Parametric estimation of inefficiency in cargo handling in Spanish ports

Juan José Díaz-Hernández · Eduardo Martínez-Budría · Sergio Jara-Diaz

Abstract Port workers services have been usually heavily regulated and reserved exclusively for a special kind of workers, dockworkers, which seems to have been the cause of serious inefficiencies worldwide. During the eighties, law reforms have been introduced to solve this problem. In this paper we analyze and decompose efficiency in cargo handling operations in 19 Spanish ports from 1990 to 1998. The method chosen is that of the parametric estimation of both allocative and technical inefficiency using panel data and a quadratic cost function. Results show that although inefficiency has decreased overall, there has been over utilization of labor regarding capital, and technical inefficiency. This supports the need of further consideration of other aspects including competition.

Keywords Parametric allocative inefficiency · Parametric technical inefficiency · Normalized quadratic cost function · Cargo handling · Port economics

JEL Classifications D21 · C33 · L92

Sending cargo through ports involves a large number of operations and agents. Among these, cargo handling is particularly relevant as it encompasses all activities related to the movement of goods inside a port. For this, cargo handling firms have to acquire equipment and hire labor. Historically, port-worker services have been heavily regulated and reserved for dockworkers or longshoremen. The original justification for this was the need to guarantee availability of professional labor to handle cargo quickly and safely as ships arrive. Port worker rolls were related to peak demands, which caused idle labor during low demand periods. This evolved towards a monopoly exercised by cargo handling unions.

The inherent market power of cargo handling workers had several effects: (i) over usage of labor; (ii) wages exceeding productivity; (iii) distorted capital-labor ratios; and (iv) highly restricted work assignments. The monopoly power exercised by the unions lasted many years, presumably translating into cost inefficiencies.

During the seventies, many factors induced capital intensive technological changes in port activities; the main one was the increasing importance of containers in the transport chain. Containers induce homogeneity in the cargo handling process, increasing loading–unloading speed and reducing the time at the port; they also increase safety of the commodities being transported and, as they reduce average cost because of some scale economies in containers ship size, they have an impact reducing ship frequency. As the technology associated with container handling requires relatively large specific investments, a critical mass is needed to make it profitable, which caused the concentration of container traffic in a few ports. Additionally, improvements in the communication and information systems made it possible to program a large percentage of ship arrivals. As the optimal combination of capital and labor had changed, by the beginning of the eighties the problems caused by labor market power became acute after the new technology of containers began

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to dominate. Port services became relatively more expensive, which reduced dramatically port competitiveness.

This prompted the introduction of new laws in the maritime sector in many parts of the world. In general the new laws dealt with the size of the payrolls, the composition of labor teams and the redesign of the restricted schedules. The reform in Spain began in 1986 introducing a more active role of cargo handling firms in the decisions regarding management and organization of the activity within the ports. In brief, today labor is playing a more rational role in cargo handling activities and many ports are now operative 24 h a day, 365 days a year. The question remains, though, regarding an objective assessment of the reforms introduced and the potential introduction of incentives to competition in labor within cargo handling in the European Union.

The main objective of this paper is to rigorously examine the effects of the reforms on the efficiency of the cargo handling sector in Spain. To do this we will study the evolution of efficiency in the period 1990–1998, distinguishing technical and allocative components. As far as we know, there are no studies attempting to measure these effects separately, although there are some recent studies that analyze both the effects of the new laws and technical change, which are summarized in Sect. 2.

We estimate a quadratic cost function with a parametric specification of allocative and technical inefficiency using panel data on 19 Spanish ports over the 1990–1998 period. This specification belongs to the family of flexible functions and has the advantage of being defined for zero output levels, a relevant property when dealing with multioutput activities because of the usual presence of some nil values for some outputs in some ports for some periods, as is the case in Spanish ports. We have adapted the model of Atkinson and Cornwell (1994a, b) to the quadratic system following the procedure established by Kumbhakar (1997).

The rest of the paper is structured as follows. Section 1 describes the procedure based on the shadow cost function approach under a quadratic specification in order to model both the allocative and technical inefficiency. In Sect. 2 the application to cargo handling in Spanish ports is presented. Finally, in Sect. 3 the main conclusions of this work are presented.

1 The model

The parametric estimation of inefficiency is a procedure where inefficiency is captured through a set of parameters that are jointly estimated with those characterizing technology that avoid what is known as Greene's problem. Atkinson and Cornwell (1994a, b) showed how both technical and allocative inefficiency can be identified in a shadow cost framework. They also demonstrated how to estimate a translog version of their model with panel data. In their setup, technical efficiency was modeled by scaling the input vector with a firm-specific parameter that appears additively in the translog cost function. Allocative inefficiency was captured by shadow prices (Toda 1976), which are parametrically related to actual prices.

Following this approach, Kumbhakar (1997) proposed a model that incorporates both technical and allocative inefficiency and showed how cost savings could be decomposed into technical and allocative components. The parametric approach has been extended by Maietta (2000) who modeled allocative inefficiency as parameters that are functions of a time trend and individual dummy variables. Atkinson and Primont (2002) showed how to estimate a shadow distance function under the assumption of cost minimization. More recently, Kumbhakar and Tsionas (2005) have estimated such a model using the Bayesian approach.

