The impact of deregulation in the hydrocarbon sector: evidence at the main Spanish ports of import of hydrocarbons (1986–2013)

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Abstract: This study evaluates the impact of deregulation and the introduction of competition in the hydrocarbon sector on the efficiency of 11 Spanish ports of import of hydrocarbons. To this end, using stochastic frontier analysis (SFA), an input-oriented distance model has been estimated for the 1986–2013 period. This paper contributes to the literature by establishing a direct correlation between the hydrocarbons' reforms and the change in port efficiency. The main conclusion was that Law 15/1992 and Law 34/1998 focused on the deregulation and the introduction of competition in the field of hydrocarbons have had a positive impact on the efficiency of the main Spanish ports of import of hydrocarbons.

Keywords: deregulation; competition; hydrocarbons; technical efficiency; stochastic frontier analysis; SFA; Spanish ports; decentralisation; over-capacity; over-investment.

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1 Introduction

International trade is a critical market area for the progress of a country's industrial landscape and economic growth. Shipping in Spain – and therefore the activity undertaken at the 46 ports of general interest[1] managed by 28 port authorities (Puertos del Estado, 2016) which have a prominent role in international trade – accounts for 31% of total cargo moved (75% of which are imports and exports) (Instituto Nacional de Estadística, 2016; Puertos del Estado, 2016). Port activity represents 1.1% of Spain's GDP and 20% of transport sector GDP (PIPE, 2016).

Port authorities, which have different traffic flows and requirements due to the large variety of cargo handled and services provided and the productive characteristics of the regions each port serves, can achieve varying levels of efficiency, depending on demand, the cargo shipped and even the technology used in the handling of that cargo. Traffic carrying petroleum products deserves special attention, as it is highly efficient; large amounts of merchandise can be unloaded using less material and human resources[2] than required for other types of traffic.

The price of hydrocarbons, the uneven distribution of oil deposits (only 1% of the energy produced in Spain corresponds to hydrocarbons; in the EU-28 the figure is 25%, and globally it is 52%) and the widespread usage (55% of world energy consumption stems from oil sources; the figures for the EU-28 and Spain are 64% and 67%, respectively) have all led to concerns among employers and governments in terms of optimising oil use and the demand for oil, and devising alternative systems for energy supply and use (IEA, 2016).

In Spain, due to the substantial consumption and limited production of petroleum products, almost all hydrocarbons used are imported. The majority of hydrocarbon imports, in the form of liquid bulk, is made by sea, and in 2013 oil products accounted for 27% of all cargo handled at Spanish ports (Puertos del Estado, 2016).

Regulations on hydrocarbons (summarised in the second section), given their significant impact on the economy as a while, have been aimed at guaranteeing supply, stabilising prices and increasing the efficiency of the sector and other sectors of the economy. Port activity is a key link in the process from production to final consumption of petroleum products and is also an indicator of the competitiveness of the overall economy.

The main aim of this study is to determine the levels of technical efficiency at the main Spanish ports of import of hydrocarbon cargo (considered as such those ports providing raw materials to oil refining facilities or handling over 1.5 million tons a year). Furthermore, this study seeks to reveal the impact on these efficiency levels of regulations on hydrocarbons enacted in the period 1986–2013 to increase the efficiency of all productive sectors and, as a result, enhance international competitiveness.

The rest of the document is structured as follows: Section 2 summarises the regulatory framework governing hydrocarbons from the creation of the oil monopoly in 1927 through to the end of the period studied. Section 3 comprises a review of the existing literature on the technical efficiency of port activity. Section 4 describes the methodology and data used in the study. Section 5 shows the specification of the econometric model finally used in the empirical analysis, and Section 6 outlines the results. Finally, Section 7 reveals the conclusions reached through this investigation.

2 Spanish regulatory framework

2.1 Background

The hydrocarbon sector in Spain has historically been structured within an oil monopoly implemented via Royal Law Decree 1142 of 1927, regarded as an essential element for industry and national defense, with gradual deregulation to meet the basic criteria for access to the European Union and move towards a common energy market.

Alongside the regulatory management of the hydrocarbon sector, measures were also implemented on exploration and exploitation, setting clear foundations for the organisation of the activity (law on the legal regime for exploration and exploitation of hydrocarbons, on 26 December 1958), the state reserves, and the modification of exploitation taxes (Law 21/1974). This rules can be considered successful given the increase in private investment and the area explored.

2.2 Legislative reforms

Spain's integration into the European Economic Community (EEC) forced substantial changes in the energy markets aimed at the creation of the European single market. The new regulations included measures to increase sector's efficiency, and to ensure market liberalisation and competition. Furthermore, the measures took into account environmental aspects and consumer rights regarding regularity, quality, and price of supply.

Law 45/1984 and Royal Decree-Law 5/1985 were designed to increase sector's efficiency and competitiveness, as well as free importation of oil products from EEC countries and the liberalisation of the trade and distribution sub-sectors.

