



Sustainability and the Spanish port system. Analysis of the relationship between economic and environmental indicators



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ABSTRACT

Research into the methodological development of alternative systems of sustainability measures is recent. In understanding sustainable development in a multi-dimensional sense, one of the most significant advances was the construction of Synthetic Indexes, applicable to different spatial spheres or to organisations, businesses, institutions, etc.

The Spanish port system of general interest comprises 46 ports integrated in 28 Port Authorities, which in 2014 moved 482,000,000 t of goods and more than 28 million passengers. This gives an idea of its importance for the Spanish economy.

Using a derivation of the procedure used to calculate the Port Sustainability Synthetic Index, in this research the analysis of the relationship that exists between the findings obtained for the economic and environmental dimensions is used. This enables the existence of links between ports and economic and environmental indicators for a sample of 16 Port Authorities of Spain to be verified.

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1. Measuring port sustainability: a review of the case study and proposals

The concern for sustainable development in port systems arose in the 1990s, leading to a huge amount of academic literature ranging from conceptual work through to design of environmental management systems, good practices, etc. On the contrary, there are very few methodological contributions to try to measure port sustainability. Exceptions would include the case of calculating the ecological footprint of ports undertaken for the Port of Gijón (Carrera Gómez et al., 2006) and subsequently extended to ports on the northern coast of Spain (Coto Millán et al., 2010); the carbon footprint study for European maritime transport (Leonardi and Browne, 2010), in the specific case of Barcelona port (Villalba and Gemechu, 2011) and for New Zealand, in which the increase of diesel consumption and its impact on greenhouse gases was analysed (Fitzgerald et al., 2011). For Barcelona, there has also been investigation into a

management system for the risks of water contamination (Grifoll et al., 2011) in a similar way as for the ports of Bulgaria (Quynh et al., 2011).

A proposal to apply Environment Management Systems (EMS) in specific ports, as well as a system of port sustainability indicators was undertaken by Peris Mora et al. (2005) for the case of Valencia as part of the Ecoport project, using a multi-criteria methodology that could be extended to European ports. A similar criterion was employed for the ports of Taiwan (Lu et al., 2012), Vietnam and Cambodia (Le et al. 2014). And lastly, Puig et al. (2015) analysed the environmental priorities of 79 European ports in accordance with their characteristics, based on the ESPO reports (ESPO, 2013) and a preliminary selection of Environmental Performance Indicators (Puig et al., 2014).

These previous contributions are clearly identified with the classic vision that identifies sustainability and the environment. If the number of proposals is already limited, those that introduce elements and dimensions befitting the integral concept of sustainable development (Martín Palmero, 2004, 49) are even fewer. The inclusion and analysis of the economic aspect stemming from the sustainability reports for Spanish ports was undertaken by Crespo et al. (2010), Asgari et al. (2015), and they applied an Analytic Hierarchy Process (AHP) to the ports of Great Britain to conduct a ranking of these ports based on economic and environmental

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aspects. Lastly, [Shiau and Chuang \(2013\)](#), using a Social Construction of Technology (SCOT) procedure, managed to identify sustainable development indicators for the Port of Keelung, with regard to environmental, economic and social dimensions.

Consequently, applied research concerning port sustainability reveals the following characteristics:

- a) In general, these involve contributions in the design of systems of indicators for specific cases using a range of methodologies.
- b) In the main they opt for identification between sustainability and the environment, and there are a few cases that actually analyse other dimensions of sustainable development or which provide quantitative systems of comparison and hierarchy between ports.

This research addresses the methodological development for calculation of a Port Sustainability Synthetic Index and, through a variation to this, the relationship that exists between the findings obtained for the economic and environmental dimensions of sustainable development is analysed. This enables a contrast of the links between both dimensions for a sample of 16 Spanish ports and a focus on orientations or guidelines with a view to improving each indicator.

