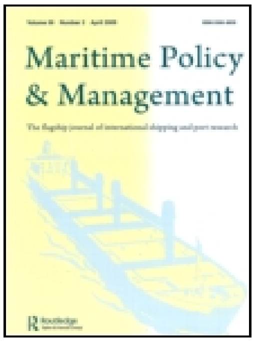

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The relationship between ‘position-port’, ‘hard-port’ and ‘soft-port’ characteristics and port performance: conceptual models

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This research study attempts to conceptualize models based on the relationship between characterization factors and port performance. By selecting a universe of the 230 largest European ports in terms of cargo throughput, 43 valid answers were obtained. Factor analysis and K–W (Kruskal–Wallis) tests were carried out taking as a reference the port performance theory. Findings reveal the existence of a relationship between port performance and its characterization factors, delving into the development of conceptualized models that contribute to deepen the knowledge of port competition structure and dynamics within Europe.

1. Introduction

Modern ports are a strategic node of the maritime chain, to where traffic flows and multiple activities and different operations are carried out, taking advantage of the proximity to markets or the freight flows towards other destinations. The port characteristics have an impact on performance allowing them to gain a competitive advantage in international markets (Tongzon and Heng 2005). According to Culinnane and Dong-Wook (2005), containerization and globalization of services have produced profound changes in ports, by demanding intermodal services integrated with liner service networks (Juang and Roe 2010). This forced the development of infrastructure facilities, increased the vessel transport capacity and favoured the emergence of hub-ports (Fleming and Hayuth 1994) serving expanded hinterlands which in turn intensified port competition (Wang and Cullinane 2006; Song 2002) and increased maritime trade (Haralambides 2002; Notteboom and Rodrigue 2005).

Ports have always played an important role favouring regional economic development (Gaur 2005). Fierce port competition and increased vessel transport capacity have demanded better port performance, largely dependent on port characteristics, such as infrastructures, specialization in cargo handling, shipping services and degree of integration in the maritime networks. Chang and Lee-Paul (2007) recognized that few studies have investigated port performance and inter-port competition.

Because of their strategic role, Estache, Perelman, and Trujillo (2005) and Gonzalez and Trujillo (2009) highlighted the need to further investigate port performance. Most authors analyse port performance by simply comparing ports and port terminals without

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*To whom correspondence should be addressed. E-mail: vitorcaldeirinha@gmail.com taking into account the characterization factors that explain their differences. Even fewer studies have attempted to conceptualize models with the goal of improving the knowledge of port competition structure/system and development. Notteboom and Rodrigue (2005) proposed a conceptual model focused on various port aspects such as location, infrastructure, governance and ownership, while Cullinane, Song, and Gray (2002) studied the influence of port ownership on performance. Liu, Liu, and Cheng (2005) investigated the differences between terminals managed by foreign companies and those operated by national ones, while trying to analyse the impact on port performance.

This study is focused on conceptualizing models grouping different port types based on the relationship between performance and characterizing factors, hoping to contribute to a better understanding of the port industry. The first objective is to evaluate the type and importance of the relationship between port characterizing factors, differentiated by 'position-port', 'hard-port' and 'soft-port'. The second is to understand the relationship between characterizing factors and port performance. Finally, the third objective is to conceptualize models based on different port-type matrices built on the relationships found between characteristics and performance and thereby contributing for a deeper understanding of the port industry competition structure. The theoretical framework is essentially based on the theory of port performance (e.g., Cullinane, Song, and Gray 2002; Tongzon and Heng 2005).

Several authors identified port location ('position-port') and infrastructure ('hard-port') as critical variables when explaining port performance and efficiency (Tongzon and Heng 2005), while others considered port management and services provided ('soft-port'). The argument lies on the fact that ports have various distinctive characteristics, such as location ('position-port'), infrastructure ('hard-port'), specialization in cargo handling, governance model or shipping services provided ('soft-port'), among others, directly affecting their operational and financial performances.

This study presents a new approach using ports with a wide range of quantitative variables as a sample, which are usually difficult to collect and, thus, not very often used by researchers, especially in what concerns the major three constructs of port characteristics, position-, hard- and soft-port, used simultaneously. Usually investigators prefer to study only one or some of the port characteristics due to availability of data, which, in most cases, is indirectly obtained, based on qualitative data.

This study presents an innovative approach not only by analyzing a wide range of quantified physical characteristics of ports but also by determining groups of ports with similar internal characteristics, distinct from other groups, which affect their performance. This will help a better understanding of the differences between ports and what ports can do in order to change to a group they aim to be as their goal.

Because investment decisions in ports are generally made according to the level of market competition, port size and capacity, further investigation on the relationships between port characterizing factors will definitely allow for a better evaluation of investment decisions when considering developing new port facilities or expanding existing ones, thereby affecting port performance. A conceptual approach is, thus, required to define models and instruments on port industry development structure/dynamics.

Following introduction, the theoretical background will assist the development of the working hypotheses. This is followed by the research methods used, including the model and variables chosen, as well as instruments used. The results achieved are then analysed. After discussion, conclusions are drawn. Implications of the study for theory are presented, including the main strengths and constraints found, before further research is suggested.

2. Theoretical background

The port characterizing factors are differentiated by the quality of existing facilities, infrastructures and level of services provided according to their degree of specialization in cargo handling and can be classified into three categories, namely, ‘position-port’, ‘hard-port’ and ‘soft-port’. The ‘position-port’ is identified by geographic location characteristics, either concerning the hinterland or the port location by sea or inland/river, as well as by the economic performance of the region where the port is situated. The ‘hard-port’ is identified by infrastructure, port size, terminal size, quayside water depth and number of existing equipment. Finally, the ‘soft-port’ includes port services, port specialization in cargo handling, governance model, shipping services provided and degree of integration in the global maritime networks.

The effect of port characterizing factors on performance has become a determinant issue not only to deal with ever-increasing port competition but also due to the economic impact on nearby regions, among other factors, such as port size and specialization degree.

Investment decisions and their implications on ports have gained critical importance in the view of increasing port competitiveness, thereby it is necessary to continue to investigate and develop conceptual models within a theoretical framework and using empirical factors.

Position-port factors: The amount of cargo handled is strongly related with the port location and that usually cannot be changed (Song and Yeo 2004), which confirms that not only ports situated nearby small economies are affected in terms of throughput and performance but also that port services demand is driven by the proximity to trade flows and consumption areas (Tongzon and Heng 2005). The port location is a determinant key of performance (Liu 1995). According to Frémont and Franc (2010), traffic flows concentrated at ports rely on the economy of the nearby hinterland. Therefore, the regional economic development should be taken into consideration when analyzing port performance, but not always location and regions are the main determinants.

Hard-port factors: The dimensional factors related with economies of scale, location, regional and port concentration have a strong influence on port performance and are certainly a determinant factor to port’s success (Notteboom 2010). Some authors suggested that the larger ports have better performance levels than smaller ones not only due to learning effects (Estache, Perelman, and Trujillo 2005; Turner, Windle, and Desner 2004; Veldman and Bückmann 2003) but also triggered by the presence of economies of scale in the port sector (Liu 1995; Wiegmans 2003). If port productivity increases with size because there are significant economies of scale, that seems to suggest that decision makers should focus on investing in larger ports and invest with caution in smaller ones, except if considering a niche market (De-Neufville and Tsunokawa 1981). This is consistent with the results presented by Hung, Lub, and Wang (2010), indicating that the existence of economies of scale optimizes port efficiency.

If ship owners select the ports to scale based on their partnerships and on their logistic networks (Tongzon and Heng 2005), then port integration with shipping services becomes a critical issue, especially concerning their playing role in the main global maritime shipping networks connecting world major ports.

The increased port specialization in cargo handling, particularly the containerization rate, was studied by Trujillo and Tovar (2007) and Medda and Carbonaro (2007), because it reflects the stage of port development, evolving from an industrial port to a modern commercial one.

The port investments depend on many factors and port characteristics, including the specialization in cargo handling that varies depending on whether the cargo is containerized, general cargo, bulk or roll-on/roll-off cargo, and that requires specific type and size of infrastructure facilities and services.

Investments in port infrastructure and its capital intensity nature were considered significant factors when explaining differences in port performance (Liu 1995), based on the fact that without expanding infrastructures or improving the service capacity a port cannot accommodate additional cargo flows and vessel demands. According to Park and De (2004), the quay capacity is a production factor related with the output of models. Garcia-Alonso and Martin-Bofarull (2007) concluded that not always the level of investment in infrastructure leads to equivalent improvements in port performance, thereby indicating that other factors such as location and integration in the global maritime networks should be studied.

Wiegmans (2003) concluded that port accessibility has a great influence on port efficiency, recognizing that improved maritime accesses may upgrade the port's position in the port hierarchy, consequently benefiting customers with significant economies of scale and substantially lower freight rates. Turner, Windle, and Desner (2004) studied the impact of both maritime and land accesses, and Gaur (2005) identified factors affecting the performance of a port, including maritime access.

Soft-port factors: In the maritime shipping side, Tongzon and Heng (2005) demonstrated that an increased port vessel calls provide a wider range of choices for ship owners, greater flexibility and smaller transit times, thereby improving port performance. Veldman and Bückmann (2003) attempted to explain the Northern Europe port's market share and their performance level using factors such as vessel frequency and transit times. Turner, Windle, and Desner (2004) studied the impact of shipping services and port equipment on port performance.

Port ownership is another port characterization factor which affects performance (Liu 1995). Under public management, there are not enough incentives to improve performance like in privately managed ports which have profit-driven objectives. This has raised the question of whether all port governance reforms have produced the same successful results. Most studies only distinguish public management from private ones, not taking into consideration the existing complexity between port ownership and management. Regarding the port governance issues, Liu, Liu, and Cheng (2005) concluded that the Chinese port terminals, with private Sino-foreign joint ventures, recorded better performance levels and the terminals with international liner service networks showed better results than those engaged in domestic shipping routes.