Law 15/1992 on urgent measures for the progressive adaptation of the oil sector to the EEC framework was another step towards a common internal energy market. These new measures meant the minimum distances between service stations (established by Royal

Decree-Law 4/1988). Furthermore, refining companies were provided with a commercial structure through CAMPSA (Petroleum Monopoly Management Company), the state-run petroleum monopoly management company. Only six months later, Law 34/1992 completed the elimination of the oil monopoly by transferring administrative control from a concession model to an authorisation system, while government kept the authority over certain issues (stockpiles, consumer rights, facility safety, maximum prices of petroleum products and the allocation of quotas for imports from countries outside the EU).

Law 34/1998 created the National Energy Commission[3] (dedicated to ensuring market competition), separated the ownership of gas transportation infrastructure (monopoly) from the service provider, and recognised free competition and entrepreneurial freedom for the business activity of hydrocarbon distribution. The new law represented a significant change in the sector, most notably the free determination of prices, the elimination of reserves for the state and network planning taking into account environmental aspects.

Law 12/2007 (the last legislative amendment in the period under study) recognised the power of the government to impose obligations on operators in the system to "protect general economic interests, consumer protection measures pertaining to the regularity, quality and price of supply, the supervision of supply security, the mandatory establishment of technical standards [...]." Measures were also included to complete the liberalisation of the sector, focusing on improving service quality and prices, eliminating the existing tariff system and guaranteeing the right to change supplier.

3 Literature review

Numerous economic studies have evaluated and demonstrated the substantial contribution of the energy sector to the economy and its growth, and these studies have given rise to policies for improved regulation of the energy sector, and oil in particular. Kilian (2008) showed that exogenous shocks in oil supply caused sharp declines in US GDP in the short-term and slight price increases in the long-term, while Yuan et al. (2008) found evidence of causality between oil consumption and economic growth regarding GDP in the short-term in China. Hamilton (2009) showed that oil price shocks, despite having different causes, had similar effects on the economy, producing overall reductions in consumer spending and largely, in-car purchases. In a recent study, Bloch et al. (2015) observed that the consumption of energy conditioned GDP growth in China and that this growth, in turn, produced energy consumption. Mirzaei and Al-Khouri (2016), in their study of the global financial crisis, observed greater resilience among oil-rich countries.

Oil prices, which are of crucial importance for the global economy, and the effects of price fluctuations, have been widely studied. Park and Ratti (2008) detected impacts of oil price shocks on the stock market that was greater than the effect on interest rates in the USA and European countries. Similar results were found by Guesmi et al. (2016), who observed fluctuations in the US stock market due to oil prices and recommended taking appropriate regulatory measures to mitigate the adverse economic impact of oil prices. González and Hernández (2016) recently found evidence in the Colombian economy (a net exporting country) of the role of consumer spending as an indirect route for the transmission of oil prices to the balance of trade and GDP, and noted that positive changes to oil prices affect GDP, while negative changes show no correlation.

Other studies have investigated the impact of oil prices on total factor productivity and technical efficiency in the industrial and service sectors. Song and Park (2011) studied the effects of changes in oil prices on the productivity of the Korean industrial sector, noting that when prices were high, fluctuations produced increasing scale effects and technological progress, while technical and allocative efficiency declined. Meanwhile, Narayan and Sharma (2014) found a direct relationship between oil prices and volatility in share performance in a study of 560 listed companies and derived trading strategies based on forecasting oil prices. Coto-Millán et al. (2015) also found evidence of the negative influence of oil prices on the technical efficiency of European airlines.

With an economic approach, port activities have historically been studied from the perspective of demand, productivity, and efficiency.

Coto-Millán et al. (2005), in a study of the period 1975–1993, found empirical evidence of the influence of national macroeconomic variables, the price of imports and maritime services on import demand. They found similar results in relation to export demand, revealing that global GDP, the price of exports and maritime services all had an impact. They also found income elasticity of imports greater than one, and lower than one in the case of exports. In a similar study of Spanish ports in the period 1994–1998, Coto-Millán et al. (2011) found a low-income elasticity of import demand for liquid bulk and higher elasticity for other imports.

Díaz-Hernández et al. (2007) used a DEA methodology to study changes in the productivity of port companies in 1994–1998. Their analysis showed that the regulatory efforts of the 80s had led to technical change, although they found no substantial differences in technical efficiency among companies.

González and Trujillo (2008) studied the impact of reforms on Spanish ports with container traffic. Using Battese and Coelli's (1988) stochastic frontier methodology on a translog-type distance function model, they showed that regulatory reforms had induced technological changes at the port authorities studied, although increases in terms of technical efficiency were not substantial. During the study period, they observed a net loss of productivity.

The analysis of the evolution of total factor productivity of Spanish port authorities undertaken by Núñez-Sánchez and Coto-Millán (2012) showed improvements in total factor productivity due to technological progress and increases in scale efficiency.

