages is. The first took place in 1992 and it was characterized by the development of new management procedures and organization structures with the objective of decentralize the port system and reinforce the autonomy of the port authorities. The second was in 1998 and insisted on the autonomy of the port authorities, regulated the participation of the regional

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[3] For more details see Gonzalez (2004).

Government in the port organization and encouraged the participation of the private sector in port activities. Both stages were designed to have an impact on efficiency. To estimate the total efficiency gains and to track the differentiated effect of each stage, we estimate a distance function using the data of a representative sample of port authorities in the Spanish port system.

4.1. The distance function

The distance function, introduced by Shephard (1953, 1970), allows the estimation of the relative efficiency of firms in relation to the technological frontier. This function is selected because of its advantages over the more standard alternatives approaches to assessing frontiers. Of particular interest here is that it makes it possible to capture multi-output processes and that it does not require the use of optimizing assumptions. Moreover, it only uses physical data and, therefore, information is not necessary for output or factor prices.

The analysis of the conditions under which port authorities perform their activities led us to the estimation of an output-oriented distance function. An output-oriented distance function is defined as the smallest scalar by which all outputs can be proportionally divided, using the same level of productive factors. This is because in the provision of infrastructure services, port authorities have some power to decide on the production level through the use of two mechanisms: commercial policies and concessions. The port authorities also perform a significant amount of marketing for their services and facilities to attract new traffic. The commercial policies complement these efforts with tariff discounts offered within limits allowed. Furthermore, as long as port authorities decide on the type of firm that can operate at the different ports, they are also deciding on the ships and goods that will be handled. For instance, a port intended to attract fish to be processed needs that freezing companies be established there, relying the final decision on that is subject on the port authority’s board of directors.

Considering this capacity to influence output, port authorities encounter certain difficulties in adjusting the productive factors used in the provision of infrastructure services, basically: berths, area and labor. The first two are quasi-fixed factors that, due to their indivisibility, find it difficult to adapt to any changes in production, especially if the changes are downward. Furthermore, although investment decisions are made by the board of directors of each port authority, in reality these decisions are coordinated by the State Ports (*Puertos del Estado*), which has the margin to decide whether to allow or limit the financing of the construction of infrastructure work. As for the labor factor, this is generally made up of officers, which makes it difficult to make adjustments, particularly when the number needs to be reduced.

4.2. The functional form

The empirical application of a distance function calls for the definition of an appropriate functional form. It is desirable for the functional form to present the following advantages: it must be flexible, it must be easy to calculate and, lastly, it must make it possible to impose the homogeneity condition. The translogarithmic functional form (hereinafter translog) meets these conditions, which is why, at present, most authors use it in all fields of research. It consists of a flexible functional form that provides a local second-order approximation to an unknown functional form. In other words, no *a priori* restrictions about production technology are assumed and, thus, the criticisms associated with certain restrictive properties of the Cobb-Douglas function are overcome.

For all these reasons, we estimate a translog distance function that, when output-oriented, can be expressed as follows:

$$\ln D_0 = \alpha_0 + \sum_{m=1}^{M} \alpha_m \ln y_{mit} + 1/2 \sum_{m=1}^{M} \sum_{n=1}^{M} \alpha_{mn} \ln y_{mit} \ln y_{mit} + \sum_{k=1}^{K} \beta_k \ln x_{kit} + 1/2 \sum_{k=1}^{K} \sum_{l=1}^{K} \beta_{kl} \ln x_{kit} \ln x_{lit} + \sum_{k=1}^{K} \sum_{m=1}^{M} \delta_{km} \ln x_{kit} \ln y_{mit} + \sum_{h=1}^{H} \psi_h d_h + \sum_{t=1}^{T} \theta_t f_t + \varepsilon_{it} \qquad (1)$$

where y is a vector of M outputs, x is a vector of K factors, i relates to the i-*th* firm, t refers to the t-*th* year, d relates to the H environment dummy variables and f to the time period dummies; α, β, δ, ψ and θ are coefficients to be estimated and ε_{it} is an error term which is discussed later. Continuous variables are expressed in relation to their deviation from the geometric mean; therefore, the first order term coefficients correspond to distance function elasticities at the sample mean points.

In order to determine the frontier, D_O needs to be equal to the unit and, in that case, the term on the left of the equation, according to the neperian logarithm, will equal zero. By definition, output distance functions assume radial expansion of outputs, therefore the homogeneity condition of degree 1 must be imposed. Following Lovell et al. (1994),[4] this condition has been imposed by standardizing the distance function with one of the outputs. This works on the assumption that homogeneity implies that:

$$D_O(x, wy) = wD_O(x, y), \qquad (2)$$

for any $w>0$.[5]

If in a translog distance function (1), any output is chosen, say y_M, so that $w = 1/y_M$, the following expression results:

$$\ln\left(D_O / y_M\right) = TL\left(x_{it}, y_{it}/y_{Mit}, d, f, \alpha, \beta, \delta, \psi, \theta\right), \qquad (3)$$

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[4] This methodology has been applied in some empirical papers (Coelli and Perelman, 1999, 2000; Morrison et al. 2000; Orea, 2002, among others).

[5] As stated by Cuesta and Orea (2002) the chosen output does not influence the results.

yielding the final expression:

$$-\ln\left(y_{Mit}\right)=TL\left(x_{it},y_{it}/y_{Mit},d,f,\alpha,\beta,\delta,\psi,\theta\right)-\ln\left(D_O\right). \quad (4)$$

In equation (4), the *–ln*(D_O) term can be interpreted as an error term which captures the technical inefficiency.

The distance function estimated is stochastic. For the purpose of estimating the equation (4), the random disturbance term must be determined. We applied the methodology developed by Battese and Coelli (1988) for panel data and applied an additive term, as suggested by Cuesta and Orea (2002), to account for the fact that we are estimating an output oriented distance function. The error term thus has the following form:

$$\varepsilon_{it}=v_{it}+u_i \quad (5)$$

where, v_{it} is a symmetrical error term, iid with a zero mean (which represents the random variables that the operator cannot control) and u_i is a one-sided negative error term (which measures the technical inefficiency of each operator that is constant over time) and is distributed independently of v_{it}.

Applied to the distance function, this yields

$$-\ln\left(y_{Mit}\right)=TL\left(x_{it},y_{it}/y_{Mit},d,f,\alpha,\beta,\delta,\psi,\theta\right)+v_{it}+u_i \quad (6)$$

This equation can be estimated by the maximum likelihood method, which requires distributional assumptions of the random shock. This assumes that v_{it} follows an $N(0, \sigma_v^2)$ distribution and u_i follows an $|N(0, \sigma_u^2)|$ distribution (Ritter and Simar, 1997).