2. Methodology

The use of individual values of variables to compare different economic, environmental or social realities normally offers irrelevant findings because they only deal with isolated data. Synthetic Indexes (SI) are aggregate indexes of simple, grouped and weighted variables based on certain scientific criteria and, therefore, they measure multi-dimensional concepts. This interrelation enables a full analysis of the reality and, consequently, the taking of decisions with regard to both the individual aspect and, above all, the integral aspect.

The SIs are for the purpose of studying organisations, productive processes, branches, companies, institutions, production and/or distribution units, etc. They adopt a pyramid structure, whereby the variables they comprise are in turn integrated into subindicators, indicators and, if applicable, dimensions. As well as being used to propitiate the comparability between different agents (such as those specified previously), they enable the formulation of efficiency and efficacy analysis, appropriate use of resources, as well as reputational aspects and, in general, all those that are defined by the appropriately selected variables.

The process of obtaining an SI requires several stages:

- a. Generation of an initial database, comprising the set of variables likely to form part of the subset or definitive database. Given the features of the SI, the variables considered must present quantitative and relative values (that allow a comparison), and therefore those that present categoric and/or quantitative values are not accepted.
- b. Identification and selection of the significant variables that will make up the final database. The information concerning the following aspects will be taken into consideration:

- The dimension where the variable fits.
- The indicator to which it belongs.
- Subindicator within which it is included.
- Specific data of the variable: definition and description of the measurement unit.
- Source of the information to calculate the values of the variable.
- Calculation method: formula for calculating the value of the variable.

- c. The values of the dimensions, if applicable, and/or of the SI is generally obtained by processing the data of the variables finally selected and with the following guidelines:

- The outliers of the variables are corrected, if necessary.
- The resulting values are typified.

- They are grouped by indicators and converted into standard normal percentiles with values of between 0 and 100
- The value of the Synthetic Index is calculated by weighting the average of the percentiles obtained for each one of the dimensions or components of the index.

This methodology allows different variants with their particularities and intermediate analysis system in accordance with the purposes of the research, or the specific characteristics of the type of institution, economic enterprise or company to which the analysis is to be applied.¹

In particular, the methodological procedure undertaken in this case comprises two completely different stages, as described below.

2.1. Origin of data

The Sustainability Reports of Spanish ports, constructed in accordance with the methodology implemented by *Puertos del Estado*, contain extremely valuable information on the performance of the 28 Port Authorities (PA) in this issue. On the basis of this and for 2012, a total of 60 variables were selected within the four dimensions of sustainable development (economic, institutional, environmental and social), which would comply with the comparability conditions required by the methodology adopted.²

The consistency and quality tests undertaken for the database corresponding to all of the PAs revealed 76.6% of valid variables. The different simulations conditioned the selection of a sample of 16 Port Authorities comprising 23 ports with data with the minimum standards of quality.³

Bearing in mind that the purpose of this research focuses on the economic and environmental dimensions of sustainable development, [Appendix A](#) shows the description and classification of variables and the groupings made for each of the dimensions dealt with.

2.2. Calculation of the value of components

Based on the selection of 33 variables, these were grouped into 13 subindicators, which in turn were concentrated in 5 indicators. Lastly, the indicators thus grouped were distributed into the two dimensions of the sustainable development to be analysed: economic and environmental. From then on, the process was carried out in accordance with the following specific guidelines:

1. The first stage of calculations is carried out based on the different values observed and obtained for each of the 33 variables for the 16 Port Authorities considered.
2. Secondly, the Z-scores are calculated, in other words the typified values of the variable, so that these are comparable.
3. Then the values of the percentiles 97.5 and 2.5 are calculated to avoid extreme values distorting the results.
4. The next and final stage of this initial process involves:

¹ [González Laxe and Martín Palmero \(2004\)](#) and [González Laxe, Martín Palmero and Fernández Francos \(2004\)](#) had already used a similar methodologic development to measure synthetic indexes of sustainability for the EU and the Spanish regions. These authors also used this method to analyse the convergence when it comes to sustainability for these regions regarding sustainable development for the period 1992–2002 ([González Laxe, Martín Palmero and Fernández Francos, 2010](#)). Finally, [González Laxe, Martín Palmero and Fernández Francos \(2005\)](#) developed an analysis about environmental and social indicators for Spanish regions also using this methodology.

