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Demand uncertainty and overcapacity in port infrastructures: the role of passengers and the effect of regulation

Incertidumbre en la demanda y sobrecapacidad en la infraestructura portuaria: el papel de los pasajeros y el efecto de la regulación

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Abstract

This paper tries to assess the possible existence of excess of capacity for the Spanish port infrastructures. In order to do this, we estimate a cost function system considering the existence of demand uncertainty of cargo and passengers for port authorities. We find that, in order to fulfil the regularity conditions of the cost function system, we have to specify both demands as uncertain. The results show the importance of passenger variability in terms of demand of variable inputs and the use of quasi-fixed input. We also demonstrate the excess of capacity from the calculation of the shadow price of the quasi-fixed input after controlling demand uncertainty. Finally, some factors as the size of the port authorities' hinterland, the relative specialization in containerised general cargo or passengers, the size of ports, the profitability rate or port regulation are considered as determinants of this excess of capacity.

Key Words: ports; uncertainty of demand; cost function; overcapacity

Resumen

Se estudia la posible existencia de exceso de capacidad en las infraestructuras portuarias españolas. Para ello se estima un sistema de costes para las autoridades portuarias españolas en el que se incluye la incertidumbre en la demanda tanto para el tráfico de mercancía como para el de pasajeros. Se ha encontrado que para que sistema de costes cumpla todas las condiciones de regularidad es necesario incluir en la especificación la incertidumbre. Los resultados muestran la importancia de la variabilidad de pasajeros dado su efecto en las demandas de los factores productivos y en el uso del input quasi-fijo. También se demuestra la existencia de sobrecapacidad a partir del cálculo del precio sombra del input quasi-fijo una vez controlada la incertidumbre de la demanda. Finalmente, algunos factores tales como el tamaño del hinterland en el que la autoridad portuaria está localizada, la especialización relativa de la autoridad portuaria en los tráficos de contenedores y pasajeros, el tamaño de los puertos o su rentabilidad han sido considerados como posibles determinantes de este exceso de capacidad.

Palabras Clave: puertos; incertidumbre en la demanda; función de costes; sobrecapacidad

1. Introduction

The Spanish port system has been the subject of significant regulatory changes during the last twenty five years. In this period, different public reforms have been carried out changing the way in which Spanish ports operate. Castillo-Manzano, López-Valpuesta and Pérez (2008), Núñez-Sánchez and Coto-Millán (2012) or Rodríguez-Álvarez and Tovar (2012) analyze the effects of port sector reforms in Spain showing that they had important effects on productivity and efficiency. These reforms have led the Spanish port authorities to operate according to the principles of a landlord port model: financial and operating autonomy, increased inter-port and intra-port competition and participation of the private sector in port activities. In this way, the port authority just provides the port infrastructure and regulates the use of port space. Port services are essentially provided by private sector operators under an authorisation or a concession regime (World Bank, 2007). However, Spanish port regulators have not allowed the existence of differences in prices among ports avoiding price-based competition. In this context, port authorities have had strong incentives to invest in capacity in order to attract more traffic of cargo and passengers. But this is not the only possible cause of port overcapacity. Haralambides (2002) identifies other factors which have guided port authorities to over-invest in capacity. Some of them are related with political issues, as the conception of ports as tools of regional development, technological issues, as capital indivisibilities (lumpy investments), economies of scale in port construction, increasing employment of containerships and larger vessels and planning issues, as the over-optimistic demand forecasts. Additionally, Luo, Liu and Gao (2012) consider that overcapacity could be a strategy for port authorities in order to gain credibility and effectiveness of preemptive measures (strategic issue). In this sense, the excess of capacity would not only attract more traffic, but also it would be a signal of reliability. This aspect is particularly relevant for those types of traffic under increased competitive pressure e.g. the case of containerised cargo or passenger traffic.

In this paper we focus on the possible existence of overcapacity in Spanish port authorities during the period 1986-2005 considering the effect of port demand variability on their costs, variable input demands and their quasi-fixed input. To achieve this aim, a system of equation formed by a short run variable cost function and input expenditures equations is estimated including proxies of demand variability for cargo and passengers. Other studies that have studied the existence of overcapacity in Spanish ports are Baños-Pino, Coto-Millán and Rodríguez-Álvarez (1999) and Rodríguez-Álvarez and Tovar (2012). Both papers demonstrate that ports authorities overuse their quasi-fixed inputs in the short- run, suggesting that adjustment in capacity investments are necessary in order to reach the long-run equilibrium. However, none of them have considered the inclusion of demand uncertainty on their specifications. Other two papers have considered demand variability in the production process of the cargo handling industry (Rodríguez-Álvarez, Tovar and Wall (2011), and Tovar and Wall (2012)). Nevertheless, both studies focus on the effect of demand uncertainty on cost efficiency, economies of scale and scope. Finally, Tovar and Wall (2014) analyse the impact of demand uncertain on port infrastructure costs. This paper is quite similar to ours but some significant differences exist, mainly methodological. Firstly, these authors focus in the cost of uncertainty whereas we analyse port overcapacity. Secondly, they do not include passengers' variability because it results non-significant when it is included in their regression. Nor they include the interactions between variability and inputs which allows to obtain the effect of uncertainty in inputs' demands. Third, variability is estimated in a different way in both papers. Tovar and Wall (2014) assume that cargo demand follows an autoregressive process of order 1 instead an autoregressive process of order 3 as we do. Moreover we approximate demand variability as predicted standard errors of this AR(3) process, however Tovar and Wall (2014) use predicted standard errors from a second regression where they regress the log of the squared estimated errors from the AR(1) process on port dummies and the lag of demand. Finally, they allows the coefficient associated with the quasi-fixed input to be positive. This fact is accepted by some authors arguing that reflects overcapacity, notwithstanding other authors consider this positive parameter as a misspecification of the model. The novelty in our study comes from that we focus on the infrastructure provision carried out by port authorities taking into account the interaction between demand uncertainty and port capacity, considered in our specification as a quasi-fixed input. In this way, we are able to observe whether the non-inclusion of demand uncertainty for cargo and passengers may cause biased results regarding the correct specification of the variable cost function. Additionally, we evaluate through a panel data model some observable factors which may partially cause the overcapacity of port authorities, taking into account both time-constant unobservable effects for every port authority and time effects.

