Productivity in Cargo Handling in Spanish Ports During a Period of Regulatory Reforms

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Abstract The objective of this research is to measure productivity changes in cargo handling operations in Spanish ports. By means of Data Envelopment Analysis and the calculation of the Malmquist indices we have decomposed those changes into efficiency and technical change effects. The study covers a period from 1994 to 1998, when the significant regulatory and technical changes introduced during the eighties had matured. The results show an improvement in productivity imputable totally to technical change, since the technical efficiency has not been corrected in that period.

Keywords Cargo handling · Spanish ports · DEA · Productivity · Efficiency · Technical change

1 Introduction

Port activities involve a number of agents that deal with different types of services. Among them, cargo handling is probably the most relevant. It encompasses all the necessary procedures since cargo arrives into the port until it is accomodated in the vessel and viceversa. This type of activity involves mainly two production factors, namely dockworkers and cranes. Different packing systems require different types, amounts and combinations of these factors, which makes it necessary to view this as a multioutput process dealing with general cargo, containers, pallets and bulk as distinct products that flow through the port.

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In the last two decades, most developped countries have witnessed a profound reform of the legislation governing the port cargo handling sector. In Spain, this legislative change started in 1986 with Royal Decree-Law 2/1986 of the 23rd of May, concerning stevedore services. The process continued in 1987 with the enactment of the regulations governing that law. These changes were later developed within the Framework Agreements signed by the Government, stevedore firms and the trade unions in 1993 and 1997. Throughout Europe, these agreements were aimed at deregulating a sector that was monopolised by—dockworkers—such that all cargo handling operations in ports were reserved exclusively for them. Supported by a highly permissive legislation, the number of dockworkers increased out of all proportion, their wage demands were met regardless of the real productivity at work, and highly restrictive labor practices and abuses became the rule within the sector (featherbedding in work teams, restricted working hours, and so on). This situation led to high rates of inactivity and excessive increases in the cost of port services that triggered an alarming fall in the competitiveness of ports.

The new legislation established that at every port a State Owned Stevedore Company (Sociedad Estatal de Estiba y Desestiba, SEED) would exist as a State company owning more than 50% of the assets, which would guarantee full decision power in an activity deemed essential for the economy. The stevedore companies would own the rest of the assets. Dockworkers in charge of cargo handling have to be officially registered with the SEED in order to be assigned a job. SEED assigns these workers on a daily basis according to the requests by the stevedore firms, following a rotation system. Only when SEED registered workers are not available the stevedore firms can hire non dockworkers on a temporary basis under very exceptional conditions.

The reform was designed to induce greater flexibility when deciding the size, composition and schedules of the work teams for a particular port service. This was no longer regulated and each stevedore firm was relatively free to decide on these aspects, within safety standards. Loading and unloading schedules opened to include holidays and nights, increasing flexibility.

Hence, although the declared intention of the reforms was to make ports more competitive by reducing the total costs of the port operation, the final objective was more important from an economic point of view. Due to its position in the transport chain and the importance of sea traffic—over 70% of Spanish international trade is transported by sea—inefficiencies in ports had major macro and micro-economic effects. As port services are inputs to firms, their costs—including inefficiency—are transmitted towards the production sector causing inflation and diminishing competitiveness. These are relevant effects as ports are important sources of income and employment growth. According to Coto-Millán and Martínez-Budría (1995), Spanish ports contribute some 3% of both the GNP and labor force.

The result of the reform can be summed up in the following points: bringing dockworkers into SEED, reducing dockworkers by 70% during this period, de-regulation of the composition of work teams and, finally, a timid opening up of the activity to temporary workers who can only work in cargo handling when there are not enough stevedores to cover demand, and the wages and working conditions have to be exactly the same as for dockworkers belonging to the SEEDs, which has mantained the stevedores monopoly in practice.

Simultaneously with the reforms, and probably accelerating them, container traffic has incresed in ports, which has caused a relevant technological change that has affected both the transport modes and the ports (Talley 2000). Carriers have restructured and ships have became container ships increasingly larger, such that ports have made large investments in cranes, container moving equipment and in terminals, aiming at making these enormous investments profitable.