² The design of the variable selection methodology for calculation of a Sustainability Synthetic Index of the Spanish Port System and the application of this was developed through a Research Agreement between the organisation *Puertos del Estado* and the University Institute of Maritime Studies of the UDC in 2013 and 2014.

³ More specifically, the definitive sample comprises 471 variable values over a total of 528 possible ones for the 16 Port Authorities, which reveals a level of 89.2% scope for the economic and environmental dimensions of sustainability.

- The value of the typified variable is corrected with the values reached for percentiles 97.5 and 2.5.
- The adjusted value of the typified variable of each indicator is obtained by calculating the simple average of the Z-scores of the variables, classified in accordance with the subindicators that make them up.
- Calculate the final values of each of the components or dimensions of sustainable development considered (economic and environmental) through the weighted average of typified variables of the indicators. The findings of these calculations are shown in Table 1.

3. Cluster analysis: Selection of the method and analysis cases

To carry out the grouping of each of the Spanish ports, the hierarchical conglomerate analysis was chosen, as this is the most appropriate one for small samples and the most suitable one for the research objective. As the number of conglomerates is not defined *a priori*, it is possible to act in an exploratory and descriptive way. This enables variables to be classified into groups so that the data in each of these groups or clusters is as uniform or a similar as possible (minimum variance) and that each of the different groups has the greatest heterogeneity possible with the others (maximum variance).

Based on the values obtained for each dimension of the sustainable development considered (which do not need to be turned into Z-scores, as they have already been typified in their preliminary analysis) the aim of this technique is to establish the type of relationships that take place between the Port Authorities and to present a map of their behaviour in the two dimensions. The observation of how the ports group in the different clusters enables an approximation of how sustainable development behaves and the possible explanations for this.

The grouping method selected in this case had been the Ward or minimum variance method. The reason lies in the fact that what is sought is to minimise intergroup variance, while simultaneously maximising uniformity within the groups which, in other words, means that the loss of information is minimal. Furthermore, the clusters generated are small and compact. However, it is highly sensitive to outliers, and it would be necessary to verify if any of those cases occurs. Consequently, with the method chosen the Euclidean distance squared is taken as the similarity measure or distance for data.

One of the most open issues in the research that uses the analysis of conglomerates technique is the lack of a selective process to determine the ideal or most reasonable number of these. This requires observation of the distances reflected between the clusters or different solutions, the conglomeration records and the dispersion of data in order to perform a correct and significant choice. Below, the performance of the appropriate calculations under the described cases is shown.

Table 1
Values by dimensions.
Source: own elaboration.

		Economic	Environmental
1	Avilés	−0.0215714	−0.3407579
2	Barcelona	0.57668571	−0.0087526
3	Bay of Algeciras	0.59794286	0.00107368
4	Bilbao	0.04391429	0.07356842
5	Cartagena	0.91168571	−0.1301053
6	Castellón	−0.0944429	−0.2846579
7	Gijón	0.00971429	−0.0597947
8	Huelva	0.14401429	0.08095263
9	Las Palmas	−0.0206714	0.42052105
10	Malaga	−0.5264000	0.39076842
11	Melilla	−0.3888143	−0.0021947
12	Motril	−0.7079714	−0.1771053
13	Santander	−0.3935000	−0.4961474
14	Valencia	0.25694286	0.14937895
15	Vigo	−0.0757571	0.24985263
16	Vilagarcía	−0.2126571	−0.1309579

4. Results

Previously, and taking into consideration the particular sensitivity of the agglomeration method to the outliers, the Kolmogorov-Smirnov normality test was carried out with the SPSS Statistics software for the distribution of values of variables in each dimension. The results are included in Table 2.

Through this test the null assumption that the variables follow normal distribution is contrasted, as the level of significance is 0.998 for the economic dimension and 0.851 for the environmental one, far above the 0.05 set as the lower limit for the normality test.