The paper is structured as follows. First, in Section 2 we present the theoretical model of port authorities considering the existence of demand uncertainty. Section 3 presents the data used and some descriptive statistics of the different variables. Section 4 shows the econometric specification of the demand variability and next, the short-run variable cost system of equations. Section 5 shows the results of the estimations. Finally, Section 6 offers some conclusions and implications.

2. Demand uncertainty and overcapacity on provision of port infrastructure and services

As we have mentioned in the introduction, Spanish port authorities follow a landlord port model. They own the infrastructure, take decisions about the use of space, construction and financing of port infrastructure, as well as decisions about the provision and allocation of space to private companies which operate in the port. The port authority is responsible for the optimal operation of the facility, public or private, and security within the port. These infrastructures usually have an indivisible nature, this means that port infrastructure cannot adapt immediately to changes in demand, and therefore ports should have minimum dimensions and infrastructures to enable them to supply its potential demand. The problem arises in those periods when there are unexpected increases in demand. If ports do not have an excess capacity to enable them to face these increases, ships may suffer delays and congestion problems which in turn may lead to their clients to replace the port with a less congested one, generating reputation problems and loss of potential shippers. Then, ports do not want to deny clients due to potential excess demand. Thus, it is important that ports have sufficient capacity to keep the probability of excess demand below a desire level. This fact encourages overcapacity in ports.

This can be modelled following Duncan (1990). Duncan develops a theoretical model which allows model the capacity service target of a firm. This model was empirically implemented by Anderson and Gaynor (1995) to hospital services.

The model assumes whether the output produced by a port authority (y_{ht}) is function of a set of inputs (x_{ht}) and demand that port faces (d_{ht}) is a random variable with a conditional distribution on realizations in previous periods (d_{ht-k}) which represents all relevant information than can be used to forecast the probability of demand exceeds capacity, we can obtain this probability which is equal to one minus the conditional distribution of the output on demand realizations in previous periods. As mentioned before, ports do not want to deny services to shippers, so they need to keep that probability under a given level α, then:

$$1-G(f(x_{ht})|d_{ht-k}) \leq \alpha \quad (1)$$

Then, if $G(f(x_{ht})|d_{ht-k})$ is invertible, we can replace $y_{ht}=f(x_{ht})$ by $f(x_{ht})=G^{-1}(1-\alpha|d_{ht-k})$. This relation describes the production process of a port which produces so that demand exceeds capacity with probably α, being the port authorities' production equal to their capacity target objective.

Therefore, the cost minimization problem is performed by adding the constraint that demand exceeds supply on average only α per cent of time to the standard cost minimization problem.

Based on the empirically implementation of Duncan (1990) model (Gaynor and Anderson, 1995) we consider two categories of inputs: quasi-fixed and variable inputs. Quasi-fixed input is the factor which cannot readily varied in response to unexpected realizations of demand (S_{ht}); and variable inputs are factors which can be purchased in spot markets and can be perfectly adjusted once actual demand is realized (x_{ht}). Variable inputs are chosen *ex ante* before demand is realized, but variable inputs can be varied in response to realizations of demand. So port authorities first choose variable and quasi-fixed inputs that minimize ex-ante cost with the constraint that demand can exceed supply on average only α per cent of time. From this minimization problem we are able to derivate ex-ante inputs demand, which depend on inputs prices, quasi-fixed input and capacity service target.

Additionally, Gaynor and Anderson (1995) suppose that the firm can adjust its variable inputs in the spot market once demand is realized. Then, in a second stage, the firm minimizes its ex-post cost, conditional on the ex-ante input demands, and subject to the production constraint. So ex-post cost can be expressed as

$$VC = VC(y_{ht}, G^{-1}(1-\alpha|d_{ht-k}), w_{ht}, S_{ht}) \quad (2)$$

Additionally, we can obtain the short run total cost function:

$$TC(y_{ht}, w_{ht}, S_{ht}, G^{-1}(1-\alpha|d_{ht-k})) = VC(y_{ht}, w_{ht}, S_{ht}, G^{-1}(1-\alpha|d_{ht-k})) + r_{ht}S_{ht} \quad (3)$$

where *TC* is the short-run total cost function, y is the vector for outputs, w is the vector of input prices, S is the quasi-fixed input, $G^{-1}(1-\alpha|d_{ht-k})$ is the target service capacity, *VC* is the short run variable cost function and r is the price of quasi-fixed input.

By minimizing the short-run total cost function we obtain the optimal quasi-fixed input level.

$$\frac{\partial TC(y_{ht}, w_{ht}, S_{ht}, \sigma_{ht})}{\partial S_{ht}} = \frac{\partial VC(y_{ht}, w_{ht}, S_{ht}, \sigma_{ht})}{\partial S_{ht}} + r_{ht} = 0 \quad (4)$$

which implies

$$-\frac{\partial VC(y_{ht}, w_{ht}, S_{ht}, \sigma_{ht})}{\partial S_{ht}} = r_{ht} \quad (5)$$

A unit increase in a quasi-fixed input has two effects. First, it increases the quasi-fixed costs. But, second, it should lower short-run total variable costs. Equation (5) shows that a port authority should expand its quasi-fixed input as long as the savings on variable costs more than offset the increase in quasi-fixed costs. In this way, in the long-run equilibrium, the port authority is using an optimal amount of the quasi-fixed input so the variable cost savings just equal the unit price of the quasi-fixed input. In fact, the left-hand side of this equation (5) shows the saving of variable costs due to the increase of the quasi-fixed input, also known as the shadow price of the quasi-fixed input (r_s). Meanwhile, the right-hand side is the unit price of the quasi-fixed input, which it should be evaluated in terms of the opportunity cost of the quasi-fixed input (r). If both prices are equal the quasi-fixed input is optimally allocated. Thus, this equality allows us to test whether overcapacity occurs in Spanish ports or not by comparing the shadow price of storage area with its actual value (Baños-Pino, Coto-Millán and Rodríguez-Álvarez, 1999) following equation (6).

$$q_{ht} = \frac{r_{ht}}{r_{sht}} \quad (6)$$

if $q_{ht} = 1$ there is a long-run optimal allocation of the quasi-fixed input. When $q_{ht} > 1$ the shadow price of the quasi-fixed input is lower than its opportunity cost so this input is being overused and thus overcapacity exists. Finally, if $q_{ht} < 1$ the quasi-fixed input is being underused, so the port authority should expand its quasi-fixed input.