Chang and Tovar (2014a), based on the parametric stochastic frontier model of Battese and Coelli (1995), studied the technical efficiency of 14 Chilean and Peruvian ports in 2004–2010. They found that the structural reform of the 90s had a positive influence on both countries, but more significantly on Chilean ports, which were more efficient than their Peruvian counterparts. They also noted that the financial crisis negatively affected efficiency in 2009 and the employment rate, the degree of mechanisation (measured by the containerisation ratio and the bulk ratio) and privatisation all had a positive impact on efficiency.

In relation to the increase in total factor productivity, Chang and Tovar (2014b) broke down productivity into technical efficiency, scale efficiency and technological change. In their study, they observed increased technical efficiency in ports, with the Chilean ports being more efficient thanks to the better implementation of regulations (with increased investment in infrastructure and technology). Total factor productivity in Chile decreased on average, while in Peruvian ports, it increased. Increases in technical efficiency and scale efficiency contributed positively to productivity improvements, although the component of technological change which is linked to capital, decreased. Among their findings, it is worth mentioning the need to implement policies in Peru aimed at accelerating reforms and encouraging investment by private companies, to achieve cost reductions and increase port competitiveness.

Recently, Coto-Millán et al. (2016) used stochastic frontier analysis (SFA) on an input-oriented distance function to study the impact of port management reforms in 1992, 1997, 2003 and 2010 (relating to decentralisation, privatisation, and introduction of competition) on the technical efficiency of 26 Spanish port authorities for the period 1986–2012. Their empirical analysis shows that the effect of the 1997 and 2003 regulations was positive and significant, whereas the regulation on decentralisation and port autonomy (1997) was the most significant contributor to efficiency.

We did not identify any studies looking at the impact of deregulation and the introduction of competition in the hydrocarbon sector on the technical efficiency of Spanish ports of import of hydrocarbons, which therefore constitutes the main contribution of this research to the existing literature.

4 Methodology and data

4.1 Methodology

In order to respond to the main objective of this research, which is to identify the levels of technical efficiency of the productive activity at the port authorities studied and to determine the impact of deregulation and the introduction of competition in the sector of hydrocarbons on said efficiency levels, we chose to use the true fixed effects methodology developed by Greene (2005). This stochastic frontier model allows for the calculation of variable inefficiency over time and for the consideration of unobserved heterogeneity among sample individuals (balanced panel data defined in Sub-section 4.2. data).

The existence of different outputs in the sample, given the various services offered by the port (handling of solid bulk, liquid bulk, and general cargo, mainly), means it is appropriate to consider the use of a distance function[4]. Introduced by Shephard (1953), the distance function identifies production technologies with multiple outputs (final products or services, Y_m) and inputs (production factors, x_n) and dispenses with the use of prices or costs of the factors[5] (Coelli et al., 2005). The general form of the distance function is shown in expression (1):

$$d_{it} = f\left(x_{1it}, ..., x_{nit}, ..., x_{Nit}, y_{1it}, ..., y_{mit}, ..., y_{Mit}\right) \tag{1}$$

where d_{it} is the distance of the i^{th} DMU from the production point to the frontier obtained in the t^{th} year.

The calculation process with distance functions requires an initial choice of output or input orientation, determined based on the higher capacity to control one or the other (Coelli et al., 2005). The organisational structure of costs and prices of port activities indicate the suitability of an input-oriented distance function, due to the greater control over production factors by the port authorities, versus the more limited capacity to control the final levels of production given their reliance on the effective demand for transport.

The formal definition of the input-oriented distance function is shown in expression (2):

$$d^I(x, y) = \max_\lambda \{\lambda : x/\lambda \in L(y)\} \tag{2}$$

where $L(y)$ represents the production isoquant, y is a vector of the services produced and x is the vector of productive factors. The distance function can take values greater than or equal to one $(d^I(x, y) \geq 1)$, being equal to one when production is on the production isoquant (production of services is carried out with complete efficiency) and higher when production is carried out with some degree of technical inefficiency.

The input-oriented distance function must meet the properties described: symmetrical, not increasing and quasi-convex in outputs, and non-decreasing, concave and homogeneous of degree one in inputs (Färe and Primont, 2012).

Developing the model requires the selection of a suitable functional form. Two functional forms widely used in the literature on technical efficiency are the Cobb-Douglas[6] (1928) and the transcendental logarithmic (referred to hereafter as translog) (Christensen et al., 1973)[7]. This study selected a Cobb-Douglas function over the more elastic translog, as the latter reduces degrees of freedom in estimation to a large extent. The distance function is presented in (3):

$$\ln d_{it}^I = \sum_{n=1}^{N} \beta_n \ln x_{nit} + \sum_{m=1}^{M} \gamma_m \ln y_{mit} + \theta_1 t + \theta_2 t^2 + \alpha_i + v_{it} \tag{3}$$

where α_i represents the effects of heterogeneity not accounted for by the variables of the model, specific characteristics of each of the port authorities included in the study, v_{it} is a random disturbance (statistical noise associated with stochastic effects, not controllable by the productive units) assumed to be independent and identically distributed according to a normal distribution, with zero mean and constant variance $\mathrm{N}(0, \sigma_v^2)$, d^I is the input-oriented distance function, x is an N-dimensional vector of inputs, y is an M-dimensional production vector and t is a time trend variable which reflects technological change in the sense of Hicks.