Performance: The main performance indicators used in several port studies are total throughput, measured either in tons or TEUs (twenty-foot equivalent unit), including hinterland and transhipment cargo, and number of vessel calls by cargo type (roll-on roll-off, break-bulk, containers, dry or liquid bulk cargo), as ports aim to attract more cargo and vessels of all types. Several authors used the total throughput in absolute value as an output variable while analyzing performance models, including Song and Yeo (2004), Barros (2003), De-Neufville and Tsunokawa (1981), Garcia-Alonso and Martin-

Bofarull (2007) and Park and De (2004). From a financial performance perspective, the port authority revenues per ton or per employee are indicators that reflect the added-value services that port users are willing to pay considering the existing infrastructures or the port location (Barros 2003; Park and De 2004; Kent and Ashar 2001; Gonzalez and Trujillo 2009; Turner, Windle, and Desner 2004).

3. Research methods

The research is based on the relationship between the port characteristics and performance. The key dimensions of exogenous port characteristics are three: the 'position-port', location and performance of the region, the 'hard-port', port size and infrastructure, and the 'soft-port', specialization in cargo handling, shipping services, global maritime chain integration and governance. The key dimensions of performance are characterized by two endogenous factors: the operational and financial performances.

Hypotheses

The objective of this research study is to contribute to a better understanding of the port industry. Assisted by a theoretical background, this study aims to investigate the relationships between port main characteristics and main performance variables (Figure 1). In order to better understand ports and the port market, detailed characteristics and performance of different groups of ports were also analysed. These groups resulted from the relationship between the two main variables studied in each hypothesis in order to determine whether there were significant differences between groups and thus determine the existence of different types of ports with very different characteristics and performance of all the port. With the characterization of the ports through the various groups, it is possible to understand the position of each port in the port market and realize what must be changed in a port in order to change from one group to another, for example, what characteristics of the port should be changed so that an expensive port becomes efficient or a bulk port becomes a large container hub port.

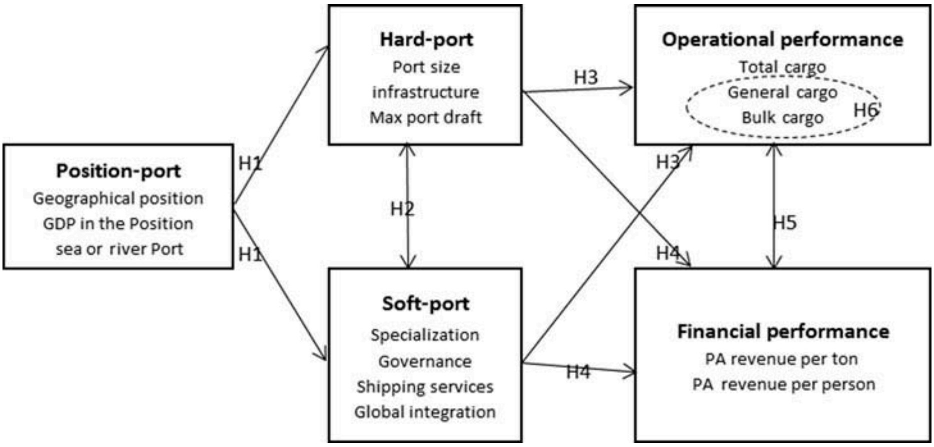

Figure 1. Diagram of the research working hypotheses.

In this context and based on the justification of theoretical background, the following hypotheses were formulated:

> Hypothesis 1: The 'position-port' influences both 'hard-port' and 'soft-port', and this relationship determines different port types. For example, the deep maritime access ports, specialized in large vessels, are located in Southern Europe, along the inter-continental axis of the Mediterranean.
>
> Hypothesis 2: The relationship between 'hard-port' and 'soft-port' determines different port types. For example, only ports with deep maritime access can have services to the larger ships.
>
> Hypothesis 3: The 'hard-port' and 'soft-port' have a positive influence on the operational performance of the port, and this relationship determines different types of port. For example, ports that receive bigger ships have a bigger cargo throughput.
>
> Hypothesis 4: The 'hard-port' and 'soft-port' have a negative influence on the financial performance of the port. For example, ports with deep maritime access and big ships are cheapest.
>
> Hypothesis 5: The relationship between the operational and the financial performance of the port authority determines different port types. For example, ports with bigger throughput are cheapest.
>
> Hypothesis 6: The relationship between the port operational performance variables, identified by general and bulk cargo, determines different port types. This hypothesis considers that small ports, bulk ports, medium ports and big ports groups have very different characteristics between them, but similar within each group.

Variables

In what concerns the key dimensions of port characteristics, the 'position-port' is identified by the port location factor, which in turn is explained by five variables: distance to Rotterdam port (DROTERD2), one of Europe's main gateway serving economic core regions; distance to Mediterranean axis (DMEDIT3), where global maritime trade routes cross east-west from China (30); seaport or inland/estuary port (SEAPORT4), distance to the nearest city (DCITY5), as modern ports tend to move away from urban centres; and, at last, the degree of economic development of the nearby region (GDPCAP17), which is identified with the 'position-port' key dimension. The 'hard-port' key construct is defined by the port size factor and infrastructure. Port size is expressed by the total quay length (QUAYL6) and the infrastructures are characterized by three variables: number of cranes per kilometre of quay (CRAINSKM7), average size of terminals (TERMSIZE8) and the quay depth (MAXDRAFT9). The 'soft-port' key construct is identified by port specialization in cargo handling, shipping services, degree of port maritime chain integration and governance model. Port specialization is explained by three variables: the unitization rate (TXUNIT10), the 'horizontalization rate' (TXHORIZO11) and the containerization rate (TXCONT12). The shipping services provided at the port are measured by two variables: the number of liner services (REGULARSHIPS13) and the average vessel size (SHIPSIZE14). Finally, the degree of port integration in global maritime chain is measured by the variable BIGSHIPO15 and the port governance model is expressed by the variable PORTPRIV16. The port performance key is identified by operational and financial performance factors. The first factor is measured by three variables: port total throughput (TOTALTON18), general cargo traffic (GENERALTON19) and liquid and solid bulk traffic (BULKTON20). While the second factor is explained by two variables: the port authority gross revenues per employee (EURPERSON21) and per ton (EURTON22).

Table 1. Variables and constructs.

Variable	Construct	Description and authors
DROTERD2	Position-port	The distance to Rotterdam port was calculated in kilometres by drawing a straight line between each port of the sample and Rotterdam port maritime entrance, with reference to the (geographical) meridian, using Google Earth software. It is a continuous variable greater than zero (Estache, Perelman, and Trujillo 2005; Song and Yeo 2004; Liu 1995).
DMEDIT3	Position-port	The distance to the Mediterranean axis was calculated in kilometres by drawing a straight line starting on the meridian of the each port of the sample and ending in the crossing point between the shores of the Mediterranean Sea in the same meridian, using Google Earth software. It is a continuous variable greater than zero (Song 2002; Estache, Perelman, and Trujillo 2005; Liu 1995).
SEAPORT4	Position-port	The variable is a dummy variable that assigns the value of 1 if the port is located on the coastline and the value of 0 if the port is inland/estuary or river one (Gonzalez and Trujillo 2009).
DCITY5	Position-port	The distance to the nearest city is calculated in kilometres by drawing a straight line from the port of the sample to the closest urban centre (Notteboom and Rodrigue 2005).
GDPCAP17	Position-port	The economic development of the region where the port is located is measured by the ratio between GDP and the population of the NUTS II region as a percentage of average European Union (EU27 = 100) (Regional Yearbook 2008, Eurostat).
QUAY6	Hard-port	The total quay length in metres refers to the size of the port built infrastructure and corresponds to the sum of all operating terminals quay length over four metres of depth (Coto-Millan, Banos-Pino, and Rodriguez-Alvarez 2000).
CRAINSKM7	Hard-port	The number of cranes per kilometre of quay is obtained by dividing the number of quay cranes, regardless its type or function, by the total quay length of operational terminals, in kilometres.
TERMSIZE8	Hard-port	The average terminal size is obtained by dividing the total cargo throughput by the number of port terminals, with independent management and physically separated, resulting in the average throughput by terminal in tons.
MAXDRAFT9	Hard-port	The quay depth, in metres, is the distance between quay depth and the hydrographical zero of the terminal with deeper water depth. It is a continuous variable greater than zero (Wang and Cullinane 2006).

(*continued*)

Table 1. Continued.

