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TECHNICAL PROGRESS AND EFFICIENCY CHANGE IN SPANISH PORT SYSTEM

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Abstract:

The Spanish Port Authorities provide their services in an increasingly competitive environment. The globalisation of the economy, new port legislation that gradually allows them a greater independence in the management of their services and the challenges they face in integrating into the pan-European transport network must force Port Authorities to reflect on ways of improving levels of efficiency and gaining competitiveness.

The aim of this paper is to assess how productivity has evolved as a result of changes in technical efficiency and technology over time. Our starting point is Farrell's technical efficiency concept (1957) but we also use nonparametric techniques of data envelopment to assess the changes in efficiency using different functions.

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1. Introduction

The activity carried out in ports is important for the whole economy. As suppliers of services in an increasingly global environment, ports must focus on international competitivity. Moreover, the intermediate input that is characteristic of a service port (for firms) makes efficiency and greater productivity become determinant factors in that competitiveness.

However, the maritime transport sector, which is closely related to the port sector, has brought about transformations in the ports, and is continuing to do so. These have their origin in the technological changes produced in the ways of transporting goods by sea. To handle goods, the port industry has therefore been forced to develop special equipment such as cranes and to adapt quays to meet the changing needs of ships.

The services supplied by the Spanish ports are governed by a port model that was reformed by the Ports Law of 1992 and though to a lesser extent, by another Ports Law in 1997, that followed the same criteria as the Law of 1992. These reforms gave port authorities greater autonomy in the management of ports, but set up a new organization *(Puertos del Estado)* to coordinate the Spanish port system[1].

In the following sections we make an empirical study of the Spanish ports. Using Malmquist index we aim to provide relevant data on how their productivity has evolved.

2. Productivity and changes in technical efficiency and progress

2.1. Changes in the technical efficiency and progress

When we analyse the total factor productivity growth, we must remember that growth may be also due to both technical progress and improved efficiency. We must also remember that inefficiencies in production (in a determined period of time), and later improvements, can be an important cause of a growth in productivity. We can therefore divide the ***changes in productivity*** into:

- ***Changes in efficiency levels or relative position to the technological frontier***: these would result from the firms ability to incorporate technical progress in the management of their production process.
- ***Technical progress***: this is related to the innovations and changes in the techniques that shift the frontier of production. This either produces a greater output with the same quantity of inputs, or the same level of output with fewer inputs.

The method used in this section follows an approach begun by ***Caves, Christensen y Diewert (1982***) who, ***by calculating the Malmquist indexes*** (Malmquist, 1953), assessed the changes in productivity in a group of production units. Later developments by ***Färe, Grosskopf, Lindgren, and Roos (1992,1994)*** allow us divide changes in productivity over time into those resulting from improvements in efficiency and those from technical progress.

2.2. Calculation of the Malmquist indexes of productivity

With the technology in a given period of time, *t*, we transforms an inputs vector, $x^t \in \Re_+^N$, into an outputs vector, $y^t \in \Re_+^M$. Following Grosskopf (1986), we can define:

$$F^t = \left[\left(x^t, y^t\right): x^t \text{ can produce } y^t\right] \tag{1}$$

Färe, Grosskopf, Lindgren and Roos (1992,1994) assume that the technology meets the Shephard axioms (1970). They then characterise the technological reference from the distance function in *inputs*:

$$D_I^t\left(x^t, y^t\right) = \sup\left[\theta_t^t : \left(x^t / \theta_t^t, y^t\right) \in F^t\right] = \inf\left[\theta_t^t : \left(x^t \cdot \theta_t^t, y^t\right) \in F^t\right]^{-1} \tag{2}$$

This function determines the maximum possible reduction of the inputs vector, x^t, that, with the same level of outputs, y^t, attains a position on the technological frontier of the period *t*. This distance is the reciprocal of the technical efficiency Farrell measure, oriented to the inputs (Farrell, 1957).

Caves, Christensen, and Diewert, (1982), CCD, suggest using the ***Malmquist indexes*** to asses changes in productivity over two periods of time. They consider the existence of inefficiency ***from the input[2] point of view***, i.e. changes in productivity are linked to variations in the ability of a firm to decrease the use of the inputs and maintain the same level of output.

INSERT FIGURE 1

This index is calculated from the ***distance functions***, i.e. the distance of a productive unit in two given time periods, K^t and K^{t+1}, with respect to the technological frontier in that same period, *t*, or to the existing frontier at another period of time, *t+1*. If we base this on the ***technology of the started period, t,*** the Malmquist index[3] of productivity is[4]:

$$IM^{t}_{CCD} = \frac{D_I^t(x^t, y^t)}{D_I^t(x^{t+1}, y^{t+1})} \qquad (3)$$

A value greater than one indicates that there has been an increment in the productivity between two periods, *t* and *t+1*. This means that, the reduction needed in the *inputs* of the later period, x^{t+1}, to situate the firm K^{t+1} (x^{t+1},y^{t+1}) on the initial technological frontier, *t*, is smaller than the reduction that the *inputs* of the initial period, x^t, need to situate K^t, (x^t,y^t), in this same frontier, *t*. If the value of expression (3) is less than one the opposite is true.