Finally, β, γ and θ are vectors of parameters subject to estimation.

The imposition of homogeneity of degree one is given by expression (4):

$$\sum_{n=1}^{N} \beta_n = 1 \tag{4}$$

The transformation of model (3) to take into account (4), which allows for econometric analysis using stochastic frontier techniques, as shown in (5), involves the normalisation of the distance function by one of the factors of production:

$$-\ln x_{Nit} = \sum_{n=1}^{N-1} \beta_n \ln x_{nit}^* + \sum_{m=1}^{M} \gamma_m \ln y_{mit} + \theta_1 t + \theta_2 t^2 + \alpha_i + v_{it} - u_{it} \tag{5}$$

where $x_{nit}^{*} = x_{nit} / x_{Nit}$ represents the productive factor n, normalised, and technical inefficiency is represented by $u_{it} = \ln d_{it}^{I}$ with truncated normal distribution with mean μ_{it} and variance σ_{μ}^{2}. The econometric model used (Greene, 2005) assumes independence in the distribution of u_{it} and v_{it}.

$$u_{it} = \pi_0 + \sum_{q=1}^{Q} \pi_q Var_{qit} + w_{it} \quad (6)$$

where π is a vector of parameters subject to estimation, Var are the variables considered as determinants of efficiency, and w_{it} is a random error defined as $N(0, \sigma_w^2)$.

The expressions (5) and (6), the functions of distance and efficiency determinants, respectively, can be estimated using the maximum likelihood method in a one-step process.

A second stage of calculation allows for estimation of the levels of technical efficiency of each port authority in each year of observation. The formulation used in this analysis is that of Jondrow et al. (1982), as defined in expression (7):

$$TE_{it} = E\left[\exp(-u_{it}) \middle| \varepsilon_{it}\right] \quad (7)$$

where $\varepsilon_{it} = v_{it} - u_{it}$.

4.2 Data

To undertake this empirical analysis, the economic and port traffic information used was obtained from the port authority reports and statistical annual for state ports (Puertos del Estado, 2016). Whilst many ports in Spain handle some traffic carrying petroleum products, the sample used in this study, has been limited to the central port authorities of import of hydrocarbons, considered as such those ports providing raw materials to oil refining facilities or handling on average over 1,500,000 tons yearly of petroleum products and derivatives.

The sample finally used is a balanced data panel with information for the period between 1986 and 2013 on 11 main Spanish ports[8] of general interest of import of hydrocarbons. Most of the ports in the sample supply raw materials to oil refining facilities distributed throughout Spain, which, as shown in Figure 1, are located close to the port terminals[9].

In day-to-day management of operations, ports use a variety of inputs for the provision of services: labour, capital, and intermediate consumption. In this empirical analysis, labour will be measured by the number of workers employed annually. Physical capital used in productive activities has been approximated by the net fixed assets related to the activity. Finally, intermediate consumption is measured by the cost of goods and services consumed in the various port activities other than labour and capital[10]. All input variables selected have frequently been used in studies on airport efficiency (Baños-Pino et al., 1999; Chang and Tovar, 2014a, 2014b; Coto-Millán et al., 2016; González and Trujillo, 2008; Núñez-Sánchez and Coto-Millán, 2012; Rodríguez-Álvarez et al., 2007).

Figure 1 Refineries in Spain

Note: The general interest ports included in the sample are (1) A Coruña, (2) Bahía de Algeciras, (3) Barcelona, (4) Bilbao, (5) Cartagena, (6) Castellón, (7) Huelva, (8) Las Palmas, (9) Málaga, (10) Santa Cruz de Tenerife, and (11) Tarragona.

Source: Own elaboration based on Puertos del Estado (2016) and Asociación Española de Operadores de Productos Petrolíferos (2016)

The services produced by the main ports of import of hydrocarbons have been grouped into four categories, according to the fundamental characteristics of their production (the main production systems of the various services): solid bulk, liquid bulk, containerised general cargo, and non-containerised general cargo (Chang and Tovar, 2014a, 2014b; Coto-Millán et al., 2016; González and Trujillo, 2008; Núñez-Sánchez and Coto-Millán, 2012; Rodríguez-Álvarez et al., 2007; Wanke and Barros, 2016).

Table 1 shows the main statistics of the variables used in the process of calculating the distance function.

