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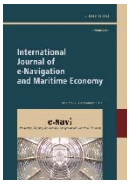

Original article

An Estimation of Cargo Handling Service Costs: Case of the Port of Saint-Brieuc, France

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Abstract

The estimation of key indicators in a firm's cost structure, such as marginal costs, economies of scale and elasticity of substitution are essential to defining the optimal pricing policy, investment and the regulation of ports. However, only a few studies have focused on the estimation of such indicators due to the unavailability of cost data on seaports. In addition, other port cost studies focused on all port activities. The output is measured as a physical product rather than as a service product. The main purpose of this paper is then to concentrate on one service, cargo handling in the port of Saint-Brieuc, and to examine the real composition of its costs. The estimation of a translog cost function suggested that the port may have an over employment of administrative staff in the handling service and a limited capacity when it comes to efficiency in the long run. The results also indicated increasing returns to scale that may suggest that the application of pricing at a marginal cost might not aid the total recovery of the outlay. These results are useful from an operational as well as an investment policy perspective.

Keywords: Cargo handling service, Cost functions, Economies of scale, marginal cost

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1. Introduction

Seaports provide a variety of services to ships, cargoes and passengers. As a key component of the logistic chain, their operation performance has a direct effect on export competitiveness and final prices. This explains the importance of setting adequate port prices and investments policies. The knowledge of a port firms' cost structure is essential then not only to decide where, when and how much to invest but also to define the optimal tariff structure and other key elements such as economies of scale.

Despite the importance of this issue, empirical studies on port cost functions are scarce and have several limitations. This fact is explained, on the one hand, by the problem of availability of data and, on the other hand, by the fact that several resources are common to many types of cargos and port users (Talley and Ng, 2015). Subsequently, the empirical studies focusing on the whole port activity, rather on a particular service, may generate biased results. Talley and Ng (2016) also highlighted the fact that in literature, port outputs are described as “service outputs” but measured as “physical outputs”, ignoring for example the goods in transit and the quality of the port service.

The main purpose of this paper is then to focus on one service, cargo handling, and analyze the cost structure of this service through the estimation of a translog cost function in the port of Saint-Brieuc, Côte d'Armor Region, northwestern France.

In fact, this paper is structured as follows. Section 2 provides a literature review on the application of cost functions to ports. Section 3 describes the theoretical form of the model and the data. Section 4 provides an empirical model and the interpretation of the results. Lastly, section 5 presents the main conclusions.

2. Literature Review

To estimate the marginal cost that can be used as a basis for pricing, and for the optimal operation of the output service at a minimal cost, it is necessary to define the service offered and more precisely factors used for production. However, in literature, cost functions are estimated for all port activity. Such results do not allow a precise estimation of the parameters of the production technology, regardless of the form of the cost function (Cobb-Douglas, flexible forms, etc.) or the number of the seaports or terminals (mono-product, multi-product cost functions). Talley and Ng (2016) addressed this shortcoming by clarifying the difference between port outputs and services and proposing joint cost functions for each output and service in the port. In this literature review, we first present the main empirical studies on the port cost function. Then, we analyze the theoretical contribution of Talley and Ng (2016) on this issue.

One of the first references in the literature on the port cost functions came from Kim and Sachish (1986). The authors considered the port activity from an integral perspective: The output is measured in tons and the cost encompasses all the port infrastructures and service costs. In order to estimate the technical change and the technology of operations in the port of Ashdod, the authors estimated a translog cost function using time series data from between 1966 to 1983. In fact, they demonstrated that when production increases by one per cent, the cost decreases by 0.765, involving the existence of increasing returns to scale. The aggregate output approach was also used by Martinez Budria (1996) who applied the Cobb-Douglas technology and Coto-Millan et *al*. (2000) who considered a stochastic frontier cost function. In these two papers, the authors assume that the technology used by the Spanish port authorities is similar, therefore, it can be analyzed through a model which can, within the error term, differentiate between fixed (changes in technology) and individual effects (differences in costs from one port to another). The authors concluded that, in both studies, the economies of scale in the Spanish port’s infrastructure exist.

