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The importance of multi output of cargo handling activities in the port industry

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The importance of multi output of cargo handling activities in the port industry

Abstract

Cargo handling activities in ports have been usually analysed using aggregate descriptions of output such as total tons moved. These activities, however, involve various heterogeneous outputs, e.g. general cargo, containers, dry and liquid bulk, and so on. The main purpose of this paper is to show that ignoring this heterogeneity may lead to two types of problems of interest to policy makers and sector regulators: the underestimation of the relevance of key dimensions (i.e. marginal costs per product and economies of scope) and a bias in the estimates of the relevance of other dimensions (economies of scale). To do so, we rely on a unique new set of data based on information collected from three cargo handling firms operating in a Spanish port between 1991 and 1999. We use it to estimate both a multi-output cost for these three operators as well as an aggregate cost function. The policy conclusions are derived from an explicit and detailed comparison of these two sets of estimates.

Key words: multiproduct, economies of scale and scope, port and cargo handling.

JEL Classification system: L9

1. Introduction: Cargo handling in multipurpose port terminals

Up to now, the analysis of cargo handling and port activities has, in general, relied on an aggregate measure of output such as total tons moved or its value, as in Chang (1978), Rekers et al. (1990), Tongzon (1993), Kim and Sachis (1986) and Martínez Budría (1996). In this paper we first follow this tradition, analyzing cargo handling activities through the estimation of a cost function with output described as total volume handled and we derive marginal costs, scale economies as well as some policy conclusions from this initial estimation. Then we compare these "traditional" results with those arising from an explicit modelling of the heterogeneity of the output. This comparison allows us to document that various ways in which the analysis based on a synthetic output indicator misleads policymaking.

2. Data and aggregate model formulation

We focus on a cost function *C(W,Y)* which represents the minimum expenditure necessary to produce *output Y* at given input prices *W*. Its estimation requires data on expenditure, production and input prices for one or more firms during one or more periods. Our data was collected directly from three private medium size firms operating within the port area of Las Palmas de Gran Canaria, one of the largest in the Spanish port system. They deal mainly with containers (87% of total volume), but also operate roll-on/roll-off cargo (ro-ro, 3%) as well as general break-bulk (general) cargo (10%). We collected 264 monthly observations from 1991 through 1999 (not all years available for all three firms).

The productive factors have been grouped into four categories: personnel, total area, capital and intermediate inputs. The personnel working in port terminals may be classified in two categories: stevedores or port workers, who handle cargo, and non-port workers, who do not (administratives, executives, maintenance and control personnel, among others). In turn, port workers are divided into two categories: those who are on the payroll (ordinary employment) and those who are not (special employment). This latter category can be recruited on a provisional basis by any company to work 6-hour shifts, under the management of the *Sociedad Estatal de Estiba y Destiba (SEED)*.

Capital encompasses all the components of tangible assets of the company —i.e. buildings, machines, etc. The monthly cost results from the addition of the accounting depreciation for the period plus the return on the active capital of the period. This rate of return evidences the compensation earned by risk-free capital, which is made up of bank interest plus a risk premium. For the period under analysis the return for both concepts amounts to 8% per annum. Lastly, the rest of the productive factors used by the company that have not been included in any of the three preceding categories, such as office supplies, water, electricity, and the like, have been classified as intermediate consumption.

Regarding occupied space, each terminal can make use of an area that has been granted under concession, which may be increased by provisionally renting —upon prior request— additional area from the port authority, turning area into a variable factor

With this information, a quadratic long run cost function (1) was estimated along with the input expenses equations (2) obtained using Shephard's lemma

$$\begin{aligned} CT &= A_0 + \alpha(y-\overline{y}) + \sum_{i=1}^{n}\beta_i(p_i-\overline{p_i}) + \phi(T-\overline{T}) \\ &+\frac{1}{2}(y-\overline{y})^2 + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_{ij}(p_i-\overline{p_i})(p_j-\overline{p_j}) \\ &+\sum_{j=1}^{n}\rho_j(y-\overline{y})(p_j-\overline{p_j}) + \lambda(y-\overline{y})(T-\overline{T}) + \sum_{i=1}^{n}\mu_i(p_i-\overline{p_i})(T-\overline{T}) \\ &+\pi(T-\overline{T})(T-\overline{T}) + \sum_{i=1}^{N}\vartheta_i D_i \end{aligned} \qquad (1)$$

$$G_i = p_i \cdot x_i = p_i \cdot \left[\beta_i + 2\gamma_{ii}(p_i-\overline{p_i}) + \sum_{j\neq i}^{m}\gamma_{ij}(p_j-\overline{p_j}) + \rho_i(y-\overline{y}) + \mu_i(T-\overline{T})\right] \qquad (2)$$

where y is the amount of output, p_i is input i price, n is the number of inputs, D_i are firm specific dummies to capture specific effects, N is the number of firms and T is time trend, included to capture possible technical change. Variables with a horizontal bar on top are sample means.