Let $Y = (Y_1,\ldots,Y_n)$ be a vector of n outputs, $X = (X_1,\ldots,X_m)$ a vector of m inputs and P the corresponding price vector, with $P^* = (k_1P_1,\ldots,k_mP_m)$ as the shadow price vector for which the combination of actual inputs is allocatively efficient. Cost minimization implies that

$$\frac{\partial F(Y,bX)/\partial(bX_i)}{\partial F(Y,bX)/\partial(bX_j)} = \frac{P_i^*}{P_j^*} = k_{ij}\frac{P_i}{P_j}; \quad (i,j = 1,\ldots,m) \tag{1}$$

where $F(Y,bX) = 0$ is the transformation function and $0 < b \leq 1$ is the parameter that corrects input oriented technical inefficiency.

In Eq. 1, $k_{ij} \geq 0$ is a parameter that indicates how the relative actual price ratio of input i to input k deviates from the relative shadow price ratio. If $k_{ij} = 1$, then the price ratios are the same and the chosen combination of production factors is allocatively efficient. On the other hand, if $k_{ij} < 1$, then the relative shadow price is lower than its relative actual price, and then the actual use of input i exceeds the allocatively efficient quantity. On the contrary, if $k_{ij} > 1$, the producer has chosen a quantity that is below the efficient level.

As pointed out by Kumbhakar (1992), it is important to include temporal variability when defining the parameters that model the distortions caused by the allocative inefficiency. As cost reductions in time can be caused both by technical change and by variations in allocative efficiency, this procedure avoids possible bias in the measure of technical change. Non negativity and time variability of the parameters k_{ijt} are imposed in the following way

$$k_{ijt} = \left(1 + \eta_{ij} + \eta_{ijt}t\right)^2 = 1 + \Omega_{ijt}; \quad -1 \leq \Omega_{ijt} < \infty; \quad i \neq k \tag{2}$$

where Ω_{ijt} is the deviation of the relative actual price from the relative shadow price between inputs i and j at period t. In what follows, the time subscript will be suppressed to simplify notation. With this reformulation of the conditions for minimizing costs in terms of shadow prices, the corresponding shadow cost function, C^*, is (Atkinson and Cornwell 1994a)

$$C^*\left(\frac{P^*}{b}, Y\right) = \min_x \left\{ \left(\frac{P^*}{b}\right)(bX)/F(Y, bX) = 0 \right\} = \frac{1}{b} C^*(P^*, Y) \quad (3)$$

Taking into account that the actual cost C is the sum of the actual expenses on each input and using the definition of shadow prices given by (2), we obtain

$$\begin{aligned} C &= \sum_{i=1}^{m} P_i X_i = 1 \Big/ b \sum_{i=1}^{m} P_i X_i(P_i^*, Y) \\ &= 1 \Big/ b \left[C(P^*, Y) - \sum_{i=1}^{m} \Omega_i P_i X_i(P^*, Y) \right] \end{aligned} \quad (4)$$

We adopt a normalized quadratic functional form for $C(P^*, Y)$ which imposes homogeneity of degree one in input prices. Let the normalized quadratic shadow cost function (NQSCF) be:

$$\begin{aligned} &\frac{1}{b} C(P^*, Y, t) \\ &= \frac{1}{b} \left[\begin{array}{l} \sum_{i=1}^{m} \alpha_i P_i^* + \sum_{r=1}^{n} \alpha_r P_k^* Y_r + \frac{1}{2} \sum_{i \neq k} \sum_{j \neq k} \alpha_{ij} P_i^* \frac{P_j^*}{P_k^*} \\ + \frac{1}{2} \sum_{r=1}^{n} \sum_{l=1}^{n} \alpha_{rl} P_k^* Y_r Y_l + \sum_{i \neq k} \sum_{r=1}^{n} \alpha_{ir} P_i^* Y_r \\ + \sum_{i \neq k} \alpha_{it} P_i^* t + \sum_{r=1}^{n} \alpha_{rt} P_k^* Y_r t + \alpha_t P_k^* t + \alpha_{tt} P_k^* t^2 \end{array} \right] \end{aligned} \quad (5)$$

The price of input k has been used in two ways. First, as a numeraire in the construction of relative prices, considering that only the ratios k_i/k_k can be identified and that the measures of the estimated allocative efficiency are in relation to input k. Atkinson and Cornwell (1994a) point out that the choice of the reference input has no effect on the log likelihood. Therefore

$$\frac{P_i^*}{P_k^*} = k_i \frac{P_i}{P_k} = (1 + \Omega_i) \frac{P_i}{P_k} \quad \text{where } k_i = \frac{k_i}{k_k} = (1 + \Omega_i); \quad i \neq k; \quad \Omega_k = 0 \quad (6)$$

The other use of price of input k is to normalize the cost function to impose homogeneity of degree one. Moreover, in (5) we have added a time trend as a *proxy* variable representing technical change that interacts with output levels and the prices of inputs.