3. Data

The sample consists of 26 port authorities which manage 45 ports considered as being of general interest in Spain. For these ports annual data from 1986 until 2005 are available, being the complete panel data set of 520 observations[1].

The data were gathered from the annual reports published by *Puertos del Estado* (several years, a and b) which provides homogeneous information about the performance of Spanish port authorities.

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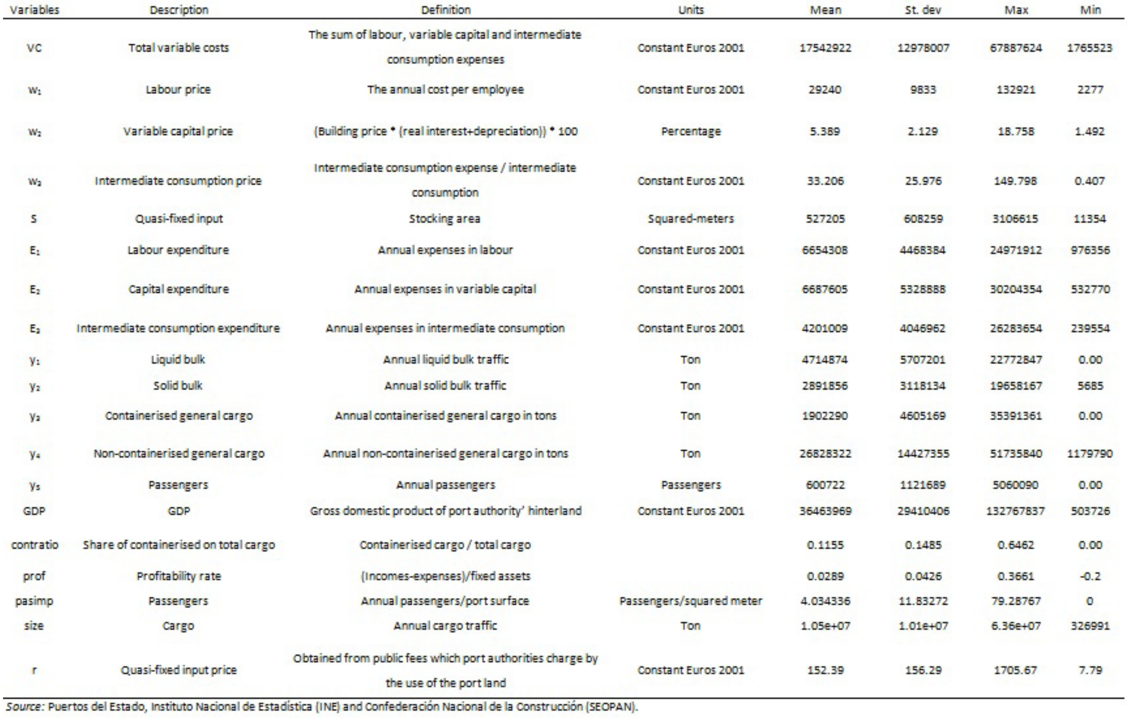
[1] It is necessary to point out that the authorities from Almería and Motril are separated since 2005. However, in order to simplify the analysis, both authorities have been considered as a unit during the whole sample period. Additionally, the Port Authority of Sevilla was not included in the analysis as it is the only river port and, therefore, its cost structure responds to a quite different technology.

The port activity is a multiproduct one, for this reason we have taken into account the following outputs: movements of liquid bulk (y_1) and solid bulk (y_2), containerised general cargo (y_3), non-containerised general cargo (y_4) and passengers (y_5).

The input variables prices are: labour price (w_1), variable capital price (w_2) and intermediate consumption price (w_3). We also consider the storage area of the port as a quasi-fixed input (S). Labour price is defined as the ratio of annual labour expenses by total employees. Variable capital price has been approximated by multiplying a building index price of public works (obtained from the reports of *Confederación Nacional de la Construcción*, SEOPAN) by the sum of long-term interest rate and the depreciation rate the port's property and equipment. The depreciation rate is calculated as the annual depreciation expenditures of each port authority over the total assets. Finally, intermediate consumption price is defined as the ratio resulted by dividing intermediate consumption expense by intermediate consumptions measured in physical units.

We also include labour (E_1), capital (E_2) and intermediate consumptions (E_3) expenses and the standard deviation of demand of total cargo and passengers traffic (σ_f and σ_p).

As we mentioned in Section 3, the market price of storage area has been included in our analysis to test whether overcapacity really occurs. This unit value, evaluated as the opportunity cost of the storage area, has been obtained from the public fees charged by port authorities to private port operators for using their public space, which *Puertos del Estado* annually publishes joint with the storage area of each port authority. In this way, given that Law 27/1992 indicates that these fees are equal to the six per cent of the land market value, we are able to determine the unit market value of the storage area.



Variables	Description	Definition	Units	Mean	St. dev	Max	Min
VC	Total variable costs	The sum of labour, variable capital and intermediate consumption expenses	Constant Euros 2001	17542922	12978007	67887624	1765523
w_1	Labour price	The annual cost per employee	Constant Euros 2001	29240	9833	132921	2277
w_2	Variable capital price	(Building price * (real interest+depreciation)) * 100	Percentage	5.389	2.129	18.758	1.492
w_3	Intermediate consumption price	Intermediate consumption expense / intermediate consumption	Constant Euros 2001	33.206	25.976	149.798	0.407
S	Quasi-fixed input	Stocking area	Squared-meters	527205	608259	3106615	11354
E_1	Labour expenditure	Annual expenses in labour	Constant Euros 2001	6654308	4468384	24971912	976356
E_2	Capital expenditure	Annual expenses in variable capital	Constant Euros 2001	6687605	5328888	30204354	532770
E_3	Intermediate consumption expenditure	Annual expenses in intermediate consumption	Constant Euros 2001	4201009	4046962	26283654	239554
y_1	Liquid bulk	Annual liquid bulk traffic	Ton	4714874	5707201	22772847	0.00
y_2	Solid bulk	Annual solid bulk traffic	Ton	2891856	3118134	19658167	5685
y_3	Containerised general cargo	Annual containerised general cargo in tons	Ton	1902290	4605169	35391361	0.00
y_4	Non-containerised general cargo	Annual non-containerised general cargo in tons	Ton	26828322	14427355	51735840	1179790
y_5	Passengers	Annual passengers	Passengers	600722	1121689	5060090	0.00
GDP	GDP	Gross domestic product of port authority' hinterland	Constant Euros 2001	36463969	29410406	132767837	503726
contratio	Share of containerised on total cargo	Containerised cargo / total cargo		0.1155	0.1485	0.6462	0.00
prof	Profitability rate	(Incomes-expenses)/fixed assets		0.0289	0.0426	0.3661	-0.2
pasimp	Passengers	Annual passengers/port surface	Passengers/squared meter	4.034336	11.83272	79.28767	0
size	Cargo	Annual cargo traffic	Ton	1.05e+07	1.01e+07	6.36e+07	326991
r	Quasi-fixed input price	Obtained from public fees which port authorities charge by the use of the port land	Constant Euros 2001	152.39	156.29	1705.67	7.79

Source: Puertos del Estado, Instituto Nacional de Estadística (INE) and Confederación Nacional de la Construcción (SEOPAN).