Having verified the nonexistence of outliers, the cluster analysis may be continued by processing the values reached for each dimension of sustainability for the 16 general interest ports that make up the sample selected under the cases and using the methodology described.

The record of conglomeration (Table 3) determines the stages into which this is formed. The process encompasses 15 stages, given that the universe comprises the 16 Port Authorities in question. The coefficients determine the Euclidean distance squared to which each case is located immediately before the merger takes place.

This record is completed with the corresponding flow diagram (Fig. 1), which allows one to deduce that in the first step (reading from right to left) two cases unite (Bay of Algeciras and Barcelona); in the second Avilés and Castellón join up; in the third stage Bilbao and Huelva merge, and so on successively until the final stage in which two large conglomerates would form. (See Fig. 2).

Lastly, the dendrogram compiled and set out in Fig. 3 determines the order and formation of the merger processes.

Among the three sources of information it is possible to carry out the corresponding simulations and choose an appropriate number of conglomerates. In the dendrogram, the distances between conglomerates represented are rescaled or standardised between 0 and 25, so that the mergers located further to the left are among more uniform elements (with smaller Euclidean distance) and those on the right are indicative of more heterogeneous conglomerates. This makes it clear that positions closer to the left should be chosen.

Observing the dendrogram, which usually assigns value 1 to the initial steps, it corresponds to the first 7 of the conglomeration record of Table 3. In a second step, the merger corresponding to steps 8 to 11 of the record takes place. And finally, in step 11 there is the merger of cases 11 (already previously merged with 16 and 12) and 10.

The simple verification of the dendrogram (and, as a consequence of the Euclidean distances from step 12 of the record), suggests not continuing with the process and opting for solutions with far greater dissimilarity and closing the same in four conglomerates. For equally visual purposes, the number of conglomerates chosen has been closed using a vertical line.

Table 2
Kolmogorov-Smirnov test.
Source: own elaboration.

		Environmental	Economic
N		16	16
Normal parameters (a, b)	Average	−0.0165	0,0062
	Typical deviation	0.24957	0,42853
Most extreme differences	Absolute	0.098	0,152
	Positive	0.098	0,152
	Negative	−0.075	−0,096
Z de Kolmogorov-Smirnov		0.392	0.610
Asympt. signif. (bilateral)		0.998	0.851

a The contrast distribution is the Normal one.

b Calculated from data.

Table 3
Record of conglomeration.
Source: own elaboration.

Step	Combined conglomeration		Coefficients	Step at which the conglomeration shows for the first time		Next step
	Congl. 1	Congl. 2		Congl. 1	Congl. 2	
1	2	3	0.0003	0	0	8
2	1	6	0.0045	0	0	9
3	4	8	0.0095	0	0	5
4	9	15	0.0256	0	0	11
5	4	7	0.0429	3	0	7
6	11	16	0.0667	0	0	10
7	4	14	0.1045	5	0	11
8	2	5	0.1852	1	0	15
9	1	13	0.2827	2	0	13
10	11	12	0.4014	6	0	12
11	4	9	0.5366	7	4	14
12	10	11	0.7258	0	10	13
13	1	10	1.1352	9	12	14
14	1	4	1.9316	13	11	15
15	1	2	3.6888	14	8	0

Through the findings obtained, it is possible to construct a scatter diagram for the number of conglomerates considered, which without question will throw more light on the appropriateness of the option chosen (Fig. 3). For better visualisation, the conglomerates formed using circles are highlighted. At the same time, the diagram axes have been divided using the appropriate reference lines on the average values (0 points), which visually facilitates the situation of the conglomerates on the chart and their characteristics. Each diagram vertex would represent a different situation: those ports located close to point A would represent the maximum economic and environmental sustainability, while those close to point C would represent the minimum values in both dimensions. Close to vertex B would be the Port Authorities with the highest economic sustainability and minimum environmental sustainability, and in D it would be exactly the opposite. Foregoing Fig. 3 shows that there are four conglomerates that have been formed, comprising the following ports:

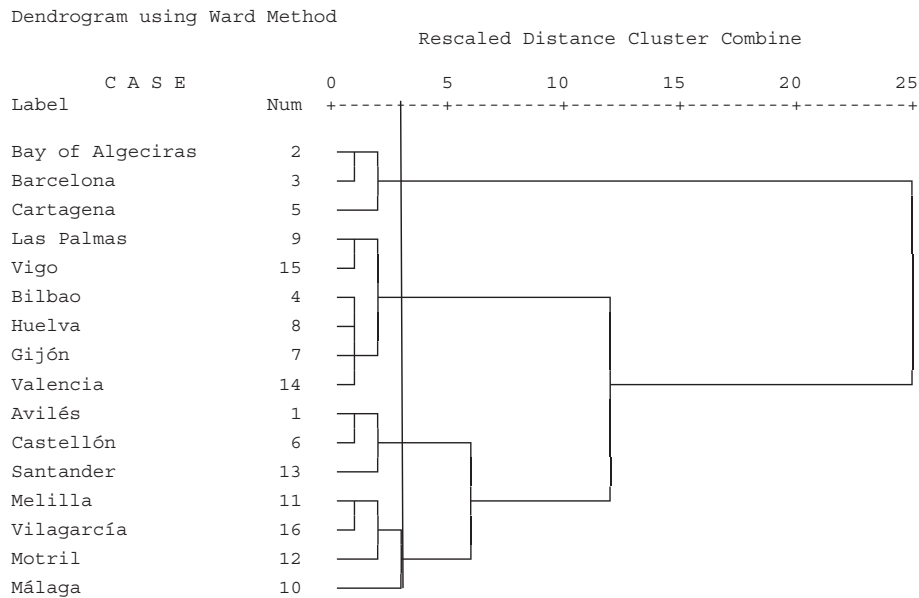
1. Aviles, Castellón and Santander.
2. The Bay of Algeciras, Cartagena and Barcelona.
3. Bilbao, Gijón, Huelva, Las Palmas, Valencia and Vigo.
4. Málaga, Melilla, Motril and Vilagarcía.

It can be seen that none of those extreme solutions or corner solutions have arisen, as there is no case located on the vertices.

Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
5 Cartagena	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3 Barcelona	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2 Bay of Algeciras	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
15 Vigo	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
9 Las Palmas	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
14 Valencia	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7 Gijón	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
8 Huelva	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4 Bilbao	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
12 Motril	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
16 Vilagarcía	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
11 Melilla	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
10 Malaga	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
13 Santander	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
6 Castellón	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1 Aviles	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Source: own elaboration

Fig. 1. Horizontal flow diagram.
Source: own elaboration.



Source: own elaboration

Fig. 2. Dendrogram. Source: own elaboration.

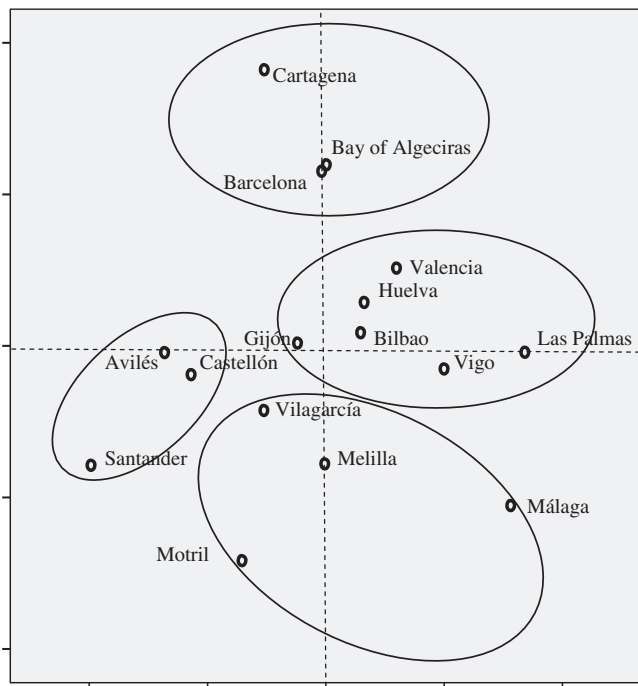
5. Discussion: economic and environmental sustainability and heterogeneity and level of specialisation of Spanish ports

With the aforementioned conglomerates formed, it would be right to ask: Do the similarities between economic and environmental sustainability of the groups of ports have anything to do with their size and/or specialisation?