Applying Shephard's lemma to the shadow cost function defined in (5), we obtain the optimal demand at the shadow prices, for input i, $X_i(P^*, Y, t)$, and for input k, $X_k(P^*, Y, t)$, which multiplying both sides by $1/b$, coincide with the actual input demands.

$$\begin{aligned} X_i &= 1/b X_i(P^*, Y, t) = 1/b \frac{\partial C(P^*, Y, t)}{\partial P_i^*} \\ &= 1/b \left(\alpha_i + \sum_{j \neq k} \alpha_{ij} \frac{P_j^*}{P_k^*} + \sum_{r=1}^{n} \alpha_{ir} Y_r + \alpha_{it} t \right); \quad (i \neq k) \\ X_k &= 1/b X_k(P^*, Y, t) = 1/b \frac{\partial C(P^*, Y, t)}{\partial P_k^*} \\ &= 1/b \left(\alpha_k + \sum_{r=1}^{n} \alpha_r Y_r - \frac{1}{2} \sum_{i \neq k} \sum_{j \neq k} \alpha_{ij} \frac{P_i^* P_j^*}{P_k^* P_k^*} \right. \\ &\qquad \left. + \frac{1}{2} \sum_{r=1}^{n} \sum_{l=1}^{n} \alpha_{rl} Y_r Y_l + \sum_{r=1}^{n} \alpha_{rt} Y_r t + \alpha_t t + \alpha_{tt} t^2 \right) \end{aligned} \quad (7)$$

Both elements of expression (7) can be decomposed in the following way

$$\begin{aligned} X_i &= 1/b \left[\alpha_i + \sum_{j \neq k} \alpha_{ij} \frac{P_j}{P_k} + \sum_{r=1}^{n} \alpha_{ir} Y_r + \alpha_{it} t + \sum_{j \neq k} \alpha_{ij} \Omega_j \frac{P_j}{P_k} \right]; \\ &(i \neq k) \\ X_k &= 1/b \left[\begin{array}{l} \alpha_k + \sum_{r=1}^{n} \alpha_r Y_r - \frac{1}{2} \sum_{i \neq k} \sum_{j \neq k} \alpha_{ij} \frac{P_i}{P_k} \frac{P_j}{P_k} \\ + \frac{1}{2} \sum_{r=1}^{n} \sum_{l=1}^{n} \alpha_{rl} Y_r Y_l + \sum_{r=1}^{n} \alpha_{rt} Y_r t + \alpha_t t + \alpha_{tt} t^2 \\ - \frac{1}{2} \sum_{i \neq k} \sum_{j \neq k} \alpha_{ij} \frac{P_i}{P_k} \frac{P_j}{P_k} (\Omega_i + \Omega_j + \Omega_i \Omega_j) \end{array} \right] \end{aligned} \quad (8)$$

The parentheses of (8) has two parts, the first being the optimal demand for inputs i and k at the observed prices, $X_{i,k}^*(P, Y, t)$, and the second is the impact of the allocative inefficiency on demand of inputs i and k, $X_{i,k}^{al}(P, \Omega)$. Adding and subtracting $X_{i,k}^*(P, Y, t) + X_{i,k}^{al}(P, \Omega)$, we obtain

$$X_{i,k} = X_{i,k}^*(P, Y, t) + X_{i,k}^{al}(P, \Omega) + (1/b - 1)\left[X_{i,k}^*(P, Y, t) + X_{i,k}^{al}(P, \Omega) \right] \quad (9)$$

where the first term is the optimal demand for inputs i and k

$$\begin{aligned} X_i^*(P, Y, t) &= \alpha_i + \sum_{j \neq k} \alpha_{ij} \frac{P_j}{P_k} + \sum_{r=1}^{n} \alpha_{ir} Y_r + \alpha_{it} t; \quad (i \neq k) \\ X_k^*(P, Y, t) &= \alpha_k + \sum_{r=1}^{n} \alpha_r Y_r - \frac{1}{2} \sum_{i \neq k} \sum_{j \neq k} \alpha_{ij} \frac{P_i}{P_k} \frac{P_j}{P_k} \\ &\quad + \frac{1}{2} \sum_{r=1}^{n} \sum_{l=1}^{n} \alpha_{rl} Y_r Y_l + \sum_{r=1}^{n} \alpha_{rt} Y_r t + \alpha_t t + \alpha_{tt} t^2 \end{aligned} \quad (10)$$

the second is the impact of the allocative inefficiency on demand of inputs i and k

$$X_i^{al}(P,\Omega) = \sum_{j\neq k} \alpha_{ij}\Omega_j \frac{P_j}{P_k}; \quad (i \neq k)$$
$$X_k^{al}(P,\Omega) = -\frac{1}{2}\sum_{i\neq k}\sum_{j\neq k} \alpha_{ij}\frac{P_i}{P_k}\frac{P_j}{P_k}(\Omega_i + \Omega_j + \Omega_i\Omega_j) \tag{11}$$

and the last term of (9) is the effect of technical inefficiency on factor i and k. This latter can be written taking into account (10) and (11).

