MARITIME POLICY & MANAGEMENT, 2016
VOL. 43, NO. 6, 683–705
http://dx.doi.org/10.1080/03088839.2016.1182653

Productivity change of the Spanish Port System: impact of the economic crisis

A. Medal-Bartual[a], M. Molinos-Senante[b,c] and R. Sala-Garrido[d]

[a]Department of Business Finance, Faculty of Economics, University of Valencia, Valencia, Spain; [b]Departamento de Ingeniería Hidráulica y Ambiental, Pontificia Universidad Católica de Chile, Santiago, Chile; [c]Facultad de Arquitectura e Instituto de Estudios Urbanos, Pontificia Universidad Católica de Chile, Santiago, Chile; [d]Department of Mathematics for Economics and Business, Faculty of Economics, University of Valencia, Valencia, Spain

ABSTRACT

The main goal of this study was to assess the impact of the economic crisis on the productivity growth of the Spanish Port System (SPS). The Malmquist Productivity Index (MPI) was estimated for the 28 Port Authorities of the SPS, for a 'non-crisis period' (2005–2008) and a 'crisis period' (2008–2011). From a policy perspective, the MPI is a very useful approach for assessing the productivity change because it can be decomposed into the catching-up index and the frontier productivity index. The results showed that the economic crisis did not impact all of the Spanish Port Authorities equally. Some Port Authorities presented higher productivity growth during the crisis period than in the non-crisis period. Further analysis by the Mann–Whitney test revealed that Port Authority investments and productivity growth were statistically related. Information provided by this study may be very useful for stakeholders and decision-makers, in terms of long-term strategic planning and improving the competitiveness of the SPS. The findings illustrate that the economic crisis should not be seen as an international tragedy, but as an opportunity to adapt port traffics and installations to new needs and market demands.

KEYWORDS
Economic crisis; Malmquist Productivity Index; Mann–Whitney test; port investments; Spanish Port System

1. Introduction

The financial crisis of 2008 has seriously damaged the economy of the European Union (EU). Negative effects are evidenced by the evolution of the real GDP growth rate for the 27 EU member nations, from 0.4 in 2007 to a minimum value of −4.5 in 2009, increasing to −0.4 in 2012 (EUROSTAT 2013). Impacts of the economic crisis have not been uniform across all economic sectors, with manufacturing being the most negatively affected sector in Europe (European Commission 2010).

In the Spanish context, the crisis began as an extension of the international financial crisis, but internal imbalances accumulated in the pre-crisis period, aggravating the situation. In the first quarter (Q1) of 2009, the GDP fell 6.3% and unemployment increased by around 800,000 people (Carballo-Cruz 2011). The high Spanish unemployment rate has been highlighted by Spanish, as well as European, authorities. Domestic demand is another important aspect that differentiates Spain from the Eurozone. Between 2008 and 2010, domestic demand in Spain fell 7.6%, whereas

CONTACT M. Molinos-Senante mmolinos@uc.cl Departamento de Ingeniería Hidráulica y Ambiental, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, Santiago, Chile

in the Eurozone it fell around 1.6% (EUROSTAT 2013). However, Spanish exportations have escaped this trend, falling only 1.3% in the same time period (ICEX 2013).

Considering that the Spanish Port System (SPS) moves 59% of all Spanish exports and 85% of all imports, representing 53% of Spanish international trade with other EU countries and 96% with non-EU countries (Puertos del Estado 2012) and taken into account that improving productivity is essential to ensure economic growth (Fernández de Guevara and Fariña 2014), we asked whether the economic crisis has impacted the productivity of the SPS, or if this industry has continued to grow (i.e. has increased its benefits owing to the rise of foreign trade). Principles of economy, effectiveness, and efficiency in the use of resources must be considered in port management (Medal-Bartual, Molinos-Senante, and Sala-Garrido 2012). In particular, the 33/2010 Spanish Act emphasized the need to improve the efficiency of Spanish Port Authorities and ensure their financial sufficiency. An analysis of how the economic crisis has impacted the productivity of Spanish Port Authorities will help managers and stakeholders in the decision-making process. Moreover, investors' decisions may be improved by identifying ports that were least impacted by the economic crisis.

As outlines Section 3, marked progress has been made in the assessment of ports' efficiency and productivity using parametric (Cullinane, Song, and Gray 2002) and non-parametric approaches (Barros, Felício, and Fernandes 2012). Although several studies have evaluated the productivity change of ports, with some even focused on Spanish ports (Núñez-Sánchez and Coto-Millán 2012; Rodríguez-Álvarez, Tovar, and Trujillo 2007), none has evaluated how the economic crisis has affected the productivity of the SPS.

The Malmquist Productivity Index (MPI) is an excellent method to assess the productivity change of any decision-making unit (DMU), as reported by Cheon, Dowall, and Song (2010). The MPI identifies the productivity growth in two consecutive periods by an index given by a ratio of distance functions. Production growth is measured using only input and output data. To estimate this index, it is necessary to establish the production frontiers and to identify efficient and inefficient DMUs. In doing so, the Data Envelopment Analysis (DEA) methodology can be used.

The objectives of this paper were as follows: (i) to assess the productivity change in 28 Port Authorities comprising the SPS for time periods before and during the economic crisis; (ii) to identify whether the catching-up index or the frontier productivity index contributes more to the productivity change, and (iii) to explore whether the investment process of the Port Authorities influences its productivity change. The main question addressed by this paper was whether the economic crisis has impacted the productivity growth of Spanish ports. To this end, the MPI was estimated from 2005 to 2008 (non-crisis period) and from 2008 to 2011 (crisis period).

The paper is organized as follows. Section 2 describes briefly the SPS and presents general information about the impact of the economic crisis in port activity. Section 3 summarizes previous studies on port productivity focusing on Iberian ports. Section 4 sets out the methodology employed in the analysis. Section 5 presents and discusses the results of the productivity change assessment, and Section 6 summarizes the main conclusions.

2. The SPS and the global economic crisis

Spain has around 8000 km of coastline, which makes it one of the countries with the longest coastline in the EU. This fact, in addition to its geographic location, makes the SPS an axis in the development of the international sea transport and a logistics platform for the South of Europe.

In Spain, there are 28 Port Authorities, with locations as shown in Figure 1. Port management follows the landlord or proprietary model, with each Port Authority providing infrastructure and land. Port Authorities regulate the use of the public domain, while private companies provide the services related to port activity, under authorization or concession. These ports are coordinated and controlled by the state agency 'Puertos del Estado' (State Ports), a body dependent on the Ministry of Public Works.

Figure 1. The Spanish Port System.
Source: Medal and Sala (2011)

The importance of the ports as links in the logistics and transport chains is unquestionable. Maritime transport has played a very active role in the enhancement of economic globalization (González-Laxe and Novo-Corti 2012) and the economic development of a country. In this sense, the SPS activity contributes nearly 20% of the GDP in the transport sector, which represents 1.1% of the Spanish GDP (Puertos del Estado 2012).

In the middle of 2008, the economic crisis which has affected most national productive sectors began to wreak havoc on port traffic of every Spanish port. In figures, as reflected in Figure 2, the total traffic of SPS decreased more than 15% from 2008 (471 million tons) to 2009 (399 million tons). The same trend can be seen in the total passenger port traffic in 2009 (25,328 thousand passengers), with a decrease over 3.3%, from passenger traffic in 2008 (26,199 thousand passengers).

It is certain that the economic and financial recession have had an outstanding impact on port traffic, as reported by González-Laxe and Novo-Corti (2012). However, the efforts made by the

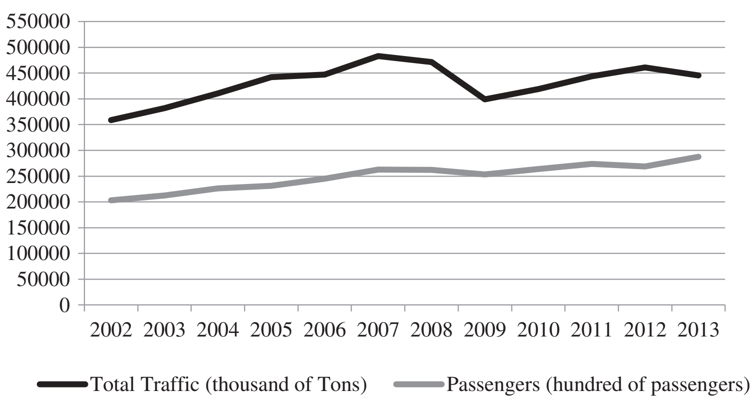

Figure 2. Traffic in the SPS from 2002 to 2013.
Source: Own elaboration from State Ports data.

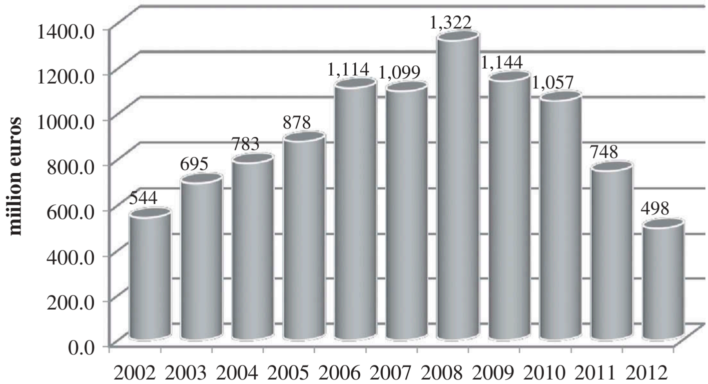

Figure 3. Investment in the SPS from 2002 to 2012.
Source: Own elaboration from State Ports data.

Spanish Port Authorities to raise levels of productivity and efficiency of its activity are having positive results, increasing total port traffics in recent years. The total traffic of the Spanish Port Authorities was 475 million tons in 2012, an increase of 3.8% over the previous year. Although this volume of traffic is closer to the historical maximum of 483 million tons achieved in 2007, we will still have to wait to recover traffic levels before the economic crisis.

In general terms, world economy was contracted and international trade plummeted considerably since 2008. But this is not the only consequence of the recent global economic crisis. Outputs in advanced companies were contracted, employment failed at an alarming rate, prices approached dangerously to the deflation zone, the volatility of international markets increased and investments went down (Fernández-Villaverde and Ohanian 2010).

The SPS is not an exception to this last consequence. Investment level in the SPS was reduced during the crisis period. This statement is confirmed by Figure 3, which summarizes the evolution of investments in the SPS. In the non-crisis years, investments increased progressively, reaching the maximum value in 2008. Investments carried out in 2008 were approved in 2007 or before; therefore, although 2008 is a crisis year, the crisis affected investment in later years. Moreover, there was a drastic reduction in investments performed in 2012 (last year available), which were fewer than those adopted in 2004. In particular, from 2010 to 2012, investments in the SPS decreased 62.33%.