Table 1: variables and simple descriptive statistics of the simple for the period 1986-2005

4. Econometric Specification

4.1. Econometric specification for demand uncertainty

Equation (2) shows that the variable cost is function of some observed variables: actual output, input prices and the quasi-fixed input which have been described in Section 2; and an unobserved one as the capacity which meets the desired turnaway probability.

As the target service capacity is not directly observable, we assume that greater demand uncertain needs greater reserve service capacity to meet this demand. Thus, the target service capacity is function of demand variability which can be approximated by the standard deviation of demand (Gaynor and Anderson, 1995; Rodríguez-Álvarez, 2011; Tovar and Wall, 2012 y 2014). So, in our study, an approximation of variability of demand for cargo and passengers, σ_f and σ_p, are included in the model.

To estimate the standard errors of demand, since the demand *ex-ante* is an unobservable variable, we use the actual traffic of cargo and passengers as a proxy. Then we estimate a demand forecast equation following Gaynor and Anderson (1995). Considering that demand depends on past realizations, an autoregressive process of order three, AR(3), has been estimated for both cargo and passengers. We adopt the following strategy for the estimation: first, we regress demand of period *t* on demand of periods *t-1*, *t-2*, *t-3* for both traffics, including not only past information, but also port authority dummies and a time trend; once we have the estimations of the AR(3) processes, we proceed to estimate their corresponding standard errors.

Thus, the cost function becomes $VC = VC(y_{ht}, \sigma_{ht}, w_{ht}, S_{ht})$ (7)

where *VC* is the variable cost, *y* is the vector of inputs, *σ* is the vector of demand uncertain variables, *w* is the vector of input prices and *S* is the input quasi-fixed.

4.2. Econometric specification for the short-run variable cost system

Once we have obtained the estimation of the demand variability variables, we proceed to specify the short-run variable cost system. For the estimation of the cost system, formed by the short run variable cost function and the input expenditure equations, a flexible functional form has been chosen, the multiproduct quadratic cost function. In this specification the variables, excepting those which are proxy of demand variability, are deviated from their means. This system of equations once the quadratic functional form has been applied is the following one:

$$\begin{aligned} VC_{ht} &= \beta_0 + \sum_{r=1}^{m} \beta_r (y_{rht} - \bar{y}_r) + \sum_{r=1}^{m} \sum_{s=1}^{m} \beta_{rs} (y_{rht} - \bar{y}_r)(y_{sht} - \bar{y}_s) + \sum_{j=1}^{n} \gamma_j (w_{jht} - \overline{w}_j) + \\ &+ \sum_{j=1}^{n} \sum_{k=1}^{n} \gamma_{jk} (w_{jht} - \overline{w}_j)(w_{kht} - \overline{w}_k) + \sum_{r=1}^{m} \sum_{j=1}^{n} \rho_{rj} (y_{rht} - \bar{y}_r)(w_{jht} - \overline{w}_j) + \lambda_S (S_{ht} - \overline{S}) + \\ &+ \sum_{r=1}^{m} \lambda_{Sr} (y_{rht} - \bar{y}_r)(S_{ht} - \overline{S}) + \sum_{j=1}^{n} \lambda_{Sj} (w_{jht} - \overline{w}_j)(S_{ht} - \overline{S}) + \zeta_f \sigma_{fht} + \zeta_p \sigma_{pht} + \\ &+ \sum_{j=i}^{n} \zeta_{fj} \sigma_{fht} (w_{jht} - \overline{w}_j) + \zeta_{fS} \sigma_{fht} (S_{ht} - \overline{S}) + \sum_{j=i}^{n} \zeta_{pj} \sigma_{pht} (w_{jht} - \overline{w}_j) + \zeta_{pS} \sigma_{pht} (S_{ht} - \overline{S}) + \\ &+ \sum_{a=1}^{A} D_a PA_a + \pi_t T + \varepsilon_{ht} \end{aligned} \tag{8}$$

The input expenditures equations can be obtained by applying the Shephard's Lemma to the cost function. Additionally, interactions of demand variability with input prices and quasi-fixed input are included in our model to allow variability gets not only into the variable cost but also in the input expenditures equations and therefore, we could test whether demand uncertainty affects input demands or not. Thus, the input expenditures equations included in the short-run variable cost function have been specified as follow:

$$E_{jht} = w_{jht} \frac{\partial VC_{ht}}{\partial w_{jht}} = w_{jht} X^{*}_{jht} = w_{jht} [\gamma_j + 2\gamma_{jj}(w_{jht} - \overline{w}_j) + \sum_{k=1}^{n} \gamma_{jk}(w_{kht} - \overline{w}_k) + \sum_{r=1}^{m} \rho_{rj}(y_{rht} - \overline{y}_r) + \lambda_{Sj}(S_{ht} - \overline{S}) + \zeta_{fj}\sigma_{fht} + \zeta_{pj}\sigma_{pht} + \nu_{ht}] \tag{9}$$

where *VC* is the variable total cost, y_r is the amount of output *r (r=1,...,5)*, w_j is the price of variable input *j (j=1,...,3)*, *S* is the quasi-fixed input, σ_f is the proxy of demand variability of total cargo moved by the Spanish port authorities, σ_p is the proxy of demand variability in the case of passengers, E_j is the input *j* expenditure, *T* is a time trend representing neutral technical change, *h=1,...,H* relates to the *h-th* authority, *t* relates to the time period and finally, to capture individual firm-specific effects, *PA* represents port authorities dummies. Those variables which have a bar on the top correspond to the sample means.