This model thus assumes that the inefficiency effects are constant over time. To be able to assess the effects of policy changes on inefficiency levels, we structured the time horizon into 3 periods and considered the port authorities to be independent across periods. This way, any change resulting from reform can be assessed within the period. The three time periods are:

(i) before the reform (1990-1992)

(ii) after the first reform (1993-1997)

(iii) after the second reform (1998-2002)

4.3. The data[6]

The heterogeneity of activities performed in ports and the diversity of commodities handled suggests the idea of limiting the study to a certain number of ports and a specific type of cargo. Given the aforementioned recommendation, this study centers its analysis on the Port Authorities of Spanish ports, which are particularly relevant in terms of container traffic.

The ports included in the sample are the country's major commercial ports and cover a broad typology of ports. The time period under analysis is from 1990 to 2002, which makes it possible to analyze the effects that the modifications to the port system carried out in the nineties had on the efficiency of each of the ports in particular and the port system in general.

The unit for analysis is the port authority. More than 70% of the ships going through Spanish ports come under the control of the nine port authorities in the sample (Algeciras, Alicante, Balearic Islands, Barcelona, Bilbao, Las Palmas, Santa Cruz de Tenerife, Valencia and Vigo). These sample authorities also handle 96% of container traffic, all of which is proof of the high concentration of this kind of traffic.

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[6] For more details about the data and variables see Gonzalez (2004) and Gonzalez and Trujillo (2005).

To describe port technology, we have used four variables representing port output (container cargo, liquid bulk, other cargo and passengers) and three productive factors (work, berths and area). Occasionally, certain specific factors may influence production activities without any possible interference from the port authorities. This study has included the existence of oil refineries and geographical location. A dummy was thus introduced to explicitly account for the oil refineries in Algeciras, Bilbao and Santa Cruz de Tenerife. Another dummy variable is included for the island ports (Balearic Islands, Las Palmas and Santa Cruz de Tenerife).

We also need to model a number of relevant changes that occurred during the period of analysis. These include, economic booms, a liberalization of maritime cabotage within the European Union, changes to ship building technology, technological changes to handling equipment to address the large expansion of container traffic. These effects are accounted for by a time dummy for each year covered by the sample. This allows us to capture the effect of factors that influence all ports equally at different points in time, other than the deregulation process.

4.4. The results

Table 4 shows the parameters estimates obtained with the output oriented distance function, which was estimated by maximum likelihood. Globally, it shows that the output distance function is well behaved.

The first-order parameters present the expected signs and are also significant. In other words, the parameters of output variables are positive and, thus, indicate that distance from the frontier increases when production grows (the output-oriented distance function takes a value between zero and one). On the contrary, first order input parameters are negative, suggesting that if inputs increase, for a given output level, the distance will be reduced. The regression results also show that the refinery and location variables matter. They both have a negative and significant coefficient.

The coefficients for the time dummies show the effects of factors that evolve over time and influence all the ports simultaneously. These coefficients are significant as of 1995, with the strongest effects taking place over the last 4 years of the total sample period.

Table 4. Parameters estimated

Table 5 reports a summary of the information that can be generated from the method proposed here to generate a picture of the relative impact of the various reforms and the results presented in Table 4. It aggregates the information generated at the level of each port.

The average story that emerges is that technical efficiency has dropped somewhat also not significantly so but that very different levels of technological change have been associated with each reform. The increase from 0.4% between 1990 and 1992 to 9.9% right after the first package of reform and the slow down (2.7%) in the gains associated with the second wave of reforms illustrates the interest of this methodology in obtained differentiating impact assessments.

Table 5: Impact of reform waves in the Spanish Port system

5. Concluding comments

The evaluation of the impact of reforms on efficiency levels in regulated industries has developed into a key issue. The underlying notion is to verify whether the proposed regulatory targets are being achieved. These objectives include the simulation of markets that are competitive for those services that are characteristically provided in terms of a monopoly. Regulators therefore need to guarantee that similar levels of efficiency to competitive markets are achieved and that the gains in efficiency achieved are shared with users. Thus, the measurement of the evolution of efficiency levels becomes a basic objective for regulators. Simultaneously, regulatory changes may also lead to the adoption of better technologies by the operators (frontier shifts). This diversity of possible effects is what creates a demand for a measure which allows the unbundling of these effects into the pure efficiency and the technological effects.

Methods for analyzing the development of efficiency are varied, and each has its pros and cons as detailed here. This study has presented a proposal that involves transforming the data in such a way that Battese and Coelli's time invariant model (1988) is shown to be variant, at least by periods of time. Our approach allows overcoming the restriction imposed by alternative modeling approaches which imply that the rate of changes in efficiency is constant over time. Our approach also has the advantage of being simple and much less data demanding that the alternatives. These characteristics are particularly useful for regulators who typically enjoy limited access to data and need to rely on relatively simple approaches.

To illustrate the proposal, a distance function was estimated because it captures the multi-output nature of the port sector without assuming somewhat implausible hypotheses regarding the economic behavior of port authorities, but instead using physical data that is much more reliable than economic data. The aim of this application was to show the impact that reforms to the Spanish port system have had on the technical efficiency of the analyzed ports.

Empirically, the paper has shown that the restructuring and the substantial reforms introduced not only changed the conditions for the development of port activities subject to regulation but also led to significant improvements in technological change. However, technical efficiency has not improved in a similar way and has in fact changed little on average. The regulatory change can be credited with a statistically significant incentive to adopt better technologies by the port authorities. This has resulted in significant improvement in their productivity.

These results are particularly relevant in practice because a third wave of reforms has just been implemented and many more changes are expected to come from future EU guidelines for the liberalization of port activities, with a potentially strong influence on container traffic.

References

Battese, G.E., and Coelli, T.J. (1988) "Prediction of Firm-Level Technical Efficiencies with a Generalized Frontier Production Function and Panel Data", *Journal of Econometrics*, 38: 387-399.

Battese, G.E., and Coelli, T.J. (1992) "Frontier Production Functions technical Efficiency and Panel Data: With Applications to Paddy Farmers in India", *Journal of Productivity Analysis*, 3: 153-169.

Coelli, T. (1996) "A Guide to Frontier Version 4.1: A Computer Program for Frontier Production Function Estimation". CEPA Working Paper Nº 96/07: University of New England, Australia.