Similarly, expression (4) can be transformed in terms of actual input prices following a procedure that resembles the one just described to decompose the observed demand. This can be done introducing (5) and (8) into (4), and then adding and subtracting $C^*(P,Y,t) + C^{al}(P,\Omega)$, which yields

$$C = C^*(P,Y,t) + C^{al}(P,\Omega) + (1/b - 1)\left[C^*(P,Y,t) + C^{al}(P,\Omega)\right] \tag{12}$$

where $C^*(P, Y, t)$ is the cost frontier at actual prices

$$C^*(P,Y,t) = \sum_{i=1}^{m}\alpha_i P_i + \sum_{r=1}^{n}\alpha_r P_k Y_r + \frac{1}{2}\sum_{i\neq k}\sum_{j\neq k}\alpha_{ij}P_i\frac{P_j}{P_k} + \frac{1}{2}\sum_{r=1}^{n}\sum_{l=1}^{n}\alpha_{rl}P_k Y_r Y_l + \sum_{i\neq k}\sum_{r=1}^{n}\alpha_{ir}P_i Y_r + \sum_{i\neq k}\alpha_{it}P_i t + \sum_{r=1}^{n}\alpha_{rt}P_k Y_r t + \alpha_t P_k t + \alpha_{tt}P_k t^2 = \sum_{i=1}^{m} P_i X_i^*(P,Y,t) \tag{13}$$

The impact of allocative inefficiency on costs, C^{al}, is

$$C^{al}(P,\Omega) = \sum_{i=1}^{m}\alpha_i\Omega_i P_i + \frac{1}{2}\sum_{i\neq k}\sum_{j\neq k}\alpha_{ij}P_i\frac{P_j}{P_k}(\Omega_i + \Omega_j + \Omega_i\Omega_j) + \sum_{i\neq k}\sum_{r=1}^{n}\alpha_{ir}\Omega_i P_i Y_r + \sum_{i\neq k}\alpha_{it}\Omega_i P_i t - \sum_{i\neq k}\Omega_i P_i X_i(P^*,Y,t) = -\frac{1}{2}\sum_{i\neq k}\sum_{j\neq k}\alpha_{ij}\Omega_i\Omega_j P_i\frac{P_j}{P_k} = \sum_{j=1}^{m} P_j X_j^{al} \tag{14}$$

To obtain the last equality in (14) we have used the value of $X_i^{al}(i = 1,\ldots,m)$ obtained in (11). Note that the cost of allocative inefficiency depends only on factor prices. This is a consequence of the quadratic functional form (Kumbhakar and Lovell 2000, Chap. 6).

The third term in the right hand side of Eq. 12 is the impact of technical inefficiency on cost, which can be trivially obtained from (13) and (14). Note that imposing $\Omega_i = 0$ and $b = 1$ in (12) and (9), i.e. disregarding inefficiencies, the neoclassical cost system is obtained.

There are various procedures to estimate the model just presented. One would be the joint estimation of the cost and the (derived) factor demand equations. This is a particularly complex approach, especially if b is specified like a parameter with individual and temporary variability, because the system is highly nonlinear in the parameters. We will use an alternative procedure that comprises two steps. First we estimate the demand ratios, which reduce the non linearity by eliminating the b parameter that measures technical inefficiency. For the system to be completely identified, it is necessary that one of the demand ratios includes the input whose price was used in the normalization. Then technical inefficiency can be calculated by running a second regression where the observed cost is on the left hand side and the sum of the adjusted optimal cost level and the allocative inefficiency cost is on the right hand side. This latter is calculated from the results in the first step.

2 An application to cargo handling in Spanish ports

Although overall port efficiency has been studied in the economic literature,[1] to the best of our knowledge, efficiency in cargo handling in a port system has been explored only by Díaz-Hernández et al. (2008); they used non-parametric techniques to estimate technical efficiency in a smaller sample of 21 ports observed during 1994–1998. In the research reported here we estimate both technical and allocative inefficiency using a cost function that contains parametric specifications for both distortions.

On related matters, Spanish Port Authorities have been analyzed by Martínez-Budría et al. (1999) and Coto-Millán et al. (2000). Container ports have been studied by Tongzon (2001), Cullinane et al. (2004), and Cullinane et al. (2006). Multipurpose terminals were studied by Rodríguez-Álvarez et al. (2007); and container terminals by Cullinane and Song (2003) and Tongzon and Heng (2005). Regarding methods, production functions and cost functions have been estimated and examined in these studies using Data Envelopment Analysis, Stochastic Frontier Analysis or distance functions.

2.1 The Spanish cargo handling sector

Different capital and labor mix are used in cargo handling services, depending on the packing, be it pallets, containers, etc, which justifies its multiproduct treatment (Jara-Díaz et al. 2006, 2008). In this case, the quadratic cost function is

[1] A general review on port performance can be seen in Cullinane et al. (2006).

appropriate because pooled data usually contains some zero outputs for some firms at some point in time.

During the eighties various countries introduced law reforms in the cargo handling sector. By 1986 in Spain the Royal Decrees 2/1986 of May 23rd and 371/1987 of March 13 introduced important changes in this type of service. As in other countries, those reforms were motivated by the growing use of containers (Talley 2000), which induced a profound technological transformation in maritime transport, in port infrastructure and in mechanic equipment, which in turn led to new techniques for the organization of labor in cargo handling. This resulted in a remarkable reduction in labor within the range of 40–60% for different countries (Zarocostas 1996). This has occurred in spite of large increases in port traffic.