The ***Malmquist index of productivity*** can be obtained in an alternative way from the ***existing technology in a later period, t+1***:

$$IM^{t+1}_{CCD} = \frac{D_I^{t+1}(x^t, y^t)}{D_I^{t+1}(x^{t+1}, y^{t+1})} \qquad (4)$$

Färe, Grosskopf, Lindgren, and Roos, (1992, 1994) suggest calculating ***an index of productivity*** oriented to the *input*, as the geometrical mean of the previous two indexes, (3) and (4). This new index solves the problem that can arise when choosing one of the technological frontiers as a reference, and therefore considering of a fixed technology:

$$IM_I(x^{t+1}, y^{t+1}; x^t, y^t) = \left\{ \left[\frac{D_I^t(x^t, y^t)}{D_I^t(x^{t+1}, y^{t+1})} \right] \left[\frac{D_I^{t+1}(x^t, y^t)}{D_I^{t+1}(x^{t+1}, y^{t+1})} \right] \right\}^{1/2} \qquad (5)$$

This new expression takes into account that the technology of reference can change over the time. It can also be rewritten and broken down into the following indexes:

$$IM_I(x^{t+1}, y^{t+1}; x^t, y^t) = \underbrace{\left[\frac{D_I^t(x^t, y^t)}{D_I^{t+1}(x^{t+1}, y^{t+1})}\right]}_{Efficiency\ change} \underbrace{\left\{\left[\frac{D_I^{t+1}(x^{t+1}, y^{t+1})}{D_I^t(x^{t+1}, y^{t+1})}\right]\left[\frac{D_I^{t+1}(x^t, y^t)}{D_I^t(x^t, y^t)}\right]\right\}^{1/2}}_{Technical\ change} \quad (6)$$

Breaking down the expression in this way, we can obtain the ***change in productivity*** between two periods, *t* and *t+1*, as a ***result of***:

- ***the variation in the levels of efficiency*** (EFFCH), which represents the change in the relative position to the technological frontier of two periods of time. This is reflected by the first term on the right of (6), in which a value greater than one indicates that the distance in *inputs* of an observation, *K*, in *t*, with respect to the frontier at the same moment *t*, is greater than the distance of that same observation, *K*, in a later period, *t+1*, with respect to the frontier of that period, *t+1*. That is, the observation is closer to the frontier and so technical efficiency is improved.
- ***Technical change*** (TECHCH), which shows how frontier movement affects productivity. This effect is included in the second term, which is the geometrical mean of two indexes. The first one measures the position of the observation K^{t+1} with respect to the technological frontier of the two periods, *t and t+1*. The second one does the same for observation K^t. The geometrical mean of these two components analyse the change in technology. A value greater than one indicates that technical progress that technical progress has impacted positively on the growth in productivity.

2.3. The Malmquist index and the technical efficiency Farrell index

The Malmquist index construction expressed by (6) requires ***the calculation of distance functions***. These functions can be obtained in several ways. In this study we have used non-parametrical techniques of data envelopment. These are known in the economic literature as "Data Envelopment Analysis".

To calculate the distance in *input* of a productive unit in relation to a technological frontier reference, we consider the ***property reciprocity between the distance function and the technical efficiency index of Farrell*** (Farrell, 1957). For this we solve a mathematical optimisation program (see Charnes, Cooper and Rodhes, 1978) and we calculate the distance of an observation in the period *t* from the technological frontier at the same moment in time[5], *t*:

$$\left[D_I^t(x_k^t, y_k^t)\right]^{-1} = Min\theta_{k,t}^t$$
$$s.t.$$
$$y_{k,t} \leq Y_t z_t \qquad (7)$$
$$X_t z_t \leq \theta_{k,t}^t x_{k,t}$$
$$z_t \geq 0$$

To calculate this distance let us consider $K = 1, 2, \ldots, k, \ldots, K$ producers using a vector of inputs, $x_{k,t} = \left(x_{k,t}^1, \ldots, x_{k,t}^N\right)_{(Nx1)} \in \Re_+^N$, to produce a vector of outputs $y_{k,t} = \left(y_{k,t}^1, \ldots, y_{k,t}^M\right)_{(Mx1)} \in \Re_+^N$. $Y_t = \left(y_{1,t}, \ldots, y_{K,t}\right)_{(MxK)}$ and $X_t = \left(x_{1,t}, \ldots, x_{K,t}\right)_{(NxK)}$, represent the output and input matrices, and $z_t = \left(z_{1,t}, \ldots, z_{K,t}\right)_{(Kx1)}$ is a vector of intensity variables.