Coelli, T. and Perelman, S. (1999) "A Comparison of Parametric and Non-Parametric Distance Functions: with Application to European Railways", *European Journal of Operational Research,* 117: 326-339.

Coelli, T. and Perelman, S. (2000) "Technical Efficiency of European Railways: a Distance Function Approach", *Applied Economics*, 32: 1967-1976.

Cornwell, C., Schmidt, P. and Sickles, R. (1990) "Production Frontiers with Cross-Sectional and Time-Series Variation in Efficiency Levels", *Journal of Econometrics*, 46: 185-200.

Cuesta, R.A. (2001): "Modelos con eficiencia técnica variante en el tiempo", en Álvarez, A. (coordinador)

Cuesta, R.A. and Orea, L. (2002) "Mergers and Technical Efficiency in Spanish Saving Banks: a Stochastic Distance Function Approach", *Journal of Banking & Finance*, 26: 2231-2247.

González, M. (2004) "Eficiencia en la provisión de servicios de infraestructura portuaria: una aplicación al tráfico de contenedores en España", tesis doctoral, Universidad de Las Palmas de Gran Canaria.

González, M. and Trujillo (2005): Reform and Infrastructure Efficiency in Spanish's Containers Ports. *The World Bank, Policy Research Working Paper*. WPS3515

Heshmati, A. and Kumbhakar, S.C. (1994) "Farm Heterogeneity and Technical efficiency: Some Results from Swedish Dairy Farms", *Journal of Productivity Analysis*, 5(1): 45-61.

Kumbhakar, S.C. (1990) "Production Frontiers, Panel Data and Time-varying Technical Inefficiency", *Journal of Econometrics*, 46: 201-211.

Kumbhakar, S.C. (1991) "Estimation of Technical Inefficiency in Panel Data Models with Firm and Time-specific Effects", *Economics Letters*, 36: 43-48.

Lee, Y.H. and Schmidt, P. (1993) "A Production Frontier Model with Flexible Temporal Variation in Technical Efficiency" in H. Fried, Lovell, C.A.K. and Schmidt, S. (eds), *The Measurement of Productive Efficiency: Techniques and Applications*, Oxford University Press, New York.

Lovell, C.A.K., Richardson, S., Travers, P. and Wood, L. (1994) "Resources and Functionings: a New View of Inequality in Australia" in Eichhorn, W. (ed.), *Models and Measurement of Welfare and Inequality*, Springer-Verlag, Berlin.

Morrison, C.J., Johnston, W.E. and Frengley, G.A.G. (2000) "Efficiency in New Zealand Sheep and Beef Farming: the Impacts of Regulation Reform", *Review of Economics and Statistics*, 82 (2): 325-337.

Orea, L. (2002) "Parametric Decomposition of a Generalized Malmquist Productivity Index", *Journal of Productivity Analysis*, 18: 5-22.

Ritter, C. and Simar, L. (1997) "Pitfalls of Normal Gamma Stochastic Frontier Models", *Journal of Productivity Analysis*, 8 (2): 121-129.

Shephard, R.W. (1953) *Cost and Production Functions*, Princeton University Press, Princeton.

Shephard, R.W. (1970) *Theory of Cost and Production Functions*, Princeton University Press, Princeton.

Table 1. Original sample presentation

Firm	Year	Output	Input
F_1	T_1	Y_{11}	X_{11}
F_2	T_1	Y_{21}	X_{21}
F_3	T_1	Y_{31}	X_{31}
F_1	T_2	Y_{12}	X_{12}
F_2	T_2	Y_{22}	X_{22}
F_3	T_2	Y_{32}	X_{32}
F_1	T_3	Y_{13}	X_{13}
F_2	T_3	Y_{23}	X_{23}
F_3	T_3	Y_{33}	X_{33}
F_1	T_4	Y_{14}	X_{14}
F_2	T_4	Y_{24}	X_{24}
F_3	T_4	Y_{34}	X_{34}

Table 2. Restructured sample

Firm	Year	Output	Input
F_1	T_1	Y_{11}	X_{11}
F_2	T_1	Y_{21}	X_{21}
F_3	T_1	Y_{31}	X_{31}
F_1	T_2	Y_{12}	X_{12}
F_2	T_2	Y_{22}	X_{22}
F_3	T_2	Y_{32}	X_{32}
F_4	T_3	Y_{13}	X_{13}
F_5	T_3	Y_{23}	X_{23}
F_6	T_3	Y_{33}	X_{33}
F_4	T_4	Y_{14}	X_{14}
F_5	T_4	Y_{24}	X_{24}
F_6	T_4	Y_{34}	X_{34}