3. Overview of port productivity studies

Significant progress has been made in the assessment of ports' productivity using both parametric and non-parametric approaches. Stochastic frontier analysis (SFA) is the most widely applied parametric method and it relies on econometric estimation assuming that the deviation from the theoretical function is attributed partly to the inefficiency and partly to the existence of measurement error (Ferro et al. 2014). Hence, SFA models are capable to account for statistical noise. Moreover, environmental variables are easier to deal with and traditional hypothesis test could be used. However, SFA requires imposing a functional form of the frontier and making particular distribution assumptions for the one-side error term associated with technical efficiency (Chang and Tovar 2014). On the other hand, within non-parametric methods, DEA is the most widely applied technique. It requires only few assumptions about the underlying technology since DEA uses the inputs and outputs of productive process to calculate the relative efficiency of each unit (port in our case study). Moreover, DEA can easily handle multiple outputs and inputs. However, since DEA is a deterministic approach, statistical noise can distort performance evaluations and traditional tests are not possible except using bootstrapping techniques.

The reviews of the existing port productivity literature by Wilmsmeier, Tovar, and Sanchez (2013) and Chang and Tovar (2014) show that the non-parametric approach is the most popular method. Following Wilmsmeier, Tovar, and Sanchez (2013) and in order to update their review, Appendix A shows a publication list on measuring productivity in ports summarizing the data, methodology, outputs and inputs used in each study.

Focusing on Spanish and Portuguese ports, some previous studies have evaluated efficiency and productivity change of them using both methodological approaches, i.e. parametric techniques in the form of SFA (Baños-Piño et al. 1999; Coto-Millán, Baños-Pino, and Rodríguez-Álvarez 2000; Barros 2005; Rodríguez-Álvarez, Tovar, and Trujillo 2007; Trujillo and Tovar 2007; González and Trujillo 2008; Díaz-Hernández, Martínez-Budría, and Jara-Díaz 2008; Núñez-Sánchez and Coto-Millán 2010; Coto-Millán, Pesquera, and Castanedo 2010; Ramos-Real and Tovar 2010; Rodríguez-Álvarez, Tovar, and Wall 2011; Núñez-Sánchez and Coto-Millán 2012; Rodríguez-Álvarez and Tovar 2012; Tovar and Wall 2015) and non-parametric techniques such as DEA (Martinez-Budria et al. 1999; Bonilla et al. 2002; Barros 2003; Bonilla et al. 2004; Barros and Athanassiou 2004; Inglada and Coto-Millán 2010; Carvalho et al. 2010; Medal and Sala 2011; Carvalho and Marques 2012; Medal-Bartual, Molinos-Senante, and Sala-Garrido 2012; Díaz-Hernández, Martínez-Budría, and Salazar-González 2014; Gutiérrez et al. 2015).

Most of studies have used production frontiers to estimate efficiency instead of cost frontiers, i.e. they have evaluated technical efficiency, with only some dedicated to estimating allocative efficiency (e.g. Baños-Pino et al. 1999; Coto-Millán, Baños-Pino, and Rodríguez-Álvarez 2000; Barros 2005; Rodríguez-Álvarez, Tovar, and Trujillo 2007, 2011; Díaz-Hernández, Martínez-Budría, and Jara-Díaz 2008; Núñez-Sánchez and Coto-Millán 2010; Díaz-Hernández, Martínez-Budría, and Salazar-González 2014). Regarding to the period of time studied, most of papers evaluated productivity change of ports across time, i.e. they incorporate changes that have occurred over a period of time (i.e. dynamic). However, some studies only inform of the efficiency of ports at a given moment in time (e.g. Bonilla et al. 2002, 2004; Carvalho et al. 2010; Medal and Sala 2011; Medal-Bartual, Molinos-Senante, and Sala-Garrido 2012; Gutiérrez et al. 2015).

The review of the existing port productivity literature also shows that the studies differ in terms of their main objectives. Some papers focus on regulatory changes and governance (González and Trujillo 2008; Díaz-Hernández, Martínez-Budría, and Jara-Díaz 2008; Carvalho et al. 2010; Rodríguez-Álvarez and Tovar 2012; Núñez-Sánchez and Coto-Millán 2012) while others evaluate issues related to the specialization of ports (Inglada and Coto-Millán 2010; Medal-Bartual, Molinos-Senante, and Sala-Garrido 2012; Tovar and Wall 2015) or the presence of economies of scale (Coto-Millán, Baños-Pino, and Rodríguez-Álvarez 2000; Ramos-Real and Tovar 2010; Gutiérrez et al. 2015).

The aforementioned literature covers a wide range of methodologies, specifications, and objectives. However, as far as we are aware, no studies of Spanish Port Authority efficiency have evaluated how the economic crisis has affected the productivity of the SPS. To the best of our knowledge, only Wilmsmeier, Tovar, and Sanchez (2013) analyzed the impact of the economic crisis in the productivity change of container terminals while this study focuses on Port Authorities. Moreover, because most of the terminals evaluated by Wilmsmeier, Tovar, and Sanchez (2013) are located on Latin America and Caribbean, three periods were evaluated namely, pre-crisis, crisis, and post-crisis. In this sense and because our work is focused on Spanish ports, we cannot consider a post-crisis period since economic crisis prevails after 2011 (last year analyzed).

4. Methodology

Our analysis was divided into two steps. In the first step, the MPI and its components were calculated for two time periods, to obtain information on the productivity change over time. In the second step, we evaluated whether investment in the Port Authorities influenced the productivity change.

4.1. *Assessment of the productivity change: the MPI*

Productivity change between time periods may be calculated in several ways. As one of the most commonly used methods, the MPI follows the non-parametric DEA approach to evaluate the performance of DMUs (i.e. the Port Authorities). The DEA is a linear programming technique that neither requires a predetermined functional form nor demands the user to set weights for each input and output (Cooper, Seiford, and Zhu 2000).

Since the MPI was first presented by Malmquist (1953), many methodological developments and empirical applications have been carried out (Caves, Christensen, and Diewert 1982; Chen 2003; Färe et al. 1992). One of the merits of the MPI is that it can be decomposed into two components: i.e. efficiency change (MECH) and technical change (MTCH) (Chen et al. 2008). Hence, it is possible to identify the factor that most contributes to the productivity change and, consequently, acts to improve the productivity. Moreover, the efficiency change can be separated into pure technical efficiency change and scale efficiency change (Färe, Grosskopf, and Margaritis 2007). However, taking into account that the research question of this paper was to address whether the economic crisis has impacted the productivity growth of SPS, we limited the decomposition of the MPI into MECH and MTCH.

The MECH, also known as the catching-up index, reflects the relative change in efficiency between periods. In the framework of the ports' efficiency, this concept involves the capacity of ports to be managed in accordance with best operational practices (i.e. to be operated on the efficient frontier). Efficiency gains due to the catching-up effect can mainly be attributed to the managerial capacity of ports in response to changes in scale efficiency and their ability to adjust to input factors in a timely manner, i.e. changes in pure technical efficiency (Cheon 2007).

The MTCH, also known as the frontier productivity index, measures the change in frontiers between two periods. Cheon (2007) suggested that institutional reforms to increase market competition represent the main driving force for maintaining ports with the latest technologies. Effective long-term strategic planning and timely capital investment are needed to improve technical efficiency.

The MPI calculates the ratio of the distances of data in each time period. Following Färe, Grosskopf, and Lovell (1994), the MPI between period t and $t+1$ can be represented as follows (Equation (1)):

$$MPI = \sqrt{\frac{d_{t+1}^{t}\left(x_{t+1}^{t}, y_{t+1}^{t}\right) d_{t+1}^{t+1}\left(x_{t+1}^{t+1}, y_{t+1}^{t+1}\right)}{d_{t}^{t}\left(x_{t}^{t}, y_{t}^{t}\right) d_{t}^{t+1}\left(x_{t}^{t+1}, y_{t}^{t+1}\right)}} \tag{1}$$

where $y \in N_{+}^{M}$ is a set of desirable outputs, and $x \in N_{+}^{N}$ is a set of inputs. The MPI may be divided into two components, MECH and MTCH, as shown in Equation (2):

$$MPI = \frac{d_{t+1}^{t+1}\left(x_{t+1}^{t+1}, y_{t+1}^{t+1}\right)}{d_{t}^{t}\left(x_{t}^{t}, y_{t}^{t}\right)} \sqrt{\frac{d_{t+1}^{t}\left(x_{t+1}^{t}, y_{t+1}^{t}\right) d_{t}^{t}\left(x_{t}^{t}, y_{t}^{t}\right)}{d_{t+1}^{t+1}\left(x_{t}^{t+1}, y_{t}^{t+1}\right) d_{t}^{t+1}\left(x_{t}^{t+1}, y_{t}^{t+1}\right)}} = MECH * MTCH \tag{2}$$

The MPI and its components can be interpreted as follows: (i) MPI > 1 means an improvement in productivity; (ii) MPI < 1 means a worsening in productivity; and (iii) MPI = 1 means productivity has not changed.

To compute the MPI (Equation (2)) using DEA methodology, several approaches can be followed. Thus, Färe, Grosskopf, and Lovell (1994) followed a radial model with input or output orientation. Subsequently, Chen (2003) used a non-radial model based on the slacks-based measure (SBM) developed by Tone (2001). A third approach based on the super-SBM model uses a non-radial and non-oriented approach (Tone 2002). In our case study, the approach developed by Färe, Grosskopf, and Lovell (1994) was followed with input orientation since Port Authorities can act to minimize the use of inputs (Carvalho and Marques 2012). By assessing 36 of the most important worldwide ports, including 16 Spanish Port Authorities, Carvalho and Marques (2012) proved that ports are characterized by overall constant returns to scale. Moreover, this approach avoids infeasibility problems as happens when variable returns to scale is assumed.

Hence, the MPI can be computed by solving four linear programming problems, shown in Equations (3)–(6):

$$\begin{aligned} &Min\theta \\ &\lambda X_t \leq \theta X_{0t} \\ &\lambda Y_t \geq Y_{0t} \\ &\lambda \geq 0 \end{aligned} \tag{3}$$

$$\begin{aligned} &Min\theta \\ &\lambda X_{t+1} \leq \theta X_{0t+1} \\ &\lambda Y_{t+1} \geq Y_{0t+1} \\ &\lambda \geq 0 \end{aligned} \tag{4}$$

$$\begin{aligned} &Min\theta \\ &\lambda X_t \leq \theta X_{0t+1} \\ &\lambda Y_t \geq Y_{0t+1} \\ &\lambda \geq 0 \end{aligned} \tag{5}$$

$$\begin{aligned} &Min\theta \\ &\lambda X_{t+1} \leq \theta X_{0t} \\ &\lambda Y_{t+1} \geq Y_{0t} \\ &\lambda \geq 0 \end{aligned} \tag{6}$$

The MPI measures only the productivity change assuming constant returns to scale. The DEA, considering variable returns to scale, does not measure the impact of production scales on efficiency, which is measured by the component MECH.