Variable	Construct	Description and authors
TXUNIT10	Soft-port	The unitization rate corresponds to the ratio between general cargo traffic and total throughput, measured in tons. General cargo includes break-bulk cargo, containerized cargo and roll-on roll-off. It is a continuous variable, between zero and one.
TXHORIZO11	Soft-port	The horizontalization rate is calculated by dividing the roll-on roll-off cargo with general cargo handled at the port, measured in tons. When this value tends to 1, it means the port is specialized in roll-on roll-off cargo, as a part of general cargo. It is a continuous variable, between zero and one.
TXCONT12	Soft-port	The containerization rate is the ratio between containerized cargo and general cargo handled at the port, being the later the most adaptable one to be transported in containers. It is a continuous variable, between zero and one (Trujillo and Tovar 2007; Hui, Seabrooke, and Wong 2004).
REGULARSHIPS13	Soft-port	The ratio between the number of direct liner services and the total of port calls is used to define shipping services and takes the form of a continuous variable, between zero and one. It aims to emphasize the importance of direct liner services (Turner, Windle, and Desner 2004).
SHIPSIZE14	Soft-port	The average size of vessels calling a port, measured in tons of 'gross tonnage', is a continuous variable, greater than zero (Turner, Windle, and Desner 2004).
BIGSHIPO15	Soft-port	The degree of integration in the global maritime networks is measured by dividing the number of liner services of the top seven container shipping operators and total number of liner services (Song and Yeo 2004).
PORTPRIV16	Soft-port	The port governance model is obtained by dividing cargo volume handled at privately operated terminals by the port's total throughput (Notteboom and Coeck 2000; Tongzon and Heng 2005).
TOTALTON18	Operational performance	The port operational performance is identified by total throughput, measured in absolute value, in terms of tons.
GENERALTON19	Operational performance	The port operational performance is identified by general cargo throughput, measured in absolute value in tons.
BULKTON20	Operational performance	The port operational performance is identified by bulk cargo throughput, measured in absolute value in tons.
EURPERSON21	Financial performance	The port financial performance is measured by port authority gross revenues per employee (Gonzalez and Trujillo 2009; Turner, Windle, and Desner 2004; Park and De 2004; Barros 2003).
EURTON22	Financial performance	The port financial performance is measured by the port authority gross revenues per ton (Gonzalez and Trujillo 2009; Turner, Windle, and Desner 2004; Park and De 2004; Barros 2003).

4. Data collection/sample and instruments

The port sample was established by selecting the 230 largest European ports in tons of total throughput obtained from the ESPO (European Sea Ports Organisation) Annual Report. To obtain qualitative information, questionnaires were sent electronically to port authorities in 2009 and 43 valid answers were obtained (18.7%) (Tables A1 and A2). The compiled data of GDP (gross domestic product) per capita of the regions nearby ports were obtained from the Eurostat Regional Yearbook and NUTII (nomenclature of territorial units) classification. For statistical evaluation, factor analysis and K–W (Kruskal–Wallis) tests were performed and the *biplot* technique was applied between the variables chosen to differentiate ports in a correlation matrix.

5. Results

The variables demonstrated a normal distribution confirming the applicability of factor analysis. The Pearson correlation indexes were significant. There was a significant correlation found between the dependent variables TOTALTON18, GENERALTON19, BULKTON20 and EURTON22, as expected, considering that they are performance variables resulting from the port activity (Table A3). Two evaluation procedures were performed using factor analysis with varimax method; the first was applied to the independent variables and the second to all independent and dependent variables in order to study the structural relationships between the (latent) factors. Factor analysis was applied to the independent variables, resulting in a model with nine variables (KMO = 0.654) (Table A4) and two components (Table 2). The first component included MAXDRAFT9, SHIPSIZE14 and TXCONT12 with a positive sign and TXUNIT10 and DMEDIT3 with a negative sign. The second component included DMEDIT3, GDPCAP17 and PORTPRIV16 with a positive sign and DROTERD2 with a negative sign. The first component is identified with deepwater ports ('hard-port'), located in Northern Europe, serving large vessels and providing specialized shipping services in containerized cargo handling ('soft-port'). The second component is identified with Mediterranean Sea ports, distant from Northern Europe, whose terminals are mainly under private sector management, and situated nearby large population areas and business centres and within regions with high GDP per capita.

The results show that the geographic location, maritime accesses and shipping services, resulting from vessel size, comprise the main port characteristics in two key dimensions: one associated with the first component, identified as 'hard/soft-port', and the other with the second component, identified as 'position-port'. In the second component, the DROTERD2 variable (concerning the distance to Rotterdam) proved to be the most

Table 2. Matrix of independent variables (rotated component matrix).

	Component	
	1	2
MAXDRAFT9	0.860	
SHIPSIZE14	0.836	
TXUNIT10	−0.694	
TXCONT12	0.557	
DMEDIT3	−0.525	0.501
DROTERD2		−0.834
GDPCAP17		0.776
PORTPRIV16		0.619

Note: Rotation method: varimax with Kaiser normalization.

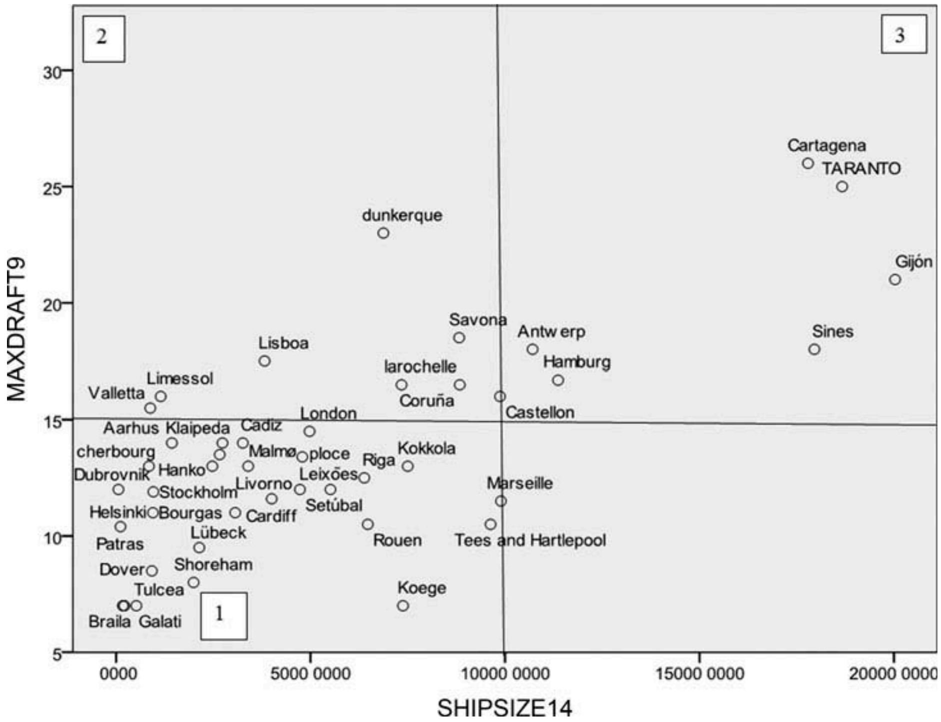

Figure 2. MAXDRAFT9 and SHIPSIZE14 variables biplot.

representative of location ('position-port'). Both variables—MAXDRAFT9, representing 'hard-port', and SHIPSIZE14, representing 'soft-port'—showed equivalent importance as representatives of the first component.

With the purpose of analyzing these relationships and conceptualizing explanatory models and aiming to better understand the characteristics of the most competitive ports, the present research focused on the most representative and meaningful variables. In the case shown in Figure 2, the variables MAXDRAFT9 and SHIPSIZE14 were adopted as emulators in the relationship between the 'hard-port' factors and 'soft-port' ones, using the biplot technique.

A positive relationship was found between the two variables because the shipping services meant to serve large vessels require existing infrastructure facilities and sufficient water depth in the access channels and quayside. Nevertheless, the results also show that some ports, despite meeting the deepwater requirements for handling large ships, are not able to attract large vessels, on average, perhaps due to other infrastructure constraints or location. The results indicate that MAXDRATF9 influences SHIPSIZE14. However, the latter is admitted to have a strong impact on port performance, as well as other variables that characterize the port. SHIPSIZE14 was chosen as a proxy variable of the first component using factor analysis, i.e., as representative of both 'hard-port' and 'soft-port' key constructs. Further analysis and testing were carried out to identify differences between the three groups of ports (Table A6). The results show that hypothesis H0 could not be rejected, meaning that at least one group had an average value different from the others in the case of DMEDIT3, TXCONT12, REGULARSHIPS13, TOTALTON18,

Table 3. Port differentiation matrix by capacity and positioning in shipping.

MAXDRAFT9	1. Ports with good maritime accesses • Ports near the Mediterranean Sea • High containerization rate • Medium number of liner vessel calls • Medium throughput and bulk cargo • Medium financial performance per ton • Although having adequate maritime accesses, they have other constraints that prevent them from being positioned in the shipping market top level of biggest ships	3. First-level ports concerning water depth and number of vessels calling • Ports with a high containerization rate • Large number of liner vessels calls • Good operational performance level of total cargo and bulk cargo handled • Low financial performance per ton
	2. Small- and medium-size ports • Ports distant from the Mediterranean Sea • Low containerization rate • Reduced liner vessels calls • Low total traffic and bulk cargo volumes • High financial performance per ton	
	SHIPSIZE14	

BULKTON20 and EURTON22 variables, besides the variables used in the biplot technique (Table 3).

Another important relationship associates variables from both components: given the SHIPSIZE14 variable, identified as 'hard/soft-port' in the first component and the DROTERD2 variable, representing the port geographic location and identified by 'position-port' in the second component, a model of port analysis was conceptualized using the biplot technique (Figure 3). The results indicate that ports are uniformly spread across approximately 2000 km away from Rotterdam and have up to 10 000 tons of gross tonnage (GT), on average, per vessel calling. The exceptions were the port of Gijon, Sines and Cartagena, which handle an average GT of 15 000–20 000 tons per vessel and are situated at 1000–2000 km away from Rotterdam. This group includes large ports built primarily to handle bulk cargo of large ocean vessels. Limessol is another exception because it is located 3000 km away from Rotterdam and experiences a low average of GT per vessel. On this analysis, ports were divided into four groups (quadrants) differentiated by location, regarding Europe (centre or periphery) and by vessel size (large or small).

K–W tests were performed in order to study the differences among them using the variables that characterize each group of ports and their performances (Table A7). The results indicate that hypothesis H0 could not be rejected, meaning that at least one group had an average value different from the others in the case of DMEDIT3, TXUNIT10, MAXDRAFT9, TOTALTON18, BULKTON20 and EURTON22 variables, besides the variables used in the biplot technique. This evaluation allowed the definition of a matrix characterizing the four groups of ports, as shown in Table 4.