The mathematical optimisation program to obtain the distance in *input* of an observation in *t* from the technological frontier existing in *t+1* is[6]:

$$\left[D_I^{t+1}(x_k^t, y_k^t)\right]^{-1} = Min\theta_{k,t}^{t+1}$$
$$s.t.$$
$$y_{k,t} \leq Y_{t+1} z_{t+1} \qquad (8)$$
$$X_{t+1} z_{t+1} \leq \theta_{k,t}^{t+1} x_{k,t}$$
$$z_{t+1} \geq 0$$

Expressions (7) and (8) have the following constraint: the technology presents constant returns of scale[7]. However, from Färe, Grosskopf, Norris and Zhang (1994), in the calculation of the Malmquist productivity index we can ***break down the technical efficiency change*** (EFFCH) into:

- ***pure efficiency change*** (PECH), this only corresponds with the technical management of the firm, irrespective of its size
- ***scale change*** (S), this derives from the size of the producer firm in relation to the optimal scale.

This breakdown allows us to identify inefficiencies of scale. For this we re-define the formal model of the distance functions involved in calculating of the efficiency change (EFFCH). In this way the problems (7) and (8) will be solved with an additional constraint that makes the sum of the elements of the *z* vector of intensities equal to one. Every firm can be then compared with firms of a similar size.

In summary, the Malmquist index under the rule of constant returns in technology (C), taking (6), and following the proposal of Färe, Grosskopf and Russell (1998), is:

$$IM_I(x^{t+1}, y^{t+1}; x^t, y^t) = \underbrace{\left[\frac{D_I^t(x^t, y^t)/C}{D_I^{t+1}(x^{t+1}, y^{t+1})/C}\right]}_{Efficiency\ Change} \underbrace{\left\{\left[\frac{D_I^{t+1}(x^{t+1}, y^{t+1})/C}{D_I^t(x^{t+1}, y^{t+1})/C}\right]\left[\frac{D_I^{t+1}(x^t, y^t)/C}{D_I^t(x^t, y^t)/C}\right]\right\}^{1/2}}_{Technical\ Change} \quad (9)$$

By introducing variable returns in technology into the calculation of the efficiency change (EFFCH), we obtain this new breakdonwn:

$$EFFCH = \frac{D_I^t(x^t, y^t)/C}{D_I^{t+1}(x^{t+1}, y^{t+1})/C} = \underbrace{\left[\frac{D_I^t(x^t, y^t)/V}{D_I^{t+1}(x^{t+1}, y^{t+1})/V}\right]}_{Pure\ Efficiency\ C^o} \bullet \underbrace{\left[\frac{S_I^t(x^t, y^t)}{S_I^t(x^t+1, y^{t+1})}\right]}_{Scale\ Efficiency\ C^o} \quad (10)$$

Following the formulation of Färe, Grosskopf and Lovell (1994) and Färe, Grosskopf and Norris (1997), the scale efficiency change (S) in the period *t* is determined by[8]:

$$S_I^t(x^t, y^t) = \left[D_I^t(x^t, y^t)/C\right] / \left[D_I^t(x^t, y^t)/V\right] \quad (11)$$

INSERT FIGURE 2

Färe, Grosskopf and Norris (1997) and Färe, Grosskopf and Russell (1998) justify the use of constant returns to scale in the calculating of distance functions involved in technical change, because it is a long-term problem. However, they use variable returns to scale for calculating the efficiency change because they consider that the scale inefficiencies are mainly short-term fine-tuning problems .

However, once these scale inefficiencies are detected we can identify the type of returns that generate them by comparing the index that is calculated by assuming variable returns with another index calculated by assuming nonincreasing returns to scale. The latter index can be formulated by changing the additional constraint on the intensity vector for another one that imposes nonincreasing returns to scale, i.e. that the sum of their elements is less than one.

The nature of a firm's inefficiencies of scale (for example, due to increasing or decreasing returns) can be determined by comparing the degree of technical efficiency of nonincreasing returns with the degree of technical efficiency with variable returns to scale: if they are different this firm has increasing returns to scale; if they are equal, it has decreasing returns, i.e. the firm would run into inefficiencies of scale due to the existence of these returns (Banker, Charnes and Cooper,1984).

3. An application to the Spanish port system: data, empirical estimation and results

3.1.- Port activity data

We collected our data from the annual statistic carried out by *Puertos del Estado* and by each Port Authority for the time period: 1988-1997. To estimate a port's Malmquist index we must define its output and input in relation to the port activity[9] (see *Table I).*

INSERT TABLE 1

a) The firms to be analysed are the 26 Port Authorities that make up the Spanish Port System.
b) Factors of production[10] are *labour*, *intermediate input*[11] and *capital*, all in real terms: *labour* for the port is based on personal working costs; *intermediate input* on cost of materials and services and the *capital* includes equipment like quays and cranes.
c) As a measure of the port activity, output is the total movement of traffic through the port.