3. The aggregate (single) output cost

In this section, we follow the tradition of the last 30 years or so in the sector and we estimate a cost function estimated for a single synthetic output. Table 1 shows all the first order coefficients that are relevant for our interpretation of results.

All first order parameters are statistically significant and have the expected signs with the exception of the trend coefficient that has a counterintuitive positive sign indicating that, everything else constant, cost increases with time. The dummy variables are both negative and similarly small, indicating that the smaller firms would exhibit some 2.3% less costs than the larger one if the three produced the mean amount. The single marginal cost estimated at the mean is 715 pesetas/ton and the corresponding value of the degree of economies of scale (the inverse of the cost-product elasticity) is S=1.959, indicating clear increasing returns. These results are fairly compatible with the average cost curve presented in Figure 1 based on the aggregated production volume. The curve looks as a traditional long run one, and graphically suggests the presence of economies of scale and, therefore, marginal costs that should fall below the average figures, i.e. less than 750 pesetas/ton, as obtained.

Marginal cost calculated at the mean production of each firm (terminal) yields little variation (from 706 to 724 pesetas/ton), but scale economies at each mean do vary, yielding 2.38, 3.01 and 1.22 for firms 1, 2 and 3 respectively, monotonically decreasing with average production.

According to these results, all three firms should be encouraged to increase production to take advantage of scale economies. All three occupy neighbouring sites. Pushing the three firms to merge and operate as one could be convenient. If optimal prices were a target, charging marginal cost per ton would require a modest subsidy or, if this is not wanted, a single second best price equal to the average cost in the neighbourhood of 1420 pesetas could be set, accepting a modest social loss. Regulation would play an important role.

INSERT TABLE 1 ABOUT HERE

INSERT FIGURE 1 ABOUT HERE

4. The multi-output cost function.[1]

In this section, we use the same information to estimate a long run cost function where outputs are individually identified, namely, the volume of containers, general cargo and ro-ro and modelled explicitly. The model specification is just as the previous function (1) and equations (2) but in this case we have a vector of outputs and each output is identified as y_i.with i going from 1 to 3, making this a multioutput cost function.

Table 2 contains all the relevant coefficients of this long run multioutput cost function. It shows very clearly that marginal cost estimates do vary across products. It also shows the expected ranking: containers exhibit the lowest value, followed by ro-ro cargo and general cargo. As the average cost figure is not useful in this case, these results were compared against maximum tariffs currently applied at the port, grouped by type of cargo. They happen to follow the same relative ranking and to be always above our marginal costs estimates, which reinforces the quality of the estimation. Note that the marginal costs for both general cargo and

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[1] This section is based on Jara Díaz et al (2005)

ro-ro are definitely larger than the maximum single figure that could be expected from the pseudo average cost curve in Figure 1.

The differences among the estimated marginal costs by product are fully consistent with the underlying technical aspects. Handling general cargo presents complicated operations to a degree where machines are less important than labour. Nevertheless, the figures per firm suggest that volume plays a role as well, as the firm that moves a larger quantity (firm 2) exhibits the lowest marginal cost for this output (see Table 3 below).

On the other hand, the marginal cost estimates for ro-ro (some 40% larger than those of the containers) seem to respond to two effects. In general, operations are simpler than those for containers, making some stages disappear, and they require less equipment. However, space is fundamental for this type of movement and its volume is lower, which seems to influence marginal cost.

INSERT TABLE 2 ABOUT HERE

The trend variable is negative, as expected, and the firm specific dummies are both small and close to 2,5 % of the cost at the mean. The global degree of scale economies is 1.64 and the product specific degree of returns to scale is practically one for all three outputs. This suggests that economies of scope are present, as these magnify specific scale economies.

The product specific degrees of scale economies are all close to unity, which suggests that the reason for the difference between the global figures on scale, are due to the possible presence of economies of scope, which magnifies scale, something impossible to verify with the aggregate approach. If we analyse all possible orthogonal partitions of the product set into two firms, one handling a single output and the other handling the other two, the degree of economies of scope are all close to 0.39. This means that it is better to handle all three cargo types with one firm than to create an additional firm to take care of one output, provided that all three outputs have to be handled. This merits further discussion.

Product specific scale economies close to one mean that the incremental cost (cost of the addition of that product to the line) is similar to the marginal variation of total cost, which fits intuition. But it also means that are economies of scope what causes overall economies of scale, due to the presence of common (non operative) costs related to non port personnel and general expenses, plus some complementarities in production provoked by common use of the surface space, labour managed by the firm, shore cranes used for containers and some form of general cargo, and so on.