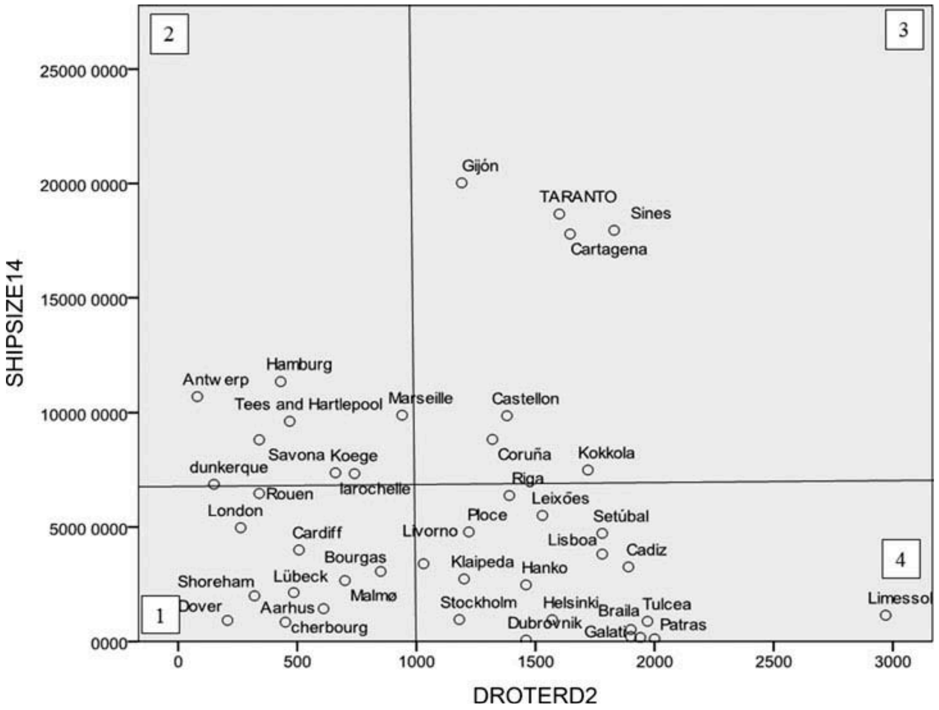

Figure 3. SHIPSIZE14 and DROTERD2 variables biplot.

Table 4. Port types matrix by shipping services and location.

SHIPSIZE14	1. Large centred ports • Ports located at the economic centre of Europe • Deepwater accesses • Large ships • Specialized in general cargo • High cargo volume • Low financial performance level per ton	3. Peripheral large ports • Ports situated at the periphery of Europe • Deepwater accesses • Large ships • Specialized in bulk cargo • High cargo volumes, bulk in particular • Low financial performance level per ton
	2. Small centred ports • Ports of Central Europe • Limited maritime accesses • Small-sized vessels • Specialized in handling general cargo • Small traffic volumes • High financial performance level per ton	4. Peripheral small ports • Ports on the periphery • Limited maritime accesses • Small-sized ships • Specialized in handling general cargo • Small traffic volumes • Good financial performance level per ton
	DROTERD2	

Table 5. Independent and dependent variables matrix (rotated component matrix).

	Component	
	1	2
SHIPSIZE14	0.908	
MAXDRAFT9	0.813	—
TXUNIT10	−0.742	
BULKTON20	0.646	0.568
EURTON22	−0.547	
GENERALTON19		0.842
SEAPORT4		−0.726

Note: Rotation method: varimax with Kaiser normalization.

Applying factor analysis with varimax method to all the independent and dependent variables resulted in a model with seven variables (KMO = 0.658) (Table A5). Two components were found: the first includes MAXDRAFT9, SHIPSIZE14 and BULKTON20 with a positive sign and TXUNIT10 and EURTON22 with a negative sign; the second component includes BULKTON20 and GENERALTON19 with a positive sign and SEAPORT4 with a negative sign.

Table 5 shows that the first component is identified with deepwater ports serving large vessels, which are specialized in handling bulk and experience high operational performance but low financial performance of the port authority, whereas the second component is associated with inland/river ports that handle high volumes of bulk and general cargo, experiencing high operational performance levels.

As outlined before, the port's geographic location and shipping services, resulting from the vessel size, can identify the main characteristics of ports. Inland/river port location has a positive impact on operational performance, whereas enhanced quality of shipping services associated with maritime accessibility has a negative effect on financial and operational performance of the port. The identification of the variables included in these two components allowed a two-by-two analysis to be carried out in search for economic meaning. By understanding the port complexity and observing each variable in detail, models were conceptualized and by so providing a deeper knowledge of the port competitive requirements, contributing to a better understanding of the port industry. The first component of factor analysis was associated with 'hard-port' and 'soft-port', while the second component was associated with operational performance and 'position-port'. Regarding the first component, the SHIPSIZE14 variable was chosen as the most representative of 'hard-port' and 'soft-port' constructs. In the second component, the operational performance was represented by two variables, GENERALTON19 and BULKTON20, which required a separate analysis. First, the BULKTON20 variable, referring to bulk cargo handling, was associated with the SHIPSIZE14 variable, related to vessel size, in order to perform the biplot analysis. However, the two variables were found to be correlated, indicating that BULKTON20 has a high weight in the first component of the factor analysis. To conclude, ports serving large-sized vessels experience better operational performance in terms of bulk cargo handled. Therefore, the GENERALTON19 variable was chosen, regarding the operational performance identified

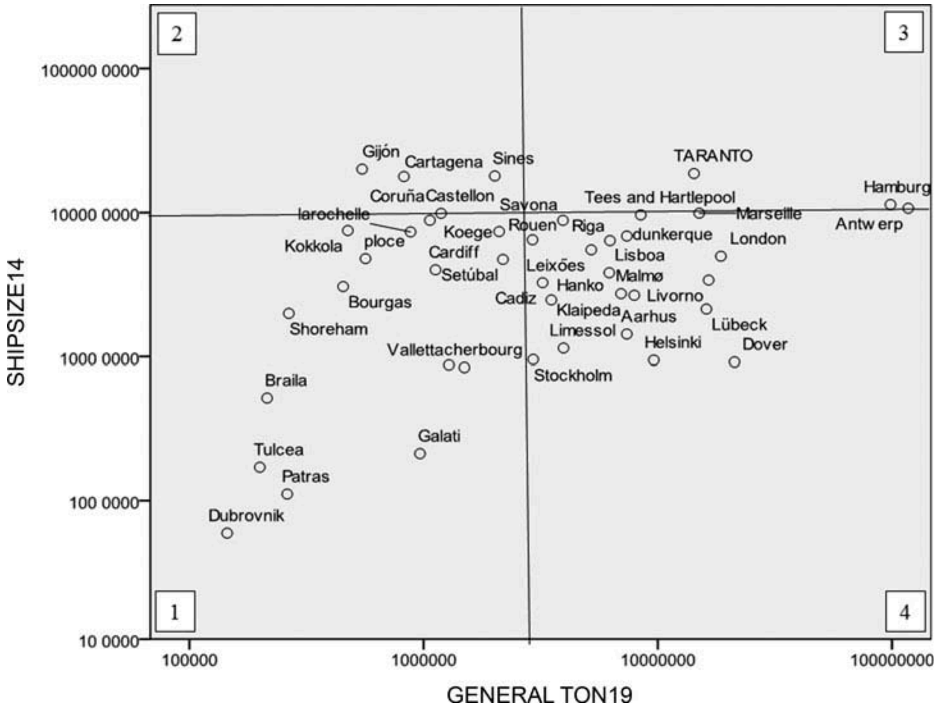

Figure 4. SHIPSIZE14 and GENERALTON19 variables biplot.

by general cargo, to be associated with the SHIPSIZE14 variable, concerning vessel size. Both variables were used as proxies of the two factor components and also as representatives of port performance (dependent variables) and port characteristics (independent variables) (Figure 4). The ports were divided into four groups according to their size (large or small) and general cargo throughput (higher or lower volumes).

K–W tests were performed in order to study the differences among them between the variables that characterize ports and their performances (Table A8). The results indicate that hypothesis H0 could not be rejected, meaning that at least one group had an average value different from the others in the case of DROTERD2, DMEDIT3, QUAYL6, TXHORIZONT11, REGULARLSHIPS13, TXUNIT10, MAXDRAFT9, TOTALTON18, BULKTON20 and EURTON22 variables, besides the variables used in the biplot technique. This evaluation has allowed the definition of a matrix characterizing the four groups of ports (Table 6).

The two components resulting from factor analysis included dependent variables. Consequently, there was a need to further investigate the different sets of port characteristics resulting from the combination of the dependent variables operational and financial performance. A conceptual relationship was thus considered between the EURTON22 variable of the first component and the TOTALTON18 variable of the second component, including GENERALTON19 and BULKTON20 variables, using biplot analysis (Figure 5). The results show that the ports with lower operational performance have better financial performance per ton, while the ports with better operational performance have

Table 6. Port types matrix by shipping services and performance.