To answer this question, the following stages of the analysis need to be continued. In addition to the Scatter Diagram (Fig. 3), which shows

the conglomerates, the SPSS Statistics software provides the calculation of the basic statistics for each of the groups formed, the results of which are included in Table 4.

Furthermore, it is possible to classify the conglomerates obtained in accordance with the overall tonnage moved and the type of traffic (bulk, whether or not the goods are containerised, use of Ro/Ro systems and, lastly, passengers, drawing a distinction between those that correspond to cruise liners and the remaining vessels).



Source: own elaboration

Fig. 3. Scatter diagram. Source: own elaboration.

Table 4
Characteristics of each conglomerate. Source: own elaboration.

Conglomera.	Statistical	Economic	Environm.	Ports
1	Average	-0.170	-0.374	Avilés
	N	3	3	Castellón
	Typ. deviation	0.197	0.110	Santander
	Minimum	-0.394	-0.496	
	Maximum	-0.022	-0.285	
2	% of total N	18.75	18.75	
	Average	0.695	-0.046	Bay of Algeciras
	N	3	3	Cartagena
	Typ. deviation	0.188	0.073	Barcelona
	Minimum	0.577	-0.130	
3	Maximum	0.912	0.001	
	% of total N	18.75	18.75	
	Average	0.060	0.152	Bilbao
	N	6	6	Gijón
	Typ. deviation	0.121	0.166	Huelva
4	Minimum	-0.076	-0.060	Las Palmas
	Maximum	0.257	0.421	Valencia
	% of total N	37.5	37.5	Vigo
	Average	-0.459	0.020	Malaga
	N	4	4	Melilla
Total	Typ. deviation	0.210	0.258	Motril
	Minimum	-0.708	-0.177	Vilagarcía
	Maximum	-0.213	0.391	
	% of total N	25	25	
	Average	0.006	-0.017	
Total	N	16	16	
	Typ. deviation	0.429	0.250	
	Minimum	-0.708	-0.496	
	Maximum	0.912	0.421	
	% of total N	100	100	

Table 5

Percentage of traffic over the sample as a whole (2012).

Source: own elaboration based on the Spanish ports (2012).

Conglomeration	Total	In bulk		Goods		RO-RO traffics	Passengers	
		Liquids	Solids	Not containerized	Containerized		Cruises	Others
1 Aviles Castellón Santander	6.53	7.12	20.09	2.79	1.39	2.09	0.36	2.03
2 Algeciras Cartagena Barcelona	43.83	50.20	21.90	45.33	46.57	82.22	51.86	65.32
3 Bilbao Gijon Huelva Las Palmas Vigo Valencia	28.50	38.09	50.01	17.31	15.29	6.09	23.91	14.27
Total	18.58	3.21	4.49	31.54	33.94	7.94	9.99	3.36
4 Malaga Melilla Motril Vilagarcía	47.09	41.30	54.50	48.85	49.23	14.02	33.91	17.63
Total	2.55	1.38	3.50	3.03	2.80	1.67	13.87	15.03
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.0

Table 5 sets out the results in vertical percentage figures, in other words with regard to the overall sample of the 16 ports that are the object of study.