Table 1 Summary statistics

		Mean	*Min.*	*Max.*	*Std. dev.*
Labour (1)	L	261	72	743	120
Capital (2)	K	365,000	56,700	1,530,000	265,000
Interm. consumptions* (2)	IC	6,778	589	36,400	5,586
Solid bulk (3)	SB	3,249	229	13,600	2,457
Liquid bulk (3)	LB	10,700	34	24,200	5,836
Containerised gen. cargo (4)	TEUS	300,526	1	2,813,495	497,932
Non-contain. gen. cargo (3)	NCGC	1,799	77	9,778	1,870

Notes: Variables in (1) number of employees, (2) thousand Euros, (3) thousand tons (4) TEU's. Monetary variables have been discounted at constant 2001 prices. *Normalisation variable.

Source: Own elaboration based on Puertos del Estado (2016)

5 Specifications

This section describes the specifications of the functions of distance, in expression (8), and of the determinants of inefficiency, in expression (9), estimated based on the true fixed effects methodology by Greene (2005).

$$\begin{aligned} -\ln IC_{it} = {} & \beta_1 \ln\left(\frac{L_{it}}{IC_{it}}\right) + \beta_2 \ln\left(\frac{K_{it}}{IC_{it}}\right) + \gamma_1 \ln SB_{it} + \gamma_2 \ln LB_{it} + \gamma_3 \ln TEUS_{it} \\ & + \gamma_4 \ln NCGC_{it} + \theta_1 t + \theta_2 t^2 + \alpha_i + v_{it} - u_{it} \end{aligned} \tag{8}$$

$$u_{it} = \pi_1 Laws\, 15\_34/1992_t + \pi_2 Law\, 34/1998_t + \pi_3 Control_t + w_{it} \tag{9}$$

Where the distance function has been defined by the factors of production used, or inputs, and the services produced, or outputs, by i^{th} the port authority in the t^{th} period. The following factors of production were included: *IC*, normalisation variable used, intermediate consumption; *L*, number of workers; and *K*, net fixed assets linked to operations. The categories of the services produced used in the study, as measured by the physical units moved in ship operations are *SB*, solid bulk; *LB*, liquid bulk; *TEUS*, containerised general cargo; and *NCGC*, non-containerised general cargo.

The function of efficiency determinants is defined by two dummy variables which include the effect of regulation in the hydrocarbon sector: *Laws 15_34/1992*, a variable which reflects the effect of two laws passed in 1992 concerning the transition and repeal of the oil monopoly, and *Law 34/1998*. In the specification of the function of determinants, the variable *control* was included, which reflects the effects of the economic crisis on the technical efficiency of the ports studied.

6 Results

This section shows, based on the empirical econometric model presented in Section 4 and the specifications in Section 5, the results of the estimation[11] of the distance function and the inefficiency effects for the sample of 11 ports over the period 1986–2013.

Table 2 Estimation results

Variables		*Coef.*	*Std. dev.*	*P-value*	
Frontier					
Labour (1)	β_1	0.461	0.039	0.000	***
Capital (1)	β_2	0.450	0.036	0.000	***
Solid bulk	γ_1	–0.097	0.025	0.000	***
Liquid bulk	γ_2	–0.027	0.010	0.004	***
Containerised (TEUS)	γ_3	–0.022	0.005	0.000	***
Non-containerised	γ_4	–0.054	0.022	0.012	**
Time	θ_1	–0.015	0.006	0.013	**
Time^2	θ_2	0.000	0.000	0.203	
Inefficiency effects, μ					
Laws 15_34/1992	π_1	–0.228	0.135	0.093	*
Law 34/1998	π_2	–0.395	0.226	0.080	*
Control	π_3	0.528	0.167	0.002	***
σ_w		0.188	0.029	0.000	***
σ_v		0.072	0.011	0.000	***
Heterogeneity, α					
A Coruña	α_1	–9.419	0.536	0.000	***
Bahía de Algeciras	α_2	–9.510	0.553	0.000	***
Barcelona	α_3	–10.312	0.566	0.000	***
Bilbao	α_4	–9.891	0.570	0.000	***
Cartagena	α_5	–9.211	0.530	0.000	***
Castellón	α_6	–8.674	0.525	0.000	***
Huelva	α_7	–9.693	0.548	0.000	***
Las Palmas	α_8	–9.897	0.548	0.000	***
Málaga	α_9	–9.242	0.515	0.000	***
Santa Cruz de Tenerife	α_{10}	–9.590	0.553	0.000	***
Tarragona	α_{11}	–9.582	0.553	0.000	***

Notes: Signification codes: '***' 0.99, '**' 0.95, '*' 0.90. (1) Variables normalised by intermediate consumptions.

Source: Own elaboration

The results obtained in the maximum likelihood estimation process are presented in Table 2. These results show correct signs in the input variable (higher levels of labour or capital lead to greater distances to the frontier) and output variables (higher levels of services produced reduce distances to the frontier) included in the distance function, all of which were significant, at levels of 95%.