SHIPSIZE14	1. Bulk cargo ports • Periphery ports • Deep maritime accesses • Large vessels calling the ports • Specialized in bulk cargo handling • High bulk cargo volume and total throughput • Low financial performance level per ton	3. Large ports handling general cargo • Deep maritime accesses • Large vessels calling the ports • Specialized in general cargo handling • High total and general cargo volumes • Low financial performance level per ton
	2. Small ports • Limited maritime accesses • Small-sized vessels • Low amount of bulk and general cargo traffic • High financial performance level per ton	4. Regional ports of general cargo • Limited maritime accesses • Small-sized vessels • Specialized in general and roll-on/roll-off cargo handling • Low volume of bulk cargo • High financial performance level per ton
	GENERALTON19	

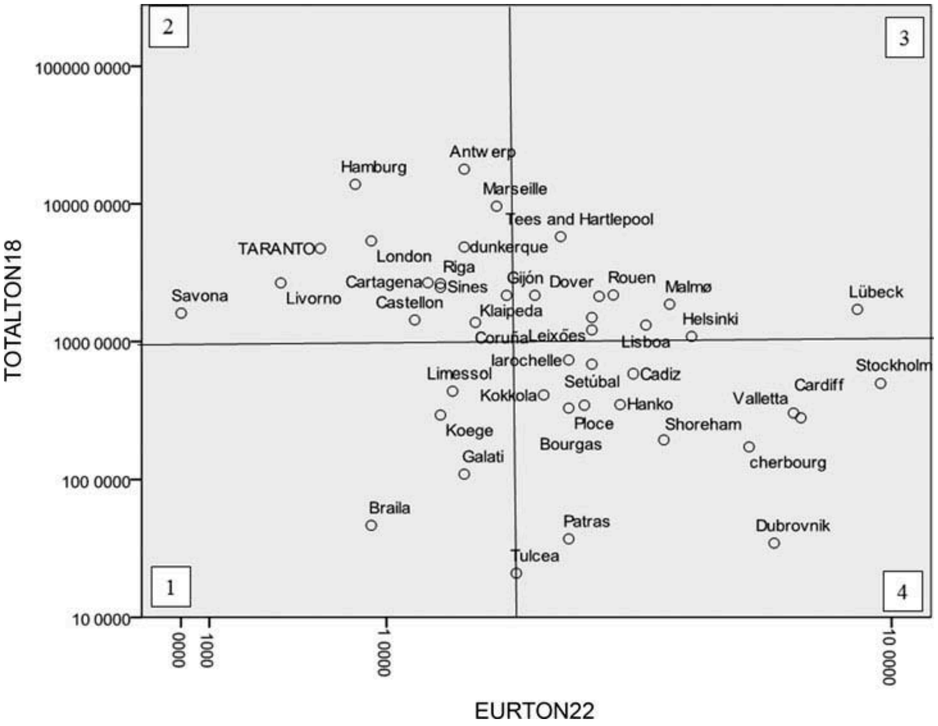

Figure 5. TOTALTON18 and EURTON22 variables biplot.

Table 7. Port types matrix by operational and financial performance.

TOTALTON18	1. Larger and inexpensive ports • Large ports with large terminals • Deep water accesses • Large vessels calling • Specialized in bulk cargo • High containerization rate • Private management • High general and bulk cargo volumes	3. Large and expensive ports • Large ports with large terminals • Medium level of water depth • Medium-sized vessels • Specialized in containers • Private management • High volume of general cargo
	2. Small and inexpensive ports • Periphery small ports with small terminals • Limited maritime accesses • Specialized in general cargo • Public management • Small volume of general cargo and bulk • (few ports applied)	4. Small and expensive ports • Small-sized ports • Medium-sized level in terms of maritime access • Small vessels • Small volume of general cargo and bulk
	EURTON22	

lower financial performance per ton. The ports were divided into four groups according to their operational and financial performances.

K–W tests were carried out to analyse the differences among them, between the variables which characterize ports and their performances (Table A9). The results indicate that hypothesis H0 could not be rejected, indicating that at least one group had an average value different from the others in the case of QUAYL6, TERMISIZE8, TXUNIT10, MAXDRAFT9, DROTERD2, TXCONT12, SHIPSIZE14, PORTPRIV16, GENERALTON19 and BULKTON20 variables, besides the variables used in the biplot technique. This evaluation has led to the definition of a matrix characterizing the four groups of ports, as shown in Table 7.

Finally, the relationship between the two aspects of operational performance was investigated: bulk cargo handled, observed in the first and second components of factor analysis, and general cargo, in the second component. It was assumed as a conceptual model the relationship between BULKTON20 and GENERALTON19 variables. The ports were then divided into four groups (Figure 6).

K–W tests were performed to determine the differences among them, between the variables which characterize ports and their performances (Appendix, Table A10). The results show that hypothesis H0 could not be rejected, meaning that at least one group had an average value different from the others in the case of TXUNIT10, TXCONT12, DROTERD2, DMEDIT3, QUAYL6, TERMSIZE8, MAXDRAFT9, SHIPSIZE14, PORTPRIV16 and EURTON22 variables, besides the variables used in the biplot technique. This evaluation has led to the definition of a matrix characterizing the four groups of ports (Table 8).

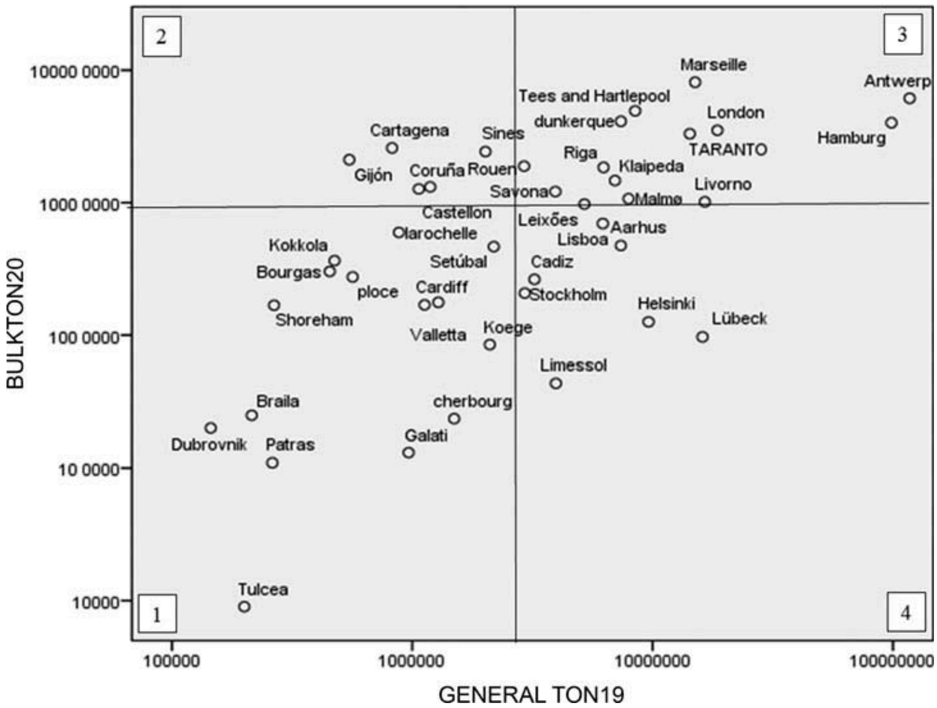

Figure 6. BULKTON20 and GENERALTON19 variables biplot.

Table 8. Port types matrix by specialization and size.

BULKTON20	1. Bulk ports • Deep maritime accesses near Mediterranean Sea • Large vessels calling the port • Specialized in bulk cargo and containers • Low financial performance per ton	3. Large and multipurpose ports • Large central Europe and multipurpose ports with large terminals privately operated • Deep maritime accesses • Specialized in container cargo • Large- and medium-sized vessels • Low financial performance level per ton
	2. Small multipurpose ports • Periphery small ports with small terminals • Small-sized vessels • Limited maritime accesses • Public management • High financial performance per ton	4. General cargo ports • North Europe large general cargo ports with large terminals, on average • Limited maritime accesses • Small vessels • High financial performance level per ton
	GENERALTON19	

6. Discussion

Considering 'position-port' factors those including port economic and geographic location, 'hard-port' factors those relative to port infrastructure and 'soft-port' factors those referring to port management and services, a relationship between 'position-port', 'hard-port' and 'soft-port' was found using factor analysis. From this analysis, it was observed that coastal ports are more specialized in handling bulk cargo while river and estuary ports are more specialized in general cargo. Therefore, port location across Europe determines the management model adopted, as privately operated ports tend to be situated in Northern Europe, where GDP per capita is higher, while Southern Europe major ports demonstrate a higher specialization in handling bulk cargo.

The study also shows that the relationship between port location relative to Rotterdam, the main Europe's gateway, and the average vessel size could be conceptualized into different types of ports. One group includes the main Northern Europe ports, which handle large vessels and are specialized in general cargo, but have a low financial performance per ton; the other group includes large European ports situated in the periphery serving large ships and more specialized in bulk handling, recording low financial performance per ton. The final two groups include smaller ports serving small vessels, specialized in general cargo handling and experiencing higher financial performance per ton.

Given the differences among port characteristics, grouping these ports by types should be considered not only when studying ports and their performances but also when new policy decisions are to be made. Therefore, the present study demonstrates that cargo volume handled at a port is strongly related with port location, 'hard-port' and 'soft-port' factors, as already described by Song and Yeo (2004). Moreover, the demand for port services is shaped by cargo throughput and consumption levels of the port's nearby region (Frémont and Franc 2010). The findings of the current study are consistent with those of Song and Yeo (2004), who stressed that cargo concentration in ports is related with the economy of the hinterland. Hypothesis 1 is therefore confirmed: 'position-port' or port location influences both 'hard-port' and 'soft-port' and that relationship has conceptualized different types of ports.