Through all of this information each group of ports may be classified as follows:

- *Conglomerate 1.* The group comprises the ports of Avilés, Castellón and Santander. It is the group with the worst results in the environmental dimension, and close to or just below the average in the economic dimension, as occurs with Santander. These are small ports (they represent 6.53% of the traffic of goods) and without any specific specialisation except for bulk solids (20.09%), distributed very evenly between the three with percentages of between 6 and 7%.
- *Conglomerate 2:* Comprising the Port Authorities of the Bay of Algeciras, Cartagena and Barcelona, it groups together the ports that obtain the best results in the economic dimension and the most balanced values in the environmental dimension (average or very close to it). These three ports make up a very large conglomerate, as they represent 43.83% of overall traffic in the sample of the 16 ports considered. More specifically, they score particularly highly in the bulk liquids section (50.20%), but only represent 21.90% of bulk solids (a position similar to that of the previous conglomerates with environmental results that are fairly negative). They likewise account for almost half of the traffic of goods, both non-containerised (45.33%) and containerised (46.37%). As well as accounting for 82.22% of Ro/Ro traffic, they are the leading ports in passenger traffic, both with regard to cruise liners (51.86%) as well as the remainder (65.32%).
- *Conglomerate 3:* This is represented by the ports (Bilbao, Gijón, Huelva, Las Palmas, Valencia and Vigo) that reveal balanced positions that are close to the average in the economic dimension and, with the exception of Gijón, positive in the environmental aspect, in which the ports of Vigo and Las Palmas stand out. This is an atypical group with regard to the size of the ports and therefore requires a specific analysis, as these seven ports jointly represent 47% of the overall traffic of the sample.

For this purpose, Table 5 has been split into two subgroups: firstly, Valencia port, and secondly, the six remaining ports. The first represents 18.5% of the overall traffic of the 16 ports considered, and it reveals some peculiarities of particular note: firstly, it is the group leader in goods, whether containerised or not containerised (33.94 and 31.54%, respectively, over the total), figures that are close to the totals of Conglomerate 2 in this section; secondly, it represents a very low percentage of bulk liquids and solids (3.21% and 4.49%, respectively), which determines the nonexistence of specific facilities for this unloading at the port and the introduction of facilities which would surely increase

the results in the economic dimension, which would suggest an approximation to group 2 with the ports of Algeciras, Cartagena and Barcelona. Consequently, with regard to Conglomerate 3 it can be stated that it would be formed by medium-sized ports and the Port of Valencia, closer to the previous one for its characteristics and circumstantially displaced for its economic results.

- *Conglomerate 4:* This is the most scattered of all (maximum typical deviation). All of its components (the ports of Malaga, Melilla, Motril and Vilagarcía) reveal negative values in economic issues (below the average) and three types of behaviour in the environmental dimension: Melilla finds itself with average values; Vilagarcía and Motril reveal negative values and, lastly, Malaga is one of the ones with the greatest environmental sustainability (only surpassed by Las Palmas, belonging to the previous conglomerate). This is a conglomerate formed by ports with a very small dimension, as they only represent 2.55% of overall traffic. They are not prominent in any of the sections, with the exception of passenger traffic (13.87% in cruise liners and 15.03% in the remainder), polarised between Malaga and Melilla.

6. Conclusions

There is growing interest in the studies and analyses referring to port sustainability, but very little in the way of contributions for empirical verification. In the Spanish case, this sensitivity and relevance is implemented in the redrafted text of the Ports Act,⁴ Article 55.4 of which sets out the obligatory nature of providing a port sustainability report every year.

The work analyses the economic and environmental dimension of the Spanish port system, setting out 5 indicators and 13 subindicators for both dimensions. A total of 14 variables were assessed for the economic dimension and 19 for the environmental dimension.

Applying the methodology set out in the research, there are four port conglomerates, grouping together 16 ports from the sample selected from the overall total of the 28 that make up the Spanish system.

The analysis conducted determines three issues:

- 1) The methodology created and subsequently used allows the ports to be grouped in accordance with their behaviour in economic and environmental issues in the year considered. It is, therefore, a static vision of the same, offering a panorama of the similarities or divergences in the behaviour of the ports in issues of sustainability. It also opens the doors to dynamic analysis (of subsequent years), which would enable measures of control and monitoring of public policies to encourage sustainable development in the port environments to be carried out, by verifying the findings achieved with these.