The new legal framework in Spain established that each port will have a state administered cargo handling society, Sociedad Estatal de Estiba y Desestiba (SEED). The form was a joint-stock company with the state holding a share larger than 50%, which ensured its leadership in decision making for an activity that was declared an essential public service. Those private firms willing to operate in this market should have part of the remaining share. The participation of each cargo handling firm depended on the size of the labor role, equipment, cargo volume and space used. Port workers involved in cargo handling have to register in a SEED list in order to be assigned according to the demands of the firms, following a rotation system. If labor demand exceeds the number of workers available, temporary workers can be hired receiving the same salary.

The legislative reform centered its goal in the reduction of the number of longshoremen and in accomplishing greater flexibility in the work teams and the hours during they provide their services. Thus, firms have more freedom to decide on the composition of work teams and to enlarge work periods, such that cargo handling services can be offered during the night and holidays if deemed necessary. The result can be summarized in the following points: (i) the payroll diminished from 12,500 port workers in 1986 to 4,100 in 1998 (ii) the deregulation of the composition of the work teams allowed for a greater active participation of private firms, and (iii) a timid opening of the activity to other firms, though always as subsidiaries and with the same wages. Thus, we expect a decrease in both types of inefficiency during the period analyzed, with particular improvements coming from better usage of dockworker services.

2.2 Data

Cargo handling activities involve essentially two factors: labor and cranes. Data sources are the State Annual Reports on Ports, the Annual Report of each port and a questionnaire that we had drawn up and presented to the *SEED*s.[2] The data from the Annual Reports of the Ports of the State have been used to get the quantities of cargo moved by each port and year included in the sample. The outputs analyzed in this study were defined according to how the merchandise is handled, which, in turn, will determine what kind of operation is needed to load or unload it. Thus, we can distinguish between general container cargo (GCC), non-containerized general cargo (NCGC) and solid bulk cargoes that are handled without special facilities (SB). The Annual Reports of each port and the information received from crane operators in ports have given us the hours worked by cranes and have permitted the calculation total expenses on this item. The questionnaire sent to all *SEED*s gave us important information on labor costs and hours worked by longshoremen.

The costs we will explain encompass the expenditure in labor (L) and the expenditure in cranes (K) associated with the handling operations for the aforementioned cargo flows. To build input price indicators, we have the total expenditure on each input and a physical measure of the input used, in this case, the number of hours worked by stevedores and the number of hours of crane use. Inflation has been accounted for.

Nineteen ports are included in this study, observed from 1990 to 1998 with the exceptions indicated (as some *SEED*s were born after 1990): Algeciras, Alicante, Bilbao, Cádiz (1992–1998), Cartagena, Castellón, Gijón, Huelva, La Coruña, Málaga (1992–1998), Palma de Mallorca, Alcudia, Motril (1992–1998), Pontevedra (1992–1998), Tenerife (1991–1998), Santander (1991–1998), Sevilla (1991–1998), Valencia and Vigo (1992–1998). With this information we built an unbalanced panel with 158 annual observations. Table 1 shows the summary statistics for the model variables.

2.3 Empirical results

As we will consider only two inputs, the model to be estimated is the ratio between capital (cranes) and labor demand equations, with the price of the former being used to normalize. Since the input demand functions are homogeneous of degree zero in k_i one of them is unidentified so we normalize k_K to be unity and estimate k_L. In this work, the time variation has been allowed.

Using capital and labor demand from (8), the econometric model to be estimated is

[2] Available in "Noticias y novedades", http://www.aneconom.ull.es/embudria/.

$$\frac{X^a_{Kft}}{X^a_{Lft}} = \frac{1/b\left(\alpha_k + \sum_{r=1}^n \alpha_r Y_{rft} - \frac{1}{2}\alpha_{LL}(1+\Omega_L)^2\left(\frac{P_{Lft}}{P_{Kft}}\right)^2 + \frac{1}{2}\sum_{r=1}^n \sum_{l=1}^n \alpha_{rl} Y_{rft} Y_{lft} + \sum_{r=1}^n \alpha_{rt} Y_{rft} t + \alpha_t t + \alpha_{tt} t^2\right)}{1/b\left(\alpha_L + \alpha_{LL}(1+\Omega_{Lt})\frac{P_{Lft}}{P_{Kft}} + \sum_{r=1}^n \alpha_{Lr} Y_{rft} + \alpha_{Lt} t\right)} + \alpha_f D_f + \upsilon_{ft} \tag{15}$$

where D_f is a dummy variable for firm f introduced to control for unobserved port heterogeneity affecting demand ratios. Finally, υ_{ft} is a standard noise error term with zero mean.

As indicated by Schmidt and Sickles (1984), using fixed effects permits the estimation of an individual measure of technical inefficiency with no need to use restrictive assumptions regarding either the distribution of the error term or independence between technical inefficiency and the levels of output and input prices. Atkinson and Cornwell (1994a) showed that input oriented technical inefficiency in a translog cost function model appears additively. As the existence of any other time invariant and specific firm characteristic would be reflected in the specific individual effect as well, this could not be interpreted entirely as technical inefficiency. However, fixed effects in the demand ratio equations would not be related with either input oriented technical inefficiency—as this does not affect the ratio—or with allocative inefficiency if this is explicitly modeled with shadow prices.

Fixed effects capture other type of elements, as cargo handling services could be affected by specific port characteristics that are beyond firm control with an impact on the capital-labor proportion. For example, this could be the case of space availability and its distribution. Therefore, fixed effects could isolate the influence of these elements.