The coefficients associated with the input variables reflect the higher weight of labour in relation to intermediate consumption than capital at the ports considered, coinciding with the results of Coto-Millán et al. (2016) and Rodríguez-Álvarez et al. (2007). The coefficients associated with the output variables reveal the greater weight of solid bulk traffic (as per Coto-Millán et al., 2016), followed by non-containerised general cargo, liquid bulk, and containerised general cargo.

The sum of the coefficients associated with the output variables (greater than –1) in the model reflects increasing returns to scale.

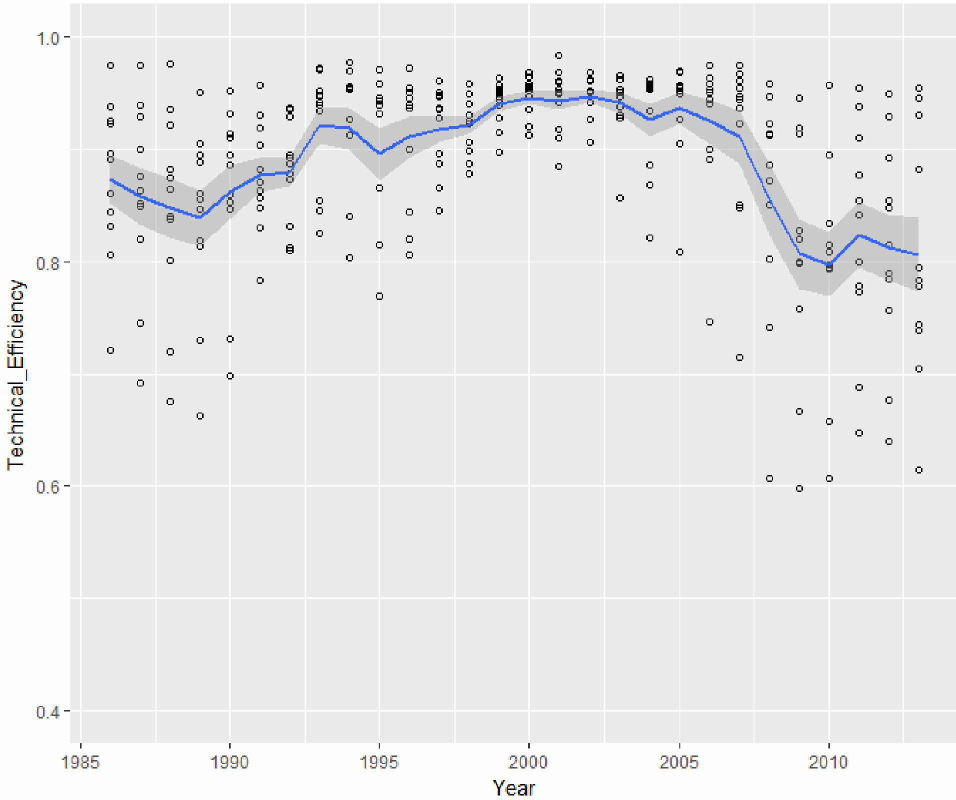
The results of the estimation process on the impact of deregulation and the introduction of competition in the field of hydrocarbons on the technical efficiency of port activities are shown in Table 2. These results indicate an opposite impact of the regulations of 1992 and 1998 (positive) versus the control variable (negative) on efficiency. The two regulatory periods considered were found to have significantly impacted the efficiency of the port authorities studied.

As explained in the second section of this text, Law 15/1992 reduced the minimum distances between vehicle supply service stations and provided commercial infrastructure petroleum refining facilities, while Law 34/1992 completed the elimination of the oil monopoly. These laws represent the regulatory efforts to increase the efficiency of the hydrocarbon sector and other sectors which depend upon it. As expected, the variable that reflects the effects of these laws contributes to increased technical efficiency (negative) at the main Spanish ports of import of hydrocarbons.

The enactment of Law 34/1998 also contributed positively to the efficiency of Spanish ports considered. This law – which had a greater impact than the ones passed in 1992 – introduced new measures to liberalise the oil[12] sector, leading to increased levels of technical efficiency, not only of the organisations directly involved in the oil sector but in all of the Spanish economy's productive sectors.

Finally, the economic crisis (variable control) that began in 2007 had a negative effect on the technical efficiency of ports (positive sign). The effect was stronger (0.528) than the impact of liberalisation and competition in the oil sector carried out by 1992 (–0.228) and 1998 (–0.395) regulations. In addition, Law 12/2007 was enacted, which adapted Law 34/1998 to Directive 2003/55/EC, implementing modifications to the gas market aimed at defining new obligations for companies in the sector, as well as at introducing competition and liberalising the sector, and in turn improving efficiency levels in other productive areas. However, it was not possible to reflect the impact of this deregulation and introduction of the competition in the Spanish and European energy sectors, as it coincided with concerns over environmental conservation, which gave rise to support for renewable energy technologies, and with the adverse effects of the crisis which continues to hamper the Spanish economy.