In spite of its economic importance, port activities—and cargo handling in particular—have received little attention in the economic literature even within the transport area. Although there are some studies focused on partial port performance, there have been few studies on port productivity. In particular, to the best of our knowledge, there are no studies on the decomposition of productivity in cargo handling. For a good review of this research area, see Cullinane et al. (2006).

The objective of this work is to evaluate the period after the introduction of the new technologies related, basically, to the container, and the legislative reforms. Both, new technologies and legislative reforms, move the productive frontier outward, i.e., produce technical change. For that, we have constructed an index to measure changes in cargo handling productivity in the Spanish port system, known as Total Factor Productivity (TFP). Our intention is to break it down into two components: one that measures technical change and the other that quantifies the changes in efficiency levels attained by each productive unit. This way, we can construct indices to identify the differences between efficiency and productivity changes. To this end, we have applied the Data Envelopment Analysis (DEA) technique to a panel of data made up of 21 ports observed from 1994 to 1998.

In the following section we present the theoretical framework. Data and results are included in Section 3. Finally, Section 4 contains the main conclusions.

2 Data envelopment analysis and Malmquist index

The study of TFP in Economic Theory is based on the idea of a production function as a representation of the current technology in a given period of time, which indicates the maximum output that can be feasibly obtained from a given set of factors and technological status. This concept is usually interpreted as a frontier that limits a firm's productive potential. In this sense, we can associate a technical change with a shift in this frontier, while an improvement in efficiency can be understood as a reduction in the distance from this frontier by a firm’s combination of factors and products. Technical progress is usually associated with a set of innovations and changes in production or management techniques, while technical efficiency is a company’s capacity to manage its resources and to adapt to the environmental conditions in which the firm operates. Hence, improvements in productivity can be broken down into changes in efficiency and technical progress.

To this end, we use the Malmquist Index (Caves et al. 1982a, b), which are constructed as ratios of distance functions and make it possible to decompose TFP variations in technical efficiency and technical changes. Efficiency analysis can be done following two different approaches, depending on whether an improvement in productivity is understood as an increase in the product obtained with a given set of factors (output oriented approach) or, alternatively, if this is interpreted as a reduction in the consumption of factors without reducing the product obtained (input oriented approach). In our study, we calculate the Malmquist Index using the input approach, as stevedore firms have no capacity to induce new traffics; they just move cargo that arrives to the port.

To construct Malmquist Index, we need to obtain technological frontiers and calculate distances to measure how far firm inputs are from it. To do this, we use the non-parametric mathematical programming approach to frontier estimation developed by Charnes et al. (1978) known as Data Envelopement Analysis (DEA). This methodology allows us to calculate a relative efficiency measurement of a Decision Making Unit (DMU), even in contexts in which multiple outputs are obtained using several inputs. DEA does not assume any particular specification for the functional form of the technological frontier, enabling us to avoid possible specification errors that impact on the efficiency measurements obtained. Charnes et al. (1978) proposed a model assuming Contant Return to Scale (CRS) that it is appropiate when all DMU's are operating at an optimal scale. The use of the CRS specification when this is not the case will result in measures of technical efficiency which are overlap with scale efficiencies. Banker et al. (1984) suggested an extension to account for Variable Return to Scale (VRS) situations. This extension permits the calculation of technical efficiency measurements devoid of these scale effects. The technical efficiency measurement obtained from a CRS DEA model is decomposed into two components: one due to scale inefficiency and one due to pure technical inefficiency. If there is a difference in the technical efficiency measurement from VRS and CRS models, then this indicates that the DMU has scale inefficiency, and that the scale inefficiency can be calculated from the difference between the VRS score and the CRS score. This measure of scale efficiency does not indicate whether the DMU is operating under increasing (IRS) or decreasing (DRS) returns to scale. This may be determined by running an additional DEA problem with non-increasing returns to scale (NIRS) imposed. If the NIRS technical efficiency measurement is equal to VRS score then decreasing returns to scale exist. If they are different then increasing returns to scale exist for that DMU.