4.3. Econometric specification for the short-run variable cost system

Finally, once overcapacity indices are obtained, we analyse some of the potential factors which cause overcapacity by equation (10). In this way we have considered variables related to the traffic composition. Usually, high percentages of containerised cargo are expected to increase the excess of capacity, given the competitive pressure of containerized traffic, with respect to solid or liquid bulk. The same applies to the case of passenger traffic, those port authorities with a greater intensity of passenger traffic present higher levels of overcapacity (*strategic issues*). Another possible explanatory factor could be related to the regulatory framework, given that Spanish port regulators follow the self-financing principle. This rule tries to mitigate possible problems of *moral hazard* with individual port authorities (*regulatory issue*). In this sense, we have included the profitability rate of each port authority. Given the Spanish port finance system, we could expect that those port authorities with better performance may finance capacity expansions. On the other hand, we may consider that these port authorities achieve better results due to the fact that they are efficient, so they do not present higher levels of overcapacity. Therefore, the effect is not clear. Another factor related with overcapacity could be the economic importance of the port authority's hinterland, proxied by the GDP of the region in which the port is located. We expect that the larger the size of the hinterland, the lower the excess port capacity, due to the lower degree of spatial competition between ports (*strategic issue*). We also included the size of the port authority, measured by total cargo loaded/unloaded. Due to the existence of important capital indivisibilities, we consider that those port authorities with higher levels of traffic present lower overcapacity problems (*technological issue*). Finally, we have added temporal dummies in order to capture common temporal factors for all port authorities (*political issues*). For instance, those legal changes which affected the whole port system that we mentioned before (reforms in 1992 and 1997). Unfortunately, these variables presumably do not totally capture all of issues mentioned in section 1: political, technological, planning or strategic issues. However, the panel structure of our data can be used to obtain consistent estimators in the presence of omitted variables. The estimation of a fixed effects model assumes that unobserved effects are constant over time. Including dummies variables for port authorities and time, we are able to capture both time-constant unobserved effects and time effects.

$$q_{ht} = \beta_0 + \beta_1 contratio_{ht} + \beta_2 GDP_{ht} + \beta_3 prof_{ht} + \beta_4 pasimp_{ht} + \beta_5 size_{ht} + \\ + \sum_{a=1}^{A} D_a PA_a + \sum_{d=1}^{D} G_d TD_d + \varepsilon_{ht} \tag{10}$$

where q are the overcapacity indices, *contratio* is the percentage of containerised cargo over total traffic, *GDP* is the gross domestic product of the hinterland where port authorities are located, *prof* is the profitability rate of port authorities, *pasimp* is the number of passengers on port surface, *size* is the total cargo traffic, *PA* is an individual dummy variable for each port authority, *TD* is a temporal dummy, *h=1,…,H* corresponds to the *h-th* authority and *t* relates to the time period.

5. Estimation and results

The system of equations (8)-(9) has been estimated by seemingly unrelated regressions (SUR) model. In order to exploit the panel data structure, a fixed effects estimator has been applied for all specifications, considering the possible existence of time-constant unobserved effects.

Table 2 shows the results of the estimation using three different specifications for the system of equations with the aim of evaluate the robustness of the results: in specification 1 demand variability is not included; specification 2 includes the existence of demand uncertainty for cargo and passengers; and finally in specification 3 we just consider passengers' variability of demand, which we discuss below. The system of equations is formed by the short-run variable cost function and their three corresponding variable input expenditure equation.

Variables	Specification 1		Specification2		Specification3	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	19 638 778	5.435	10 447 635	1.918	9 119 287	1.841
w_1	201.52	49.128	142.43	2.858	102.11	3.884
w_2	1 188 425	55.075	1 131 607	3.389	773 994.4	5.189
w_3	12 064 408	36.143	12 706 663	4.486	10 472 473	15.115

Table 2: Estimation of the short run variable cost system using three different specifications.

Variables	Specification 1		Specification2		Specification3	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
y_1	0.046	0.410	0.088	0.726	0.074	0.624
y_2	0.395	1.853	0.454	1.843	0.491	2.012
y_3	0.122	0.591	0.361	1.643	0.394	1.920
y_4	0.561	1.049	0.078	0.133	0.164	0.283
y_5	2.081	3.180	2.077	2.531	2.022	2.500
S	2.408	1.848	-30.601	-3.546	-31.559	-3.776
w_1*w_1	-0.001	-9.200	-0.000	-8.551	-0.001	-8.612
w_2*w_2	-8466.79	-2.671	-8207.31	-2.300	-7557.81	-2.166
w_3*w_3	-4 550 047	-9.390	-4 137 815	-8.003	-4 224 733	-8.161
y_1*y_1	0.000	-0.622	0.000	-1.303	0.000	-1.333
y_2*y_2	0.000	-0.560	0.000	0.794	0.000	0.627
y_3*y_3	0.000	-2.789	0.000	-2.837	0.000	-2.919
y_4*y_4	0.000	1.389	0.000	2.048	0.000	1.998
y_5*y_5	0.000	0.145	0.000	1.167	0.000	1.261
S*S	0.000	-0.211	0.000	-0.791	0.000	-0.627
w_1*w_2	6.761	6.018	8.067	7.119	8.136	7.243
w_1*w_3	28.041	1.218	28.606	1.231	22.109	0.951
w_2*w_3	314 356.2	4.653	294 835.5	4.077	281 494.8	3.918
y_1*y_2	0.000	5.601	0.000	5.212	0.000	5.324
y_1*y_3	0.000	-1.394	0.000	0.428	0.000	0.439
y_1*y_4	0.000	-0.733	0.000	-1.549	0.000	-1.604
y_1*y_5	0.000	-1.427	0.000	-1.786	0.000	-1.660
y_2*y_3	0.000	-0.525	0.000	-0.233	0.000	-0.364
y_2*y_4	0.000	-2.542	0.000	-1.318	0.000	-1.252
y_2*y_5	0.000	2.984	0.000	2.892	0.000	2.857
y_3*y_4	0.000	3.337	0.000	2.850	0.000	2.788
y_3*y_5	0.000	2.597	0.000	1.431	0.000	1.367
y_4*y_5	0.000	-0.955	0.000	-2.606	0.000	-2.726
w_1*y_1	0.000	2.558	0.000	3.029	0.000	2.825
w_1*y_2	0.000	3.191	0.000	2.669	0.000	2.667
w_1*y_3	0.000	-0.037	0.000	0.970	0.000	0.898
w_1*y_4	0.000	1.219	0.000	0.526	0.000	0.472
w_1*y_5	0.000	2.493	0.000	2.088	0.000	2.085
w_2*y_1	0.037	9.600	0.039	9.034	0.037	8.999

Table 2: Estimation of the short run variable cost system using three different specifications (cont.)