Regarding the multiproduct analysis of port activity, two studies were applied in infrastructure (Jara Diaz et *al*.; 1997, 2002) and two studies focused on the Loading and Unloading Companies in Spain (Martinez Budria et *al*. 1998, Tovar et *al*., 2005). Jara Diaz et *al*. (1997; 2002) for instance estimated a long-run multi-output quadratic function in order to determine the specific marginal costs of each product and distinguish between the economies of scale and the economies of scope for infrastructure services. They found that the cargo movement is more expensive than the other activities that use infrastructure. The study of Martinez Budria et al. (1998) led to the conclusion of increasing returns of scale. On their part, Tovar et al. (2005) found similar results.

The studies we have mentioned above consider only the physical output measures, ignoring that seaports also offer service outputs. There is also an inherent uncertainty in specifying as to what infrastructure and service costs are related. Talley and Ng (2016, page 2) stated that services have some characteristics that distinguish them from goods and that the physical measures used in the literature are not representative of the service output. For example, the authors explained the characteristic of simultaneity of a port service as follows: "…at least two distinct parties must be involved in its provision. Alternatively, if either party is unwilling to be involved in the provision of a service, then the service will not occur or be provided i.e. in order for port cargo service to occur, a shipper must be willing to provide cargo via a carrier to a port for port service and the port must also be willing to accept this cargo and provide it with port cargo service". Then, to take into account the characteristic of simultaneity, the cargo handling service provided by the port in passing cargo through the port has to be considered. The authors also suggested considering quality measures of port services, such as safety and security inspection. As a consequence, Talley and Ng (2016) drew up several cost functions (for port cargo, port vessel and port vehicle services) taking into account the difference between providing a port service and its output.

Based upon these findings and suggestions, we developed, in the next section, a cost function for the cargo handling service in the port of Saint-Brieuc.

3. Cargo handling service Short-run cost function

3.1. The objective function

Parametric cost functions implicitly assume that a firm aims at choosing the optimal combination of factors of production, owing that input prices are considered to be exogenous. A main advantage exists when we select the estimation of a short run cost function instead of a long run one: the short-run marginal cost pricing considers the scarcity of the capacity when it is sub-optimal, and it may be used to discourage its use (short-run marginal cost is higher than long-run marginal cost). It is also encouraging for the use of infrastructure when its capacity is over-optimal (short run marginal cost is lower than long-run marginal cost, Bennathan and Walters, 1979). It is in this vein that we selected our model, which is based on a mono-product short-run variable cost function and is defined as:

$$C^v = f(Y, W, F) \quad (1)$$

Where C^v is minimal variable short-run total cost, Y is the level of production, W is a vector of the variable input prices, F is a set of fixed factors to be specified later. This cost function assumes that the port minimizes the variable cost, given the service level of the port, the exogenous variable input prices and the fixed inputs.

3.2. Data and specification of variables

The data used in this study comes from panel data (2011-2015) of six different products handled in the port of Saint-Brieuc. These products can be classified into two categories: bulk (4 of them) and break bulk cargoes (2).

The dependent variable (C^v) is the sum of the operational costs. The output Y is measured by the number of handled tons. This measure includes all the types of handled cargoes which pass through the port. The estimation of cost functions also requires information on the prices of the variable factors of production and the quantities of the fixed factors. In the beginning, three factors were selected. The first one concerns the expenses in the real estate (EI). This variable includes the maintenance and repair costs and the rent for warehouses and from concessions. The second factor $NPHM$ is the number of administrative workers. We included in this measure the inspection and control employees, to take into account the quality of the handling service. Finally, auxiliary expenses (DA) include the purchase of various materials and supplies. The analysis of the correlation matrix of these factors with the output (Table 1) confirms that the fixed factors are unrelated. Furthermore, the correlation coefficients in relation to the service level are respectively equal to -0.11 for EI and -0.03 for $NPHM$. However, a high correlation (0.95) close to the unity was observed between the output and the auxiliary expenses (DA). This suggests that the port adjusts these expenses with the level of production. Since the auxiliary expenses mainly include expenses from electricity, a proxy for the price of this factor (WDA) was obtained by dividing the total amount of auxiliary expenses by the number of working hours of cranes, the main source of electricity consumption.