4.2. *Influence of port investments on the productivity change*

To evaluate if Port Authority investments influence the productivity change, Port Authorities were grouped based on their investment trends. Subsequently, we checked for statistically significant differences in MPI scores between the groups, by applying the Mann–Whitney test. This non-parametric test is equivalent to the traditional analysis of variance (ANOVA) approach, except that the Mann–Whitney test does not require assumptions of homoscedasticity and normalcy of the sample.

The hypothesis to be tested is as follows:

- H_0 = The *k* samples come from the same population.
- H_1 = Some samples come from another population.

The defined null hypothesis was accepted if the level of statistical significance (p-value) was >0.05 (i.e. the groups of Port Authorities are not significantly different from each other, but similar). The null hypothesis was rejected if the p-value was ≤0.05 (i.e. the groups of Port Authorities are statistically different) (Molinos-Senante, Hernandez-Sancho, and Sala-Garrido 2014).

5. Sample description

The sample of our study is the totality of Port Authorities comprising the SPS which involves 28 Port Authorities that are coordinated and controlled by the state agency 'Puertos del Estado' (State Ports). Hence, the sample consists of 28 Port Authorities whose data have been obtained from annual reports of Puertos del Estado.

Diverse input and output variables are used in the literature for measuring the efficiency and productivity change of ports, as evidenced in a review by Wilmsmeier, Tovar, and Sanchez (2013). The most recent trend has been to consider the traffic of each port as its output. Hence, in accordance with Bonilla et al. (2004), Cheon, Dowall, and Song (2010), and Díaz-Hernández, Martínez-Budría, and Jara-Díaz (2008), among others, we considered the traffic volumes as the output variables. Moreover, recent studies (Núñez-Sánchez and Coto-Millán 2012; Tovar and Wall 2015) also integrate the number of passengers as output. Hence, in this study four outputs were considered namely: liquid bulk (LB), solid bulk (SB), general commodities (GC) (each expressed in thousands of tonnes), and number of passengers (PASS). Following Chang and Tovar (2014), the inputs of the analysis were the labor costs (LAB) and equipment or fixed assets (FA) of the Port Authorities (expressed in thousands of euros). They were deflated using the Spanish Customer Price Index to adjust them for inflation. According to Puertos del Estado (2012), FA are non-current assets that include intangible assets, real estate investments, and long-term financial investments.

DEA methodology makes a series of homogeneity assumption about the units under assessment. First, the units are assumed to be undertaking similar activities and producing comparable products. In this sense, as it was reported by Tovar and Wall (2015) the fact that the Port Authorities under study are in the same country has the advantage that the accounting data are uniform and comparable. Moreover, these Port Authorities face the same regulations. A second assumption is related with the number of Port Authorities, inputs, and outputs. Hence, according to 'Coopers' rule', the number of units must be higher than or equal to $\max\{m * s; 3(m+s)\}$, where m is the number of inputs and s is the number of outputs involved in the DEA study (Cooper, Seiford, and Tone 2007). In this paper, 4 outputs, 2 inputs, and 28 Port Authorities are considered. Therefore, the 'Cooper's rule' is met.

The main aim of this work was to evaluate how the economic crisis has impacted the productivity change of the SPS. Therefore, the MPI was estimated for two time periods: the 'non-crisis period' from 2005 to 2008, and the 'crisis period' from 2008 to 2011. Table 1a and Table 1b summarize the mean, standard deviation (SD), minimum and maximum values of the inputs and outputs of each Spanish Port Authority for the 2005–2011 period, showing the impact of the economic crisis on Port Authority investments.

6. Results and discussion

6.1. *Productivity change in the non-crisis period (2005–2008)*

Table 2 presents the evaluation of productivity growth in Spanish Port Authorities using the MPI, decomposed into the MECH and MTCH. For the non-crisis period, in average terms, the productivity of the SPS increased 35.8% across the 3 years (i.e. 11.9% yearly). Table 2 and Figure 4 show that productivity improved in 19 of the 28 Port Authorities (68%), while the remaining 9 Port Authorities (32%) had worsened productivity.

Table 1a. Sample description.

	Average						Standard deviation					
	Outputs (10^3 tons)				Inputs (10^3 €)		Outputs (10^3 tons)				Inputs (10^3 €)	
Port Authority	LB	SB	GC	PASS	FA	LAB	LB	SB	GC	PASS	FA	LAB
A Coruña	7652	4438	1268	63,023	403,211	6426	756	518	236	31,641	234,045	652
Alicante	136	1668	1564	333,429	188,300	4948	38	414	232	30,351	10,614	334
Almería	5	6307	596	1,083,965	131,810	5051	3	1341	63	92,324	22,782	447
Avilés	645	3083	1248	0	123,597	3908	106	448	185	0	13,659	204
B. de Algeciras	21,311	2652	44,674	4,901,134	641,399	15,768	1688	586	4517	272,955	141,334	1467
Bahía de Cádiz	112	2557	2485	262,722	240,340	7415	33	967	455	86,511	10,449	550
Baleares	1978	2318	8794	5,417,700	341,370	13,204	227	287	859	270,636	37,618	1473
Barcelona	11,463	4052	30,256	3,049,310	1,562,503	30,888	733	257	3719	552,063	218,005	3124
Bilbao	20,834	4261	9263	171,244	769,479	13,759	1910	793	906	11,120	30,219	951
Cartagena	18,142	5082	941	56,285	262,094	6859	2086	901	134	30,613	25,720	453
Castellón	7903	3294	1666	216	216,062	4795	513	724	328	352	38,842	651
Ceuta	991	71	913	2,227,041	103,554	6831	187	35	53	280,338	5262	571
Ferrol-San Cibrao	1874	8290	666	3281	197,707	4308	786	737	121	2975	22,207	878
Gijón	1332	19,658	837	11,498	745,346	7683	150	3049	324	20,420	300,048	268
Huelva	14,937	7513	481	6620	402,073	8873	3206	1462	166	11,392	21,275	1050
Las Palmas	4723	1773	16,541	1,219,028	715,667	12,904	140	516	1660	343,168	43,450	1594
Málaga	75	2100	3046	706,264	184,151	6692	29	558	1357	204,781	17,427	690
Marín y Ría de Pont.	2	1016	878	0	71,403	3144	3	62	91	0	9223	216
Melilla	72	84	691	537,687	120,252	4412	3	18	42	92,993	19,582	845
Motril	1370	1247	197	15,424	68,558	2419	97	325	33	27,071	7697	530
Pasajes	1	3281	2121	0	121,299	6785	0	820	188	0	4691	707
S.C. Tenerife	8855	1892	6528	4,672,917	456,193	9163	905	531	797	211,259	36,984	844
Santander	372	5140	1383	182,648	309,524	6635	57	858	217	35,570	5488	327
Sevilla	296	2789	1997	15,800	392,785	5809	71	309	170	3331	87,395	223
Tarragona	18,958	11,903	2341	3800	432,510	9572	876	1655	1124	3717	49,357	617
Valencia	4674	6361	45,754	463,501	1,159,316	17,616	1573	2110	9736	127,719	263,049	1899
Vigo	77	693	3685	191,121	220,738	8946	13	134	440	52,270	24,728	1106
Vilagarcía	293	578	235	4552	59,749	2759	89	98	55	1309	12,847	378

Source: State ports (2005–2011).

One of the smallest Spanish Port Authorities, Motril, had the highest productivity increase (MPI = 2.220). Santander and Valencia had the most decreased productivity (MPI = 0.730 and MPI = 0.757); due to their MECH being particularly low since the other component of the MP (MTCH) was greater than 1. For the 9 Port Authorities with declining productivity, the average MPI was 0.867, illustrating that the worsening in productivity in those Port Authorities was not very significant (4.1% per year). Moreover, 3 Port Authorities (Bahía of Algeciras, Melilla, and Motril) improved their productivity by more than 100%.

Next, we evaluated which component (MECH or MTCH) contributed more to the productivity change of each Port Authority. Table 2 and Figure 4 illustrate that MECH and MTCH followed opposite trends. The mean value of MECH was less than one, and the catching-up index decreased 5.8% per year on average. Analyzed Port Authorities moved away from efficient production by 17.5% across 2005–2008. The mean value for the frontier shift index was greater than one, and the technological frontier had a positive offset of 68.5% (22.8% per year). Based on the mean MECH and MTCH values, it can be concluded that in the non-crisis period, only the frontier productivity index contributed positively to the improvement in SPS productivity. Our results are consistent with the work of Núñez-Sánchez and Coto-Millán (2012), who established that an improvement of SPS productivity from 1986 to 2005 was due to positive technical changes, while the efficiency growth rate was negative, as in our case.

Regarding the MECH and MTCH for individual Port Authorities, only 5 Port Authorities (Alicante, Marín-Pontevedra, Melilla, Motril, and Vigo) increased their catching-up index (i.e. moved to the efficient frontier by adopting better operational practices). The MECH of some of the largest Spanish Port Authorities, such as Valencia, Bilbao, Tarragona, and Barcelona, was less than 0.7. On the other hand, the MTCH, which partially reflects the capital investment, was greater than 1 for all 28 Port

Table 1b. Sample description.