Figure 2 Technical efficiency evolution (1986–2013) (see online version for colours)



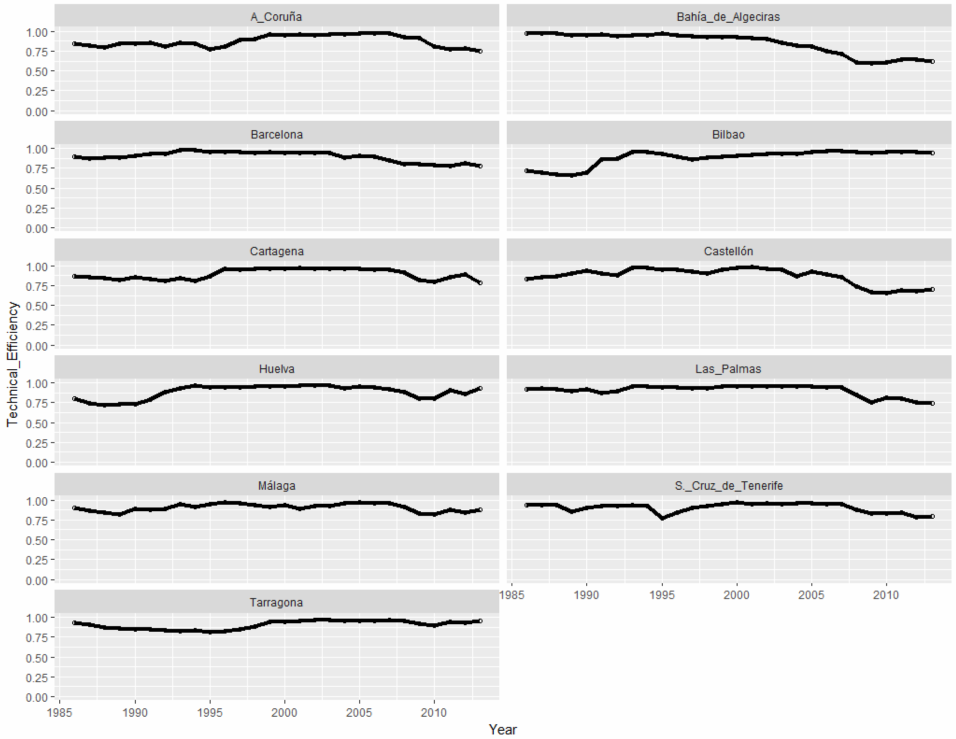
Source: Own elaboration

Figure 2 shows the evolution of technical efficiency of the ports included in the sample throughout the 1986–2013 period. Results show that the average efficiency score of the Spanish ports of import of hydrocarbons is 0.85. A growing tendency was observed from 1995 to 2002. In 2002, efficiency levels began to contract, and this decrease intensified after the onset of the economic crisis to reach a low of 79.8% in 2010. This downturn coincided with the concerns over environmental conservation, which gave rise to support for renewable energy technologies[13].

The evolution of port efficiency is similar to the previously estimated by Rodríguez-Álvarez and Tovar (2012), Núñez-Sánchez and Coto-Millán (2012) and Díaz-Hernández et al. (2014). Rodríguez-Álvarez and Tovar (2012) calculated the efficiency of the Spanish port infrastructure in the period 1993–2007 and found evidence of inefficient behaviour, with inefficiency worsening from 2003. The authors argued that Spanish ports were subject to legislation, which left them no control over pricing policies. As a consequence, the competitive strategy of ports rested on the manipulation of those variables under the control of ports, the most relevant of which was investment policy.

Thus, investment in port capacity has been the most important strategic variable for inter-port competition given that the port fees are uniform throughout the entire Spanish port system. As demonstrated by Núñez-Sánchez and Coto-Millán (2012), this type of inter-port competition has led to overcapacity and technical efficiency losses. In the same vein, Díaz-Hernández et al. (2014) found evidence of inefficiency determined primarily by the improper use of quasi-fixed inputs which increased costs by an average of almost 8%. Thus, the significant expansions of port capacity over this period may have caused overcapacity and, therefore, have increased inefficiency.

Figure 3 Technical efficiency evolution by port authority (1986–2013)



Source: Own elaboration

Figure 3 shows the temporary evolution of the 11 Spanish ports by efficiency. The port authority with the highest average level of efficiency was Malaga, followed, with similar average levels of technical efficiency, by Tarragona, Las Palmas, and Santa Cruz de Tenerife. In 2013, once the study was completed, none of the Spanish ports studied had returned to pre-crisis technical efficiency levels, and only Tarragona, Bilbao and Huelva had come close. The explanation behind this different performance should rest in the evolution of the variables related to the production function. As argued by Hidalgo-Gallego et al. (2015), in some ports there was an under-utilisation of capital in relation to labour, at the same time that there was an over-investment process due to a politically-influenced decentralisation process.