Table 1: Correlation Matrix

	PM	OUTI	DA	EI	NPHM	Y
PM	1					
OUTI	0.72	1				
DA	0.45	0.90	1			
EI	0.11	-0.48	-0.34	1		
NPHM	-0.63	-0.45	-0.11	0.27	1	
Y	0.62	0.81	0.95	-0.11	-0.03	1

When providing cargo handling services, other factors of production, which vary with the level of service, are required: labor and equipment. The port worker category led us to distinguish between temporary and permanent workers. The cost of labor (WPM) was then derived from the total aggregated cost of labor and the total aggregated number of working hours (*PM*). For the equipment, we recorded some information about the number of working hours for cranes, lifting and carrying equipment (*OUTI)* for different kinds of products. The cost of equipment is the sum of the amortization during the considered period and the expenses of repair and maintenance (The wages of maintenance workers are included in WPM instead). To incorporate the opportunity cost of capital, we added an annual rate of return taken from the annual Treasury bill rate (between 3% and 4% for the period under analysis). Finally, the initial capital cost for equipment ($WOUTI$) was calculated by dividing the total cost of equipment by the aggregated number of worked hours (*OUTI).*

4. Econometric model and estimation results

4.1. The econometric model

When estimating a cost function, flexible forms (i.e. quadratic and translog cost functions) are preferable trying to avoid restrictions imposed by the initial choice of the function. The flexible cost functions do not lead, for instance, to restrictions on the degree of homogeneity, homotheticity, or to assumptions on returns to scale and substitution elasticities that can be deduced directly from the data (Dodgson, 1985). Quadratic and multioutput flexible functions require a large amount of relevant data. Owing to the limited number of available observations, we selected a mono-product translog cost function that can be written as follows:

$$\ln C^v = \alpha_0 + \alpha_Y \ln Y + \frac{1}{2}\alpha_{YY}(\ln Y)^2 + \sum_i^n \beta_i \ln W_i + \frac{1}{2}\sum_i^n \beta_{ii}(\ln W_i)^2 + \sum_i^n \sum_{j\neq i}^n \beta_{ij} \ln W_i \ln W_j + \sum_i^n \alpha_{iY} \ln W_i \ln Y + \gamma_{NPHM} \ln NPHM + \frac{1}{2}\gamma_{NPHM\,NPHM}(\ln NPHM)^2 + \alpha_{Y\,NPHM} \ln Y \ln NPHM + \sum_i^n \pi_{iNPHM} \ln W_i \ln NPHM + \delta_{EI} \ln EI + \frac{1}{2}\delta_{EI\,EI}(\ln EI)^2 + \alpha_{YEI} \ln Y \ln EI + \sum_i^n \phi_{iEI} \ln W_i \ln EI + \sum_k^m \upsilon_k D_k$$
$$\beta_{ij} = \beta_{ji} \;;\; i,j = PM, OUTI, DA, \;\; n=3, \; m=5 \qquad (2)$$

Where C^v is the total variable port cost; Y is the service level, W_i is a set of three variable input prices for port work (WPM), equipment ($WOUTI$) and a proxy for the price of the auxiliary expenses (WDA). *NPHM* and *EI* are assumed to be fixed in the short run. We also introduced five dummy variables (*k*=*P*1, *P*2, *P*3, *P*4, *P*5)[1] to identify the effect of each product on the total cost. A dummy was deleted (*P*6) to avoid multicolinearity. Moreover, the relevant share equations have to be estimated simultaneously with the cost function. Using the Shephard's lemma (equation 3), the variable translog cost function can be logarithmically differentiated, yielding the cost shares associated with each variable input.

$$S_i = \partial \ln C^v / \partial \ln W_i = \beta_i + \sum_j \beta_{ij} \ln W_j + \alpha_{iY} \ln Y + \pi_{iNPHM} \ln NPHM + \varphi_{iEI} \ln EI$$
$$i,j = PM, OUTI, DA \qquad (3)$$

Since the data are mean-scaled for each variable, the logarithm will be equal to zero, and the mean share of the factor will equal its own price coefficient β_i in order to facilitate the interpretation of the results.