INSERT TABLE 2

Table 3 shows the development of port activity from the volume of traffic that passes through each port. We can see that the total goods passing through the Spanish Port System has had an average annual increase of 2.17% between 1988 and 1992. Moreover, in the later period (1992-1997) this rate has risen to 3.78%. In the second time period, the Baleares Port Authority had the greatest growth[12] (35.62%), followed by Valencia (15.07%) and Marín-Pontevedra (14.65%). On the other hand Ceuta had the lowest growth, and the data for some of the other ports were negative e.g. Almería-Motril (-7.50%).

INSERT TABLE 3

Bahía de Algeciras, Tarragona, Barcelona, Bilbao and Valencia contributed more than 47% of the total volume of goods for 1997. During this time period (1988 to 1997) the contribution of all these ports increased, except for Bilbao, whose contribution decreased.

3.2. Empirical estimation and results

We first estimated the year to year[13] efficiency levels of Spanish ports for the period: 1988-1997. Using expression (7), we obtained an efficiency index for our sample, and assuming a technology with constant returns to scale. We then assumed variable returns, and we re-calculated expression (7), with the added constraint of the intensity vector mentioned in section 2.3.

Secondly, and following Färe, Grosskopf, Lindgren and Roos's method (1994) we calculated the Malmquist indexes of productivity for the Spanish port system, from expression (9). The property of reciprocity between the distance functions and the efficiency technical index, presented by the expressions (7) and (8), help us to obtain the distance functions needed to calculate the Malmquist index. The efficiency levels are initially calculated, and then used to determine the Malmquist indexes of productivity, taking into account technology with constant returns to scale.

This method obtains the trajectory of the productivity of each port and breaks it down into two factors: the variation in technical efficiency level and technical change.

Finally, under the assumption of variable returns to scale, the technical efficiency variation has been broken down into pure technical efficiency change and a residual component (expression (10)). This expression represents the changes in scale efficiency, i.e., the variations in the differences between constant returns and variable returns to scale in the technology.

We can see the technical efficiency results from a static point of view, assuming a technology with constant returns to scale and another with variable returns. Table 4 presents two types of results: those equal to one and those less than one. If the results are equal to one the Port Authority is situated on the boundary of the Spanish port system frontier associated to that year. Results less than one indicate that the Port Authority is situated below the frontier, which reflects technical inefficiency.

INSERT TABLE 4

The mean for 1988-1997 shows that the Bahía de Algeciras Port Authority is technically efficient for each period. Moreover, it is the only one to maintain its position on the frontier under constant return to scale in the technology during this period. It shares this position with a different port authority every year.

When we include the variable returns to scale in the calculation, we can break down the technical efficiency into two elements: pure efficiency and scale production efficiency. During the period of our study, the Bahía de Algeciras Authority determined "the *most productive scale size"* and is therefore the only port that does not present scale inefficiencies in any year.

The other port authorities show some type of returns: either increasing ones or decreasing ones. Moreover, some of them show a change in return from 1988 to 1997. However, in the last year, 1997, most of ports had increasing returns to scale, which implies that they have productive size inefficiencies. Bahía de Algeciras, Ceuta and Ferrol-San Ciprián are the exceptions. There are no scale inefficiencies for these port authorities.

We have made a dynamic analysis of productivity by calculating the Malmquist indexes for each port, using changes in efficiency levels and technical progress. We have analysed the evolution of productivity from 1988 to 1997 to ascertain whether the greater autonomy in port management (begun with the change of legislation of 1992) has improved productivity in either of its components.

INSERT TABLE 5

Malmquist indexes greater than one indicate an improvement in productivity. Indexes less than one indicate a deterioration. This is also true for the Malmquist indexes of the components. Moreover, these indicators show the relative performance related to the best practice represented by the "port system frontier".

Table 5 shows that, between 1988 and 1997, for the mean on this period, the productivity of 13 Port Authorities increased, the productivity of 9 Port Authorities decreased, and in the other 4 Port Authorities it did not change. We can see that the mean of the productivity increased by 1.3% (we can obtain this number by subtracting one to the mean value).

We can analyse the reasons for this by breaking down the Malmquist index into two parts: technical efficiency change and technological change. In mean terms, for the whole sample the improvements in productivity are due more to technological progress (3.5%) than to technical efficiency change (-2.1%).

The results of technical efficiency change indicate five Port Authorities improved their technical efficiency, i.e., they were closer to the efficient frontier of each period. According to the efficiency level of the more efficient ports (the frontier), an increse in a port's efficiency level indicates that (from 1988 to 1997) it was closer the frontier, which means that its efficiency level is closer to the efficiency level of the more efficient ports.