Table 3. Structure of the panel of data

T_1	T_2	T_3	T_4
F_1	F_1	0	0
F_2	F_2	0	0
F_3	F_3	0	0
0	0	F_4	F_4
0	0	F_5	F_5
0	0	F_6	F_6

Table 4. Parameters estimated

Variables and parameters			t-test	Variables and parameters			t-test
Intercept	α_0	0.2283	3.69	ln (liquid bulk). ln (other goods)	α_{34}	0.2622	3.73
*Outputs**				ln (liquid bulk). ln (berth)	δ_{31}	0.4988	4.96
ln(passenger)	α_1	0.1636	(a)	ln (liquid bulk). ln (surface)	δ_{32}	-0.1723	-2.34
ln (container)	α_2	0.2454	5.15	ln (liquid bulk). ln (labor)	δ_{33}	-0.1941	-1.83
ln (liquid bulk)	α_3	0.1051	2.96	ln (other goods). ln (berth)	δ_{41}	-0.9739	-5.18
ln (other goods)	α_4	0.4860	8.32	ln (other goods). ln (surface)	δ_{42}	-0.3557	-2.06
Inputs				ln (other goods). ln (labor)	δ_{43}	0.3064	1.53
ln (berth)	β_1	-0.3658	-2.69	ln (berth). ln (surface)	β_{12}	0..9816	3.14
ln (surface)	β_2	-0.2564	-4.02	ln (berth). ln (labor)	β_{13}	0.4278	1.12
ln (labor)	β_2	-0.7728	-6.48	ln (surface). ln (labor)	β_{23}	0.3913	1.03
Cross terms				*Temporal effects*			
ln (passenger). ln (passenger)	α_{11}	0.0399	(a)	D 1991	θ_1	0.0149	0.43
ln (container). ln (container)	α_{22}	-0.3432	-2.07	D 1992	θ_2	-0.0081	-0.20
ln (liquid bulk). ln (liquid bulk)	α_{33}	-0.0573	-2.02	D 1993	θ_3	0.0783	1.66
ln (other goods). ln (other goods)	α_{44}	-0.8545	-6.60	D 1994	θ_4	-0.0592	-1.15
ln (berth). ln (berth)	β_{11}	-2.0697	-4.15	D 1995	θ_5	-0.2107	-3.65
ln (surface). ln (surface)	β_{22}	-1.2459	-4.15	D 1996	θ_6	-0.2862	-4.62
ln (labor). ln (labor)	β_{33}	-0.7509	-0.99	D 1997	θ_7	-0.3158	-4.95
ln (passenger). ln (container)	α_{12}	-0.0420	(a)	D 1998	θ_8	-0,3845	-5.74
ln (passenger). ln (liquid bulk)	α_{13}	-0.1766	(a)	D 1999	θ_9	-0.4828	-7.33
ln (passenger). ln (other goods)	α_{14}	0.1787	(a)	D 2000	θ_{10}	-0.5065	-7.42
ln (passenger). ln (berth)	δ_{11}	0.3250	(a)	D 2001	θ_{11}	-0.5089	-7.34
ln (passenger). ln (surface)	δ_{12}	0.0160	(a)	D 2002	θ_{12}	-0.5034	-7.15
ln (passenger). ln (labor)	δ_{13}	-0.0633	(a)	*Environmental variables*			
ln (container). ln (liquid bulk)	α_{23}	-0.0283	-0.50	Location	Ψ_1	-0.2523	-3.33
ln (container). ln (other goods)	α_{24}	0.4135	3.09	Refinery	Ψ_2	-0.4868	-7.74
ln (container). ln (berth)	δ_{21}	0.1501	0.75	*Other ML parameters*			
ln (container). ln (surface)	δ_{22}	0.5119	2.61	ε standard deviation	σ_ε	0.0164	3,21
ln (container). ln (labor)	δ_{23}	-0.0489	-0.22	σ^2_u / σ^2_ε	γ	0.7415	7.21

(a) indicates parameters calculated by application of the homogeneity condition.

Table 5: Impact of reform waves in the Spanish Port system

Periods	Average technical efficiency (%)	Technological change (%)
1990-1992	92.1	0.4
1993-1997	92.1	9.9
1998-2002	91.3	2.7
1990-2002	91.9	4.2

Tracking the stepwise effects of regulatory reforms over time: a "back-door" approach

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Abstract

Most of the literature on the efficiency effects of regulatory reforms ignores the gradual nature of the implementation of these reforms. This paper describes a new simple data manipulation which minimizes data requirements to measure econometrically the impact on efficiency of each stage of multi-stages regulatory reforms. The approach can easily be implemented using standard stochastic frontier software programs. It is illustrated with data on the Spanish port system which went through a two-stage reform during the 1990s.

Tracking the stepwise effects of regulatory reforms over time: a "back-door" approach

1. Introduction

The 1990s were characterized by widespread efforts to liberalize public services in the hope of increasing their efficiency.[1] In most instances, reformers were aware of the need for a residual regulatory role for the public sector to ensure a fair distribution of the efficiency gains between the users and the natural monopolies (e.g the supply of infrastructure in port or railways services, water or energy distribution services). Sector differences and differences in the complexity of the political context have however resulted in different strategies to get to the regulatory role. In many instances, the reformers have had to adopt a gradual and slow distancing from self regulated monopolies rather than a shock approach to reform.

The different stages of the gradual approaches all contribute in different ways in determining the total efficiency gains achieved by reform packages. Getting a "broad" sense of where the biggest bang for the buck can be achieved can come in handy in designing new reform packages. Data limitations are however typically so strong that it is difficult to get much more than anecdotal evidence on the relative impact of the various reform stages.

This paper proposes a simple "back door" method to address the problem. It allows an unbundling of the total gains achieved by a reform package and to assign credit for the relative contribution to efficiency changes to each stage of the reforms. The approach is illustrated with an assessment of the impact of the gradual regulatory reforms adopted in the Spanish port sector during the 1990s.

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[1] There are some papers that illustrate the effects in regulatory changes (Estache et al. 2002; Anstine, 2004) or the efficiency or cost structure in regulated industries (Grosskopf et al., 2006; Jara-Díaz et al., forthcoming).

The paper is structured as follows: section 2 offers a survey of the literature analyzing the evolution of the efficiency over time. Section 3 describes our methodological proposal. Section 4 discusses the distance function we rely on to get to the total efficiency gains. Section 5 shows how we can unbundle the sources of efficiency gains with an application to the Spanish port reform experience. The discussion includes a description of the data, the model and the most important results. Section 6 concludes.

2. A brief survey of the literature

The literature offers roughly two groups of models to track the temporal variation of efficiency that emerged in the early 1990s. The first group of models was based on the traditional models of panel data and estimated the frontier by means of corrections of the least square method. In these models, the definition of the temporal structure of efficiency is derived from the independent term (through the individual effects). There are however various ways of getting to the evolution of efficiency within this first group of models.

Cornwell, Schmidt and Sickles (1990) were the pioneers. They suggested that the evolution of efficiency should follow a quadratic function of time, making it possible for efficiency to also vary between firms. This made the model highly flexible, although the price to be paid was that it required a lot of data. This is a major inconvenience in regulated sectors, where lack of data is a common problem, both in the cross-section and longitudinal dimensions. Lee and Schmidt (1993) proposed another type of panel data model in which efficiency varies in the same way between firms. Although this model requires less data than the previous one, it imposes that the efficiency varies in the same way for all the firms. From the perspective of the analysis of the impact of regulatory reforms, the main drawback of these models is their failure to allow for any distinction between the effects of a change in efficiency and the effects of neutral technical progress. This is an important limitation since reforms can influence both dimensions and do so differently and at different points in time.

A second group of models often used in this context consists of stochastic frontier models. In these models, the pattern of variance in efficiency is modeled using the error term, assuming a distributional assumption. They can also be separated into those that specify a common pattern of variance of efficiency between firms and those that allow the efficiency to vary in a differentiated way for each firm. The formers include the proposal suggested by Kumbhakar (1990) in which the inefficiency term is specified as an exponential function of time and the Battese and Coelli (1992) model, who propose a unique time parameter to catch efficiency variability over time for all firms. The main difficulty for the practical implementation of these approaches is the restriction that efficiency follows similar patterns overtime for all firms. Assuming similar patterns for all firms is not a very plausible assumption in most cases, as less inefficient firms have a greater margin for improvement than more efficient ones.