To comply with the necessity for the cost function (2) to be homogeneous of degree one in variable input prices, a doubling of all variables input prices has also been considered. We then imposed the following restriction on the parameters of the equation system:

$$\sum \beta_i = 1, \;\; \sum \alpha_{iY} = 0, \;\; \sum_i \beta_{ij} = \sum_j \beta_{ij} = 0, \;\; \sum_i \pi_{iNPHM} = 0 \;\; and \;\; \sum_i \phi_{iEI} = 0$$

One share equation is not considered to avoid singularity.

[1] For reasons related to confidentiality, products are coded as follows: P1, P2, P3, P4 for the bulk cargoes and P5, P6 for the break bulk cargoes.

Our final econometric model, then, consists of the variable cost function plus two share equations, with additive error terms. This system was estimated using the iterative technique of Zellner (1962), which is known as the Seemingly Unrelated Regression method. The Wald test was applied to check the validity of the various theoretical restrictions, then, under the null hypothesis, $W \sim \chi^2_Q$ (Q is the number of restrictions). This test was used to check the homotheticity of technology in the port and the unitary elasticity of substitution.

4.2. Estimation results

In this section, we will present the estimation results of our system of equations. The parameters are presented in table 2. While table 3 gives the results of the Wald test for parameter restrictions.

4.2.1. Restriction tests

Homothetic technology implies that the input proportions depend only on the input-price ratios. This also means that the demand for input is independent of the level of output ($\alpha_{iY} = 0$), which is quite restrictive in the port industry. In our study, the Wald test rejects the null hypothesis of homothetic technology in the port of Saint-Brieuc. The estimation also stresses that the elasticity of substitution for the port is not equal to the unity and therefore the production technology cannot be properly estimated using a Cobb-Douglas cost function, which assumes a unitary elasticity of substitution.

According to the estimation results (table 2), the cost function appears to be non-decreasing with regard to output and input prices as required by cost minimization. We also found that the equipment accounts for about 51% of the total variable costs, auxiliary expenses for 25% and port labor for 24%. This result is quite low compared to other estimations (76% in Kim and Sachish, 1986; 53% in Tovar et *al.*, 2005 and 43% in Coto-Millan et *al.*, 2000). The reason for this is because there is no Central Office of Labor; therefore, handling firms can recruit temporary workers paid at the minimum wage rather than stevedores. Labor costs in the port of Saint-Brieuc are considered to be three times lower than those of other French seaports.

The dummy variables also appear to be significant. Furthermore, the results stress that handling product P1 is less expensive than handling P3, the latter being less expensive than both P2 and P4. Finally, the handling of P6, (the dummy taken as a reference) is the most expensive. The handling process shows that the handling of P1 only concerns unloading operations while the handling of P3 implies only loading operations that require one to mobilize cranes for a longer period. Moreover, in the category of non-agro-alimentary bulk cargoes (P2, P3 and P4), the productivity for P3 is estimated at 160 tons per hour while it reaches 131 tons per hour for P2 and between 100 tons per hour (for import operations) and 200 (for export operations) for P4. It therefore explains why in our estimates one ton of P3 requires less labor and equipment than one ton of P2 and P4. Finally, the results stress that handling the break bulk cargoes (P5 and P6) is the most costly, because it mainly comprises of loading operations that are slower and more expensive. When it comes to the difference between the handling costs of the two categories of products, the cost for bulk cargoes is between 1.5 and €2 and around €5 for the break bulk products.