Equations 1 to 6 represent the different linear programming problems that have to be solved in order to obtain the input oriented models. Assume there are n inputs and m outputs for each of N firms. The $n \times N$ inputs matrix, $\mathbf{X}$, and the $m \times N$ output matrix, $\mathbf{Y}$, represent the data for all N firms. The inputs and outputs of the firm i are the column vectors $\boldsymbol{x_i}$ and $\boldsymbol{y_i}$.

$$min_{\theta,\lambda}\theta \tag{1}$$

$$st \quad -\mathbf{y_i} + Y\lambda \geq 0 \tag{2}$$

$$\theta \mathbf{x_i} - X\lambda \geq 0 \tag{3}$$

$$\lambda \geq 0 \tag{4}$$

$$\mathbf{N1}'\lambda = 1 \tag{5}$$

$$\mathbf{N1}'\lambda \leq 1 \tag{6}$$

N1 is vector of ones, and $\boldsymbol{\lambda}$ is a $N\times 1$ vector of constants. The value of the scalar θ ($\theta \leq 1$) is the efficiency score for the *i*-th firm, the value of 1 indicating a technically efficient firm, according to the Farrell (1957) measure. The problem must be solved N times. The input oriented CRS and VRS approaches depend on the constraints considered. The combination of Eqs. 1– 4 form the CRS model, the Eqs. 1–5 form the VRS model, while Eqs. 1–4 and 6 impose the NIRS.

3 Empirical analysis

3.1 Data collection

The production function of the cargo handling operation is made up basically of 3 outputs: containerised general cargo (CGC), non containerised general cargo (NCGC) and solid bulk that uses no specialized facility (SB), and 2 inputs: labor hours and crane hours. For a description of port production from a microeconomic viewpoint, see Cullinane and Talley (2006) and Jara-Díaz et al. (2006).

The data base was constructed collecting information on inputs and outputs from different sources. A questionnaire was sent to all Spanish SEEDs in which information was requested about labor hours assigned to cargo handling by all dockworkers between 1994 and 1998. Crane hours, in turn, have been obtained from two sources: the Annual Reports of the ports—for State cranes—and another survey for the hours of work of the privately owned cranes. The information on the outputs has been taken from the Annual Reports of the ports for 1994–1998.

Our goal is to study cargo handling in every port, not each firm doing cargo handling. The ports for which complete information was obtained are: Algeciras, Alicante, Almeria, Bilbao, Cadiz, Cartagena, Castellon, Gijon, Huelva, La Coruña, Malaga, Palma de Mallorca, Alcudia, Motril, Pontevedra, S/C de Tenerife, La Palma, Santander, Sevilla, Valencia and Vigo. The final panel data contains 105 observations.

3.2 Results

Using the VRS model presented in the preceding section we have calculated Farrell's efficiency indexes (Farrell 1957) for each year and port as shown in Table 1. The average value is 0.903 suggesting that inputs usage could have been reduced by nearly 10%.

In order to identify those chatacteristics that are shared by the most efficient ports, we have examined different hypothesis using the Rank-Sum Test developed by Wilcoxon, Mann and Whitney (see Chapter 7 in Cooper et al. 2000). This method is one of the nonparametric tests based on the ranking of data and it is used to verify

Table 1 Farrell's technical efficiency indices for Spanish ports

Port	1994	1995	1996	1997	1998	Mean
Algeciras	1.000	1.000	1.000	1.000	1.000	1.000
Alicante	0.760	1.000	1.000	1.000	0.865	0.912
Almería	1.000	1.000	1.000	1.000	1.000	1.000
Bilbao	1.000	1.000	1.000	1.000	1.000	1.000
Cádiz	0.869	1.000	0.821	1.000	0.925	0.904
Cartagena	0.901	0.938	0.926	0.983	1.000	0.993
Castellón	0.839	0.845	0.786	0.743	0.725	0.756
Gijón	0.797	0.910	0.811	0.822	0.750	0.814
Huelva	0.935	0.946	0.961	1.000	1.000	0.987
La Coruña	1.000	0.986	0.946	0.967	1.000	0.980
Málaga	0.769	0.730	0.723	0.716	0.683	0.717
P. Mallorca	0.757	0.713	0.783	0.850	0.848	0.799
Alcudia	1.000	1.000	1.000	1.000	1.000	1.000
Motril	0.958	0.901	0.836	0.831	0.776	0.860
Pontevedra	0.948	0.968	1.000	0.889	0.945	0.951
S/C Tenerife	0.851	0.874	0.774	0.791	0.757	0.743
La Palma	0.952	0.925	0.889	0.932	0.903	0.935
Santander	0.867	0.810	0.790	0.737	0.711	0.751
Sevilla	1.000	1.000	1.000	0.978	0.944	0.984
Valencia	0.904	0.959	0.899	0.876	0.915	0.811
Vigo	0.943	0.973	0.935	0.889	0.928	0.950
Mean	0.907	0.932	0.886	0.896	0.895	0.903