INSERT FIGURE 1

The technical change represents the changes in the technological frontier between 1988 and 1997. Almost every port (21) had technical progress, i.e., the frontier situation in 1988 was better than in 1997.

The greatest mean evolution of the Malmquist index and its two components was in 1995 (1.168) and the lowest was in 1989 (0.946). Moreover, in the period in which the Port Authorities had the greatest amount of management autonomy, 1993-1997, the values are higher, while before 1993 productivity did not increase and, in some cases, it even decreased.

Table 6 shows the changes from 1989 to 1988 and from 1995 to 1994. Technical efficiency is broken down into pure efficiency variation, and another component that reflects changes in production scale. In 1989, on average, the negative change in technical efficiency was due to the decrease in pure efficiency, since scale efficiency improved. However, the positive change in the technical efficiency in 1995 was due in equal measure to pure efficiency and scale efficiency.

INSERT TABLE 6

4. Conclusions

We have studied the productivity of the Spanish port system using a Malmquist Index. Our results show that every port significantly increased its productivity between 1988 and 1997 as a result of both technical progress and greater efficiency. Moreover, the technical change have more effect in mean and aggregate terms . A number of factors are behind this increased productivity in port activity. These include the greater autonomy given to the port authorities via new legislation in 1992 and innovations in port infrastructure brought about by technological changes in the maritime transport of goods.

This research is still in progress, however, and improvements will be introduced as we begin to find a methodological framework for studying the efficiency of the ports and their relationship with industrial location. Our conclusions are therefore only preliminary.

We are currently widening our investigation by incorporating factors such as multiple product (we can differentiate between dry-bulk cargo, liquid-bulk cargo, general cargo and containers), analysis of determinant factors behind efficiency levels and improved productivity, principal-agent relations and market structures, and the relationship between port activity and industrial location.

The importance of studying the port sector is demonstrated by the European Union Green Paper on seaports (European Commission, 1997). We must also remember that ports are not only in competition with each other but with other modes of transport. Port policy decisions have therefore become a key factor in determining how best to develop a port's activity, while the criteria for designing and implementing policies for the provision of infrastructure in the Spanish port system must make improvements in efficiency a clear objective if Spanish ports are to become more competitive in the Pan-European transport network.

Notes

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1 Nombela, G. and Trujillo, L. (1999) made a more detailed description of the Spanish port sector.

2 They also consider inefficiency from the output point of view. In this case they interpret the differences in productivity as the ability to increase output without an additional consumption of inputs.

3 Malmquist introduced this concept in relation with consumer utility level .

4 Under constant returns to scale, $D_I(x,y) = (D_O(x,y))^{-1}$, (see Färe, Grosskopf and Lovell, 1994)

5 We can obtain the distance in *t+1* from the technology in this same period of time by substituting *t* for *t+1 in (7).*

6 To calculate the distance in *t+1* from the technology in *t*, we substitute *t* for *t+1* and *t+1* for *t* in (8).

7 Ray, S.C. y Desli, E. (1997) propose another formulation. They calculate the Malmquist productivity index under variable returns to scale in technology, and apply these returns to the distance functions used to measure both technical progress and efficiency change.

8 To calculate the scale efficiency change in *t+1*, we must replace *t* for *t+1* in (11).

9 Roll, Y. and Hayuth, Y. (1993), suggest applying non-parametrical techniques of data envelopment to study port efficiency. With this mathematical approach they obtain relative efficiency levels for hypothetical ports. First, they define the *outputs* and the *inputs*. The former include cargo, service level, user satisfaction and ship called; the latter comprises labour, capital and uniformity of cargo.

10 Frankel, E. (1987), defines a several return port indicators and differentiates two types: on one hand are financial indicators (more in relation with the operating account), and on the other hand are operational indicators (in reference with quay usage). Moreover, Jansson and Shneerson (1982) believe that the principal factors of production in an analysis of the port production function should be, among others, quays, port cranes, stevedoring labour, administrative staff and transit storage space.

11 The change in port legislation in 1992 affected port accountancy. However, we have selected the expenses getting homogeneity in our period of time.

12 Concrete water traffic

13 Martínez, E. (1999) made a static study of the efficiency of the Spanish port system for: 1993-1997, with port activity characterised by two *outputs*: the total cargo and the rent of port facilities. He establishes a port classification using a complex criterion given by port size and the composition for the output vector. The efficiency of the ports in each group is then ranked for each year, and the periods are compared.