⁴ Royal Legislative Decree 2/2011, of 5 September (Official State Journal of 20 October).

- 2) It can be stated that, based on a heterogeneous sample of Spanish ports, the groupings obtained using the technique employed show that there is a major causal and direct relationship between the size of the ports (measured in accordance with overall traffic) and the different levels of environmental and economic sustainability of the same. Similarly, as set out in the discussion, the level of specialisation conditions and determines the results in both dimensions.
- 3) The analysis emphasises the huge diversity of the Spanish port system with regard to the specific singularities of the Port Authorities, given that there are large, medium and small ports with different levels of specialisation, commercial and maritime integration, and with different allocations in terms of infrastructure and services. For this reason, the analysis conducted underlines this configuration and facilitates the application of measures and instruments to improve the efficiency of policies.
- 4) Since it has been proved that it is possible to measure environmental sustainability in the Spanish Port System with indicators, it seems to be feasible to make progress and carry out measures for their evaluation, benchmarking, as well as the possibility to fulfil specific codes.

Not all Port Authorities fulfil the requirement specified in the Port Law about having a series of indicators of sustainability. In this sense, it would be advisable to carry out the establishment of penalties to those entities not fulfilling the requirement or showing a negative evolution in these indicators. For example, Spanish regulations establish conditions to achieve tax discounts, with bigger discounts related to better sustainability, but these regulations do not specify anything if not reached the required level. Despite that, Spanish Port Law is one of the most advanced in Europe in this sense: there is no any other European Port Law including indicators of sustainability. Recently, ESPO (2016) has started to recommend a code of conduct, although only for cruises and ferries.

- 5) Lastly, there are two actions that could bring along positive effects. The first one refers to the possibility of having a specific department in each Port Authority working directly and closely with the local community in order to avoid environmental damages. The second one would be to get the European harmonization of these indicators of sustainability; this would make possible a better planning of the port system and it would avoid the environmental dumping, making that some ports become a refuge for not environmentally friendly activities.

Appendix A. Description of the variables

A.1. Economic dimension

Indicator	Subindicator	Description
Economic structure	Value generated and productivity	Turnover per employee
		EBIDTA per employee
	Economic and financial situation	Return on assets
		EBIDTA by tonnes
Business and servicing	Level and structure of investments	Debt servicing
		Unused assets
		Operating costs/operating revenue
	Business	Public investment/cash flow
		Third-party investment/public investment
		Asset renewal rate
		Occupancy rate/net turnover
Services	Activity rate/net turnover	
	Tonnes per square metre service area	
	Tonnes per metre active dock	

A.2. Environmental dimension

Indicator	Subindicator	Description
Environmental management	Economic behaviour of the PA in environmental issues	Investments associated to the introduction of an environmental management system
		Costs associated to the introduction of an environmental management system
Eco-efficiency	Environmental training	Investments in environmental characterisation and monitoring
		Costs in environmental characterisation and monitoring
	Energy consumption	Costs in terrestrial cleaning
		Costs in cleaning the water surface
Environmental quality	Efficiency in ground use	Percentage of workers with environmental training
		Percentage of the terrestrial service area occupied on asset facilities
	Water consumption	Percentage of electricity consumption by the service zone surface area
Percentage of fuel consumption by the service zone surface area		
Environmental quality	Quality of interior waters	Percentage of water consumption by the service zone surface area
		Percentage of terrestrial surface area that has rainfall collection network
	Wastewater treatment	Percentage of service zone surface area that has rainfall collection network
		Percentage of the terrestrial service zone that has a water treatment network (irrespective of where it discharges and the treatment received)
Recovery of waste	Recovery of waste	Percentage of the terrestrial service zone that has a treatment network connected to the municipal collector or WWTP
		Percentage of surface area that discharges into septic tanks
	Recovery of waste	Percentage of SUW recovery
		Percentage of hazardous waste recovery
		Percentage of recovery of oils

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