4.2.2. Long run equilibrium

Estimations about the long-run cost function assume that ports are in a long run equilibrium. We were in a position to test our model for potential over-capitalization or the supply of over-administrative staff by focusing on the relationship between the long-run and short-run costs. The long run cost function is given as :

$$C_{LT} = C^V(Y, WPM, WOUTI, WDA, EI, NPHM) + p_{EI}EI + p_{NPHM}NPHM \qquad (4)$$

Where p_{EI} is the cost of physical capital and p_{NPHM} is the price of the administrative staff. Long term cost minimization provided equation 4 to be minimized in relation to *EI* and *NPHM*, owing that *Y*, *WPM*, *WOUTI*, *WDA* are assumed to be exogenous and that C^v has already been minimized.

Table 2: Parameter estimates of the translog cost function

Variable	Parameter	Estimate	t-value
Constant	α_0 *	0.206342	1.726208
Y	α_Y ***	0.859214	13.75828
Y*Y	α_{YY} ***	0.422574	3.888925
WPM	β_{PM} ***	0.245521	12.52849
WOUTI	β_{OUTI} ***	0.519935	40.61479
WDA	β_{DA} ***	0.253794	20.18403
WPM*WPM	$\beta_{PM\,PM}$ ***	0.301575	3.105113
WOUTI*WOUTI	$\beta_{OUTIOUTI}$ ***	0.158383	2.827699
WDA*WDA	β_{DADA} ***	0.256480	3.761886
WPM*WDA	$\beta_{PM\,DA}$ *	-0.042179	-1.756481
WPM*WOUTI	$\beta_{PM\,OUTI}$ **	-0.107823	-2.315256
WOUTI*WDA	$\beta_{OUTI\,DA}$ **	-0.012478	-2.445432
WOUTI*Y	$\alpha_{OUTI\,Y}$ ***	0.148255	8.005366
WPM*Y	$\alpha_{PM\,Y}$ **	0.060541	2.238354
WDA*Y	α_{DAY} ***	-0.312015	-11.28970
NPHM	γ_{NPHM} ***	0.538030	2.715153
NPHM*NPHM	$\gamma_{NPHM\,NPHM}$ ***	25.845326	3.873013
EI	δ_{EI} ***	-1.257814	-4.821203
EI*EI	$\delta_{EI\,EI}$ ***	30.770005	2.928652
D_{P1}	υ_{P1} ***	-1.299545	-15.71025
D_{P2}	υ_{P2} ***	-0.548151	-13.77709
D_{P3}	υ_{P3} ***	-0.768022	-8.026676
D_{P4}	υ_{P4} ***	-0.561242	-16.26192
D_{P5}	υ_{P5} ***	-0.158799	-4.817337

* significant at 10%, ** significant at 5%, *** significant at 1%

Equation: Total cost	
R-squared	0.988943
Adjusted R-squared	0.970850
S.E. of regression	0.120965
Durbin-Watson stat	1.690006
Mean dependent var	-0.251245
S.D. dependent var	0.745242
Sum squared resid	0.155859
Equation: Cost share for machinery	
R-squared	0.834644
Adjusted R-squared	0.815565
S.E. of regression	0.059057
Durbin-Watson stat	1.601568
Mean dependent var	0.498517
S.D. dependent var	0.337520
Sum squared resid	0.088106
Equation: Cost share for labour	
R-squared	0.363272
Adjusted R-squared	0.289803
S.E. of regression	0.116520
Durbin-Watson stat	0.568925
Mean dependent var	0.228372
S.D. dependent var	0.138265
Sum squared resid	0.353000

Table 3: Wald test

Restriction	No. of restrictions	χ^2 values in the hypothesis	Critical χ^2
Homothetic	2	75.70***	9.21
Unitary elasticity of substitution	3	11.82***	11.34