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Figure 1. Technical change and efficiency change

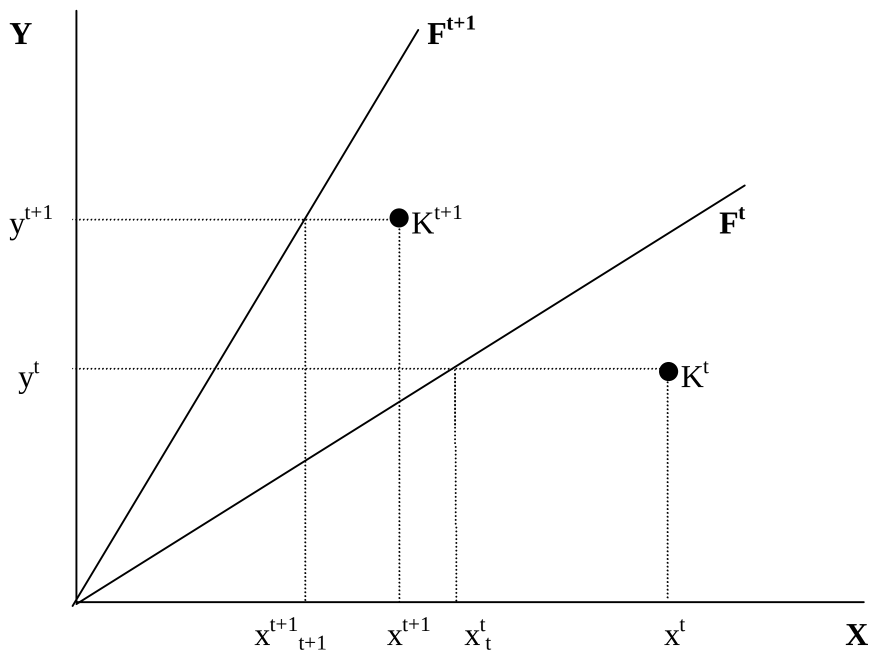
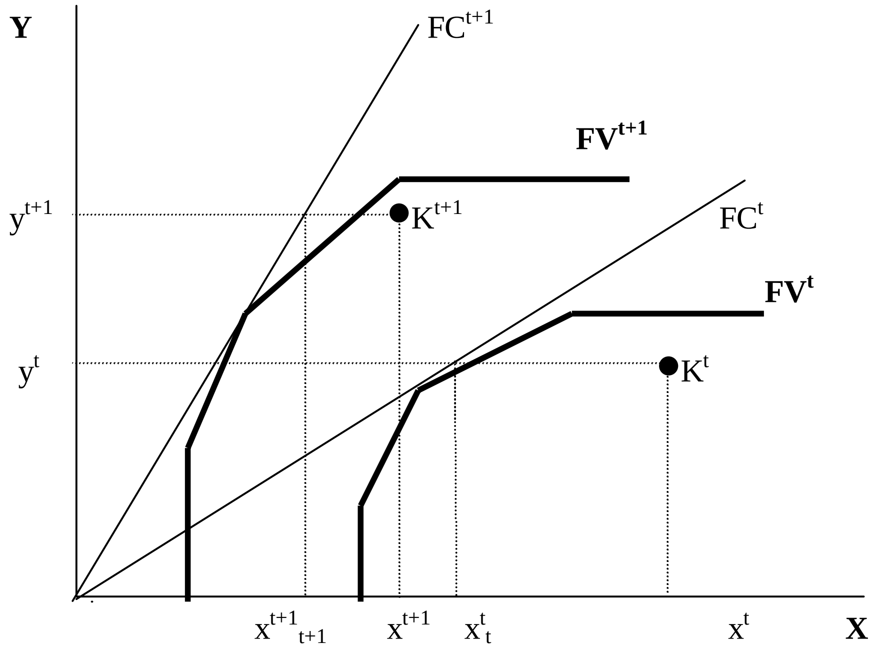


Figure 2. Efficiency change: pure technical efficiency and scale efficiency



Frontier with variable returns to scale (FV)

Frontier with constant returns to scale (FC), or "*the most productive scale size*" from Banker, Charnes and Cooper (1984).

Table 1. Sample description

Variable	Description	Units
y_1	Goods	Traffic tonnes
x_1	Labour	Working Cost
x_2	Intermediate Cost	Purchases and services
x_3	Capital	Lineal meters of quays
x_4	Capital	Number of cranes

Table 2. Statistical summary of variables

1988	Quays	Cranes	Working C.	Intermediate C.	Traffic
Maximum	13,442	257	2,779	1,410	29,181
Minimum	843	9	122	45	396
Mean	4,136	54	824	385	8,964
Standard deviation	3,122	61	642	347	7,632
1992	**Quays**	**Cranes**	**Working C.**	**Intermediate C.**	**Traffic**
Maximum	13,147	219	2,524	3,333	30,560
Minimum	931	7	177	68	584
Mean	4,620	50	860	624	9,740
Standard deviation	3,210	51	568	714	8,470
1997	**Quays**	**Cranes**	**Working C.**	**Intermediate C.**	**Traffic**
Maximum	11,275	264	2,377	2,421	40,047
Minimum	847	1	211	75	643
Mean	4,534	43	772	522	11,213
Standard deviation	2,844	51	468	490	9,942