	Maximum						Minimum					
	Outputs (10^3 tons)				Inputs (10^3 €)		Outputs (10^3 tons)				Inputs (10^3 €)	
Port Authority	LB	SB	GC	PASS	FA	LAB	LB	SB	GC	PASS	FA	LAB
A Coruña	8534	4438	1648	128,563	762,256	6987	6601	3191	1015	33,757	163,024	5303
Alicante	189	1668	1852	370,190	198,129	5342	86	720	1260	285,415	165,658	4473
Almería	9	6307	701	1,182,834	156,064	5548	2	3213	536	926,699	93,809	4274
Avilés	814	3615	1488	1	142,319	4170	523	2293	984	0	102,891	3668
B. de Algeciras	23,895	2708	52,270	5,224,923	793,546	17,045	19,589	1475	39,468	4,445,503	421,303	13,232
Bahía de Cádiz	169	4406	3037	397,554	254,386	8009	74	1637	1963	153,345	225,308	6641
Baleares	2206	2318	9938	5,793,708	411,492	14,953	1578	1643	7955	5,060,090	298,417	10,707
Barcelona	12,531	4108	35,185	3,835,062	1,790,208	34,360	10,536	3506	26,117	2,208,330	1,197,110	26,377
Bilbao	23,057	5832	9908	185,388	823,585	14,967	17,861	3828	7279	152,201	743,664	12,294
Cartagena	20,848	5371	1139	104,294	303,050	7306	15,122	3114	729	29,073	228,313	6131
Castellón	8949	4017	2138	849	260,007	5580	7354	1866	1130	0	164,753	3880
Ceuta	1195	142	999	2,603,786	109,277	7611	611	67	861	1,863,128	94,241	5783
Ferrol-San Cibrao	2678	9781	834	9423	220,627	5381	822	7435	558	564	161,356	3201
Gijón	1470	19,658	1466	57,096	1,082,069	8095	1038	12,456	489	1225	322,844	7328
Huelva	21,689	7604	716	29,781	428,750	9972	12,927	4181	283	0	369,531	7282
Las Palmas	4919	1773	18,217	1,677,101	753,281	14,493	4547	524	13,617	780,603	646,541	10,849
Málaga	116	2100	4538	985,038	201,458	7386	34	767	1275	470,160	160,857	5665
Marín y Ría de Pont.	10	1016	978	1	80,967	3403	1	847	762	0	59,523	2818
Melilla	77	84	763	642,733	142,333	5337	68	33	641	397,744	87,962	3187
Motril	1543	1247	259	75,886	75,322	2946	1273	453	162	2335	55,231	1482
Pasajes	1	3281	2372	1	130,008	7485	1	1247	1818	0	114,981	5869
S.C. Tenerife	9585	1987	7449	4,953,777	499,031	10,243	7261	782	5741	4,346,650	401,194	7973
Santander	426	5140	1683	246,700	317,509	7245	278	2880	1107	154,254	303,387	6361
Sevilla	364	2828	2243	21,422	505,669	6107	204	1998	1704	11,788	277,514	5453
Tarragona	20,594	13,626	3755	11,719	503,157	10,300	17,907	9279	1176	752	372,949	8529
Valencia	5968	7323	58,571	716,443	1,480,040	19,878	1380	2374	33,121	335,803	769,357	14,671
Vigo	95	702	4315	253,637	251,108	10,065	58	381	3073	129,268	187,704	7072
Vilagarcía	416	613	304	6927	75,555	3211	189	339	131	3126	41,572	2272

Source: State ports (2005–2011).

Table 2. MPI, MECH, and MTCH of Spanish Port Authorities for 2005–2008.

Port Authority	MPI	MECH	MTCH
A Coruña	1.835	0.951	1.930
Alicante	1.974	1.055	1.871
Almería	1.618	1.000	1.618
Avilés	1.416	0.848	1.670
B. de Algeciras	2.005	1.000	2.005
Bahía de Cádiz	1.022	0.998	1.024
Baleares	1.106	0.863	1.282
Barcelona	1.261	0.622	2.027
Bilbao	0.890	0.511	1.742
Cartagena	1.201	0.949	1.265
Castellón	0.850	0.504	1.688
Ceuta	0.895	0.324	2.763
Ferrol-San Cibrao	0.871	0.502	1.735
Gijón	1.925	1.000	1.925
Huelva	1.241	0.971	1.278
Las Palmas	1.366	0.699	1.954
Málaga	0.896	0.548	1.635
Marín y Ría de Pont.	1.430	1.094	1.308
Melilla	2.119	1.414	1.498
Motril	2.220	1.190	1.865
Pasajes	0.968	0.814	1.190
S.C. Tenerife	1.476	1.000	1.476
Santander	0.730	0.502	1.455
Sevilla	1.856	0.949	1.955
Tarragona	0.949	0.597	1.589
Valencia	0.757	0.470	1.610
Vigo	1.507	1.038	1.452
Vilagarcía	1.653	0.701	2.358
Mean	1.358	0.825	1.685
STD deviation	0.458	0.262	0.351

Authorities in the SPS. Hence, from 2005 to 2008, there was a positive shift of the efficient frontier of the SPS, increasing the international competitiveness of the SPS. Bahía of Algeciras, which supported the highest traffic in the SPS, also showed substantial improvement in the frontier productivity index (MTCH = 2.005), which contributed to increase its productivity by more than 100%. Although other large Port Authorities, such as Barcelona and Valencia, showed significantly improved MTCH results, in contrast to Bahía of Algeciras, the decline in the MECH involved a more moderate rise (Barcelona) or even a decrease (Valencia) in productivity.

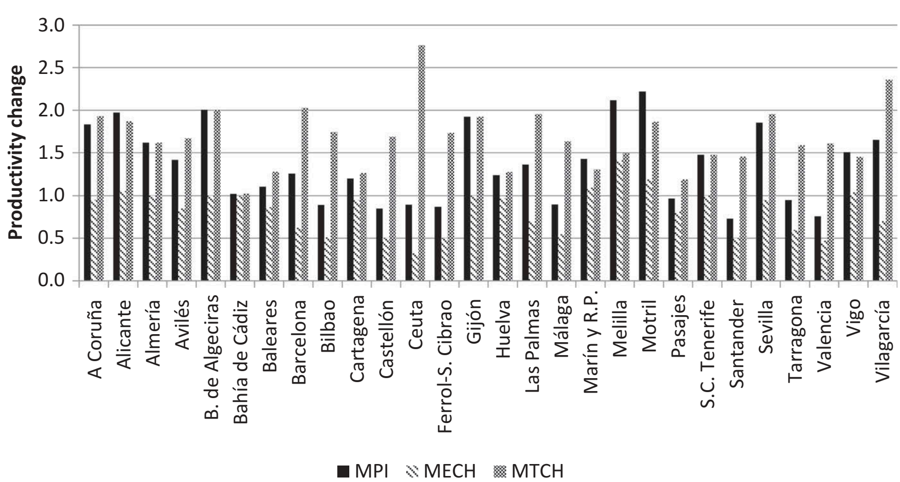

Figure 4. MPI, MECH, and MTCH of Spanish Port Authorities for 2005–2008.

6.2. *Productivity change in the crisis period (2008–2011)*

As shown in Table 3 and Figure 5, the mean MPI was greater than 1 in the period from 2008 to 2011, indicating that the productivity of the SPS improved during the economic crisis period. Specifically, productivity increased 8.6% per year across the 3 years.

The productivity increased for 21 of 28 Spanish Port Authorities (which represents 75% of the ports in the SPS). The port A Coruña showed the greatest increase (MPI = 3.361), largely due to the catching-up effect (MECH = 3.216). From a policy perspective, the operational practices introduced in this port from 2008 to 2011 should be analyzed because they were responsible for most of the increased productivity. Tarragona had the most decreased productivity of all ports. Its MTCH was higher than 1, whereas MECH was lower than 1, indicating that the only contributor to the decreased productivity was the catching-up index.

In contrast to the non-crisis period, in the crisis period, the average values of MECH and MTCH were quite similar and higher than 1. In other words, both components contributed positively to the improvement of the productivity. The SD of the MPI was around 48% of the mean value, indicating a degree of divergence within the 28 evaluated Port Authorities. A similar value was obtained for the MECH, although the SD for the MTCH was significantly lower, illustrating that divergences in the shift of the efficient frontier were small.

6.3. *Comparison of the productivity change between the non-crisis and crisis periods*

Table 4 summarizes differences in the MPI, MECH, and MTCH values between the crisis and non-crisis periods. A positive (or negative) value reflects an improved (or worsened) productivity change of the Port Authorities during the crisis compared to the non-crisis period. In other

Table 3. MPI, MECH, and MTCH of Spanish Port Authorities for 2008–2011.

Port Authority	MPI	MECH	MTCH
A Coruña	3.361	3.216	1.045
Alicante	1.365	1.247	1.095
Almería	1.401	1.000	1.401
Avilés	1.005	1.063	0.946
B. de Algeciras	1.109	1.000	1.109
Bahía de Cádiz	0.978	0.934	1.048
Baleares	1.303	1.356	0.961
Barcelona	1.101	1.144	0.962
Bilbao	1.163	1.189	0.978
Cartagena	1.150	0.597	1.927
Castellón	1.009	1.083	0.932
Ceuta	0.994	1.000	0.994
Ferrol-San Cibrao	1.290	1.000	1.290
Gijón	1.043	0.801	1.302
Huelva	1.109	1.127	0.984
Las Palmas	1.389	1.389	1.000
Málaga	1.500	1.497	1.002
Marín y Ría de Pont.	0.885	0.624	1.418
Melilla	0.950	0.872	1.089
Motril	1.193	0.610	1.957
Pasajes	1.182	1.176	1.005
S.C. Tenerife	1.191	1.199	0.993
Santander	0.953	1.000	0.953
Sevilla	1.298	1.380	0.941
Tarragona	0.868	0.601	1.444
Valencia	1.365	1.335	1.023
Vigo	0.899	0.934	0.963
Vilagarcía	2.135	1.923	1.110
Mean	**1.257**	**1.149**	**1.142**
STD deviation	**0.485**	**0.502**	**0.271**

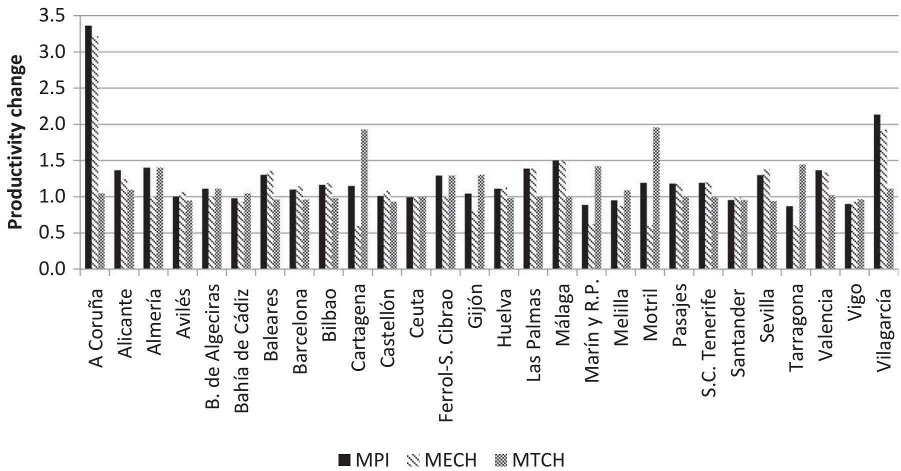

Figure 5. MPI, MECH, and MTCH of Spanish Port Authorities for 2008–2011.

words, by computing the difference in MPI values between the two periods, we could evaluate whether the Port Authorities showed a turnaround in their productivity growth.