Table 1 Summary statistics for the model variables

Variable	Mean	SD	Unit
COST	1,711.7	2,051	Thousand of millions of ptas.
CGC	1,271.8	2,959.9	Thousand of tons
NCGC	488.0	604.1	Thousand of tons
SB	1,275.8	1,134.6	Thousand of tons
K	14,254	14,346	Capital (Crane) hours per year
L	205,563	236,391	Labor hours per year
PK	37,177	10,886	Ptas. per capital hour
PL	5,103	1,235	Ptas. per labor hour
SK	0.35	0.15	Capital cost share
SL	0.65	0.15	Labor cost share
Ports	19		
Years	9 (unbalanced)		

Equation 15 was estimated using non-linear least squares allowing for heteroskedasticity and autocorrelation of unknown form by employing the Newey and West (1987) covariance matrix estimator with a lag of three periods. Results are shown in Table 2. The computed R^2 value for the fitted model is 0.962 that indicates that the model fits the data well. Most of the coefficients are significant at the 0.05 level using a two-tailed test calculated from the robust standard errors.

The shadow cost function corresponds to a well-behaved production function only if it is monotonically increasing in shadow input prices and output quantities, and concave and linear homogeneous in shadow input prices. Monotonicity is checked by determining if the calculated values of the input demands and cost are positive, which occurs for

Table 2 Estimates of demand ratio equation parameters

Parameter	Estimate	*t* ratio	Port dummy	Estimate	*t* ratio
α_{K}	0.011	4.521	DAlgeciras	0.0027	5.459
α_{L}	0.152	2.326	DAlicante	0.0031	4.748
α_{LL}	−0.110	−2.543	DBilbao	0.0129	5.644
α_{CGC}	0.720	2.503	DCádiz	0.0038	4.299
α_{NCGC}	2.366	2.640	DCartagena	0.0101	15.443
α_{SB}	0.327	2.515	DCastellón	0.0074	5.673
α_{T}	−0.016	−3.047	DGijón	0.0062	8.406
α_{CGCCGC}	−0.047	−1.985	DHuelva	0.0070	6.022
$\alpha_{NCGCNCGC}$	−0.027	−2.593	DLa Coruña	0.0093	5.351
α_{SBSB}	0.101	2.219	DMálaga	0.0073	9.001
$\alpha_{CGCNCGC}$	−0.047	−0.989	DMallorca	0.0141	12.215
α_{NCGCSB}	−0.606	−2.723	DAlcudia	0.0198	21.208
α_{CGCSB}	0.065	1.923	DMotril	0.0024	3.586
α_{CGCPL}	0.092	2.221	DPontevedra	0.0060	6.455
α_{NCGCPL}	0.109	3.740	DTenerife	0.0085	3.079
α_{SBPL}	0.063	3.023	DSantander	0.0108	10.587
α_{TT}	−0.003	−19.32	DSevilla	0.0160	13.679
α_{TPL}	−0.054	−5.210	DValencia	0.0041	5.021
α_{TCGC}	−0.006	−2.843	DVigo	0.0077	3.755
α_{TNCGC}	0.002	1.454			
α_{TSB}	0.007	2.213			
η_{L}	−0.134	−2.976			
η_{Lt}	0.004	2.483			

all observations. Concavity is checked by determining if the principal minors of the Hessian matrix have the correct alternating signs. In this application, the Hessian matrix is a negative semi definite matrix and therefore concavity in input prices is satisfied. As the NQSCF fulfils homogeneity of degree one in prices by construction, the shadow cost function underlying Eq. 15 presents all the theoretical properties and can be regarded as an adequate representation of the productive structure of cargo handling activities in Spanish ports.

We tested three hypotheses related to allocative inefficiency: (a) total absence $(\eta_L = \eta_{Lt} = 0)$, (b) absence of the permanent component $(\eta_L = 0)$, and (c) absence of temporal variability $(\eta_{Lt} = 0)$. These restrictions have been analyzed using the Wald test. The value obtained for hypothesis (a) is 19.37, larger than the critical value of the χ^2 with 2 degrees of freedom at the 1% level of significance, which means that absence of allocative inefficiency is rejected. The values for the test in cases (b) and (c) are 81.48 and 12.98, respectively. In the first case, the Wald statistic is larger than the critical value of χ^2 with 1 degree of freedom at the 1 percent level of significance, which rejects the hypothesis of absence of a permanent component. In case (c), the Wald statistic is larger than the critical value of χ^2 with 1 degree of freedom at the 5% level of significance. This result shows that allocative distortion vary over time.

With the estimated values of η_L and η_{Lt} we calculated the series for k_{Lt} using Eq. 2. The average value of k_{Lt} is 0.785, which indicates that the capital-labor mix chosen within this sector was based upon relative prices that were 78.5% of the actual ones. Note that as η_{Lt} is positive, k_L increases continuously in time, reflecting an improvement in the choice of input combinations, which is the likely result of the new conditions that permit to assemble work teams closer to what demand needs and better suited for the new type of equipment. This has increased the capital-labor ratio and the partial correction of the existing allocative inefficiency. As shown in Table 2 all fixed effects are statistically significant and positive. So, two effects with opposite sign are detected: allocative inefficiency caused a reduction of the optimal capital-labor ratio while the fixed effect increased it. If the fixed effects had not been included the allocative inefficiency effect would have been underestimated.[3]

Using expression (11) and (14), we estimated the effects of allocative inefficiency on the demand for labor and capital and on costs, for each port. Results are shown in Table 3. The average values of allocative inefficiency by port confirm our previous intuition regarding the relative

[3] A restricted version of the model was estimated, eliminating fixed effects. Allocative efficiency indices are lower than the unrestricted version by 4.2%.