*** Significant at 1%

The conditions for the long run cost minimization are then derived from the envelop conditions which state that:

$$(\partial C^V / \partial EI)_{EI=EI*} = -p_{EI} \quad (5a)$$

$$(\partial C^V / \partial NPHM)_{NPHM=NPHM*} = -p_{NPHM} \quad (5b)$$

Where $EI*$ and $NPHM*$ respectively stand for the optimal values of physical capital stock and the optimal number of administrative staff. Equation (5a) induces that the long-term cost minimization is reached when the variable cost saved by substituting the last unit of physical capital for variable inputs is equal to the marginal input cost of that unit, p_{EI}. A similar interpretation applies to (5b). Consequently, if the appropriate model to be selected is the long term function, the cost elasticities for physical capital and for administrative staff should both be negative. It appears that the coefficient associated with EI in the model is negative and significant. EI encompasses the expenses for real estate (maintenance and repair, renting costs for warehouses and concession). The negativity of this parameter stresses that the total cost decreases if the investment in storage capacity and maintenance expenses were to be increased. At the same time, the results show that the cost elasticity associated with administrative staff is positive and significant. This result would suggest that the total costs would decrease if administrative staff were to be reduced, without any changes to the quantity of the provided services. Owing to the idea that this elasticity should be negative, if the port is in a long run equilibrium path, we then conclude that the short run model is the most appropriate one.

4.2.3. Marginal cost and economies of scale

E The first order output term is positive, significant and therefore indicates that a one percent change in the output is associated with 0.86 percent increase in costs (Equation 6).

$$\partial \ln(C^v)/\partial \ln(Y) = \alpha_Y + \alpha_{YY} \ln Y + \sum_i^n \alpha_{iY} \ln W_i + \alpha_{YNPHM} \ln NPHM + \alpha_{YEI} \ln EI = 0.86 \quad (6)$$

We then transformed the equation into a marginal cost equation:

$$C_m = \partial \ln(C^v)/\partial \ln(Y) * \hat{C}^v / Y = 1.22 \quad (7)$$

To estimate economies of scale, we used previous findings by Christensen and Greene (1976) or Caves et *al.* (1979). According to their definition, we defined short run economies of scale as:

$$EE = 1 - \partial \ln(C^v)/\partial \ln(Y) = 1 - \alpha_Y - \alpha_{YY} \ln Y - \sum_i^n \alpha_{iY} \ln W_i - \alpha_{YNPHM} \ln NPHM - \alpha_{YEI} \ln EI \quad (8)$$

EE is positive when dealing with economies of scale and negative otherwise. Using mean-scaled data, with the last four terms on the right hand side of the previous equation being equal to zero, we found a coefficient equal to 0.129. This result is consistent with previous studies on economies of scale for ports applied either to infrastructures or services. In our specific case, the recent construction of a new terminal, which cannot be used at any tide level, might probably explain this result.

5. Conclusions

The aim of this paper was to carry out case study research to address the gaps in the existing levels of knowledge around cost structure in the port services. Indeed, the existing empirical studies have some limits due to the use of global statistics for the port activity. For this reason, we focus on the costs of one service: cargo handling in the port of Saint-Brieuc. Furthermore, as Talley and Ng (2016) noticed, the literature describes the port output as a service product but measures it as a physical one. Therefore, we have been careful when taking into account the characteristics of a seaport "service" in the construction of our model. For example, we consider data for all the six treated goods including those that pass through the seaport. The quality of the cargo handling service is also measured through the inspection and control employees.

The result estimation and the application of the Wald test show that the chosen model is appropriate. Our results also suggest that the port may have an over employment of administrative staff and a limited capacity when it comes to its long term efficiency. Policymakers are advised to invest in storage capacity, to avoid congestion, and review their employment policy. Lastly, a finding from this paper comes from the estimation of economies of scale as well as from marginal costs. The results suggest that increasing returns to scale exist and, therefore, the application of tariffs at a marginal cost might not help cover the total costs in case the port authority decides to set a price cap equal to the marginal cost.

Further research needs to be undertaken to give more conclusive results. This would require a larger database that includes all the costs for the other port services (services to vessels, to vehicles, etc.). This would give an insightful analysis into the service costs and may result in a policy guideline on this area of seaport management.

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