The average difference in MPI between the crisis and non-crisis periods for the SPS was negative (−0.102); thus, the productivity growth worsened slightly in consequence of the economic crisis. In this context, the study conducted by Wilmsmeier, Tovar, and Sanchez (2013) which assessed the productivity change of 20 container terminals in 10 countries in the Latin America and the Caribbean and in Spain for the period 2005–2011, evidenced that for these ports, productivity increased by 18.8% between 2005 and 2008 and by 2.2% from 2008 to 2011. It means that while productivity improved during the period of crisis, the percentage of improvement was notably smaller than in previous years. Nevertheless, in our case study, the SD was large, indicating significant differences across the Spanish Port Authorities. Totally, 12 out of 28 Port Authorities presented positive differences in their MPIs, i.e. showed higher productivity growth during the crisis than in the non-crisis period. In other words, the crisis positively impacted the productivity change of these Port Authorities.

A Coruña demonstrated the greatest increase in productivity between the two periods, due to a significant increase in MECH. The MTCH of this Port Authority was negative, illustrating that it was better in the non-crisis than in the crisis period. In contrast, the productivity growth of the Melilla Port Authority worsened substantially during the crisis period, with both MECH and MTCH contributing to this trend (i.e. both were negative). Divergent average values of the two components of the productivity index were found for the 28 Spanish Port Authorities. The average value of MECH was positive (0.324), meaning that the catching-up index grew more in the crisis than in the non-crisis period (Table 4). Based on its definition, a positive value of MECH indicates that, in average terms, the evaluated Port Authorities exhibited improved managerial practices. Thus, with the economic crisis, the Port Authorities' managers have had to strive to improve the Port Authorities' management.

Only 7 of the 28 Port Authorities (Bahía de Cádiz, Cartagena, Gijón, Marín-Pontevedra, Melilla, Motril, and Vigo) presented a negative value of MECH. These Port Authorities moved away from the efficient frontier. The MECH was substantially improved during the crisis period for some other Port Authorities, particularly A Coruña, Vilagarcía, Málaga and Valencia. These Port Authorities increased their productivity and efficiency despite the economic crisis. All of these Port Authorities were specialized in one kind of traffic. From a policy perspective, the practices and conditions of these Port Authorities require special attention to identify the causes of their improvement.

Table 4. Difference in MPI, MECH, and MTCH of Spanish Port Authorities between 2005–2008 and 2008–2011.

Port Authority	MPI	MECH	MTCH
A Coruña	1.526	2.265	−0.885
Alicante	−0.609	0.192	−0.776
Almería	−0.217	0.000	−0.217
Avilés	−0.411	0.215	−0.724
B. de Algeciras	−0.896	0.000	−0.896
Bahía de Cádiz	−0.044	−0.064	0.024
Baleares	0.196	0.493	−0.321
Barcelona	−0.160	0.522	−1.065
Bilbao	0.273	0.678	−0.764
Cartagena	−0.051	−0.352	0.662
Castellón	0.159	0.579	−0.757
Ceuta	0.098	0.676	−1.769
Ferrol-San Cibrao	0.419	0.498	−0.445
Gijón	−0.882	−0.199	−0.623
Huelva	−0.133	0.156	−0.294
Las Palmas	0.023	0.690	−0.954
Málaga	0.604	0.949	−0.633
Marín y Ría de Pont.	−0.545	−0.469	0.110
Melilla	−1.169	−0.542	−0.409
Motril	−1.026	−0.580	0.092
Pasajes	0.214	0.363	−0.185
S.C. Tenerife	−0.285	0.199	−0.483
Santander	0.223	0.498	−0.501
Sevilla	−0.558	0.431	−1.015
Tarragona	−0.081	0.004	−0.145
Valencia	0.608	0.865	−0.587
Vigo	−0.608	−0.104	−0.489
Vilagarcía	0.482	1.222	−1.248
Mean	**−0.102**	**0.324**	**−0.542**
STD deviation	**0.581**	**0.594**	**0.480**

First, A Coruña is important for LB traffic. This Port Authority showed an average overall traffic growth of 2.88% in 2010 (A Coruña Port Annual Report 2010). The growth of LB traffic, mainly of fuels, was related to the 'Repsol' refinery located near A Coruña. This 'captive traffic' provided the port with stable LB traffic that was independent of the economic crisis.

Second, Vilagarcía is the smallest Port Authority of the SPS. Traffic began to recover for this port in 2011 (Vilagarcia Port Annual Report 2011). A fundamental factor for this traffic increase was the reactivation of a container terminal. In 2011, some important steps were taken in this regard, such as: the start of operations of the new commercial dock, and the start of construction work in the Ferrazo esplanade.

Third, Málaga is a small Port Authority in the south of Spain which showed a slight recovery in its traffics during the crisis period. A fundamental part of this success was due to the efforts of every participant in container traffic, which resulted in costs being lowered as much as possible (Malaga Port Annual Report, 2010).

Fourth, the Port Authority of Valencia is traditionally specialized in containers. Valencia moved 64 million tons in 2010, representing a 10.81% increase over 2009. Container traffic increased 15.1%, reached 4.2 million twenty-foot equivalent units (TEUs), the highest level in the history of the SPS. This Port Authority underwent marked expansion in recent years, with a total investment in 2010 exceeding 171 million euros (Valencia Port Annual Report, 2010).

To summarize the results, Port Authorities that demonstrated substantially improved MECH values during the crisis period were usually specialized Port Authorities that maintained or enhanced their main traffics. Most of them made important investment efforts in recent years, even during the economic crisis.

Returning to the data in Table 4, unlike the average value of MECH, the average value of MTCH for the SPS was negative, illustrating that the technological frontier had a negative offset.

Among other information, the frontier productivity index provides information about the technology upgrades of facilities, i.e. it is strongly related to capital investment in ports. Only 4 of the 28 Port Authorities presented a positive shift in the efficient frontier, verifying that the investment level in the SPS was reduced during the crisis period (Figure 3).

A comparison of the MPI during the two time periods verified that the economic crisis negatively impacted the productivity growth of the SPS. Although the productivity of Spanish Port Authorities, in average terms, still improved during the crisis years, the growth rate of the productivity was lower than in the non-crisis period. From an analysis of the evolution of the two components of the MPI, we can conclude that a main reason for the productivity decrease was a lack of investment in the Port Authorities to upgrade technologies.

Nevertheless, the economic crisis did not impact all of the Port Authorities equally. Results at the port-level verified remarkable differences among the Port Authorities. In particular, the productivity growth of some Port Authorities (e.g. La Coruña, Málaga, Valencia, and Vilagarcía, among others) was higher during the crisis than in the non-crisis period; therefore, these Port Authorities were not impacted by the economic crisis. From a policy perspective, the reason for this positive growth was an improvement in management strategies; from 2008 to 2011, the shift of the efficient frontier was negative for these Port Authorities.

6.4. *Influence of port authority investments on the productivity change*

As reported in Section 6.3, Port Authorities with the highest improvements in productivity change were those that made important investment efforts, even during the economic crisis, against the general trend of the SPS. The most efficient Port Authorities of the SPS (see Table 4) were characterized by large increases in their investments, through the extension of their installations or modernization, in the last years. The next step is to test, from a statistical perspective, whether investment and productivity change were related. We applied the non-parametric Mann–Whitney test to assess whether there were statistically significant differences in the mean values of MPI, MECH, and MTCH between Port Authorities based on their investment trends. For the two time periods analyzed, Port Authorities comprising the SPS were categorized into groups, according to whether their investments per unit of traffic were higher or lower than the average. According to Annual Statistics of State Ports, investments are the total executed investment of the SPS in tangible, intangible, and financial assets.

The p-values of the Mann–Whitney tests (Table 5) showed that investment and productivity growth (MPI) were related from a statistical standpoint. Port Authorities with above-average investments showed a greater increase in productivity in both periods (crisis and non-crisis) compared to Port Authorities with below-average investments. The Mann–Whitney test confirmed that Port Authorities which made an investment effort during the crisis period were less impacted by the crisis than ports whose investments were reduced during the crisis period. Therefore, we have confirmed that investment in the Port Authorities was a determinant factor of their productivity growth.

Investments during the crisis period were statistically significant to explain the MECH. Port Authorities that expanded or modernized their assets during the economic crisis improved its

Table 5. p-Value of the Mann–Whitney test.

	Investments		
	Non-crisis period	Crisis period	Difference
MPI	0.003	<0.001	0.029
MECH	0.430	<0.001	0.184
MTCH	0.008	0.848	0.836

Grey boxes indicate that, for these parameters, differences between groups are statistically significant.

efficiency. However, the Mann–Whitney test did not allow us to confirm whether investment before the crisis was a relevant variable in the results of the catching-up index. Hence, investments made before the crisis did not contribute to the improvement of the efficiency of the Port Authorities, but Port Authorities that invested during the crisis showed the capacity of being more efficient, operating nearer efficient frontier.

The explanation for how Port Authority investments affected the MTCH is the opposite for that of the MECH. Investments were statistically significant in the frontier productivity index during the years before the crisis, but not in the crisis period, according to the investment trend of the last years. As shown in Figure 3, investments before the crisis were much higher than those during the crisis. Therefore, the investment process before the crisis increased market competition and improved technical efficiency. However, the decrease of investments during the crisis was not relevant to the technical change.

7. Conclusions

The main aim of this study was to assess whether the economic crisis has impacted the productivity growth of the SPS, which includes 28 Port Authorities. To this end, the MPI was estimated for two periods: 2005–2008 (non-crisis period) and 2008–2011 (crisis period). This index was chosen as an indicator of the productivity change because it can be decomposed into two indexes, i.e. the catching-up index (MECH) and the frontier productivity index (MTCH).

From a policy perspective, it is extremely important to differentiate whether the improvement or worsening of Port Authorities' productivity was associated with one or both components of the MPI. MECH involves the capacity of ports to be managed in accordance with best operational practices, whereas MTCH is more related to long-term strategic planning and capital investment. Decision-makers and port managers should adopt different strategies to improve productivity depending on the MECH and MTCH values. The results indicate that several aspects should be considered from a policy perspective. During the non-crisis period, the SPS showed increased productivity due exclusively to the positive shift of the efficient frontier, while Port Authorities moved away from efficient production. Thus, from 2005 to 2008, the SPS increased its international competitiveness. During the crisis period, Spanish Port Authorities also improved their productivity; however, both MECH and MTCH contributed to this improvement.

The economic crisis has not impacted all of the Spanish Port Authorities equally. Some Port Authorities (12 of 28) presented greater productivity growth during the crisis period than in the non-crisis period, i.e. the crisis positively impacted their productivity change. After analyzing the main characteristics of those Port Authorities, we concluded that the best Port Authorities were usually specialized Port Authorities that maintained or enhanced their main traffics (e.g. LB traffic in A Coruña and container traffic in Valencia) and made significant investment efforts (e.g. A Coruña, Valencia, and Vilagarcia), even during the economic crisis. Deeper statistical analysis allowed us to conclude that Port Authorities which expanded or modernized their assets during the economic crisis years positively changed their efficiency, by operating nearer the efficient frontier.