Table 3. Total port traffic (thousands of tonnes)

	Traffic share			Average annual growth (%)	
Port Authorities	**1988**	**1992**	**1997**	**88-92**	**92-97**
Alicante	1.03	1.07	0.75	3.44	-4.85
Almería-Motril	3.87	3.39	2.06	-1.23	-7.50
Bahía de Algeciras	10.18	11.86	13.74	6.64	8.33
Bahía de Cádiz	1.39	1.22	1.20	-1.25	3.29
Baleares	2.75	2.27	4.78	-2.62	35.62
Barcelona	7.85	7.44	8.74	0.72	8.84
Bilbao	12.52	12.07	7.92	1.18	-6.12
Cartagena	4.42	4.78	3.38	4.38	-4.68
Castellón	3.02	2.88	2.88	0.96	3.71
Ceuta	1.43	1.75	1.55	8.39	0.39
Ferrol-San Ciprián	1.50	1.92	2.51	9.70	12.73
Gijón-Avilés	6.00	6.46	5.90	4.23	1.30
Huelva	4.66	4.21	5.04	-0.44	9.41
La Coruña	5.40	5.24	3.92	1.35	-3.46
Las Palmas	4.14	3.84	4.28	0.22	7.04
Málaga	3.53	3.66	3.04	3.15	-1.09
Marín-Pontevedra	0.32	0.35	0.48	4.59	14.65
Melilla	0.17	0.25	0.26	15.59	3.93
Pasajes	1.63	1.63	1.32	2.30	-1.81
Sta. C. de Tenerife	5.48	4.99	5.13	-0.26	4.60
Santander	1.66	1.51	1.57	-0.29	5.06
Sevilla	1.16	1.31	1.38	5.79	5.29
Tarragona	9.77	9.83	10.68	2.34	6.25
Valencia	4.65	4.50	6.26	1.27	15.07
Vigo	1.27	1.35	1.04	3.76	-2.80
Villagarcía	0.21	0.23	0.22	5.42	2.53
TOTAL	100.00	100.00	100.00	2.17	3.78

Table 4. Average index on the relative efficiency (1988-1997)

Port Authorities	Constant returns		Variable returns		Scale efficiency		Type of return	
	Mean	**St. Deviat.**	**Mean**	**St. Deviat.**	**Mean**	**St. Deviat.**	**1988**	**1997**
Alicante	0.19	0.03	0.55	0.10	0.34	0.06	increa	increa
Almería-Motril	0.73	0.25	0.85	0.16	0.84	0.16	increa	increa
Bahía de Algeciras	1.00	0.00	1.00	0.00	1.00	0.00	*	*
Bahía de Cádiz	0.22	0.05	0.45	0.04	0.49	0.07	increa	increa
Baleares	0.44	0.16	0.59	0.18	0.73	0.06	increa	increa
Barcelona	0.34	0.03	0.36	0.03	0.94	0.03	decrea	increa
Bilbao	0.44	0.06	0.76	0.31	0.67	0.25	decrea	increa
Cartagena	0.71	0.13	0.77	0.09	0.92	0.08	increa	increa
Castellón	0.95	0.08	1.00	0.00	0.95	0.08	*	increa
Ceuta	0.71	0.21	1.00	0.00	0.71	0.21	increa	*
Ferrol-San Ciprián	0.93	0.09	1.00	0.00	0.93	0.09	increa	*
Gijón-Avilés	0.47	0.04	0.50	0.04	0.94	0.05	decrea	increa
Huelva	0.49	0.07	0.54	0.07	0.90	0.07	increa	increa
La Coruña	0.74	0.19	0.83	0.11	0.88	0.12	decrea	increa
Las Palmas	0.29	0.07	0.35	0.06	0.81	0.07	increa	increa
Málaga	0.73	0.10	0.90	0.05	0.82	0.10	increa	increa
Marín-Pontevedra	0.17	0.03	1.00	0.00	0.17	0.03	increa	increa
Melilla	0.11	0.04	1.00	0.00	0.11	0.04	increa	increa
Pasajes	0.27	0.06	0.48	0.07	0.56	0.12	increa	increa
Sta. C. de Tenerife	0.61	0.08	0.69	0.07	0.88	0.06	increa	increa
Santander	0.21	0.04	0.38	0.06	0.56	0.10	increa	increa
Sevilla	0.16	0.03	0.35	0.09	0.46	0.05	increa	increa
Tarragona	0.75	0.12	0.78	0.14	0.96	0.04	decrea	increa
Valencia	0.33	0.05	0.36	0.04	0.90	0.06	decrea	increa
Vigo	0.27	0.05	0.54	0.04	0.50	0.08	increa	increa
Villagarcía	0.11	0.02	1.00	0.00	0.11	0.02	increa	increa
Mean	0.48		0.69		0.70			
Standard Deviation	0.28		0.24		0.29			