To overcome the inconveniences of the previous models, new proposals have been developed that make it possible to vary the differentiated efficiency for each firm (Kumbhakar, 1991; Heshmati and Kumbhakar, 1994; Cuesta, 2000[2]). While they address the basic issues conceptually, they do so at some costs. First, they suffer from major theoretical econometric problems which have been discussed in Coelli et al. (2005) for instance. Moreover, for applied work, the fundamental issue with these models is that they require a large quantity of data, as the number of parameters to be estimated increases with the number of firms.

A most general solution to the econometric problems of the above models could be offered however by the Battese and Coelli (1988) proposal. This is a model with time invariant efficiency. Therefore, although it is applied to panel data, it evaluates the efficiency of each firm at a single moment in time and does not resolve the question of measuring regulatory changes as a temporal evolution of the efficiency of each firm. For gradual reforms impact assessments, however, the model cannot be used as is because it

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[2] For a more detailed survey about temporal variation in inefficiency see Cuesta (2001).

yields time invariant efficiency estimates. Indeed, although it applies to panel data, it evaluates the efficiency of each firm at a single point in time. Their method is however much more flexible than what these authors recognized and could be used, thanks to a simple data transformation, to track the impact of reforms on the evolution of efficiency at the firm level as discussed in the next section.

3. The model transformation

None of the models surveyed in Section 2 allows a diagnostic of the relative reaction of firm specific performance to the various components of a reform package. There is thus a need to transform time invariant models into models that are time “variant” over chunks of periods. This is a major limitation for a wide range of policy applications.

It turns out that a simple transformation of the data samples is enough to make Battese and Coelli’s model (1988) capable of measuring the efficiency of firms in different time periods. This is achieved simply by creating groups of firms by periods. These groups, despite actually containing the same firms, are tabulated in a different way for each period, so that what are simulated are different firms. In this way, the model, on recognizing “new firms”, evaluates the corresponding efficiency of each group of firms which simply correspond to the same set of firms at different observation periods (i.e. the impact of a sequence of reforms can then be tracked over time).

For example, assume that there is a panel of data made up of 3 firms (called F_1, F_2 and $F_{3)}$, for which we have information for four years (T_1, T_2, T_3 and T_4). These firms produce product Y_{ij} by means of input X_{ij} (i refers to the firm and j to the time period). The usual way of incorporating the information into the software program is shown in la Table 1.[3]

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[3] At least three software programs allow the estimation of the Battese and Coelli’s model (1988): FRONTIER (Coelli, 1996), LIMDEP and STATA.

Table 1. Original sample presentation

For the sake of the argument, we also assume that a change of regulation occurs in year 3 and that its effects carry over into the next year. This implies that we have to consider that the firms in years 3 and 4 are independent of the firms in the first two years. This is done by naming the firms F_4, F_5 and F_6, respectively. Thus, the information should be incorporated as shown in Table 2.

Table 2. Restructured sample

It should be observed that, as the firms are really the same, despite being assigned different codes, the data referring to the variables is entered in the same order. This means that the result is an incomplete panel of data that is expressed as in Table 3, where T_1 to T_4 refer to the time period and F_1 to F_6 to the firms.

This way, the end result is the time invariant efficiency of firms F_1, F_2, F_3, F_4, F_5 and F_6. As firms F_4, F_5 and F_6, are in fact F_1, F_2 and F_3, in another period, the change in efficiency obtained from the comparison between the two sets is really the time variation of the efficiency of firms F_1, F_2 and F_3. The main assumption justifying the new sample organization is that regulatory reforms have had a major impact on firms' operations and the same firm can be considered as a different and independent entity (decision making unit) before and after the reform.

Table 3. Structure of the panel of data

4. Empirical application

In order to demonstrate the suitability of the proposed transformation, we model Spain's gradual approach to port reform during the 1990s. The specifics of these reforms are not of interest here but the fact that it involves two main stages is since it allows a simple illustration of our methodological proposal.[4]

The reforms, their sequence and of their timing can be summarized as follows for our purpose. The first stage of the reform took place in 1992. It was characterized by the development of new management procedures and organization structures. Its main purpose was to decentralize the port system and to reinforce the autonomy of the port authorities. The second stage was in 1998. It further increased the autonomy of the port authorities, regulated the participation of the regional Government in the port organization and encouraged the participation of the private sector in port activities. Both stages were designed to have an impact on efficiency. To estimate the total efficiency gains and to track the differentiated effect of each stage, we estimate a distance function using the data of a representative sample of port authorities in the Spanish port system.

4.1. The distance function

The distance function, introduced by Shephard (1953, 1970), allows the estimation of the relative efficiency of firms in relation to the technological frontier. This function is selected because of its advantages over the more standard alternatives approaches to assessing frontiers. Of particular interest here is that it makes it possible to capture multi-output processes and that it does not require the use of optimizing assumptions. Moreover, it only uses physical data and, therefore, information is not necessary for output or factor prices. [5]

The analysis of the conditions under which port authorities perform their activities demands the estimation of an output-oriented distance function. An output-oriented distance function is defined as the smallest scalar by which all outputs can be

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[4] For more details see Gonzalez (2004).

[5] This methodology has increasingly common in empirical papers on infrastructure industries, e.g. (Coelli and Perelman, 1999, 2000; or on regulated industries, e.g. Morrison et al. 2000, among others).

proportionally divided, using the same level of productive factors. This is because in the provision of infrastructure services, port authorities have some power to decide on the production level through the use of two mechanisms: commercial policies and concessions. In addition, port authorities encounter certain difficulties in adjusting the productive factors used in the provision of infrastructure services, basically: berths, area and labor.

4.2. The functional form

The empirical application of a distance function calls for the definition of an appropriate functional form. It is desirable for the functional form to present the following advantages: it must be flexible, it must be easy to calculate and, lastly, it must make it possible to impose the homogeneity condition. The translogarithmic functional form (hereinafter translog) meets these conditions. It consists of a flexible functional form that provides a local second-order approximation to an unknown functional form. In other words, no *a priori* restrictions about production technology are assumed.