The results of both factor analysis demonstrate that 'hard-port' and 'soft-port' factors are correlated, such as the case of the port maritime access and vessel size relationship in the first analysis and between bulk cargo handling specialization and container one, as well as between port maritime access and bulk cargo handling specialization in the second analysis. Therefore, the relationship between the maritime port access ('hard-port') and vessel size ('soft-port') has conceptualized different types of ports, whose distinction has important implications for port management. One of the groups includes small- and medium-sized ports, distant from the Mediterranean Sea, which serve few liner shipping services and record low throughput and bulk cargo volumes, but experience high financial performance per ton. The other group includes good maritime access ports, located in the Mediterranean Sea, which have medium liner service calls, medium levels of total traffic and bulk cargo and medium financial performance per ton. A third group includes top-level ports in terms of maritime accesses and number of vessel calls in liner services, which have high containerization rates and a good operational performance in total traffic and bulk cargo volumes handled, but a poor financial performance per ton. This relationship can be justified based on the fact that large-sized vessels cannot call ports with limited maritime access channels, but improving maritime accessibility is not enough to attract larger vessels as in the case of many ports of the sample that have other constraints that prevent them from being engaged in the larger-sized shipping networks. Hypothesis 2 is thus confirmed: the relationship between 'hard-port' and 'soft-port' conceptualizes different types of ports.

The relationship between 'hard-port' and 'soft-port' with port performance was demonstrated using the second factor analysis, as port maritime accesses, the average vessel size and bulk cargo traffic were found to be related. Finally, the relationship between vessel size and general cargo traffic has conceptualized different types of ports, contributing to this investigation. One of the groups includes bulk specialized ports with deep maritime accesses serving large vessels, handling considerable amounts of total throughput and bulk traffic, but experiencing poor financial performance per ton. The other group includes large general cargo specialized ports with deep maritime accesses serving large vessels, with high volumes of total traffic and general cargo ones, but achieving poor financial performance per ton. The small ports in the third group have limited maritime accesses serving small-sized vessels, generate small general and bulk cargo volumes, but experience high financial performance per ton. The last group includes regional ports with limited maritime access serving small-sized vessels, that demonstrate a specialization degree in general and roll-on/roll-off cargo handling, but register low total general cargo volumes and show high financial performance per ton.

The results of the study confirm that both port infrastructure investment and capital intensity factors can explain performance differences among ports (Liu 1995), because without providing adequate infrastructures and services, the ports cannot handle cargo growth and attract more vessels, although it is not a sufficient condition.

Contrary to Cullinane et al. (2004) conclusions, the study indicates that the port terminal size influences operational performance, as the results achieved indicate that the ports with better global operational performance have larger terminals among their characteristics. A similar conclusion was found when analyzing the quay length variable influence on performance, consistent with the results of Park and De (2004). These findings confirm that port size, measured by the total quay length, is a determinant variable when explaining the performance of ports (Liu 1995; Wiegmans 2003) in the presence of economies of scale (Table 4).

This study also confirms that with the identical maritime access conditions the ports attract different vessel sizes, positioning them in different levels of port hierarchy and thereby affecting their operational and financial performances. The results reveal that if port performance increases with size, triggered by significant economies of scale, then decision makers are recommended to invest more in larger ports and invest with caution in smaller ones (De-Neufville and Tsunokawa 1981), which can also be related with existing learning effects in larger ports that contribute for enhancing performance (Estache, Perelman, and Trujillo 2005; Gonzalez and Trujillo 2009; Turner, Windle, and Desner 2004) (Table 4). Accessibilities are an essential element affecting port performance, as the results shown in Table 5 reveal, because upgrading maritime accesses can improve the port position in port hierarchy system, allowing its users to benefit from economies of scale and thereby providing lower freight rates with significant gains in terms of competitive advantages and attractiveness.

This research could not demonstrate that the vessel frequency leads to better port performance levels.

Although it is recognized that ship owners choose the ports to call according to their partnerships and global shipping networks, highlighting the importance of being engaged in those networks connecting world major ports (Tongzon and Heng 2005), the results obtained could not confirm the relationship with port performance. The results demonstrate that maritime services, measured by vessel size, have a strong positive correlation with operational performance, expressed by bulk cargo volumes, and a negative correlation with financial performance, expressed by the port authority's revenue per ton (Table 5). The results, as shown in Figure 4, suggest that vessel size positively explains much of the port's operational performance in handling general cargo only when considering two separate groups: the bulk ports and the remaining ones. From the results obtained in Table 5, it can be concluded that specialization in cargo handling, expressed by the unitization rate, indicating the port's development stage (evolving from industrial port to commercial one), has a positive relationship with the port operational performance and a negative relationship regarding the financial performance. The results found in Table 2 confirm that port ownership and management structure are one of the port characterizing factors that are correlated with the geographic location across Europe and with the economic development of the nearby region. These factors are also related with operational performance because the ports recording higher cargo volumes have increased private sector participation in management (Table 7). Hypothesis 3 is thus confirmed: the 'hard-port' and 'soft-port' have a positive impact on port operational performance and this relationship has conceptualized different types of ports.

Using the second factor analysis, a positive correlation was found between 'hard-port' and 'soft-port' factors with operational performance and a negative correlation with financial performance, namely, with cargo throughput. It was confirmed that the presence of economies of scale in larger ports has triggered changes to lower port dues, giving a more intensive use of infrastructures to attract more cargo. Although there are small ports with low port dues and large ones that are expensive, most of the large ports have lower port dues than smaller ones (Table 7). The lower port dues of the large ports have an influence on the financial performance per ton of the companies working at the port and port authorities. Therefore, hypothesis 4 is confirmed: the 'hard-port' and 'soft-port' factors have a negative influence on the financial performance of the port.

The port characterizing factors' impact on port performance is determinant, given the existence of fierce competition between ports and given their contribution to regional economic development, namely, port size, capacity and specialization degree, among others. Analyzing the type of port characteristics that influence operational and financial performance is an innovative approach that attempts to define a new port hierarchy according to performance, classifying them into groups with homogeneous characteristics. This new approach aims to provide a better understanding of the port strategic position and future developments, thus affecting its performance and also contributing to achieving socioeconomic and commercial objectives of port stakeholders.

In order to gain competitive advantages over competitors, port investments have been increasingly demanding, which determines the need to further develop models to improve their knowledge, within a conceptual framework of theoretical and empirical factors.

However, these investments depend on many factors and port characteristics, such as the specialization in cargo handling operations that vary depending on whether the cargo is containerized, general cargo, bulk or roll-on/roll-off cargo, thereby requiring specific infrastructure facilities and services. Therefore, it was possible to divide the ports into four groups with homogenous and distinctive characteristics, when combining port total throughput, in tons, with the port authority revenues per ton, measured in Euros. One of the groups includes ports with large stacking areas, deep maritime accesses for large vessels, with low port dues, specialized in handling bulk, experiencing a high containerization rate of general cargo, privately managed and recording considerable volumes of general cargo and bulk cargo. The other group includes large but expensive ports, with large stacking areas, deep maritime accesses serving medium-sized ships, specialized in handling general cargo, with private management and generating high volumes of general cargo (Table 7). The small ports with low port dues are included in the third group, which have limited maritime accesses, serving small-sized vessels, specialized in handling general cargo, managed by the public sector, achieving a small general cargo and bulk cargo volumes. Finally, the last group includes small and expensive ports, with medium maritime access serving small vessels and with reduced volume of general cargo and bulk cargo. Evidence supports hypothesis 5: the relationship between the port operational performance and the port authority financial performance has conceptualized different types of ports.

It was possible to group the ports by types with homogeneous intra-group and specific characteristics when combining the variables bulk cargo and general cargo handled, expressed in tons.

One group includes bulk ports with deep maritime accesses, which handle large vessels and have low financial results per ton. The other group includes large multipurpose ports, with large stacking areas, privately operated and with average maritime accesses, serving large- and medium-sized ships and registering low financial performance per ton. The small multifunctional ports grouped is characterized by small stacking areas, managed by the public sector, with limited maritime access allowing for small ships, but registering good financial results per ton. Finally, the forth group includes the largest ports in terms of general cargo, with adequate maritime accesses to serve medium- to large-sized vessels, but registering a low financial performance per ton. Hypothesis 6 is thus accepted: the relationship between the port operational performance variables, expressed through general cargo and liquid and solid bulk cargo, has conceptualized different port types.

7. Conclusions

The study confirms that the financial performance and operational performance are affected by various port characterizing factors—'hard-port' and 'soft-port'—which in turn are influenced by 'position-port' factors, indirectly influencing the performance of the port. The port characteristics can be resumed into three main components represented by the 'position-port' factor of location, through distance to Rotterdam; by the 'hard-port' factor of port infrastructure, through the maritime accessibility and by the 'soft-port' factor of shipping services through vessel size, without significant loss of information.

The 'hard-port' factors have a negative effect on the financial performance of the port authority per ton, but a positive influence on operational indicators of port throughput. The 'soft-port' factors such as shipping services, expressed through ship size, have shown a strong positive correlation with operational performance, through the bulk cargo volume, and a negative correlation with financial performance, through the port authority's revenue per ton. The combination of the variables vessel size and maritime accessibility, vessel size and distance to Rotterdam, vessel size and general cargo traffic, total throughput and port authority revenue per ton, as well as bulk cargo and general cargo volumes, has defined paradigm relationships for examining the types of port characteristics that determine the operational performance and financial one. Knowing the type of port characteristics that have an impact on operational and financial performances is an innovative approach, which allowed classifying ports into groups with homogeneous characteristics according to their performance. This facilitates a clear understanding of the port's development stage and the strategic decisions needed to develop it.

Further research should extend this paradigm relationship analysis to include an enlarged sample of ports from other contexts, especially investigating different groups of ports in terms of size and vocation, including those from other continents.

One of the main limitations was the size of the sample. The main strength was the diversity of variables used and ports considered in the sample.

References

Barros, C. P. 2003. "Incentive Regulation and Efficiency of Portuguese Port Authorities." *Maritime Economics and Logistics* 5 (1): 55–69.