Finally, scale economies are noted for the two smallest firms as the calculated values for S are 2.26 and 2.13. For the largest one, this value is 1.08, reflecting nearly constant returns to scale. These results coupled with those regarding scope suggest that the two small firms could be allowed to merge, as they are located in neighbouring sites. This would maintain some degree of competition in the market.

5. Comparisons and discussion.

The comparison of the results of the cost functions estimated from the two specifications of product offers a wide range of insights along various dimensions, including the dispersion of marginal costs of the various outputs, the economies of scale as well as the economies of scope as seen in Table 3. These should be of interest to a wide range of policy makers, including reformers, regulators and competition agencies.

Table 3 shows that the marginal cost estimates for containers are some 4%

larger than the corresponding figures obtained from the aggregate model. However, ro-ro marginal costs are between 44% and 55% larger than the single figure for each firm. The most impressive differences are found for general cargo, where marginal costs are more than 170% larger for the disaggregate model than for the original one. Moreover, note that for the disaggregated models, the differences in marginal cost estimates among terminals are very small and the order is the same. The similarity of the figures for marginal costs for the aggregate estimate of the fist model and the estimate for containers in the second model seems to be a consequence of the important volume of containers at each terminal, which vary from 76 to 97%.

INSERT TABLE 3 ABOUT HERE

The firm specific dummies become some 10% more negative than in the aggregate model. It keeps a relatively low value for the constant, which is an estimate of the cost of the largest firm at the mean. However, the time coefficient becomes negative, as expected.

Regarding scale economies with multiple outputs (see Appendix), the overall figure of 1.64 is smaller than the 1.96 obtained with the aggregate model. But this hides even larger differences when individual firms are considered, as the three figures drop from 2.38, 3.01 and 1.22 to 2.26, 2.13 and 1.08 respectively when output is correctly specified. This means that the largest terminal has reached constant returns. Therefore, the policy conclusions change dramatically, as the aggregate results suggest that merging could be desirable from a cost viewpoint, charging an optimal price of about 1420 pesetas per ton moved, while the disaggregate model would call for the two smallest firms to join operations, keeping competition with the largest that has already reached constant returns. Different prices should be charged for the movement of one ton moved in a container, as a ro-ro, or as fractioned general cargo, with prices above 760, 1120 and 2040 pesetas/ton respectively, the extra charge depending on the price elasticity of demand.

6. Conclusions.

Port activities have been usually analysed describing output through some synthetic measure of total volume of cargo moved. Inputs required, however, differ according to the type of cargo handled. Furthermore, input combinations also vary depending on the packaging. When output is described as a scalar hiding multiple outputs, the observed variation in total output (volume) may reflect a wide range of variations in each of the individual outputs

This causes various important problems. For instance, if product specific marginal costs are actually very different, a single synthetic figure will mislead any discussion on optimal pricing. Also, the impossibility of estimating economies of scope will bias the estimate of scale economies, because potential advantages (or disadvantages) of joint production will not be captured properly. These problems have various policy implications.

The first is from the viewpoint of a regulator concerned with the optimal pricing of the sector activities. In this context, this note shows how important it is to recognize the consequences of the failure to model explicitly the cost diversity associated with the output diversity. This failure can lead to very significant distortions in resources allocations in an industry in which residual monopoly power or at least the risks of collusion between a few operators can be quite important.

From the viewpoint of a competition agency, the note clearly illustrates the value of making better use of the information available on the composition of the output. Indeed, in the case analyzed here, the multioutput approach makes a clear case to allow only two of the three terminals to merge while with the single output model would have endorsed the merger of the three operators.

From the point of view of a sector reformer, in addition to providing some evidence on the existence of a limit to the unbundling into terminals of port activities, the paper also shows that reformers should consider more carefully the limits to specialization in the sector. Indeed, the information on the economies of scope generated by the multioutput approach provides some guidance on the optimal market structure for the industry. It shows that the operators are better off not specializing, competing on the three main business lines available instead. This is an important consideration in an industry undergoing, or subject to pressure to undergo, restructuring around the world and in which specialization is often one of the expected outcomes.

Overall, what this note highlights is that the proper approach to analyse port activities is multi-productive, and the consequences of not taken into account this important fact are quite relevant for the adequate regulation in cargo handling port activities. Single output studies could suggest erroneous structures.

Acknowledgements.