The output oriented translog distance function can be expressed as follows:

$$\begin{aligned} \ln D_0 = \alpha_0 + \sum_{m=1}^{M} \alpha_m \ln y_{mit} + 1/2 \sum_{m=1}^{M} \sum_{n=1}^{M} \alpha_{mn} \ln y_{mit} \ln y_{mit} + \\ \sum_{k=1}^{K} \beta_k \ln x_{kit} + 1/2 \sum_{k=1}^{K} \sum_{l=1}^{K} \beta_{kl} \ln x_{kit} \ln x_{lit} + \sum_{k=1}^{K} \sum_{m=1}^{M} \delta_{km} \ln x_{kit} \ln y_{mit} + \\ \sum_{h=1}^{H} \psi_h d_h + \sum_{t=1}^{T} \theta_t f_t + \varepsilon_{it} \end{aligned} \qquad (1)$$

where y is a vector of M outputs, x is a vector of K factors, i relates to the i-*th* firm, t refers to the t-*th* year, d relates to the H environment dummy variables and f to the time period dummies; α, β, δ, ψ and θ are coefficients to be estimated and ε_{it} is an error term which is discussed later. Continuous variables are expressed in relation to their deviation from the geometric mean; therefore, the first order term coefficients correspond to distance function elasticities at the sample mean points.

In order to determine the frontier, D_O needs to be equal to the unit and, in that case, the term on the left of the equation, according to the neperian logarithm, will equal zero. By definition, output distance functions assume radial expansion of outputs, therefore the homogeneity condition of degree 1 must be imposed. Following Lovell et al. (1994), this condition has been imposed by standardizing the distance function with one of the outputs. This works on the assumption that homogeneity implies that:

$$D_O\left(x, wy\right) = wD_O\left(x, y\right), \tag{2}$$

for any w>0. [6]

If in a translog distance function (1), any output is chosen, say y_M, so that $w = 1/y_M$, the following expression results:

$$\ln\left(D_O/y_M\right) = TL\left(x_{it}, y_{it}/y_{Mit}, d, f, \alpha, \beta, \delta, \psi, \theta\right), \tag{3}$$

yielding the final expression:

$$-\ln\left(y_{Mit}\right) = TL\left(x_{it}, y_{it}/y_{Mit}, d, f, \alpha, \beta, \delta, \psi, \theta\right) - \ln\left(D_O\right). \tag{4}$$

In equation (4), the *–ln*(D_O) term can be interpreted as an error term which captures the technical inefficiency.

The distance function estimated is stochastic. To estimate equation (4), the random disturbance term must be determined. We applied the methodology developed by Battese and Coelli (1988) for panel data and applied an additive term, as suggested by Cuesta and

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[6] As stated by Cuesta and Orea (2002) the chosen output does not influence the results.

Orea (2002), to account for the fact that we are estimating an output oriented distance function. The error term thus has the following form:

$$\varepsilon_{it} = v_{it} + u_i \tag{5}$$

where, v_{it} is a symmetrical error term, iid with a zero mean (which represents the random variables that the operator cannot control) and u_i is a one-sided negative error term (which measures the technical inefficiency of each operator that is constant over time) and is distributed independently of v_{it}.

Applied to the distance function, this yields

$$-\ln\left(y_{Mit}\right) = TL\left(x_{it}, y_{it}/y_{Mit}, d, f, \alpha, \beta, \delta, \psi, \theta\right) + v_{it} + u_i \tag{6}$$

This equation can be estimated by the maximum likelihood method, which requires distributional assumptions of the random shock. This assumes that v_{it} follows an $N(0, \sigma_v^2)$ distribution and u_i follows an $|N(0, \sigma_u^2)|$ distribution (Ritter and Simar, 1997).

This model thus assumes that the inefficiency effects are constant over time. To be able to assess the effects of policy changes on inefficiency levels, we structured the time horizon into 3 periods and considered the port authorities to be independent across periods. This way, any change resulting from reform can be assessed within the period. The three time periods are:

(i) before the reform (1990-1992)

(ii) after the first reform (1993-1997)

(iii) after the second reform (1998-2002)

4.3. The data[7]

The time period under analysis is relatively long since it spans from 1990 to 2002. This is long enough to track down the effects of a gradual regulatory reform. For that period, we have data on 9 port authorities. This dataset makes it possible to analyze the effects that the modifications to the port system carried out in the nineties had on the efficiency of each of the ports in particular and the port system in general. The authorities covered by our sample handle 96% of container traffic. Hence, the policy implications of our diagnostic should be quite representative.

The data available for each port authority for this period is standard in the literature on ports economics.[8] We have four variables representing port output (container cargo, liquid bulk, other cargo and passengers) and three productive factors (work, berths and area). Occasionally, certain specific factors may influence production activities without any possible interference from the port authorities. This study has included the existence of oil refineries and geographical location. A dummy was thus introduced to explicitly account for the oil refineries. Another dummy variable is included for the island ports.

To ensure the good quality of our econometric work, we also modeled a number of relevant changes that occurred during the period of analysis. These include, economic booms, a liberalization of maritime cabotage within the European Union, changes to ship building technology, technological changes to handling equipment to address the large expansion of container traffic. These effects are accounted for by a time dummy for each year covered by the sample. This allows us to capture the effect of factors that influence all ports equally at different points in time, other than the regulation process. In other words, it improves our estimates of the assessment of the impact of regulatory reforms.

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[7] For more details about the data and variables see Gonzalez (2004) and Gonzalez and Trujillo (2005).

[8] See Coelli et al (2003)

4.4. The results

Table 4 shows the parameters estimates obtained with the output oriented distance function, which was estimated by maximum likelihood. Globally, it shows that the output distance function is well behaved. The first-order parameters present the expected signs and are also significant. In other words, the parameters of output variables are positive and, thus, indicate that distance from the frontier increases when production grows (the output-oriented distance function takes a value between zero and one). On the contrary, first order input parameters are negative, suggesting that if inputs increase, for a given output level, the distance will be reduced. The regression results also show that the refinery and location variables matter. They both have a negative and significant coefficient.

The coefficients for the time dummies show the effects of factors that evolve over time and influence all the ports simultaneously. These coefficients are significant as of 1995, with the strongest effects taking place over the last 4 years of the total sample period.

Table 4. Parameters estimated

To better focus on the main concern of this paper, Table 5 reports a summary of the information that can be generated from the method proposed here. It gives a picture of the relative impact of the various reforms, aggregating the information generated at the level of each port. The average story that emerges is that technical efficiency has dropped somewhat also not significantly so but that very different levels of technological change have been associated with each reform. In other words, the explicit modelling of the gradual approach of reform is proving to be relevant since it reveals that each stage has a different impact on various sources of efficiency changes.