Variables	Specification 1		Specification2		*Specification*3	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
w_2*y_2	0.050	7.401	0.049	6.703	0.049	6.701
w_2*y_3	-0.006	-0.822	-0.001	-0.187	-0.003	-0.353
w_2*y_4	0.265	9.990	0.244	8.211	0.241	8.156
w_2*y_5	0.029	1.170	0.021	0.773	0.023	0.848
w_3*y_1	0.2538	4.9251	0.2878	5.3237	0.2718	5.0674
w_3*y_2	0.5027	5.7013	0.5573	6.2074	0.5679	6.3425
w_3*y_3	0.9822	8.6022	1.0592	8.9493	1.0600	9.0717
w_3*y_4	-0.5324	-1.7675	-0.6907	-2.1528	-0.7139	-2.2788
w_3*y_5	1.7095	5.1400	1.9119	4.8382	1.8545	5.0708
y_1*S	0.0000	0.6420	0.0000	0.8116	0.0000	0.8784
y_2*S	0.0000	-0.3342	0.0000	-1.6195	0.0000	-1.6096
y_3*S	0.0000	1.7051	0.0000	1.4205	0.0000	1.4400
y_4*S	0.0000	-3.4990	0.0000	-2.8740	0.0000	-2.9274
y_5*S	0.0000	-0.1713	0.0000	-0.4685	0.0000	-0.3759
w_1*S	0.0001	9.8926	0.0001	10.7469	0.0001	10.7889
w_2*S	0.7215	13.0702	0.7678	12.7776	0.7686	12.8243
w_3*S	5.9322	8.2092	5.8692	7.7626	5.8303	7.8056
T	-82 874.10	-2.5428	-10 4891.70	-2.5836	-102 416.40	-2.5524
T^2	10 659.91	2.5745	11 753.74	2.0020	11 616.72	2.0049
σ_p			254 903.20	4.5027	256 314.20	4.6066
σ_p*S			0.8139	4.2152	0.7883	4.2336
σ_p*w_1			1.8556	3.0210	2.0191	3.5186
σ_p*w_2			8795.81	2.6778	8956.81	2.7516
σ_p*w_3			16 193.16	0.5491	32 667.42	2.1532
σ_f			-2043.98	-0.4103		
σ_f*S			-0.0048	-0.6062		
σ_f*w_1			-0.0915	-0.8177		
σ_f*w_2			-952.45	-1.1345		
σ_f*w_3			-4551.01	-0.6862		

* Port authorities dummies have been omitted

Table 2: Estimation of the short run variable cost system using three different specifications (cont.)

	Specification 1	**Specification 2**	**Specification 3**
Observations	520	442	442
R^2	0.955	0.961	0.961
Adjusted R^2	0.946	0.951	0.952
S.E. of regression	3006937	2917533	2892551
R^2labour expenditure equation	0.567	0.641	0.641
R^2capital expenditure equation	0.771	0.772	0.772
R^2intermediate consumption expenditure equation	0.659	0.669	0.670

Table 3: Descriptive statistics of the estimation of the short run variable cost system using three different specifications.

We observe that specification 1 satisfies some of the regularity conditions: the short-run variable cost function is non-decreasing and quasi-concave in variable inputs prices, non-decreasing in outputs and homogeneous of degree one in input prices[2]. However, the coefficient related to the quasi-fixed area is positive and statistically different from zero. So according to this specification, one square meter increase of the storage area increases short-run variable costs. Some previous studies argue that this result indicates that firms are operating with considerable excess capacity (Viton, 1981). Nevertheless, we consider that the short-run variable cost function does not fulfill the regularity conditions and hence it does not capture the implicit technology. This fact shows that not taking into account demand uncertain can lead to misspecifications.

In specification 2 we include the existence of demand uncertainty for port authorities. Appendix A includes the estimates of the autoregressive processes (*AR(3)*) from which the demand variability variables have been obtained. The models perform well, satisfying the regularity conditions. In this way, first order coefficients related to the variable input prices are positive and statistically significant. For the case of outputs, parameters related to solid bulks, containerised cargo and passengers are positive and statistically different from zero. Given that the variables are deviated with respect to their means, output coefficients can be interpreted as the marginal cost of each category of traffic at the sample mean. Non-containerised general cargo and liquid bulk have positive coefficients but not different from zero. Additionally, we find evidence of the existence of technological progress since the coefficient associated to the trend is negative and significant. The coefficients related with demand variability of cargo and its interactions are all non-significant whereas the parameters associated to uncertainty for passenger traffic are significant, with only one exception ($\sigma_p w_3$). In this sense, the coefficient related to the demand uncertainty of passengers (σ_p) shows us that those ports which faces higher variability in their demand incurs in higher costs than those with lower uncertainty, for a given level of passengers. Moreover, regarding the interactions between the demand uncertainty passenger variable with input prices we conclude that port authorities increase the use of their labour and variable capital input in respond to demand uncertainty.

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[2] Unlike other functional forms for modeling the cost function the condition of homogeneity of degree one is imposed, in the case of the quadratic functional form we carry out a hypothesis testing procedure. In our case, the null hypothesis could not be rejected, so we conclude that short-run variable cost function is homogeneous of degree one.

Regarding the storage area coefficient, it is negative and statistically significant at the sample mean. So one square meter increase of the storage area decreases short-run variable costs by 30.6 €. Therefore, the inclusions of demand uncertainty variables in our system of equations achieve capture adequately the technology of port authorities.

Given that demand variability of cargo and its interactions are all non-significant, we calculate Specification 3, in which we just consider demand uncertainty of passengers. As we observe, results do not change substantially.