Meanwhile, the turnaround in the productivity growth of the remaining Port Authorities was the opposite. During the crisis period, the catching-up index for these Port Authorities, in average terms, grew more than in the non-crisis period; i.e. the Port Authorities improved their managerial strategies to improve their productivity. The frontier productivity index worsened during the crisis years due to a general reduction in investments in the SPS. Although the investment process before the crisis increased market competition and improved the technical efficiency of the system, the investment process during the crisis was not relevant to the technical change. This result is consistent with the figures of the SPS, which showed a 62.33% reduction in investments from 2008 to 2012.

Information provided by this study may be very useful for stakeholders and decision-makers for long-term strategic planning and improving the competitiveness of the SPS. In contrast to the general opinion, the economic crisis is not synonymous with general losses. The economic impact has not been the same in every Port Authority. In particular, Port Authorities that increased their level of investment during the crisis period (e.g. by modernizing, adapting, or expanding their installations) have managed to become more efficient than before the economic crisis, thereby improving the productivity and international competitiveness of the SPS. We suggest that the economic crisis of 2008 be seen as an opportunity to adapt Port Authority traffics and installations to meet new needs and market demands.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Al-eraqui, A. S., A. T. Khader, and A. Mustafa. 2009. "DEA Malmquist Index Measurement in Middle East and East African Container Terminals." *International Journal of Shipping and Transport Logistics* 1 (3): 249–259. doi:10.1504/IJSTL.2009.027533.

Baños-Pino, J., P. Coto-Millan, and A. Rodriguez-Alvarez. 1999. "Allocative Efficiency and Over-Capitalization: An Application." *International Journal of Transport Economics* 26 (2): 181–199.

Barros, C. 2012. "Productivity Assessment of African Seaports." *African Development Review* 24 (1): 67–78. doi:10.1111/afdr.2012.24.issue-1.

Barros, C. P. 2003. "The Measurement of Efficiency of Portuguese Sea Port Authorities with DEA." *International Journal of Transport Economics* 30 (3): 335–354.

Barros, C. P. 2005. "Decomposing Growth in Portuguese Seaports: A Frontier Cost Approach." *Maritime Economics & Logistics* 7: 297–315. doi:10.1057/palgrave.mel.9100140.

Barros, C. P., and M. Athanassiou. 2004. "Efficiency in European seaports with DEA: Evidence from Greece and Portugal." *Maritime Economics and Logistics* 6 (2): 122–140. doi:10.1057/palgrave.mel.9100099.

Barros, C. P., J. A. Felício, and R. L. Fernandes. 2012. "Productivity Analysis of Brazilian Seaports." *Maritime Policy & Management* 39 (5): 503–523. doi:10.1080/03088839.2012.705033.

Barros, C. P., and N. Peypoch. 2007. "Comparing Productivity Change in Italian and Portuguese Seaports using the Luenberger Indicator Approach." *Maritime Economics & Logistics* 9: 138–147. doi:10.1057/palgrave.mel.9100176.

Barros, C. P., and N. Peypoch. 2012. "Productivity Assessment of African Seaports with Biased Technological Change." *Transportation Planning and Technology* 35 (6): 663–675. doi:10.1080/03081060.2012.710033.

Bonilla, M., T. Casasus, A. Medal, and R. Sala. 2004. "An Efficiency Analysis with Tolerances of the Spanish Ports System." *International Journal of Transport Economics* XXXI (3): 379–400.

Bonilla, M., A. Medal, T. Casaus, and R. Sala. 2002. "The Traffic in Spanish Ports: An Efficiency Analysis." *International Journal of Transport Economics* 29 (2): 215–230.

Bottasso, A., M. Conti, and C. Ferrari. 2011. "Efficiency and Productivity Growth in a Sample of Italian Container Terminals." *International Journal of Transport Economics* 38 (2): 107–122.

Bo-xin, F., S. Xiang-qun, and G. Zi-jian. 2009. "DEA-Based Malmquist Productivity Index Measure of Operating Efficiencies: New Insights with an Application to Container Ports." *Journal of Shanghai Jiaotong University* 14 (4): 490–496. doi:10.1007/s12204-009-0490-8.

Carballo-Cruz, F. 2011. "Causes and Consequences of the Spanish Economic Crisis: Why the Recovery is Taken so Long?" *Panoeconomicus* 58: 309–328. doi:10.2298/PAN1103309C.

Carvalho, P., and R. C. Marques. 2012. "Using Non-Parametric Technologies to Estimate Returns to Scale in the Iberian and International Seaports." *International Journal of Shipping and Transport Logistics* 4 (3): 286–302. doi:10.1504/IJSTL.2012.047493.

Carvalho, P., R. C. Marques, Á. Fonseca, and P. Simões. 2010. "Governance and Comparative Performance of Iberian Peninsula Seaports. An Application of Non-Parametric Techniques." *International Journal of Transport Economics* 37 (1): 31–51.

Caves, D. W., L. R. Christensen, and W. E. Diewert. 1982. "Multilateral Comparisons of Output, Input and Productivity Using Superlative Index Numbers." *Economical Journal* 92 (365): 73–86.

Chang, V., and B. Tovar. 2014. "Efficiency and Productivity Changes for Peruvian and Chilean Ports Terminals: A Parametric Distance Functions Approach." *Transport Policy* 31: 83–94. doi:10.1016/j.tranpol.2013.11.007.

Chen, P. C., M. M. Yu, C. C. Chang, and S. H. Hsu. 2008. "Total Factor Productivity Growth in China´s Agricultural Sector." *China Economic Review* 19 (4): 580–593. doi:10.1016/j.chieco.2008.07.001.
Chen, Y. 2003. "A Non-Radial Malmquist Productivity Index with an Illustrative Application to Chinese Major Industries." *International Journal of Production Economics* 83 (1): 27–35. doi:10.1016/S0925-5273(02)00267-0.
Cheon, S. 2007. "Evaluating Impacts of Institutional Reforms on Port Efficiency Changes: Malmquist Productivity Index for World Container Ports." 2nd Annual National Urban Freight Conference, Long Beach, CA, December 5–7.
Cheon, S., D. E. Dowall, and D.-W. Song. 2010. "Evaluating Impacts of Institutional Reforms on Port Efficiency Changes: Ownership, Corporate Structure, and Total Factor Productivity Changes of World Container Ports." *Transportation Research Part E: Logistics and Transportation Review* 46 (4): 546–561. doi:10.1016/j.tre.2009.04.001.
Cooper, W. W., L. M. Seiford, and K. Tone. 2007. *Data Envelopment Analysis*. New York, NY: Springer.
Cooper, W. W., L. M. Seiford, and J. Zhu. 2000. "A Unified Additive Model Approach for Evaluating Inefficiency and Congestion with Associated Measures in DEA." *Socio-Economic Planning Sciences* 34 (1): 1–25. doi:10.1016/S0038-0121(99)00010-5.
Coto-Millán, P., J. Baños-Pino, and A. Rodríguez-Álvarez. 2000. "Economic Efficiency in Spanish Ports: Some Empirical Evidence." *Maritime Policy and Management* 27 (2): 169–174. doi:10.1080/030888300286581.
Coto-Millán, P., M. A. Pesquera, and J. Castanedo. 2010. "Impact of New Technology on Port Administration." In *Essays on Port Economics*, 251–268. Heidelberg: Physica-Verlag.
Cullinane, K. P. B., D. W. Song, and R. Gray. 2002. "A Stochastic Frontier Model of the Efficiency of Major Container Terminals in Asia: Assessing the Influence of Administrative and Owner Ship Structures." *Transportation Research Part A* 36: 743–762.
De Neufville, R., and K. Tsunokawa. 1981. "Productivity and Returns to Scale of Container Ports." *Maritime Policy & Management* 8 (2): 121–129. doi:10.1080/03088838100000033.
De, P. 2006. "Total Factor Productivity Growth: Indian Ports in the Era of Globalisation." *Maritime Economics & Logistics* 8 (4): 366–386. doi:10.1057/palgrave.mel.9100164.
Díaz-Hernández, J. J. 2003. "Descomposición de la productividad, la eficiencia y el cambio técnico a través de la función de costs cuadrática. Una aplicación a la operación de estiba en España." PhD Thesis, Universidad de La Laguna.
Díaz-Hernández, J. J., E. Martínez-Budría, and S. Jara-Díaz. 2008. "Productivity in Cargo Handling in Spanish Ports during a Period of Regulatory Reforms." *Networks and Spatial Economics* 8: 287–295. doi:10.1007/s11067-007-9056-1.
Díaz-Hernández, J. J., E. Martínez-Budría, and J. J. Salazar-González. 2014. "Measuring Cost Efficiency in the Presence of Quasi-Fixed Inputs Using Dynamic Data Envelopment Analysis: The Case of Port Infrastructure." *Maritime Economics & Logistics* 16 (2): 111–126. doi:10.1057/mel.2013.28.
Estache, A., B. T. de la Fé, and L. Trujillo. 2004. "Sources of Efficiency Gains in Port Reform: A DEA Decomposition of a Malmquist TFP Index for Mexico." *Utilities Policy* 12 (4): 221–230. doi:10.1016/j.jup.2004.04.013.
European Commission. 2010. "Impact of the Economic Crisis on Key Sectors of the EU – The Case of the Manufacturing and Construction Industries." http://ec.europa.eu/enterprise/newsroom/cf/_getdocument.cfm?doc_id=5633
EUROSTAT. 2013. "National Accounts and GDP." Accessed 10 February 2015. http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/National_accounts_%E2%80%93_GDP
Färe, R., S. Grosskopf, and C. A. K. Lovell. 1994. *Production Frontiers*. Cambridge: Cambridge University Press.
Färe, R., S. Grosskopf, and D. Margaritis. 2007. "Efficiency and Productivity: Malmquist and More." In *The Measurement of Productivity Efficiency and Productivity Growth*, edited by H. O. Fried, C. A. K. Lovell, and S. S. Schmidt. New York: Oxford University Press.
Fernández de Guevara, J., and J. Fariña. 2014. *La empresa española ante la crisis del modelo productivo: productividad, competitividad e innovación*. Madrid: Fundación BBVA.
Fernández-Villaverde, J., and L. Ohanian. 2010. "The Spanish Crisis from a Global Perspective." *Documentos de trabajo (FEDEA)* 3: 1–60.
Ferro, G., E. J. Lentini, A. C. Mercadier, and C. A. Romero. 2014. "Efficiency in Brazil's Water and Sanitation Sector and Its Relationship with Regional Provision, Property and the Independence of Operators." *Utilities Policy* 28: 42–51. doi:10.1016/j.jup.2013.12.001.
Färe, R., S. Grosskopf, B. Lindgren, and P. Roos. 1992. "Productivity Changes in Swedish Pharamacies 1980-1989: A Non-Parametric Malmquist Approach." *Journal of Productivity Analysis* 3 (1–2): 85–101. doi:10.1007/BF00158770.
González, M. M., and L. Trujillo. 2008. "Efficiency Measurement in the Port Industry: A Survey of the Empirical Evidence." *Journal of Transport Economics and Policy* 43 (2): 157–192.