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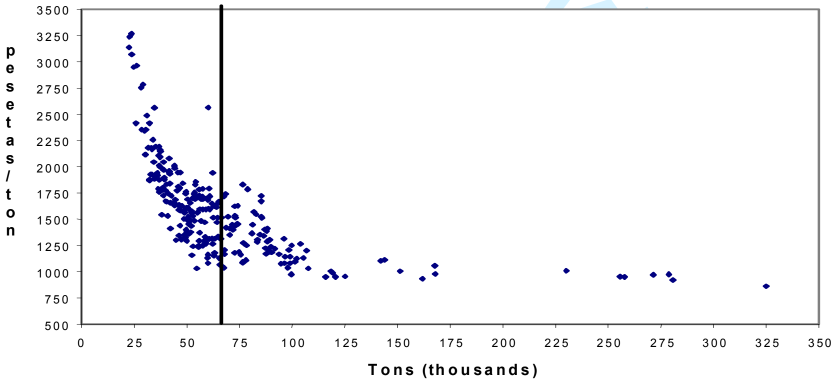
Table 1. First order coefficients from the long run aggregated model.

Parameter	Estimate	***t*-statistic**
Total cost at the mean (thousand ptas)	**95960.00**	**120.23**
Marginal cost (ptas/ton)	**715.90**	**33.18**
Demand for ordinary workers (worked hours)	**1.56**	**62.86**
Demand for special workers (worked hours)	**2.33**	**42.28**
Demand for intermediate consumption (thousand ptas)	**981.39**	**87.59**
Demand for total area (m^2)	**61755.30**	**103.51**
Demand for capital (thousand ptas)	**575120.00**	**38.43**
Demand for non-port workers (number of men)	**0.02**	**72.55**
Trend	**83.30**	**2.55**
Dummy T1 (thousand ptas)	**-2227.64**	**-10.98**
Dummy T2 (thousand ptas)	**-2212.13**	**-8.25**

Figure 1. Average Cost Curve.



Source: Tovar de la Fé (2002).

Table 2. First order coefficients from the long run multioutput cost function

Parameter	Estimate	*t*-statistic
Total cost at the mean	**96680.2**	**140.02**
Marginal cost containers (ptas/ton)	**744.568**	**28.4829**
Marginal cost general cargo (ptas/ton)	**1973.57**	**14.192**
Marginal cost ro-ro cargo (ptas/ton)	**1055.81**	**2.96036**
Demand for ordinary workers (worked hours)	**1.57645**	**69.7386**
Demand for special workers (worked hours)	**2.33895**	**45.8603**
Demand for intermediate consumption (thousand ptas)	**982.53**	**87.2994**
Demand for total area (m^2)	**61592.9**	**106.851**
Demand for capital (thousand ptas)	**583266**	**40.6078**
Demand for non-port workers (number of men)	**0.021919**	**76.6747**
Trend	**-67.0148**	**-1.96005**
Dummy T1(thousand ptas)	**-2460.71**	**-11.1526**
Dummy T2 (thousand ptas)	**-2479.14**	**-7.86803**

Source: Jara-Díaz et al. (2005).

Table 3. Marginal costs (MC) and scale economies (ES) by firm for the two models

	Model with aggregated output		Model with disaggregated output	
Terminal 1			MC containers (ptas/ton)	743,866(*)
	MC (ptas/ton)	720,232(*)	MC general cargo (ptas/ton)	1993,92(*)
			MC ro-ro cargo (ptas/ton)	1116,78(*)
	ES	2,38113(*)	ES	2,2577(*)
Terminal 2			MC containers (ptas/ton)	735,383(*)
	MC (ptas/ton)	706,529(*)	MC general cargo (ptas/ton)	1914,77(*)
			MC ro-ro cargo (ptas/ton)	1017,11(*)
	ES	3,00650(*)	ES	2,1259(*)
Terminal 3			MC containers (ptas/ton)	757,006(*)
	MC (ptas/ton)	724,277(*)	MC general cargo (ptas/ton)	2031,77(*)
			MC ro-ro cargo (ptas/ton)	1053,38(*)
	ES	1,21561(*)	ES	1,0752(*)
sample mean	ES	1,95901(*)	ES	1,64416(*)
			ES containers	1,00548(*)
			ES general cargo	1,00147(*)
			ES ro-ro cargo	1,08108(*)

* statistically significant at 5%.

On the proper modelling of multioutput port cargo handling costs

Abstract

Cargo handling activities involve various heterogeneous outputs, e.g. general cargo, containers, dry and liquid bulk, and so on. These activities in ports, however, have been usually analysed using aggregate descriptions of output such as total tons moved. The main purpose of this paper is to show that ignoring this heterogeneity may lead to two types of problems: (i) the underestimation of the relevance of key dimensions (i.e. marginal costs per product and economies of scope) and (ii) a bias in the estimates of the relevance of other dimensions (economies of scale). To do so, we rely on a unique new dataset on three cargo handling firms operating in a Spanish port between 1991 and 1999. We use it to estimate both a multi-output cost for these three operators as well as an aggregate cost function. The policy conclusions are derived from an explicit and detailed comparison of these two sets of estimates.