For the record, our results suggest that the first stage of the reforms delivered the biggest impact and that this was quite significant. The increase from 0.4% between 1990 and 1992 to 9.9% right after the first package of reform is indeed strong. The slow down (2.7%) in the gains associated with the second wave of reforms is notable but it shows that efficiency gains from the second stage of reforms have nonetheless been worth the effort.

Table 5: Impact of reform waves in the Spanish Port system

5. Concluding comments

The evaluation of the impact of reforms on efficiency levels in regulated industries is important for at least two reasons. The first is that the debates around the desirability of reforms in regulated industries often lack the necessary quantitative support necessary to assess where efficiency gains have actually been achieved or not. Measuring the efficiency effects of reforms, even gradual, allows more technical and less ideological assessments of reforms. Second, the measurement of efficiency has recently developed into a core business issue for regulators since they are expected to assess the scope for redistribution to the users of possible rents achieved by monopolistic providers. Gains can come from better efforts to improve performance, from the adoption of better technologies or from both. Any method of relevance to regulators needs to distinguish between these two sources of efficiency changes. The upshot is that the measurement of the evolution of efficiency levels is now a basic objective for many regulators and policy analysts.

In practice, analysts and regulators face major data constraints to conduct robust efficiency evaluations which allow fair assessments of the regulated operators. The data constraints are even stronger when the effects of various stages of reforms need to be isolated. The main contribution of this paper is the development of a simple method which minimizes the data requirements for a wide range of situation in which it is important to assess the efficiency of gradual reforms at each stage of these reforms. Our proposal involves the transformation of the available data in such a way that Battese and Coelli's time invariant model (1988) becomes variant, at least by blocks of time which can each be matched with a specific reform stage.

The relevance of the proposal has been illustrated with a case study of the gradual reform of the Spanish port system. The assessment has revealed very significant differences in the impact achieved by the two stages of reforms both in terms of the effort levels achieved by the operators (catching up effects) and in terms of the adoption of new technologies (frontier shift effects). From an analytical perspective, it is thus interesting to be able to monitor the effects of the various stages of reforms. From a regulatory view point, the method is particularly useful in that it allows the regulator to distinguish the evolution of the behavior of individual operators over time and to use this information as part of its regulatory decisions.

References

Anstine, D.B. (2004) "The impact of the regulation of the cable television industry: the effect on quality-adjusted cable television prices", *Applied Economics,* 36, 8: 793-802.

Battese, G.E., and Coelli, T. (1988) "Prediction of Firm-Level Technical Efficiencies with a Generalized Frontier Production Function and Panel Data", *Journal of Econometrics*, 38: 387-399.

Battese, G.E., and Coelli, T. (1992) "Frontier Production Functions technical Efficiency and Panel Data: With Applications to Paddy Farmers in India", *Journal of Productivity Analysis*, 3: 153-169.

Coelli, T. (1996) "A Guide to Frontier Version 4.1: A Computer Program for Frontier Production Function Estimation". CEPA Working Paper Nº 96/07: University of New England, Australia.

Coelli, T. and Perelman, S. (1999) "A Comparison of Parametric and Non-Parametric Distance Functions: with Application to European Railways", *European Journal of Operational Research,* 117: 326-339.

Coelli, T. and Perelman, S. (2000) "Technical Efficiency of European Railways: a Distance Function Approach", *Applied Economics*, 32: 1967-1976.

Coelli, T., A. Estache, S. Perelman and L. Trujillo (2003) *A Primer on Efficiency Measurement for Utilities and Transport Regulators*, World Bank Institute Publications, Studies in Development Series

Coelli, T., Rao, D.S.P., O'Donnell, C.J., and Battese, G.E. (2005*) An Introduction to Efficiency and Productivity Analysis*, 2nd edition, Springer

Cornwell, C., Schmidt, P. and Sickles, R. (1990) "Production Frontiers with Cross-Sectional and Time-Series Variation in Efficiency Levels", *Journal of Econometrics*, 46: 185-200.

Cuesta, R.A. (2000) "A Production Model with Firm-Specific Temporal Variation in Technical Inefficiency: with application to Spanish Dairy Farms", *Journal of Productivity Analysis*, 13, 139-158.

Cuesta, R.A. (2001) "Modelos con eficiencia técnica variante en el tiempo", in Álvarez, A. (ed.), *La medición de la eficiencia y la productividad,* Editorial Pirámide, Madrid, Spain.

Cuesta, R.A. and Orea, L. (2002) "Mergers and Technical Efficiency in Spanish Saving Banks: a Stochastic Distance Function Approach", *Journal of Banking & Finance*, 26: 2231-2247.

Estache, A., González, M. and Trujillo, L. (2002) "Efficiency Gains from Port Reform and the Potential for Yardstick Competition: lessons from México", *World Development*, 30 (4), 545-560.

González, M. (2004) "Eficiencia en la provisión de servicios de infraestructura portuaria: una aplicación al tráfico de contenedores en España", tesis doctoral, Universidad de Las Palmas de Gran Canaria.

González, M. and Trujillo (2005) Reform and Infrastructure Efficiency in Spanish's Containers Ports. *The World Bank, Policy Research Working Paper*. WPS3515.

Grosskopf, S. Self, S. and Zaim, O. (2006) "Estimating the efficiency of the system of healthcare financing in achieving better health", *Applied Economics*, 38, 13, 1477-1488.

Heshmati, A. and Kumbhakar, S.C. (1994) "Farm Heterogeneity and Technical efficiency: Some Results from Swedish Dairy Farms", *Journal of Productivity Analysis*, 5(1): 45-61.

Jara-Díaz, S. Tovar, B. and Trujillo, L. (forthcoming) "On the Proper Modelling of Multioutput Port Cargo Handling Costs", *Applied Economics*.

Kumbhakar, S.C. (1990) "Production Frontiers, Panel Data and Time-varying Technical Inefficiency", *Journal of Econometrics*, 46: 201-211.

Kumbhakar, S.C. (1991) “Estimation of Technical Inefficiency in Panel Data Models with Firm and Time-specific Effects”, *Economics Letters*, 36: 43-48.

Lee, Y.H. and Schmidt, P. (1993) “A Production Frontier Model with Flexible Temporal Variation in Technical Efficiency” in H. Fried, Lovell, C.A.K. and Schmidt, S. (eds), *The Measurement of Productive Efficiency: Techniques and Applications*, Oxford University Press, New York.