From deriving the variable cost with respect the quasi-fixed input, it is possible to calculate the shadow price of storage area (r_s) for all observations in order to test the possibility of overcapacity, by comparing r_s with the market price of the storage area (r). Figure 1 shows the mean values of that ratio (q) for each port authority. All authorities present levels of q higher than one, excepting Bahía de Cádiz, so we can affirm that overcapacity occurs in most of the Spanish port authorities. The highest levels correspond to Ceuta and Melilla which are considered as strategic ports given that are located in Africa, followed by port authorities located in islands (Baleares, Las Palmas and Tenerife), Huelva and Alicante.

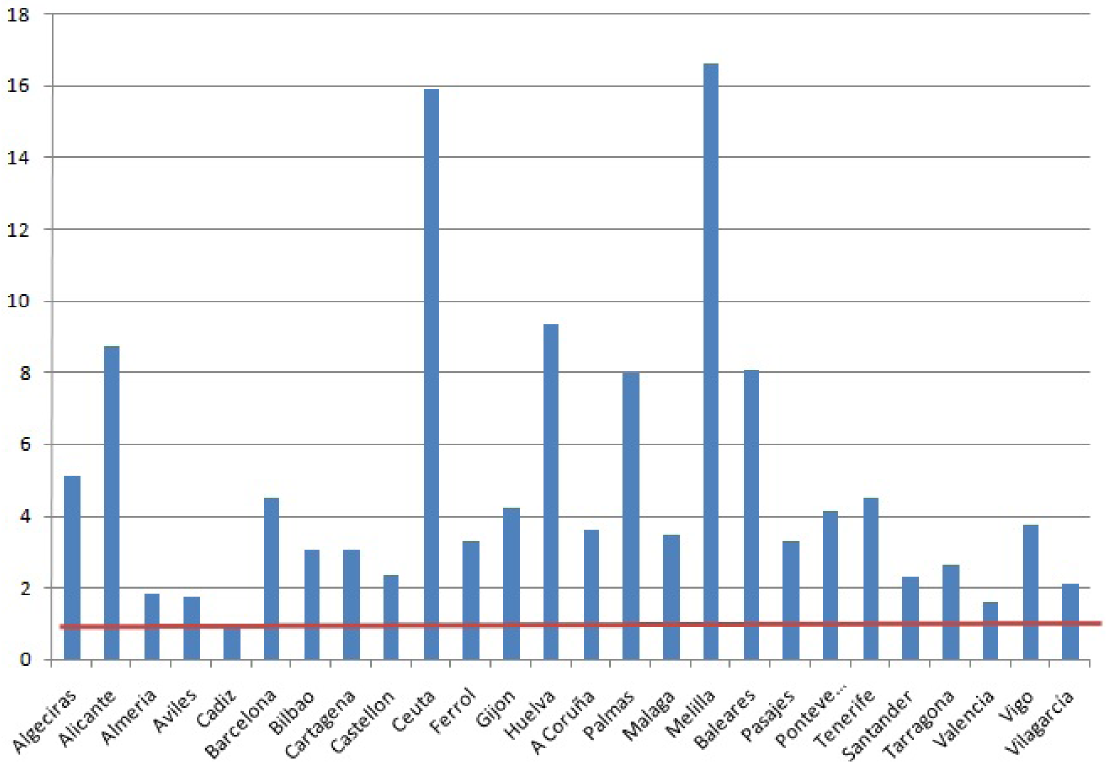

Figure 1: Overcapacity indices (qh) for each port authority evaluated at their means

On the other hand, in Figure 2 we focus on the evolution of these indices for the whole Spanish port system. As we observe overcapacity has increased over the time distinguishing two different periods. During the first one, between 1986 until 1996, overcapacity increases, after the admission of Spain in the European Common Market and the first important reform of port authorities (Act 27/1992). The second period, starts in 1998 one year after the 1997 reform (Act 62/1997), in which public regional governments were allowed appoint members of the port authority governing board. This new regulatory change increases the conception of ports as tools of regional development. Additionally, as we mentioned in the introduction, in this period port regulators have not allowed the existence of differences in prices among ports avoiding price-based competition (3rd Transitory Regulation of Law 62/1997).Within this context, port authorities had strong incentives to invest in capacity rather than prices.

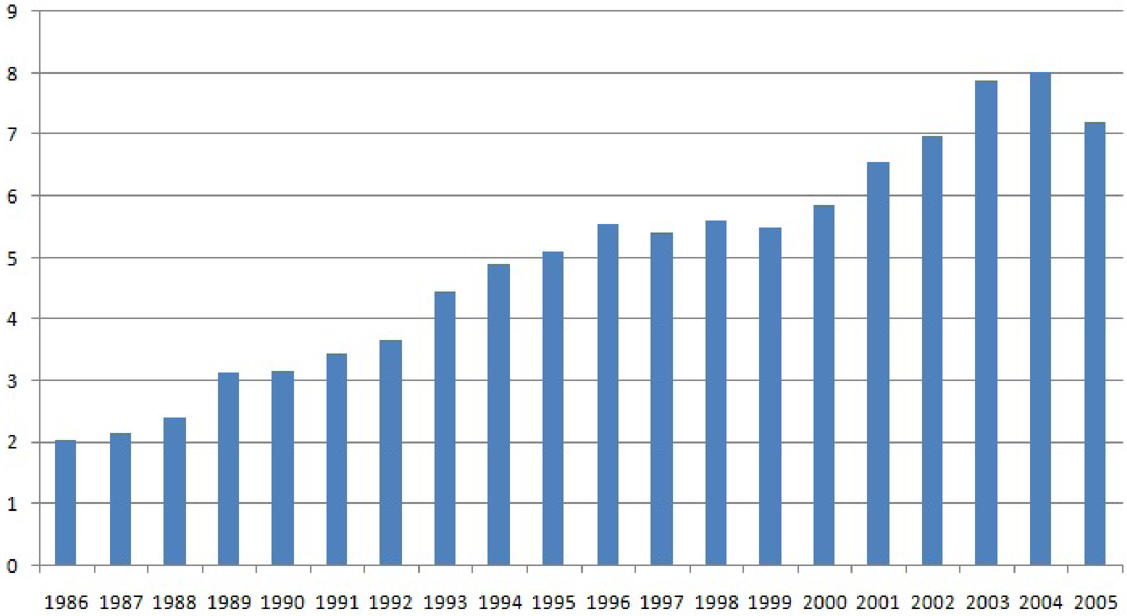

Figure 2: Evolution of overcapacity indices (q_t) for the period 1986-2005

Therefore, although we have included demand variability in our short-run variable cost function, we observe that overcapacity in Spanish port system still remains. This fact could suggest that there would be other additional factors which could explain the overcapacity of the Spanish port authorities during this period. So we have evaluate these possible factors of overcapacity. In this way, we have first estimated equation (10) by OLS. Table 3 reports the results.