Key words: multiproduct, economies of scale and scope, port and cargo handling.

JEL Classification system: L9

1. Introduction

Up to now, the analysis of cargo handling and port activities has, in general, relied on an aggregate measure of output such as total tons moved or its value, as in Chang (1978), Rekers et al. (1990), Tongzon (1993), Kim and Sachis (1986) and Martínez Budría (1996). In this paper we first follow this tradition, analyzing cargo handling activities through the estimation of a cost function with output described as total volume handled and we derive marginal costs, scale economies as well as some policy conclusions from this initial estimation. Then we compare these "traditional" results with those arising from an explicit modelling of the heterogeneity of the output. This comparison shows that the usual type of analysis based on a synthetic output indicator can mislead policymaking, particularly in terms of marginal costs, which affects pricing, and economies of scale and scope, which helps detecting optimal industry structure.

2. Variables description and cost model

We focus on a cost function $C(W,Y)$ which represents the minimum expenditure necessary to produce *output* Y at given input prices W. Its estimation requires data on expenditure, production and input prices for one or more firms during one or more periods. Our data was collected directly from three private medium size firms operating within the port area of Las Palmas de Gran Canaria, one of the largest in the Spanish port system. They deal mainly with containers (87% of total volume), but also operate roll-on/roll-off cargo (ro-ro, 3%) as well as general break-bulk (general) cargo (10%). We collected 264 monthly observations from 1991 through 1999 (not all years available for all three firms).

The productive factors have been grouped into four categories: personnel, total area (surface space) occupied for cargo handling, capital and intermediate inputs. The personnel working in port terminals may be classified in two categories: stevedores or port workers, who handle cargo, and non-port workers, who do not (administratives, executives, maintenance and control personnel, among others). In turn, port workers are divided into two categories: those who are on the payroll (ordinary employment) and those who are not (special employment). This latter category can be recruited on a provisional basis by any company to work 6-hour shifts, under the management of the *Sociedad Estatal de Estiba y Destiba (SEED)*. The price of each type of labour is calculated as the corresponding monthly expenses divided by the number of worked hours.

Capital encompasses all the components of tangible assets of the company —i.e. buildings, machines, etc. The monthly capital cost results from the addition of the accounting depreciation for the period plus the return on the active capital of the period. This rate of return evidences the compensation earned by risk-free capital, which is made up of bank interest plus a risk premium. For the period under analysis the return for both concepts amounts to 8% per annum. The price of capital is calculated as the ratio of the capital cost over the active capital of the period (net fixed assets under exploitation for a given period).

Regarding occupied space, each terminal can make use of an area granted under concession by the port authority. This surface may be increased by provisionally renting additional area from the port authority, turning the total area used by the operator into a variable production factor, as it can be accommodated on demand. It is measured in square meters, and its price is calculated as the ratio of the area-related monthly expenses over the total area used that corresponding month.

Lastly, the rest of the productive factors used by the company that have not been included in any of the three preceding categories, such as office supplies, water, electricity, and the like, have been classified as intermediate consumption. The price of electricity has been used as an index of the price of intermediate consumption, as the price of the other components do not undergo changes.

The total monthly production expenses for each of the terminals result from the aggregation of expenses over all the productive factors defined above. Among those factors, labor shows the largest share of terminal expenditure in the sample, representing an average of 53% of the monthly expenses[1]. Note that this is the same figure obtained by Cullinane et al. (2003) for Korean container terminals.

This data was used to estimate a quadratic long run cost function (1) and the input expenses equations (2) obtained using Shephard's lemma

$$\begin{aligned} CT &= A_0 + \alpha(y-\overline{y}) + \sum_{i=1}^{n}\beta_i(p_i-\overline{p_i}) + \phi(T-\overline{T}) \\ &+ \frac{1}{2}(y-\overline{y})^2 + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_{ij}(p_i-\overline{p_i})(p_j-\overline{p_j}) \\ &+ \sum_{j=1}^{n}\rho_j(y-\overline{y})(p_j-\overline{p_j}) + \lambda(y-\overline{y})(T-\overline{T}) + \sum_{i=1}^{n}\mu_i(p_i-\overline{p_i})(T-\overline{T}) \\ &+ \pi(T-\overline{T})(T-\overline{T}) + \sum_{i=1}^{N}\vartheta_i D_i \end{aligned} \qquad (1)$$

$$G_i = p_i \cdot x_i = p_i \cdot \left[\beta_i + 2\gamma_{ii}(p_i-\overline{p_i}) + \sum_{j\neq i}^{m}\gamma_{ij}(p_j-\overline{p_j}) + \rho_i(y-\overline{y}) + \mu_i(T-\overline{T})\right] \qquad (2)$$

where y is the amount of output, p_i is input i price, n is the number of inputs, D_i are firm specific dummies to capture specific effects, N is the number of firms and T is time trend, included to capture possible technical change. Variables with a horizontal bar on top are sample means.