Chang, Y. T., and T. W. Lee-Paul. 2007. "Overview of Interport Competition: Issues and Methods." *Journal of International Logistics and Trade* 99 (5): 99–121.

Coto-Millan, P., J. Banos-Pino, and A. Rodriguez-Alvarez. 2000. "Economic Efficiency in Spanish Ports: Some Empirical Evidence." *Maritime Policy and Management* 27 (2): 169–174.

Culinnane, K., and S. W. Dong-Wook. 2005. "The Application of Mathematical Programming Approaches to Estimating Container Port Production Efficiency." *Journal of Productivity Analysis* 24: 73–92.

Cullinane, K., D. W. Song, J. Ping, and T. F. Wang. 2004. "An Application of DEA Windows Analysis to Container Port Production Efficiency." *Review of Network Economics* 3 (2): 184–206.

Cullinane, K. 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 Ownership Structures." *Transportation Research Part A* 36 (8): 743–762.

De-Neufville, R., and K. Tsunokawa. 1981. "Productivity and Returns to Scale of Container Port." *Maritime Policy and Management* 8 (2): 121–129.

Estache, A., S. Perelman, and L. Trujillo. 2005. "Infrastructure Performance and Reform in Developing and Transition Economies: Evidence from a Survey of Productivity Measures." Working Paper 3514, World Bank Policy Research.

Fleming, D. K., and Y. Hayuth. 1994. "Spatial Characteristics of Transportation Hubs: Centrality and Intermediacy." *Journal of Transport Geography* 2 (1): 3–18.

Frémont, A., and P. Franc. 2010. "Hinterland Transportation in Europe: Combine Transport Versus Road Transport." *Journal of Transport Geography* 18 (4): 548–556.

Garcia-Alonso, L., and M. Martin-Bofarull. 2007. "Impact of Port Investment on Efficiency and Capacity to Attract Traffic in Spain: Bilbao Versus Valencia." *Maritime Economics and Logistics* 9 (3): 254–267.

Gaur, P. 2005. "Port Planning as a Strategic Tool: A Typology." Working paper, Institute of Transport and Maritime Management Antwerp, University of Antwerp.

Gonzalez, M. M., and L. Trujillo. 2009. "Efficiency Measurement in the Port Industry: A Survey of the Empirical Evidence." *Journal of Transport Economics and Policy* 43 (2): 157–191.

Haralambides, H. E. 2002. "Competition, Excess Capacity and Pricing of Port Infrastructure." *International Journal of Maritime Economics* 4 (4): 323–347.

Hui, E., W. Seabrooke, and G. Wong. 2004. “Forecasting Cargo Throughput for the Port of Hong Kong: Error Correction Model Approach.” *Journal of Urban Planning and Development* 130 (4): 195–203.

Hung, S., W. Lub, and T. Wang. 2010. “Benchmarking the Operating Efficiency of Asia Container Ports.” *European Journal of Operations Research* 203 (3): 706–713.

Juang, Y., and M. Roe. 2010. “Study of Success Factors of Development Strategies for Intermodal Freight Transport Systems.” *Journal of Eastern Asia Society for Transportation Studies* 8.

Kent, P., and A. Ashar. 2001. “Port Competition Regulation: A Tool for Monitoring for Anti-Competitive Behaviour.” *International Journal of Maritime Economics* 3 (1): 27–51.

Liu, B. L., W. L. Liu, and C. P. Cheng. 2005. “Efficiency Analysis of Container Terminals in China: An Application of DEA Approach.” Working paper, Institute of Transportation Economics of Nankai University.

Liu, Z. 1995. “The Comparative Performance of Public and Private Enterprises: The Case of British Ports.” *Journal of Transport Economics and Policy* 29 (3): 263–274.

Medda, F., and G. Carbonaro. 2007. “Growth of Container Seaborne Traffic in the Mediterranean Basin: Outlook and Policy Implications for Port Development.” *Transport Reviews* 27 (5): 573–587.

Notteboom, T., and J. P. Rodrigue. 2005. “Port Regionalization: Towards a New Phase. Port Development.” *Maritime Policy & Management* 32 (3): 297–313.

Notteboom, T. C., and J. van den Broeck Coeck. 2000. “Measuring and Explaining the Relative Efficiency of Container Terminals by Means of Bayesian Stochastic Frontier Models.” *International Journal of Maritime Economics* 2 (2): 83–106.

Notteboom, T. E. 2010. “Concentration and the Formation of Multi-Port Gateway Regions in the European Container Port System: An Update.” *Journal of Transport Geography* 18 (4): 567–583.

Park, R. K., and P. De. 2004. “An Alternative Approach to Efficiency Measurement of Seaports.” *Maritime Economics and Logistics* 6 (1): 53–69.

Song, D.-W. 2002. “Regional Container Port Competition and Co-Operation: The Case of Hong Kong and South China.” *Journal of Transport Geography* 10 (2): 99–110.

Song, D. W., and K. T. Yeo. 2004. “A Competitive Analysis of Chinese Container Ports Using the Analytic Hierarchy Process.” *Maritime Economics and Logistics* 6 (1): 34–52.

Tongzon, J., and W. Heng. 2005. “Port Privatization, Efficiency and Competitiveness: Some Empirical Evidence from Container Terminals.” *Transportation Research Part A* 39 (5): 405–424.

Trujillo, L., and B. Tovar. 2007. “The European Port Industry: An Analysis of Its Economic Efficiency.” *Maritime Economics and Logistics* 9 (2): 148–171.

Turner, H., R. Windle, and M. Desner. 2004. “North American Container Port Productivity: 1984–1997.” *Transportation Research Part E* 40 (4): 339–356.

Veldman, S., and E. Bückmann. 2003. “A Model on Container Port Competition, an Application for the West European Container Hub-Ports.” *Maritime Economics and Logistics* 5 (1): 3–22.

Wang, T. F., and K. Cullinane. 2006. “The Efficiency of European Container Terminals and Implications for Supply Chain Management.” *Maritime Economics and Logistics* 8 (1): 82–99.

Wiegmans, B. 2003. *Performance Conditions for Container Terminals*. Amsterdam: Vrije University.

Appendix

Table A1. Port sample.

	Port	Country
1	Aarhus	Denmark
2	Antwerp	Belgium
3	Bourgas	Bulgaria
4	Braila	Romania
5	Cadiz	Spain
6	Cardiff	UK
7	Cartagena	Spain
8	Castellon	Spain
9	Cherbourg	France
10	Coruña	Spain
11	Dover	UK
12	Dubrovnik	Croatia
13	Dunkerque	France
14	Galati	Romania
15	Gijón	Spain
16	Hamburg	Nederland
17	Hanko	Finland
18	Helsinki	Finland
19	Klaipeda	Lithuania
20	Koege	Denmark
21	Kokkola	Finland
22	Larochelle	France
23	Leixões	Portugal
24	Limessol	Cyprus
25	Lisboa	Portugal
26	Livorno	Italy
27	London	UK
28	Lübeck	Germany
29	Malmo	Malmo
30	Marseille	France
31	Patras	Greece
32	Ploce	Croatia
33	Riga	Latvia
34	Rouen	France
35	Savona	Italy
36	Setúbal	Portugal
37	Shoreham	UK
38	Sines	Portugal
39	Stockholm	Sweden
40	Taranto	Italy
41	Tees and Hartlepool	UK
42	Tulcea	Romania
43	Valletta	Malta

Table A2. Descriptive statistics.

Variable	*N*	Mean	SD
DROTERD2	43	1148.65	670.777
DMEDIT3	43	1226.53	848.101
SEAPORT4	43	0.72	0.454
DCITY5	43	3.59	5.865
QUAYL6	43	8510.19	13 246.584
CRAINSKM7	43	3.62793	3.033383
TERMSIZE8	43	2.48E + 06	2.72E + 06
MAXDRAFT9	43	13.73	4.525
TXUNIT10	43	0.4387456	0.30757091
TXHORIZ11	43	0.2114998	0.29902372
TXCONT12	43	0.352236	0.31767226
REGULARLSHIPS13	43	0.0039209	0.0033917
SHIPSIZE14	43	5655.55814	5.33E + 03
GDPCAP17	43	90.05	25.548
TOTALTON18	43	23 285 127.1	3.61E + 07

Table A3. Pearson correlation.