Lovell, C.A.K., Richardson, S., Travers, P. and Wood, L. (1994) “Resources and Functionings: a New View of Inequality in Australia” in Eichhorn, W. (ed.), *Models and Measurement of Welfare and Inequality*, Springer-Verlag, Berlin.

Morrison, C.J., Johnston, W.E. and Frengley, G.A.G. (2000) “Efficiency in New Zealand Sheep and Beef Farming: the Impacts of Regulation Reform”, *Review of Economics and Statistics*, 82 (2): 325-337.

Ritter, C. and Simar, L. (1997) “Pitfalls of Normal Gamma Stochastic Frontier Models”, *Journal of Productivity Analysis*, 8 (2): 121-129.

Shephard, R.W. (1953) *Cost and Production Functions*, Princeton University Press, Princeton.

Shephard, R.W. (1970) *Theory of Cost and Production Functions*, Princeton University Press, Princeton.

Table 1. Original sample presentation

Firm	Year	Output	Input
F_1	T_1	Y_{11}	X_{11}
F_2	T_1	Y_{21}	X_{21}
F_3	T_1	Y_{31}	X_{31}
F_1	T_2	Y_{12}	X_{12}
F_2	T_2	Y_{22}	X_{22}
F_3	T_2	Y_{32}	X_{32}
F_1	T_3	Y_{13}	X_{13}
F_2	T_3	Y_{23}	X_{23}
F_3	T_3	Y_{33}	X_{33}
F_1	T_4	Y_{14}	X_{14}
F_2	T_4	Y_{24}	X_{24}
F_3	T_4	Y_{34}	X_{34}

Table 2. Restructured sample

Firm	Year	Output	Input
F_1	T_1	Y_{11}	X_{11}
F_2	T_1	Y_{21}	X_{21}
F_3	T_1	Y_{31}	X_{31}
F_1	T_2	Y_{12}	X_{12}
F_2	T_2	Y_{22}	X_{22}
F_3	T_2	Y_{32}	X_{32}
F_4	T_3	Y_{13}	X_{13}
F_5	T_3	Y_{23}	X_{23}
F_6	T_3	Y_{33}	X_{33}
F_4	T_4	Y_{14}	X_{14}
F_5	T_4	Y_{24}	X_{24}
F_6	T_4	Y_{34}	X_{34}

Table 3. Structure of the panel of data

T_1	T_2	T_3	T_4
F_1	F_1	0	0
F_2	F_2	0	0
F_3	F_3	0	0
0	0	F_4	F_4
0	0	F_5	F_5
0	0	F_6	F_6

Table 4. Parameters estimated

Variables and parameters			t-test	Variables and parameters			t-test
Intercept	α_0	0.2283	3.69	ln (liquid bulk). ln (other goods)	α_{34}	0.2622	3.73
*Outputs**				ln (liquid bulk). ln (berth)	δ_{31}	0.4988	4.96
ln(passenger)	α_1	0.1636	(a)	ln (liquid bulk). ln (surface)	δ_{32}	-0.1723	-2.34
ln (container)	α_2	0.2454	5.15	ln (liquid bulk). ln (labor)	δ_{33}	-0.1941	-1.83
ln (liquid bulk)	α_3	0.1051	2.96	ln (other goods). ln (berth)	δ_{41}	-0.9739	-5.18
ln (other goods)	α_4	0.4860	8.32	ln (other goods). ln (surface)	δ_{42}	-0.3557	-2.06
Inputs				ln (other goods). ln (labor)	δ_{43}	0.3064	1.53
ln (berth)	β_1	-0.3658	-2.69	ln (berth). ln (surface)	β_{12}	0..9816	3.14
ln (surface)	β_2	-0.2564	-4.02	ln (berth). ln (labor)	β_{13}	0.4278	1.12
ln (labor)	β_2	-0.7728	-6.48	ln (surface). ln (labor)	β_{23}	0.3913	1.03
Cross terms				*Temporal effects*			
ln (passenger). ln (passenger)	α_{11}	0.0399	(a)	D 1991	θ_1	0.0149	0.43
ln (container). ln (container)	α_{22}	-0.3432	-2.07	D 1992	θ_2	-0.0081	-0.20
ln (liquid bulk). ln (liquid bulk)	α_{33}	-0.0573	-2.02	D 1993	θ_3	0.0783	1.66
ln (other goods). ln (other goods)	α_{44}	-0.8545	-6.60	D 1994	θ_4	-0.0592	-1.15
ln (berth). ln (berth)	β_{11}	-2.0697	-4.15	D 1995	θ_5	-0.2107	-3.65
ln (surface). ln (surface)	β_{22}	-1.2459	-4.15	D 1996	θ_6	-0.2862	-4.62
ln (labor). ln (labor)	β_{33}	-0.7509	-0.99	D 1997	θ_7	-0.3158	-4.95
ln (passenger). ln (container)	α_{12}	-0.0420	(a)	D 1998	θ_8	-0,3845	-5.74
ln (passenger). ln (liquid bulk)	α_{13}	-0.1766	(a)	D 1999	θ_9	-0.4828	-7.33
ln (passenger). ln (other goods)	α_{14}	0.1787	(a)	D 2000	θ_{10}	-0.5065	-7.42
ln (passenger). ln (berth)	δ_{11}	0.3250	(a)	D 2001	θ_{11}	-0.5089	-7.34
ln (passenger). ln (surface)	δ_{12}	0.0160	(a)	D 2002	θ_{12}	-0.5034	-7.15
ln (passenger). ln (labor)	δ_{13}	-0.0633	(a)	*Environmental variables*			
ln (container). ln (liquid bulk)	α_{23}	-0.0283	-0.50	Location	Ψ_1	-0.2523	-3.33
ln (container). ln (other goods)	α_{24}	0.4135	3.09	Refinery	Ψ_2	-0.4868	-7.74
ln (container). ln (berth)	δ_{21}	0.1501	0.75	*Other ML parameters*			
ln (container). ln (surface)	δ_{22}	0.5119	2.61	ε standard deviation	σ_ε	0.0164	3,21
ln (container). ln (labor)	δ_{23}	-0.0489	-0.22	σ^2_u / σ^2_ε	γ	0.7415	7.21

(a) indicates parameters calculated by application of the homogeneity condition.

Table 5: Impact of reform waves in the Spanish Port system

Periods	Average technical efficiency (%)	Technological change (%)
1990-1992	92.1	0.4
1993-1997	92.1	9.9
1998-2002	91.3	2.7
1990-2002	91.9	4.2