whether the differences between two groups are significant. We have analyzed six hypothesis:

1. Ports with total traffic volume above the average exhibit the same efficiency indices as those with total traffic below that average.
2. Ports where CGC represents the higuest percentage of the traffic exhibit the same efficiency indices as the rest.
3. Same as 2 with NCGC.
4. Same as 2 with SB.
5. Ports with specialized container terminals exhibit the same efficiency indices as those without.
6. Ports with a majority of privately owned cranes exhibit the same efficiency indices as the rest.

The null hypothesis at a 5% significance level was accepted in all cases but one. This means that neither cargo type nor crane property nor the presence of container specialized terminals explain efficiency differences. Hypothesis 1 was rejected with a 5% significance level, meaning that traffic volume does play a role in efficiency as measured by Farrell's index. Ports with a relatively large traffic volume exhibit an average efficiency index of 0.96 much larger than the average 0.89 of the rest.

In Table 2 we show average Malmquist's indexes by port, which yields an average TFP annual growth of 2%. The analysis by port reveals significant differences. Most exhibit increases in productivity, from 9.7% in Alicante to 2.3% in Valencia and Algeciras. Others exhibit losses up to around 4% in Motril, S/C de Tenerife and Vigo.

Regarding the components behind the changes in TFP, technical change (which is present in most ports) is the main source of productivity. There is a group of ports

Table 2 Mean of Malmquist's indexes by port

Port	Technical efficiency change	Tecnical change	Pure technical efficiency change	Scale efficiency change	TFP change
Algeciras	1.000	1.023	1.000	1.000	1.023
Alicante	1.045	1.050	1.013	1.032	1.097
Almería	1.000	1.042	1.000	1.000	1.042
Bilbao	1.000	1.002	1.000	1.000	1.002
Cádiz	1.030	1.026	0.988	1.043	1.057
Cartagena	1.027	1.047	1.001	1.026	1.075
Castellón	0.962	1.043	0.928	1.037	1.003
Gijón	0.987	1.007	0.991	0.996	0.994
Huelva	1.018	1.057	0.995	1.023	1.076
La Coruña	1.003	1.022	1.002	1.001	1.025
Málaga	0.969	1.027	0.936	1.035	0.995
P. Mallorca	1.031	1.022	0.981	1.051	1.054
Alcudia	1.000	1.083	1.000	1.000	1.083
Motril	0.946	1.013	0.945	1.001	0.958
Pontevedra	1.003	1.000	1.001	1.002	1.003
S/C Tenerife	0.970	0.989	0.943	1.029	0.959
La Palma	0.985	0.993	0.982	1.003	0.978
Santander	0.953	1.029	0.915	1.042	0.981
Sevilla	0.986	1.061	0.985	1.001	1.046
Valencia	1.004	1.019	0.961	1.045	1.023
Vigo	0.978	0.975	0.978	1.000	0.954
Mean	0.995	1.025	0.978	1.017	1.020

that exhibit a positive change in technical efficiency, which contributes even more to productivity increases: Alicante, Cádiz, Cartagena, Huelva and Mallorca. There are others, however, where the reduction in technical efficiency actually counterbalances the effect of technical change on productivity (Castellón, Gijón, Málaga, Motril y Tenerife, Santander, Sevilla y Vigo).