3. The aggregate (single) output cost

In this section, we follow the tradition of the last 30 years or so in the sector and we estimate a cost function for a single synthetic output. Table 1 shows all the first order coefficients that are relevant for our interpretation of results.

All first order parameters are statistically significant and have the expected signs with the exception of the trend coefficient that has a counterintuitive positive sign indicating that, everything else being constant, cost increases with time. The

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[1] Total area, capital and intermediate consumption represent 13%, 8%, and 26%

dummy variables are both negative and similarly small, indicating that the smaller firms would exhibit some 2.3% less costs than the larger one if the three produced the mean amount. The single marginal cost estimated at the mean is 715 pesetas/ton and the corresponding degree of economies of scale (the inverse of the cost-product elasticity) is S=1.959, indicating clear increasing returns.[2] These results are fairly compatible with the average cost curve presented in Figure 1 based on the aggregated production volume. The curve looks as a traditional long run one, and graphically suggests the presence of economies of scale and, therefore, marginal costs that should fall below the average figures, i.e. less than 750 pesetas/ton.

Marginal cost calculated at the mean production of each firm (terminal) yields little variation (from 706 to 724 pesetas/ton), but scale economies at each mean do vary, yielding 2.38, 3.01 and 1.22 for firms 1, 2 and 3 respectively, monotonically decreasing with average production.

According to these results, all three firms should be encouraged to increase production to take advantage of scale economies. As they occupy neighbouring sites, pushing the three firms to merge and operate as one could be convenient. If optimal prices were a target, charging marginal cost per ton would require a modest subsidy. If it is not a goal, a single second best price equal to the average cost in the neighbourhood of 1420 pesetas could be set, accepting a modest social loss. For synthesis, the single output approach yields clear implications for regulation, as increasing returns suggest that a single operator would be cost-efficient, but price regulation should be imposed. We will see in the next section that this is not necessarily so.

INSERT TABLE 1 ABOUT HERE

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respectively.

INSERT FIGURE 1 ABOUT HERE

4. The multi-output cost function.[3]

In this section, we use the same information to estimate a long run cost function where outputs are individually identified, namely, the volume of containers, general cargo and ro-ro, which are modelled explicitly. The model specification is just as the previous function (1) and equations (2) but in this case we have a vector of outputs and each output is identified as y_i.with *i* going from 1 to 3, making this a multioutput cost function.

Table 2 contains all the relevant coefficients of this long run multioutput cost function. It shows very clearly that marginal cost estimates do vary across products. It also shows the expected ranking: containers exhibit the lowest value, followed by ro-ro cargo and general cargo. As average cost figures are undefined in a multioutput context, these results were compared against maximum tariffs currently applied at the port, grouped by type of cargo. They happen to follow the same relative ranking and to be always above our marginal costs estimates, which reinforces the quality of the estimation. Note that the marginal costs for both general cargo and ro-ro are definitely larger than the maximum single figure that could be expected from the pseudo average cost curve in Figure 1.

INSERT TABLE 2 ABOUT HERE

The differences among the estimated marginal costs by product are fully consistent with the underlying technical aspects. Handling general cargo presents complex operations to a degree where machines are less important than labour.

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[2] **Note: 1 Euro ( ) = 166.386 pesetas**

[3] This section is based on Jara Díaz et al (2005)

Nevertheless, the figures per firm suggest that volume plays a role as well, as the firm that moves a larger quantity (firm 2) exhibits the lowest marginal cost for this output (see Table 3 below).

On the other hand, the marginal cost estimates for ro-ro (some 40% larger than those of the containers) seem to respond to two effects. In general, operations are simpler than those for containers, making some stages disappear, and they require less equipment. However, space is fundamental for this type of movement and its volume is lower, which seems to influence marginal cost.

The trend variable is negative, as expected, and the firm specific dummies are both small and close to 2,5 % of the cost at the mean. The global degree of scale economies is 1.64 and the product specific degree of returns to scale is practically one for all three outputs. This suggests that economies of scope are present, as these magnify specific scale economies.

The product specific degrees of scale economies are all close to unity (see Table 3 below), which suggests that the reason for the difference between the global figures on scale, are due to the possible presence of economies of scope, which magnifies scale, something impossible to verify with the aggregate approach. If we analyse all possible orthogonal partitions of the product set into two firms, one handling a single output and the other handling the other two, the degree of economies of scope are all close to 0.39. This means that it is better to handle all three cargo types with one firm than to create an additional firm to take care of one output, provided that all three outputs have to be handled. This merits further discussion.