Table 3 Effects of allocative inefficiency

Port	Cost of allocative inefficiency % (C^{al}/C^*)	Percent over-utilization of labor	Percent under-utilization of capital
Algeciras	5.4	3.5	1.2
Alicante	9.0	14.2	14.0
Bilbao	3.6	3.8	1.2
Cádiz	13.1	8.4	8.3
Cartagena	8.7	18.9	11.6
Castellón	9.1	14.3	4.1
Gijón	13.0	21.0	13.1
Huelva	11.7	19.0	7.3
La Coruña	8.2	12.8	3.3
Málaga	11.0	23.3	17.9
P. Mallorca	9.0	11.7	5.5
Alcudia	10.2	10.5	5.6
Motril	15.9	18.0	11.4
Pontevedra	10.6	7.9	4.5
Tenerife	15.0	9.5	7.1
Santander	9.3	24.0	6.3
Sevilla	8.9	27.7	4.6
Valencia	8.4	8.5	3.3
Vigo	13.7	10.5	8.1
Mean	10.2	14.1	7.3

over-utilization of labor. On average, labor was relatively over-utilized by 14.1% while crane-hours were relatively under-utilized by 7.3%. This erroneous choice of input mix has translated into expenses that are on average 10.2% larger than the minimum cost. Note that two of the largest ports of the Spanish system, Algeciras and Valencia, exhibit the best levels of allocative efficiency; both handle a large container traffic served by big private firms.

As explained earlier, technical inefficiency is calculated by running a second regression where the observed (actual) cost is on the left hand side and the sum of the adjusted optimal cost level and the allocative inefficiency cost is on the right hand side. The right hand side is calculated from the results in the first step using the parameters reported in Table 2 to evaluate expressions (13) and (14) to obtain the adjusted optimal cost level $\left(\hat{C}^*\right)$ and the allocative inefficiency cost $\left(\hat{C}^{al}\right)$. Then the technical inefficiency parameters b_{it} are estimated from the following equation:

$$C^{a}_{ft} = \sum_{f} (1/b_{ft}) D_f \left[\hat{C}^*_{ft} + \hat{C}^{al}_{ft}\right] + \xi_{ft}, \tag{16}$$

where D_f is a port dummy variable, $(1/b)_{ft} = \beta_f + \beta_{ft} t$ in order to account for port and time variability, and ξ_{ft} is a standard noise error term with zero mean.

The estimation was done using the robust covariance matrix estimator for pooled OLS. Results are shown in

Table 4 Estimates of technical inefficiency parameters

Port	β_f estimate	t ratio	β_{ft} estimate	t ratio
Algeciras	1.059	10.348	−0.0067	−3.641
Alicante	1.154	3.689	−0.0115	−5.124
Bilbao	1.107	6.432	−0.0076	−5.522
Cádiz	1.160	6.743	0.0097	2.687
Cartagena	1.100	8.311	−0.0092	−7.829
Castellón	1.106	7.458	−0.0058	−6.388
Gijón	1.110	7.325	0.0018	2.715
Huelva	1.123	8.217	−0.0013	−2.612
La Coruña	1.170	6.845	0.0020	3.775
Málaga	1.091	7.986	0.0023	3.814
Mallorca	1.082	5.731	−0.0023	−3.190
Alcudia	1.114	5.023	−0.0009	−4.435
Motril	1.153	5.748	−0.0028	−4.241
Pontevedra	1.095	4.811	−0.0017	−2.713
Tenerife	1.172	8.768	−0.0074	−2.516
Santander	1.180	7.224	0.0009	2.418
Sevilla	1.093	8.912	−0.0025	−7.457
Valencia	1.096	8.729	−0.0117	−2.463
Vigo	1.122	7.455	−0.0079	−5.834

Table 4. The computed R^2 value for the fitted model is 0.968. All parameters are statistically significant at the 0.05 level using a two-tailed test calculated from robust standard errors.[4] We have tested the hypothesis of constancy of both parameters β_f and β_{ft} across ports using the likelihood ratio (LR) test. The value of −2logLR is 135.8, larger than the critical χ^2 with 36 degrees of freedom at the 1% significance level, which rejects the hypothesis. Table 4 shows that all ports present a permanent component of technical inefficiency ($\beta_f > 1$), but it also shows that this inefficiency decreases in time for the fourteen ports that present a negative value for β_{ft}; it increases in time for the remaining five ports.

From the results in the two models, we have calculated Farrell's (1957) efficiency indices for each observation. The allocative efficiency index is given by the ratio between the optimum cost and the optimum and allocative inefficiency cost obtained from (13) and (14). The technical efficiency index defined as the ratio between the optimum and allocative inefficiency cost and the (fitted) actual cost, is obtained from *b*. Finally, their product yields Farrell's cost efficiency index. Table 5 shows the mean of each of the three indices for each port.