As technical change is the main force behind productivity growth, it is relevant to analyze potential common factors within those ports that seem to have taken advantage of those changes. Once again the Rank-Sum Test developed by Wilcoxon, Mann and Whitney will prove useful to verify exactly the same six hypothesis previously examined but now regardin technical change. The null hypothesis was accepted at a 5% significance level in cases 2, 3 and 4, which means that cargo type does not explain the differences in technical change. On the other hand, the nulll hypothesis was rejected at a 5% significance in cases 1, 5 and 6. This means that traffic volume, private crane property and the presence of container specialized terminals explain the difference in technical change rates, which are in average 9% larger than that of the rest. We believe that the organizational and technological changes contributed to increase productivity, particularly under the conditions behind cases 1, 5 and 6. It seems that the presence of private stevedore firms in the design of the work teams, in the acquisition of equipment and in the general management of container terminals has had positive effects on productivity.

As indicated in Section 2 the changes in the technical efficiency indices (second column in Table 2) could be explained by pure technical efficiency change or by scale efficiency change. To examine this we have applied the approaches behind Eqs. 1 to 6 in order to compare the indices obtained under both the VRS and NIRS

Table 3 Annual averages of Malmquist's indexes

Period	Change in technical efficiency	Technical change	Pure technical efficiency change	Scale efficiency change	Change in TFP
1994–1995	1.037	1.014	1.011	1.026	1.052
1995–1996	1.010	1.009	0.986	1.024	1.019
1996–1997	1.005	1.032	0.967	1.038	1.037
1997–1998	0.929	1.045	0.947	0.981	0.971
Mean	0.995	1.025	0.978	1.017	1.020

assumptions. Following this procedure we have identified the type of returns to scale exhibited by each port each year. The results obtained show that the main force behind changes in technical efficiency is scale efficiency change, meaning that ports have been adjusting their traffic to the efficient scale. However, there seems to be no relation with the type of returns under which each port operates, as there are ports that have increase scale efficiency under IRS (Alicante, Castellón y Mallorca) and others that have improved under DRS (Cádiz, Cartagena, Huelva, Santander, Tenerife y Valencia).

Table 3 shows the evolution of productivity changes and its components. We can see that behind an average annual increase in productivity of 2% hides an initial growth by 5.2% ending with a reduction by 2.9% in 1998. In order to explain this evolution we have calculated the annual averages of technical efficiency changes and technical change. We can first observe that technical change is the main cause of the productivity increase; rising slightly during the period. Secondly, there is a gradual reduction in technical efficiency during the whole period, which seems to be explained by the pure technical efficiency change. Improvements in scale efficiency seems to be insufficient to compensate for the drop in pure technical efficiency.

4 Synthesis and conclusions

In this paper we have evaluated the deregulation process which took place in port cargo handling in Spain. Such process did concide with a period of deep technological change. In order to carry out the study we have analysed the evolution of Total Factor Productivity using the Malmquist index. We have been able to decompose TFP into technical efficiency and technical change. The former has been decomposed in turn into pure technical efficiency and scale efficiency components. We have used the DEA technique in order to find the efficent frontiers and then calculate the distances from the observed points for the construction of Malmquist indices. We have used data from 1994 to 1998, i.e. the five years following the constitution of the first SEED under the new regulation.

Average efficiency of the ports studied was in 1998 about the same as it was in 1994, i.e., around 90%. Overall efficiency improved at the beginning of the analysed period but fell afterwards, so that by 1998 it was 1.2 percentage points below 1994. This relatively small loss of efficiency was due to a drop in pure technical efficieny that was not compensated by the increase in average scale efficiency. Ports with a relatively large traffic volume exhibit an average efficiency index larger than the average of the rest.

Secondly, we have calculated TFP and its decomposition. Technical change seems to be the element that has caused the increse in productivity, as technical efficiency has remained constant. The ports that exhibit the larger rates of technical change are those that present relatively large traffic volumes, with specialized container terminals and where there is an important presence of privately owned cranes.

Finally, the evolution of TFP and its components shows a large effect at the beginnig of the period followed by a systematic decline such that it ends with a net loss of productivity. Technical change plays a positive role during the period while there is a gradual reduction in technical efficiency due to a decrease in pure technical efficiency, in spite of a better adjustmeny of ports to the efficient scale.

We believe that a new legislation pushing further on efficiency seems to be required, aiming at increasing competition within the stevedore sector.

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