7 Conclusions

For decades, the Spanish regulations on hydrocarbons have been aimed at promoting the efficiency of the sector, which is considered strategic and influential for overall production and consumer spending. This paper sets out to provide a useful contribution to the existing literature by establishing a direct correlation between the hydrocarbon reforms and the change in efficiency at the main Spanish ports of import of hydrocarbons.

The main aim of this study is to evaluate the impact of deregulation and the introduction of competition in the hydrocarbon sector on the technical efficiency of the primary 11 ports of import of hydrocarbons, located in Spain, over the period 1986–2013. To this end, the true fixed effects stochastic frontier methodology proposed by Greene (2005) was used, which takes into account the heterogeneity of port authorities. The frontier used in the study is a distance function, which is considered the best option in productive schemes with various inputs and outputs. Upon analysing the results, four main conclusions were drawn.

The first conclusion, in line with the results of Coto-Millán et al. (2016) and Díaz-Hernández et al. (2014), is an under-utilisation of capital in relation to labour in the port sector. As regards outputs, solid bulk has the highest weighting in the production process of the main Spanish ports of import of hydrocarbons, followed by non-containerised general cargo, liquid bulk, and containerised general cargo.

The second conclusion is that the average efficiency score of the leading Spanish ports of import of hydrocarbons is 0.85 over the 1986–2013 period. A growing tendency was observed from 1995 to 2002. In 2002, efficiency levels began to contract, and this decrease intensified after the onset of the economic crisis to reach a low of 79.8% in 2010. This downturn coincided with the concerns over environmental conservation, which gave rise to support for renewable energy technologies. Further research would, therefore, be needed to determine the causes of the 2003–2010 fall in efficiency levels. Additionally, there is evidence of increasing returns to scale in the sector. This result reveals that increasing the level of inputs still produces a growth of outputs more than proportional.

The third conclusion is that the technical efficiency of the port authorities in the sample followed similar trends over the study period. With certain differences, technical efficiency trended upwards until 2002, with a sharp reduction after 2007. Further to the completion of the study period, the port authorities analysed still had not recovered pre-crisis levels.

Finally, the deregulation of the oil sector carried out in Spain as part of the European Monetary Union in 1992 and 1998, aimed at liberalising the sector and introducing competition, had positive effect on the technical efficiency of the main Spanish ports of import of hydrocarbons. On the contrary, the economic crisis that began in 2007 had a strong negative impact on their technical efficiency, which was greater than the impact of the deregulatory efforts and the introduction of competition.

Our results are meaningful to policymakers. The above findings are significant in terms of furthering hydrocarbon deregulation and liberalisation policies in Spain. The above findings are also significant in terms of promoting competition in the hydrocarbon industry.

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Notes

1 Ports of general interest are those identified in Annex 1 of the consolidated law on state ports and merchant marine, Royal Legislative Decree 2/2011, as defined in Article 4.

2 The unloading system – oil is pumped from the vessel – does not require berthing in the dock (which can reduce draft restrictions). The oil can be transported by piping systems to its final destination or to storage tanks.

3 The National Energy Commission was established as a consultative body of the administration for participation in the authorisation of facilities, regulation and planning in the energy sector. It also acts as an arbitration body.

4 The existing port literature includes many studies using distance functions. For more information, see Baños-Pino et al. (1999), Lan and Lin (2006), Rodríguez-Álvarez et al. (2007), González and Trujillo (2008), Núñez-Sánchez and Coto-Millán (2012), Cullmann et al. (2012), Chang and Tovar (2014a, 2014b), Medal-Bartual et al. (2016) and Coto-Millán et al. (2016), among others.

5 As Núñez-Sánchez and Coto-Millán (2012) point out in their analysis of the impact of public reforms on the productivity of Spanish ports, the use of cost functions should be avoided in areas of strong regulation and public property, as minimising costs is not a key objective.

6 The Cobb-Douglas function applied to distance functions has been used in Greene (2005), Kumbhakar (2012), Kumbhakar et al. (2013) and Huang et al. (2016), among others.

7 The translog function applied to distance functions has been used in González and Trujillo (2008), Díaz-Hernández et al. (2014), Mellah and Ben Amor (2016) and Coto-Millán et al. (2016), among others.

8 A Coruña, Bay of Algeciras, Barcelona, Bilbao, Cartagena, Castellón, Huelva, Las Palmas, Málaga, Santa Cruz de Tenerife and Tarragona.

9 Except for Puertollano, which receives the raw material form the port of Cartagena, the other refineries are located in the port's catchment's area.

10 Observations of containerised cargo with a value of zero have been replaced by the value of one to avoid the need to eliminate them when taking logarithms and introducing them into the calculations. It is not expected that the change made to the database will have a substantial impact on the results of the calculation.

11 The results of estimation were performed using Stata 12.0 econometric package.

12 The separation of the owner of the gas transport infrastructure from the service provider and the recognition of free enterprise or free pricing are among the key liberalisation measures implemented through Law 34/1998.

13 Plan for the promotion of renewable energies (2000–2010) and Spanish renewable energies plan (2005–2010).