Product specific scale economies close to one mean that the incremental cost (cost of the addition of that product to the line) is similar to the marginal variation of total cost, which fits intuition. But it also means that are economies of scope what causes overall economies of scale, due to the presence of common (non operative) costs related to non port personnel and general expenses, plus some complementarities in production provoked by common use of the surface space, labour managed by the firm, shore cranes used for containers and some form of general cargo, and so on.

Finally, note that the two smallest firms exhibit strongly increasing returns to scale as the calculated values for S are 2.26 and 2.13. For the largest one, however, this value is 1.08, reflecting nearly constant returns to scale. These results coupled with those regarding scope suggest that the two small firms could be allowed to merge, as they are located in neighbouring sites. This would maintain some degree of competition in the market.

5. Aggregate versus disaggregate models.

The comparison of the results of the cost functions estimated from the two specifications of product offers a wide range of insights along various dimensions, including the dispersion of marginal costs of the various outputs, the economies of scale as well as the economies of scope as seen in Table 3. These should be of interest to a wide range of policy makers, including reformers, regulators and competition agencies[4].

Table 3 shows that the marginal cost estimates for containers are some 4% larger than the corresponding figures obtained from the aggregate model. However, ro-ro marginal costs are between 44% and 55% larger than the single figure for each firm. The most impressive differences are found for general cargo, where marginal costs are more than 170% larger for the disaggregate model than for the original one. Moreover, note that for the disaggregated models, the differences in marginal cost estimates among terminals are very small and the order is the same. The similarity of the figures for marginal costs for the aggregate estimate of the

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[4] The role that multioutput cost function estimation could play in the debate about regulation is recognised in other sectors as well. For example, Fraquelli et al. (2004)

first model and the estimate for containers in the second model seems to be a consequence of the important volume of containers at each terminal, which vary from 76 to 97%.

INSERT TABLE 3 ABOUT HERE

The firm specific dummies become some 10% more negative than in the aggregate model. It keeps a relatively low value for the constant, which is an estimate of the cost of the largest firm at the mean. However, the time coefficient becomes negative, as expected.

Regarding scale economies with multiple outputs, the overall figure of 1.64 is smaller than the 1.96 obtained with the aggregate model. But this hides even larger differences when individual firms are considered, as the three figures drop from 2.38, 3.01 and 1.22 to 2.26, 2.13 and 1.08 respectively when output is correctly specified. This means that the largest terminal has reached constant returns. Therefore, the policy conclusions change dramatically, as the aggregate results suggest that merging could be desirable from a cost viewpoint, charging an optimal price of about 1420 pesetas per ton moved, while the disaggregate model would call for the two smallest firms to join operations, keeping competition with the largest that has already reached constant returns. Different prices should be charged for the movement of one ton moved in a container, as a ro-ro, or as fractioned general cargo, with prices above 760, 1120 and 2040 pesetas/ton respectively, the extra charge depending on the price elasticity of demand.

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analyzed scope and scale economies in multi-utilities; and Sav (2004) applied this methodology to the higher education for public and private sector .

6. Conclusions.

Port activities have been usually analysed describing output through some synthetic measure of total volume of cargo moved. Inputs required, however, differ according to the type of cargo handled. Furthermore, input combinations also vary depending on the packaging. When output is described as a scalar hiding multiple outputs, the observed variation in total output (volume) may reflect a wide range of variations in each of the individual outputs

This causes various important problems. For instance, if product specific marginal costs are actually very different, a single synthetic figure will mislead any discussion on optimal pricing. Also, the impossibility of estimating economies of scope will bias the estimate of scale economies, because potential advantages (or disadvantages) of joint production will not be captured properly. These problems have various policy implications.

The first is from the viewpoint of a regulator concerned with the optimal pricing of the sector activities. In this context, this paper shows how important it is to recognize the consequences of the failure to model explicitly the cost diversity associated with the output diversity. This failure can lead to very significant distortions in resources allocations in an industry in which residual monopoly power or at least the risks of collusion between a few operators can be quite important.

From the viewpoint of a competition agency, the paper clearly illustrates the value of making better use of the information available on the composition of the output. Indeed, in the case analyzed here, the multioutput approach makes a clear case to allow only two of the three terminals to merge while results with the single output model would have endorsed the merger of the three operators.

From the point of view of a sector reformer, in addition to providing some evidence on the existence of a limit to the unbundling into terminals of port activities, the paper also shows that reformers should consider more carefully the limits to specialization in the sector. Indeed, the information on the economies of scope generated by the multioutput approach provides some guidance on the optimal market structure for the industry. It shows that the operators are better off not specializing, competing on the three main business lines available instead if the three are to be produced. This is an important consideration in an industry undergoing, or subject to pressure to undergo, restructuring around the world and in which specialization is often one of the expected outcomes.