*There are no observe scale inefficiencies

Table 5. Malmquist productivity index, average annual changes 1988-1997

Port Authorities	IM_I	Cº TEC	Cº EF	CºETP	Cº EE
Alicante	1.006	1.046	0.961	1.023	0.939
Almería-Motril	0.896	0.997	0.899	0.957	0.940
Bahía de Algeciras	1.009	1.009	1.000	1.000	1.000
Bahía de Cádiz	0.973	1.053	0.924	0.971	0.952
Baleares	1.045	1.053	0.993	0.989	1.003
Barcelona	1.045	1.048	0.998	0.991	1.007
Bilbao	1.004	1.040	0.966	0.900	1.073
Cartagena	0.969	0.998	0.971	0.989	0.982
Castellón	0.980	1.007	0.973	1.000	0.973
Ceuta	1.202	1.100	1.092	1.000	1.092
Ferrol-San Ciprián	1.015	0.994	1.021	1.000	1.021
Gijón-Avilés	1.039	1.057	0.982	0.992	0.990
Huelva	1.032	1.045	0.987	1.004	0.983
La Coruña	0.950	1.019	0.932	0.967	0.964
Las Palmas	0.978	1.035	0.945	0.965	0.979
Málaga	1.010	1.052	0.960	0.993	0.967
Marín-Pontevedra	1.052	1.026	1.025	1.000	1.025
Melilla	1.060	1.043	1.016	1.000	1.016
Pasajes	1.033	1.049	0.984	1.024	0.962
Sta. C. de Tenerife	1.002	1.044	0.959	0.976	0.983
Santander	0.974	1.044	0.933	0.992	0.941
Sevilla	1.076	1.014	1.062	1.072	0.990
Tarragona	1.015	1.016	1.000	0.998	1.001
Valencia	1.040	1.055	0.985	0.999	0.986
Vigo	0.991	1.044	0.949	0.982	0.967
Villagarcía	0.985	1.017	0.969	1.000	0.969
Mean	1.013	1.035	0.979	0.991	0.988

Table 6. Technical efficiency change and its decomposition
Average annual changes

	1988-1989			*1994-1995*		
Port Authorities	**CºEF**	**CºETP**	**CºEE**	**CºEF**	**CºETP**	**CºEE**
Alicante	0.789	0.885	0.892	1.083	1.211	0.894
Almería-Motril	0.882	1.000	0.882	0.940	1.002	0.939
Bahía de Algeciras	1.000	1.000	1.000	1.000	1.000	1.000
Bahía de Cádiz	0.695	0.815	0.853	1.111	1.059	1.049
Baleares	0.737	0.749	0.984	0.825	0.742	1.112
Barcelona	1.140	1.023	1.115	1.050	1.059	0.991
Bilbao	1.056	1.000	1.056	1.085	1.111	0.977
Cartagena	0.907	0.919	0.987	1.442	1.279	1.128
Castellón	1.000	1.000	1.000	0.933	1.000	0.933
Ceuta	1.335	1.000	1.335	1.401	1.000	1.401
Ferrol-San Ciprián	1.202	1.000	1.202	1.000	1.000	1.000
Gijón-Avilés	1.102	1.080	1.020	1.022	1.046	0.978
Huelva	0.942	0.928	1.016	1.196	1.203	0.993
La Coruña	1.115	1.106	1.008	1.010	0.979	1.031
Las Palmas	0.713	0.776	0.919	1.029	0.942	1.093
Málaga	1.032	1.038	0.994	0.976	1.048	0.931
Marín-Pontevedra	0.935	1.000	0.935	1.219	1.000	1.219
Melilla	1.046	1.000	1.046	0.766	1.000	0.766
Pasajes	1.131	1.033	1.094	1.054	1.075	0.980
Sta. C. de Tenerife	0.825	0.834	0.989	0.879	0.854	1.029
Santander	0.764	0.742	1.030	0.719	0.717	1.004
Sevilla	0.965	1.011	0.955	1.454	1.377	1.056
Tarragona	1.091	1.218	0.896	0.900	0.895	1.005
Valencia	1.076	1.086	0.991	1.175	1.175	1.001
Vigo	1.132	1.014	1.116	0.942	1.005	0.938
Villagarcía	1.046	1.000	1.046	1.101	1.000	1.101
Mean	0.974	0.965	1.009	1.035	1.020	1.015

Grafic 1.Malmquist index and its decomposition

(1988-1997)