[4] When the second stage model contains variable constructed from parameters estimated in the first stage, the covariance matrix of the second stage estimator includes noise induced by the first-stage estimates. We have applied the procedure of Murphy and Topel (1985) that give the correct asymptotic covariance matrix of the two stage estimation with least squares when both stages use the same observations.

Table 5 Farrell's efficiency indices

Port	Allocative efficiency index	Technical efficiency index	Cost efficiency index
Algeciras	0.957	0.972	0.930
Alicante	0.862	0.905	0.780
Bilbao	0.937	0.932	0.873
Cádiz	0.828	0.854	0.707
Cartagena	0.859	0.945	0.812
Castellón	0.914	0.926	0.846
Gijón	0.865	0.895	0.774
Huelva	0.888	0.895	0.795
La Coruña	0.922	0.849	0.782
Málaga	0.830	0.909	0.754
P. Mallorca	0.942	0.933	0.879
Alcudia	0.903	0.901	0.813
Motril	0.832	0.873	0.726
Pontevedra	0.906	0.917	0.830
Tenerife	0.926	0.870	0.806
Santander	0.892	0.845	0.753
Sevilla	0.87	0.923	0.803
Valencia	0.933	0.959	0.895
Vigo	0.916	0.907	0.831
Mean	0.894	0.905	0.809

Results show that technical inefficiency has caused an average cost increase of 9.5%. Just as in the allocative inefficiency analysis, the largest ports with private cargo handling firms and serving an important container volume show the best technical efficiency indices. Overall, inefficiency has caused an average cost increase of 19.1%. The study of the results do not permit the identification of any common factor which contributes to explain the differences among the inefficiency levels, at least other than the already mentioned in relation to the private management of the big container ports. That is the reason why we have been led to believe that the differences in management abilities are the ultimate cause of the disparity in inefficiency levels.

Finally, the average annual values of the three efficiency indices are shown in Table 6 in order to evaluate the effects of the reform. Allocative and technical efficiency has improved by 5.5% and 8.7%, respectively, which makes an overall increase of 14.7% between 1990 and 1998. In spite of this encouraging result, there are still some unresolved matters in the Spanish cargo handling service system.

3 Conclusions

As in most countries, cargo handling activities in Spain have been characterized by heavy regulation and a

Table 6 Time evolution of Farrell's efficiency indices

Year	Allocative efficiency index	Technical efficiency index	Cost efficiency index
1990	0.871	0.884	0.770
1991	0.881	0.869	0.765
1992	0.872	0.858	0.748
1993	0.889	0.881	0.783
1994	0.897	0.902	0.809
1995	0.900	0.918	0.827
1996	0.908	0.927	0.842
1997	0.913	0.942	0.860
1998	0.919	0.961	0.883
Mean	0.894	0.905	0.809

monopolistic labor supply, which has caused oversized payrolls after the introduction of capital intensive technologies. During the eighties, law reforms began to be introduced worldwide, prompted by the profound technological change provoked by the increasing use of containers. Payroll reductions, freedom in team formation and schedule flexibility were the main observed results in Spain and other countries. Nevertheless, there are doubts regarding the effects of these reforms on the level of efficiency within the sector.

In this paper, we have analyzed efficiency in cargo handling activities in Spain during the nineties, when the reforms had been in effect for some time. We have used the parametric approach adapted to the quadratic cost function, applied to a sample of 19 ports observed during the period 1990–1998. Inefficiency has been estimated in both allocative and technical dimensions, evaluating the impact on both input demands and costs as well. Results in the average reveal an over-utilization of labor by 14.1% while crane-hours were relatively under-utilized by 7.3%. Inefficiency has caused expenses 19.1% larger than the minimum cost (average in the period), were allocative inefficiency bears 9.5% and technical inefficiency is responsible of the remaining 9.6%. The evolution in time of these indices show that both allocative and technical inefficiency have decreased by 5.5% and 8.7%, respectively, which means a decrease of cost inefficiency by 14.7%.

Cargo handling activities in Spanish ports have experienced a reduction in the level of inefficiency in general, but both types of inefficiencies are still present by the end of the period, which suggests the need to consider further reforms. The European Union has proposed twice, during 2003 and 2006, further liberalization measures in cargo handling services which have been resisted by the workers' unions. As an example, during 2006 the possibility of replacing dockworkers with the own ship crew for loading and unloading activities was explored unsuccessfully. This is an example of the tension generated in a historically labor-monopolistic sector when technological improvements allow the increase of overall productivity. As we have shown here, the change in legislation during the 1980s improved the situation, but we think that the model based on reforms without modifying the competitive conditions is finished.

Acknowledgements This research has been funded by Ministerio de Educación y Ciencia, Plan Nacional de I+D+I, España, Grant SEC2002-01940ECO; by Fondecyt, Chile, Grant 1080140, and the Millennium Institute on Complex Engineering Systems. We are particularly grateful for the suggestions in form and contents made by the Associate Editor on earlier versions of this paper. We also thank Julio Afonso-Rodríguez and Jorge V. Pérez-Rodríguez for their helpful econometric comments. Remaining errors are, of course, ours.

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