	OLS		**2SLS**	
Variables	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
const	4.515	2.273	1.488	0.460
contratio	14.009	5.253	19.224	2.321
GDP	-8.68E-08	-4.553	0.000	-2.936
prof	7.295	1.505	24.156	1.773
pasimp	0.283	7.797	0.370	2.070
size	-1.35E-07	-3.104	0.000	-2.033

Table 4: Determinants of overcapacity

	OLS		2SLS	
Variables	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
Alicante	1.980	1.072	3.535	1.083
Almería-Motril	0.152	0.093	1.850	0.838
Avilés	-4.729	-2.281	-1.786	-0.534
Bahía de Cádiz	-2.847	-1.585	-0.931	-0.315
Barcelona	3.197	2.430	4.129	1.869
Bilbao	-0.201	-0.134	2.760	0.960
Cartagena	-2.659	-1.462	-0.327	-0.117
Castellón	-0.722	-0.432	1.472	0.558
Ceuta	-8.017	-3.091	-9.857	-1.072
Ferrol-San Cibrao	-2.071	-1.089	0.504	0.173
Gijón	-0.838	-0.439	2.292	0.705
Huelva	7.695	4.997	10.635	4.170
A Coruña	-1.106	-0.622	1.466	0.522
Las Palmas	-1.980	-1.102	-0.573	-0.168
Málaga	1.058	0.617	3.614	1.440
Melilla	2.692	1.237	4.739	1.415
Baleares	-2.659	-1.417	-0.918	-0.341
Pasajes	-1.698	-0.867	1.563	0.480
Marín y Ría de Pontevedra	-3.200	-1.611	-1.159	-0.362
Santa Cruz de Tenerife	-4.168	-2.425	-2.323	-0.974
Santander	-4.744	-2.235	-1.661	-0.486
Tarragona	4.934	3.601	7.566	2.524
Valencia	-6.718	-4.437	-6.412	-1.886
Vigo	-5.961	-3.030	-5.051	-1.299
Vilagarcía	-3.459	-1.654	-0.070	-0.020
D88	-0.526	-0.686	-0.951	-0.768
D89	0.463	0.597	-0.028	-0.028
D90	0.690	0.886	0.201	0.222
D91	1.184	1.511	0.761	0.799
D92	1.520	1.928	1.038	0.966
D93	2.538	3.223	2.686	2.435
D94	2.941	3.718	2.598	3.264

Table 4: Determinants of overcapacity (cont.)

	OLS		2SLS	
Variables	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
D95	3.578	4.488	3.381	4.366
D96	3.999	4.970	3.785	4.398
D97	3.908	4.771	3.857	5.087
D98	4.164	4.991	3.960	4.654
D99	4.076	4.762	3.722	4.458
D00	4.705	5.336	4.308	4.626
D01	5.596	6.147	5.155	5.244
D02	6.279	6.692	5.828	5.085
D03	7.399	7.632	6.940	5.034
D04	7.309	7.639	6.903	5.142
D05	6.849	7.023	6.445	3.853
Observations		520		494
R^2		0.706		0.701
Adjusted R^2		0.676		0.668
S.E. of regression		3.141		3.229

Table 4: Determinants of overcapacity (cont.)

The coefficient related to the share of containerised cargo on total traffic (*contratio*) and passenger traffic (*pasimp*) are positive and statistically significant, thus suggesting that the specialization on these types of traffic may lead the port authority to overinvest in capacity. On the other hand, the coefficient related to the hinterland size of the region where port authorities are located (*GDP*) has a negative and significant impact on excess of capacity. So, port authorities located in larger regions present lower excess capacity problems. The variable which controls the size of the port authority (*size*) also present a statistically positive coefficient. The existence of important fixed-capital indivisibilities or lumpy investments could explain these results. The estimation also indicates that the profitability rate of port authorities (*prof*) is not a significant variable. We also observe that both port authorities and time effects are highly significant. It is particularly interesting to analyse how coefficients related to time effects are not statistically different from 1986 until 1992, but in 1993 start to diverge. This result may suggest the effect of 1992 port reform on excess of capacity. We observe a similar effect after 2000, from which the coefficients increase in greater proportion than in previous years. Nevertheless, a potential pitfall of the results is that OLS do not consider possible problems of endogeneity in some explanatory. In order to solve this potential problem, we estimate (16) using Two-Stage Least Squares (TSLS) using as instruments lags of *contratio*, *pasimp*, *size* and *prof*. The results confirm the relationships explained before, but in this case the coefficient related to profitability rate of port authorities (*prof*) turn to be statistically significant, so there is a positive and significant correlation between excess of capacity and higher profit rates. Finally, temporal dummies bear out conclusions from figure 2, showing two different trends in overcapacity. Highest level of overcapacity with respect to the reference year, 1987, are those corresponding to the subsequent years to entry on force of the Law 62/1997. On the other hand, overcapacity seems to fall in the periods after Law 48/2003 came of force. This law is stricter with the objective of self-financing and operational costs coverage than the previous ones.

6. Conclusions and implications

This study analyses the overcapacity of the Spanish port authorities, taking into account the potential effect of the demand variability of cargo and passengers on the Spanish port authorities' productive process. Then, we have estimated jointly a short-run variable cost function with their corresponding input expenditure equations using three different specifications in order to check the robustness of the results. In the first specification, demand uncertainty has not been included in the model having found specification errors. Furthermore, although we have modelled cargo and passenger uncertainty demand, just demand variability of passengers and its interactions with the input prices and the quasi-fixed input are significant, which shows the importance of passengers in port studies. The results show that for a given level of output, those port authorities which face greater demand incurs in higher costs and use more variable inputs than those with less uncertain demand. On the other hand, we have demonstrated that overcapacity exists in port authorities and some determinants related to technological, strategic, political or regulatory issues, as specialization in certain traffics, port profitability or the size of their hinterlands affect to their excess of capacity. Additionally, we can distinguish two different trends in overcapacity indices for the whole Spanish port system, concurring one of them with the subsequent years to come into force Law 62/1997 when public regional governments have more competences in the port authorities' performance. It seems that an improvement in overcapacity levels occur after Law 48/2003.

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