González-Laxe, F., and I. Novo-Corti. 2012. “Competitividad de los puertos españoles: respuestas del Sistema portuario ante la crisis económica.” XIV Reunión Económica Mundial, 2012, Universidad de Jaén, Jaén, May 29–June 1.

Guerrero, C., and C. Rivera. 2009. “Mexico: Total Productivity Changes at the Principal Container Ports.” *CEPAL Review* 99: 173–185.

Guironnet, J., N. Peypoch, and B. Solonandrasana. 2009. “A Note on Productivity Change in French and Italian Seaports.” *International Journal of Shipping and Transport Logistics* 1 (3): 216–226. doi:10.1504/IJSTL.2009.027531.

Gutiérrez, E., S. Lozano, B. Adenso-Díaz, and P. González-Torre. 2015. “Efficiency Assessment of Container Operations of Shipping Agents in Spanish Ports.” *Maritime Policy and Management* 42 (6): 591–607.

Haralambides, H., M. Hussain, C. P. Barros, and N. Peypoch. 2010. “A New Approach in Benchmarking Seaport Efficiency and Technological Change.” *International Journal of Transport Economics* 37 (1): 77–96.

ICEX. 2013. “Spanish Exports and Imports.” Accessed 10 February 2015. http://www.icex.es/icex/cda/controller/pageICEX/0,6558,5518394_5518974_5536731_0_0_-1,00.html

Inglada, V., and P. Coto-Millán. 2010. “Analysis of Technical Efficiency and Rate of Return on Investment in Ports.” In *Essays on Port Economics*, 287–304. Heidelberg: Physica-Verlag.

Kim, M., and A. Sachish. 1986. “The Structure of Production, Technical Change and Productivity in a Port.” *The Journal of Industrial Economics* 35 (2): 209–223. doi:10.2307/2098359.

Lozano, S. 2009. “Estimating Productivity Growth of Spanish Ports Using a Non-Radial, Non-Oriented Malmquist Index.” *International Journal of Shipping and Transport Logistics* 1 (3): 227–248. doi:10.1504/IJSTL.2009.027532.

Malmquist, S. 1953. “Index Numbers and Indifference Surfaces.” *Trabajos de Estadistica* 4: 209–242. doi:10.1007/BF03006863.

Martín, M. 2002. “El Sistema portuario español: regulación, entorno competitive y resultados. Una aplicación del análisis envolvente de datos.” PhD Thesis, Universitat Rovira I Virgili.

Martinez-Budria, E., R. Diaz-Armas, M. Navarro-Ibanez, and T. Ravelo-Mesa. 1999. “A Study of the Efficiency of Spanish Port Authorities Using Data Envelopment Analysis.” *International Journal of Transport Economics* 26 (2): 237–253.

Medal, A., and R. Sala. 2011. “An Efficiency Ranking of Spanish Seaports Using FDH Methodology.” *International Journal of Transport Economics* XXXVIII (2): 199–224.

Medal-Bartual, A., M. Molinos-Senante, and R. Sala-Garrido. 2012. “Benchmarking in Spanish Seaports: A Tool for Specialization.” *International Journal of Transport Economics* 39 (3): 329–348.

Molinos-Senante, M., F. Hernandez-Sancho, and R. Sala-Garrido. 2014. “Benchmarking in Wastewater Treatment Plants: A Tool to Save Operational Costs.” *Clean Technologies and Environmental Policy* 16: 149–161.

Núñez-Sánchez, R., and P. Coto-Millán. 2010. “Excess Capacity, Economic Efficiency and Technical Change in a Public-Owned Port System: An Application to the Infrastructure Services of Spanish Ports.” In *Essays on Port Economics*, 269–285. Heidelberg: Physica-Verlag.

Núñez-Sánchez, R., and P. Coto-Millán. 2012. “The Impact of Public Reforms on the Productivity of Spanish Ports: A Parametric Distance Function Approach.” *Transport Policy* 24: 99–108. doi:10.1016/j.tranpol.2012.07.011.

Port Authority of A Coruña. 2010. “A Coruña Port Annual Report.” Accessed February 2015. http://www.puertocoruna.com/adjuntos/cTexto/memoriacomercial2010.pdf

Port Authority of Málaga. 2010. “Malaga Port Annual Report.” Accessed 10 February 2015. http://www.puertomalaga.com/web/guest/memorias

Port Authority of Valencia. 2010. “Valencia Port Annual Report.” Accessed 10 February 2015. http://www.valenciaport.com/en-US/AreaProfesional/PublicacionesGuias/SectorPortuario/Documents/MemoriaAnual2010_ing.pdf

Port Authority of Vilagarcía. 2011. “Vilagarcia Port Annual Report.” Accessed 10 February 2015. http://www.portovilagarcia.es/es/publicaciones/memorias-anuales/book/20.html?page=75

Puertos del Estado. 2012. “Informe de gestión del Sistema Portuario de Titularidad Estatal.” Accessed 10 February 2015. https://www.puertos.es/sites/default/files/informe-ptos_2012.pdf

Ramos-Real, F. J., and B. Tovar. 2010. “Productivity Change and Economies of Scale in Container Port Terminals.” *Journal of Transport Economics and Policy* 44 (2): 231–246.

Rodríguez-Álvarez, A., and B. Tovar. 2012. “Have Spanish Port Sector Reforms during the Last Two Decades Been Successful? A Cost Frontier Approach.” *Transport Policy* 24: 73–82. doi:10.1016/j.tranpol.2012.06.004.

Rodríguez-Álvarez, A., B. Tovar, and L. Trujillo. 2007. “Firm and Time Varying Technical and Allocative Efficiency: An Application to Port Cargo Handling Firms.” *International Journal of Production Economics* 109: 149–161. doi:10.1016/j.ijpe.2006.12.048.

Rodríguez-Álvarez, A., B. Tovar, and A. Wall. 2011. “The Effect of Demand Uncertainty on Port Terminal Costs.” *Journal of Transport Economics and Policy* 45 (2): 303–328.

Sachish, A. 1996. "Productivity Functions as a Managerial Tool in Israeli Ports." *Maritime Policy & Management* 23 (4): 341–369. doi:10.1080/03088839600000094.
Song, B., and Y. Cui. 2014. "Productivity Changes in Chinese Container Terminals 2006-2011." *Transport Policy* 35: 377–384. doi:10.1016/j.tranpol.2014.04.011.
Tone, K. 2001. "A Slacks-Based Measure of Efficiency in Data Envelopment Analysis." *European Journal of Operational Research* 130: 498–509. doi:10.1016/S0377-2217(99)00407-5.
Tone, K. 2002. "A Slacks-Based Measure of Super-Efficiency in Data Envelopment Analysis." *European Journal of Operational Research* 143 (1): 32–41. doi:10.1016/S0377-2217(01)00324-1.
Tovar, B., and A. Wall. 2015. "Can Ports Increase Traffic while Reducing Inputs? Technical Efficiency of Spanish Port Authorities Using a Directional Distance Function Approach." *Transportation Research Part A: Policy and Practice* 71: 128–140.
Trujillo, L., and B. Tovar. 2007. "The European Port Industry: An Analysis of Its Economic Efficiency." *Maritime Economics & Logistics* 9 (2): 148–171. doi:10.1057/palgrave.mel.9100177.
Wilmsmeier, G., B. Tovar, and R. J. Sanchez. 2013. "The Evolution of Container Terminal Productivity and Efficiency under Changing Economic Environments." *Research in Transportation Business & Management* 8: 50–66. doi:10.1016/j.rtbm.2013.07.003.

Appendix A

Table A. Summary of previous papers on measuring productivity in ports.

Author	Year	Data	Methodology	Outputs	Inputs
De Neufville and Tsunokawa	1981	5 USA ports 1970–1978	No parametric engineering	Containerized cargo	Quay length Quay crane
Kim and Sachish	1986	1 Israeli port 1966–1983	Parametric TCF, TFP index	Total cargo	Price of labor Price of capital
Sachish	1996	2 Israeli ports 1966–1990	No parametric engineering	Throughput	Labor Building Equipment
Martín	2002	27 Spanish ports 1990–1999	No parametric DEA, Malmquist TFP index	Solid bulk Cargo general	Number of workers Intermediate consumption Land area Berth length
Díaz-Hernández	2003	21 Spanish ports 1990–1998	Parametric SFA, CCF Quadratic exact TFP index	Containerized cargo Non-containerized cargo Solid bulk	Price of labor Price of capital
Estache et al.	2004	11 Mexican ports 1996–1999	No parametric DEA, Malmquist TFP index	Throughput	Number of workers Berth length
Barros	2005	10 Portuguese ports 1990–2000	Parametric SFA, TCF, Malmquist TFP index	Number of ships Total cargo	Capital price Labor price
De	2006	13 Indian ports 1980–2003	Parametric CDPF TFP index	Traffic	Gross fixed capital stock Employees
Barros and Peypoch	2007	34 Italian & Portuguese ports 1994–1998	No parametric DEA Luenberger TFP index	Containers Sales Liquid bulk Dry bulk Ship	Total operational costs Personnel Investment
Díaz-Hernández et al.	2008	21 Spanish ports 1994–1998	No parametric DEA, Malmquist TFP index	Containerized cargo Non-containerized cargo Solid bulk	Labor Crane
Al-Eraqui et al.	2009	22 container terminal in Middle East & East African 2000–2005	No parametric DEA, Malmquist TFP index	Total ships call Total throughput	Berth length Quay crane Handling equipment Terminal area

(*Continued*)

Table A. (Continued).