Overall, what this note highlights is that the proper approach to analyse port activities is multi-productive. Ignoring this important fact may distort regulatory decisions in the cargo handling port activities. Single output studies could suggest erroneous structures. which ultimately would hurt the users of these port services.

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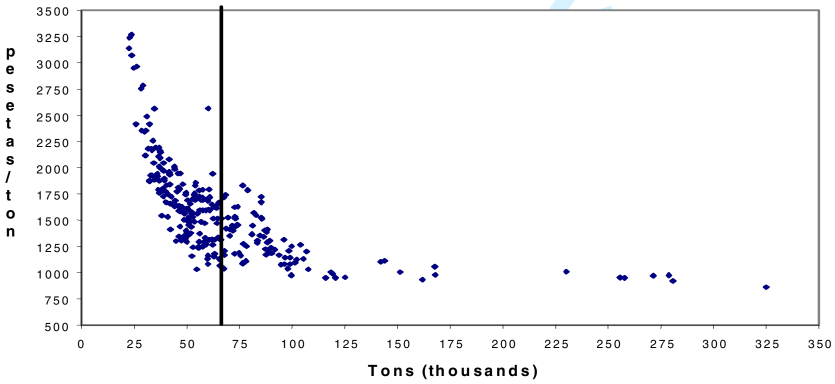
Table 1. First order coefficients from the long run aggregated model.

Parameter	Estimate	*t*-statistic
Total cost at the mean (thousand ptas)	**95960.00**	**120.23**
Marginal cost (ptas/ton)	**715.90**	**33.18**
Demand for ordinary workers (worked hours)	**1.56**	**62.86**
Demand for special workers (worked hours)	**2.33**	**42.28**
Demand for intermediate consumption (thousand ptas)	**981.39**	**87.59**
Demand for total area (m^2)	**61755.30**	**103.51**
Demand for capital (thousand ptas)	**575120.00**	**38.43**
Demand for non-port workers (number of men)	**0.02**	**72.55**
Trend	**83.30**	**2.55**
Dummy T1 (thousand ptas)	**-2227.64**	**-10.98**
Dummy T2 (thousand ptas)	**-2212.13**	**-8.25**

Note: 1 = 166.386 pesetas

Figure 1. Average Cost Curve.



Source: Tovar (2002).

Note: 1 = 166.386 pesetas

Table 2. First order coefficients from the long run multioutput cost function

Parameter	Estimate	*t*-statistic
Total cost at the mean	**96680.2**	**140.02**
Marginal cost containers (ptas/ton)	**744.568**	**28.4829**
Marginal cost general cargo (ptas/ton)	**1973.57**	**14.192**
Marginal cost ro-ro cargo (ptas/ton)	**1055.81**	**2.96036**
Demand for ordinary workers (worked hours)	**1.57645**	**69.7386**
Demand for special workers (worked hours)	**2.33895**	**45.8603**
Demand for intermediate consumption (thousand ptas)	**982.53**	**87.2994**
Demand for total area (m^2)	**61592.9**	**106.851**
Demand for capital (thousand ptas)	**583266**	**40.6078**
Demand for non-port workers (number of men)	**0.021919**	**76.6747**
Trend	**-67.0148**	**-1.96005**
Dummy T1(thousand ptas)	**-2460.71**	**-11.1526**
Dummy T2 (thousand ptas)	**-2479.14**	**-7.86803**

Source: Jara-Díaz et al. (2005).

Note: 1 = 166.386 pesetas

Table 3. Marginal costs (MC) and scale economies (ES) by firm for the two models

	Model with aggregated output		Model with disaggregated output	
Terminal 1			MC containers (ptas/ton)	743,866(*)
	MC (ptas/ton)	720,232(*)	MC general cargo (ptas/ton)	1993,92(*)
			MC ro-ro cargo (ptas/ton)	1116,78(*)
	ES	2,38113(*)	ES	2,2577(*)
Terminal 2			MC containers (ptas/ton)	735,383(*)
	MC (ptas/ton)	706,529(*)	MC general cargo (ptas/ton)	1914,77(*)
			MC ro-ro cargo (ptas/ton)	1017,11(*)
	ES	3,00650(*)	ES	2,1259(*)
Terminal 3			MC containers (ptas/ton)	757,006(*)
	MC (ptas/ton)	724,277(*)	MC general cargo (ptas/ton)	2031,77(*)
			MC ro-ro cargo (ptas/ton)	1053,38(*)
	ES	1,21561(*)	ES	1,0752(*)
sample mear	ES	1,95901(*)	ES	1,64416(*)
			ES containers	1,00548(*)
			ES general cargo	1,00147(*)
			ES ro-ro cargo	1,08108(*)

- statistically significant at 5%.

Note: 1 = 166.386 pesetas