Author	Year	Data	Methodology	Outputs	Inputs
Bo-xin et al.	2009	10 container terminal in China 2001–2006	No parametric DEA, Malmquist TFP index	Port activity Density of liner ship	Overall strength & development potential Hardware equipment abilities Economic strength of port's hinterland
Guerrero and Rivera	2009	7 Mexican ports 2000–2007	No parametric DEA, Malmquist TFP index	Containers handled	Berth length Storage area Yard gantry cranes Quayside gantry cranes
Guironnet et al.	2009	37 Italian & French ports. 2003–2004	No parametric DEA Luenberger TFP index	Liquid bulk Solid bulk	Number of workers Capital invested
Lozano	2009	28 Spanish port authorities 2002–2006	No parametric DEA, Malmquist TFP index	Total port traffic Total TEU´s Total ship calls	Stocking area Berth length Cranes Tugs
Cheon et al.	2010	98 world ports 1991 and 2004	No parametric DEA, Malmquist TFP index	Total throughput	Berth length Terminal area Capacity of container quayside and mobile cranes
Ramos-Real and Tovar	2010	3 multipurpose terminals 1991–1999	Parametric statistical, CCF Quadratic exact TFP index	Containers Ro-Ro cargo General break-bulk cargo	Price of non-port worker Price of ordinary port worker Price of special port worker Price of capital Price of intermediate consumption Price of area
Haralambides et al.	2010	16 Middle East & East African ports 2005–2007	No parametric DEA Luenberger TFP index	Total throughput Total ship calls	Number of workers Total cost Number of quay cranes
Bottasso et al	2011	5 Italian terminal containers 2001–2008	Parametric SFA, CDPF TFP index	Total throughput	Number of workers Non-labor operating expenditure Crane Terminal area
Núñez-Sánchez and Coto-Millán	2012	27 Spanish port authorities 1986–2005	Parametric SFA TFP index	Solid bulk Liquid bulk Containerized cargo Non-containerized cargo Passengers	Labor Intermediate consumption Storage area
Barros	2012	23 ports in Angola, Mozambique, and Nigeria 2004–2010	Parametric DEA Luenberger TFP indicator	Number of ship calls Total tons embarked Total number of containers embarked and disembarked	Depth of the berths Total area Quay cranes Employees
Barros et al.	2012	Brazilian ports 2004–2014	No parametric DEA Malmquist TFP index	Ship calls Total tons embarked Total number of containers embarked and disembarked	Depth of berths Total area Quay cranes Employees

(*Continued*)

Table A. (Continued).

Author	Year	Data	Methodology	Outputs	Inputs
Barros and Peypoch	2012	African ports 2002–2008	Parametric DEA Luenberger TFP indicator	20-foot equivalent units Dry bulk Liquid bulk	Depth of berths Number cranes Employees
Wilmsmeier et al	2013	20 container terminals in Latin America and the Caribbean and Spain 2005–2011	No parametric DEA Malmquist TFP index	Total throughput	Terminal area Ship-to-shore crane capacity equivalent Labor
Song and Cui	2014	26 container terminals in China 2006–2011	No parametric DEA Malmquist TFP index	Containers handled	Workers Quay length Bridge cranes
Chang and Tovar	2014	14 Chilean and Peruvian terminal ports 2004–2010	Parametric SFA TRPF TFP index	Containerized cargo General rolling freight Bulk cargo	Labor Stock of net fixed assets
Tovar and Wall	2015	26 Spanish port authorities 1993–2012	Parametric SFA CCF TFP index	Containerized cargo Solid bulk cargo Liquid bulk cargo General non-containerized cargo Passengers	Labor and supplies Building and infrastructure Deposit surface area

DEA = Data Envelopment Analysis, SFA = Stochastic Frontier Analysis, CDPF = Cobb–Douglas Production Function, TFPF = Translog Production Function, TCF = Translog Cost Function, CCF = Quadratic Cost Function, TFP = Total Factor Productivity.
Source: Own elaboration based on Wilmsmeier, Tovar, and Sanchez (2013).

Appendix B

Table B1. Malmquist Productivity Index (MPI) of Spanish Port Authorities, 2005–2011.

Port Authority	MPI (2005/2006)	MPI (2006/2007)	MPI (2007/2008)	MPI (2008/2009)	MPI (2009/2010)	MPI (2010/2011)
A Coruña	1.855	1.828	1.823	3.101	3.604	3.398
Alicante	2.191	2.137	1.643	1.200	1.287	1.647
Almería	1.560	1.834	1.481	1.210	1.369	1.660
Avilés	1.719	1.444	1.144	0.752	1.269	1.064
B. de Algeciras	2.014	2.027	1.974	0.985	1.129	1.227
Bahía de Cádiz	1.113	1.493	0.642	0.817	1.043	1.098
Baleares	1.148	1.148	1.028	1.200	1.412	1.305
Barcelona	1.322	1.277	1.187	1.022	1.113	1.172
Bilbao	0.967	0.855	0.852	1.109	1.242	1.142
Cartagena	1.124	1.129	1.364	0.945	1.120	1.437
Castellón	0.826	0.931	0.799	0.836	1.038	1.183
Ceuta	0.885	0.946	0.857	0.922	0.943	1.128
Ferrol-San Cibrao	0.928	0.795	0.896	1.119	1.089	1.761
Gijón	1.872	1.983	1.922	0.841	1.195	1.128
Huelva	1.229	1.246	1.248	0.884	1.244	1.239
Las Palmas	1.459	1.391	1.256	0.980	1.651	1.656
Málaga	1.179	0.904	0.675	0.989	1.716	1.988
Marín y Ría de Pont.	1.713	1.423	1.201	0.781	0.868	1.023
Melilla	2.209	2.180	1.976	0.810	0.944	1.120
Motril	2.313	2.123	2.227	1.174	1.161	1.248
Pasajes	1.019	0.934	0.954	1.098	1.393	1.081
S.C. Tenerife	1.527	1.560	1.351	1.075	1.221	1.287
Santander	0.664	0.848	0.690	0.785	1.044	1.057
Sevilla	2.049	1.677	1.859	1.203	1.293	1.404
Tarragona	0.932	1.073	0.854	0.789	0.927	0.894
Valencia	0.771	0.771	0.729	1.247	1.428	1.429
Vigo	1.633	1.605	1.306	0.679	1.124	0.953
Vilagarcía	1.646	1.647	1.666	1.741	1.584	3.527
Mean	1.424	1.400	1.271	1.082	1.302	1.438

Table B2. Malmquist efficiency change (MECH) of Spanish Port Authorities, 2005–2011.

Port Authority	MECH (2005/2006)	MECH (2006/2007)	MECH (2007/2008)	MECH (2008/2009)	MECH (2009/2010)	MECH (2010/2011)
A Coruña	1.047	0.936	0.878	3.601	3.449	2.678
Alicante	1.132	1.105	0.939	1.290	1.227	1.226
Almería	1.000	1.000	1.000	1.000	1.000	1.000
Avilés	1.085	0.852	0.660	0.947	0.955	1.328
B. de Algeciras	1.000	1.000	1.000	1.000	1.000	1.000
Bahía de Cádiz	1.158	1.445	0.594	0.860	1.104	0.858
Baleares	0.863	0.863	0.863	1.356	1.356	1.356
Barcelona	0.626	0.605	0.635	1.136	1.124	1.172
Bilbao	0.533	0.500	0.500	1.264	1.137	1.170
Cartagena	0.949	0.949	0.949	0.597	0.597	0.597
Castellón	0.504	0.554	0.457	1.130	1.084	1.037
Ceuta	0.324	0.324	0.324	1.000	1.000	1.000
Ferrol-San Cibrao	0.502	0.502	0.502	1.000	1.000	1.000
Gijón	1.000	1.000	1.000	0.801	0.801	0.801
Huelva	1.005	0.910	1.001	1.050	1.228	1.110
Las Palmas	0.731	0.663	0.704	1.133	1.728	1.369
Málaga	0.719	0.527	0.434	1.131	1.677	1.769
Marín y Ría de Pont.	1.302	1.112	0.903	0.686	0.595	0.595
Melilla	1.591	1.338	1.329	0.859	0.885	0.872
Motril	1.190	1.190	1.190	0.610	0.610	0.610
Pasajes	0.893	0.731	0.825	1.254	1.419	0.915
S.C. Tenerife	1.000	1.000	1.000	1.199	1.199	1.199
Santander	0.461	0.616	0.445	0.880	1.231	0.923
Sevilla	1.009	0.848	0.998	1.567	1.470	1.139
Tarragona	0.597	0.597	0.597	0.601	0.601	0.601
Valencia	0.470	0.470	0.470	1.335	1.335	1.335
Vigo	1.117	1.077	0.929	0.828	1.239	0.793
Vilagarcía	0.701	0.701	0.701	1.923	1.611	2.295
Mean	0.875	0.836	0.780	1.139	1.216	1.115

Table B3. Malmquist technical change (MTCH) of Spanish Port Authorities, 2005–2011.

Port Authority	MTCH (2005/2006)	MTCH (2006/2007)	MTCH (2007/2008)	MTCH (2008/2009)	MTCH (2009/2010)	MTCH (2010/2011)
A Coruña	1.771	1.954	2.077	0.861	1.045	1.269
Alicante	1.936	1.933	1.749	0.931	1.049	1.344
Almería	1.560	1.834	1.481	1.210	1.369	1.660
Avilés	1.585	1.695	1.734	0.794	1.329	0.801
B. de Algeciras	2.014	2.027	1.974	0.985	1.129	1.227
Bahía de Cádiz	0.962	1.033	1.081	0.951	0.945	1.279
Baleares	1.330	1.331	1.191	0.885	1.041	0.962
Barcelona	2.112	2.110	1.869	0.900	0.990	1.000
Bilbao	1.815	1.710	1.703	0.878	1.092	0.976
Cartagena	1.184	1.189	1.437	1.583	1.876	2.407
Castellón	1.640	1.680	1.746	0.740	0.957	1.141
Ceuta	2.733	2.920	2.644	0.922	0.943	1.128
Ferrol-San Cibrao	1.848	1.583	1.785	1.119	1.089	1.761
Gijón	1.872	1.983	1.922	1.049	1.492	1.408
Huelva	1.223	1.369	1.247	0.842	1.013	1.116
Las Palmas	1.995	2.098	1.783	0.865	0.955	1.210
Málaga	1.640	1.715	1.554	0.875	1.023	1.124
Marín y Ría de Pont.	1.315	1.280	1.330	1.138	1.457	1.718
Melilla	1.388	1.630	1.487	0.943	1.067	1.283
Motril	1.943	1.784	1.871	1.925	1.902	2.045
Pasajes	1.142	1.277	1.157	0.875	0.981	1.182
S.C. Tenerife	1.527	1.560	1.351	0.896	1.018	1.073
Santander	1.440	1.378	1.552	0.892	0.848	1.145
Sevilla	2.030	1.978	1.862	0.768	0.879	1.233
Tarragona	1.561	1.797	1.430	1.312	1.542	1.488
Valencia	1.640	1.640	1.552	0.934	1.069	1.070
Vigo	1.462	1.490	1.406	0.820	0.907	1.201
Vilagarcía	2.349	2.349	2.376	0.905	0.983	1.537
Mean	1.679	1.726	1.655	0.998	1.129	1.333