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
DROTERD2																							
DMEDIT3	1	–0.372*																					
SEAPORT4	2	0.079	–0.093																				
DCITY5	3	–0.014	–0.01	–0.098																			
QUAYL6	4	–0.335*	0.126	–0.351*	–0.012																		
CRAINSKM7	5	–0.001	0.09	–0.321*	0.072	0.004																	
TERMSIZE8	6	–0.099	0.192	0.066	–0.105	0.121	0.217																
MAXDRAFT9	7	0.023	–0.363*	0.232	0.283	0.23	0.076	0.021															
TXUNIT10	8	0.108	0.214	–0.08	–0.208	0.088	–0.353*	–0.033	–0.430**														
TXHORIZ11	9	–0.253	0.306*	0.256	0.004	–0.111	–0.420**	0.11	–0.241	0.544**													
TXCONT12	10	0.053	–0.26	–0.073	–0.037	0.328*	0.277	0.063	0.391**	–0.199	–0.297												
REGULAR LSHIPS13	11	0.117	–0.311*	–0.109	–0.006	0.312*	0.136	–0.169	0.264	–0.068	–0.315*	0.619**											
SHIPSIZE14	12	–0.091	–0.24	0.048	0.257	0.219	0.177	0.089	0.703**	–0.580**	–0.373*	0.321*	0.312*										
BIGSHIPO15	13	0.019	0.043	0.084	0.031	–0.011	0.352*	0.176	0.17	–0.435**	–0.221	0.285	–0.047	0.182									
PORTPRIV16	14	–0.391**	–0.04	–0.24	0.238	0.309*	0.019	0.196	0.364*	–0.153	0.008	0.109	0.015	0.208	–0.164								
GDPCAP17	15	–0.464**	0.274	0.044	0.031	0.303*	–0.385*	–0.057	0.069	0.198	0.371*	0.04	0.239	0.025	–0.276	0.328*							
TOTALTON18	16	–0.420**	0.043	–0.320*	0.083	0.829**	0.173	0.164	0.319*	–0.038	– 0.119	0.435**	0.399**	0.438**	0.062	0.287	0.313*						
GENERALTON19	17	–0.379*	0.129	–0.335*	–0.047	0.889**	0.069	0.131	0.18	0.23	–0.014	0.375*	0.384*	0.217	–0.052	0.256	0.376*	0.903**					
BULKTON20	18	–0.354*	–0.075	–0.215	0.22	0.528**	0.254	0.161	0.403**	–0.358*	– 0.216	0.391**	0.309*	0.591**	0.186	0.247	0.149	0.847**	0.537**				
EURPERSON21	19	–0.03	0.185	0.283	0.273	0.062	–0.144	–0.055	0.384*	–0.054	0.119	–0.054	0.002	0.403**	–0.043	–0.04	0.122	0.092	0.048	0.12			
EURTON22	20	–0.07	0.256	0.149	–0.233	–0.212	–0.342*	–0.032	–0.295	0.258	0.533**	–0.225	–0.278	–0.468**	–0.209	–0.061	0.186	–0.314*	–0.186	–0.387*	–0.094		
DEABCC23	21	–0.119	–0.049	–0.126	0.093	0.18	–0.061	0.076	–0.045	–0.053	0.018	0.039	0.156	–0.009	0.184	0.13	0.208	0.129	0.154	0.063	–0.099	–0.012	
DEACCR24	22	–0.129	–0.041	0.006	–0.025	–0.035	–0.186	0.232	–0.064	–0.096	0.023	–0.122	0.031	–0.024	0.142	0.25	0.188	–0.079	–0.04	–0.106	–0.099	0.084	0.791**

Notes: *Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Table A4. KMO and Bartlett's test: independent variables.

Kaiser–Meyer–Olkin measure of sampling adequacy		0.654
Bartlett's test of sphericity	Approximatechi-square	94.426
	df	28
	Sig.	0.000

Table A5. KMO and Bartlett's test: independent and dependent variables.

Kaiser–Meyer–Olkin measure of sampling adequacy		0.658
Bartlett's test of sphericity	Approximate chi-square	108.855
	df	21
	Sig.	0.000

Table A6. Kruskal–Wallis tests applied for each group of ports (SHIPSIZE14 vs. MAXDRAFT9).

Group SHIPSIZE MAXDRAFT	1	2	3	Total	Chi-square	*df*	Asymp. sig.
N	29	8	6	43			
DROTERD2	21.55	24.00	21.50		0.250	2	0.883
DMEDIT3	26.41	10.69	15.75		11.567	2	0.003
SEAPORT4	21.33	25.31	20.83		1.145	2	0.564
DCITY5	20.62	25.06	24.58		1.108	2	0.575
QUAYL6	20.91	19.44	30.67		3.409	2	0.182
CRAINSKM7	21.14	24.00	23.50		0.426	2	0.808
TERMSIZE8	20.72	21.50	28.83		2.089	2	0.352
MAXDRAFT9	15.00	34.50	39.17		28.226	2	0.000
TXUNIT10	24.97	16.63	14.83		5.038	2	0.081
TXHORIZ11	24.29	16.69	18.00		3.074	2	0.215
TXCONT12	18.78	26.06	32.17		6.767	2	0.034
REGULARLSHIPS13	19.03	24.50	33.00		6.542	2	0.038
SHIPSIZE14	17.31	25.13	40.50		17.565	2	0.000
BIGSHIPO15	21.53	24.44	21.00		0.487	2	0.784
PORTPRIV16	20.38	23.44	27.92		2.594	2	0.273
GDPCAP17	21.55	22.06	24.08		0.214	2	0.899
TOTALTON18	18.86	22.13	37.00		10.374	2	0.006
GENERALTON19	21.48	20.75	26.17		0.789	2	0.674
BULKTON20	18.10	24.75	37.17		11.931	2	0.003
EURPERSON21	21.07	18.63	31.00		3.821	2	0.148
EURTON22	25.55	18.50	9.50		8.899	2	0.012
DEABCC23	21.88	20.94	24.00		0.217	2	0.897
DEACCR24	21.95	22.25	21.92		0.004	2	0.998

Table A7. Kruskal–Wallis tests applied for each group of ports (SHIPSIZE14 vs. DROTERD2).

Group SHIPSIZE DROTERD	*N*	DROTERD2	DMEDIT3	SEAPORT4	DCITY5	QUAYL6	CRAINSKM7	TERMSIZE8	MAXDRAFT9	TXUNIT10	TXHORIZ11	TXCONT12	REGULARLSHIPS13	SHIPSIZE14	BIGSHIPO15	PORTPRIV16	GDPCAP17	TOTALTON18	GENERALTON19	BULKTON20	EURPERSON21	EURTON22	DEABCC23	DEACCR24
1	11	8.86	29.45	22.14	19.14	22.64	18.45	23.00	17.86	23.14	25.86	19.50	17.00	17.36	22.18	25.64	26.05	22.45	25.27	20.50	21.45	29.68	24.64	24.86
2	7	10.50	23.29	18.79	15.79	25.00	28.14	23.00	24.29	21.00	21.21	26.14	28.71	34.71	18.79	25.36	30.29	31.43	30.14	32.29	23.07	13.14	23.93	24.36
3	4	30.00	9.63	28.00	33.88	24.75	20.63	28.25	40.63	5.75	18.00	28.25	29.00	41.50	20.38	26.13	15.38	34.25	18.00	35.50	35.00	9.75	20.38	19.88
4	21	31.19	20.02	21.86	23.31	20.14	22.07	19.95	19.86	24.83	21.00	20.74	21.05	16.48	23.29	18.19	18.38	16.29	18.33	16.79	19.45	23.26	20.29	20.12
Total	43																							
Chi-square		30.794	8.358	2.279	6.252	1.079	2.603	1.664	10.865	7.904	1.643	2.431	5.112	22.388	0.960	5.117	7.442	12.117	5.888	13.100	5.225	11.634	1.133	1.409
df		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Asymp. sig.		0.000	0.039	0.517	0.100	0.782	0.457	0.645	0.012	0.048	0.650	0.488	0.164	0.000	0.811	0.163	0.059	0.007	0.117	0.004	0.156	0.009	0.769	0.704

Table A8. Kruskal–Wallis tests applied for each group of ports (SHIPESIZE14 vs. GENERALTON19).

Group SHIPSIZE GENERALTON	*N*	DROTERD2	DMEDIT3	SEAPORT4	DCITY5	QUAYL6	CRAINSKM7	TERMSIZE8	MAXDRAFT9	TXUNIT10	TXHORIZ11	TXCONT12	REGULARLSHIPS13	SHIPSIZE14	BIGSHIPO15	PORTPRIV16	GDPCAP17	TOTALTON18	GENERALTON19	BULKTON20	EURPERSON21	EURTON22	DEABCC23	DEACCR24
1	24	24.92	21.25	21.73	21.67	17.63	22.92	18.38	17.90	21.92	18.15	18.48	20.19	17.71	21.65	19.85	18.31	14.33	15.21	16.75	18.63	24.94	22.13	23.63
2	4	28.50	8.50	28.00	30.50	23.88	21.75	31.00	38.00	2.75	17.00	29.00	31.25	40.00	20.38	20.75	19.38	31.00	12.75	33.75	29.00	10.75	21.38	17.63
3	5	13.60	23.30	15.10	19.60	31.20	27.80	30.20	27.40	21.40	24.60	31.60	32.00	38.20	20.90	27.20	26.90	40.60	38.40	40.40	24.10	12.00	24.10	23.20
4	10	16.60	28.55	23.70	20.60	27.15	17.00	23.00	22.75	30.20	31.95	22.85	17.65	17.00	24.05	25.05	29.45	27.50	33.80	20.70	26.25	24.45	20.90	19.25
Total	43																							
Chi-square		6.456	7.486	4.335	2.213	7.370	2.784	6.251	10.044	13.679	9.596	6.175	7.045	20.932	0.502	2.956	6.891	23.892	26.553	18.543	4.264	8.087	0.234	1.417
df		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Asymp. sig.		0.091	0.058	0.228	0.529	0.061	0.426	0.100	0.018	0.003	0.022	0.103	0.070	0.000	0.918	0.398	0.075	0.000	0.000	0.000	0.234	0.044	0.972	0.702

Table A9. Kruskal–Wallis tests applied for each group of ports (TOTALTON18 vs. EURTON22).

Group SHIPSIZE GENERALTON	*N*	DROTERD2	DMEDIT3	SEAPORT4	DCITY5	QUAYL6	CRAINSKM7	TERMSIZE8	MAXDRAFT9	TXUNIT10	TXHORIZ11	TXCONT12	REGULARLSHIPS13	SHIPSIZE14	BIGSHIPO15	PORTPRIV16	GDPCAP17	TOTALTON18	GENERALTON19	BULKTON20	EURPERSON21	EURTON22	DEABCC23	DEACCR24
1	4	33.50	19.63	17.25	23.38	16.50	22.75	9.50	9.75	34.25	15.25	13.38	19.50	12.75	16.88	10.00	14.75	8.25	15.00	8.00	12.13	10.38	23.25	22.50
2	13	17.88	17.23	21.38	22.00	30.54	24.96	28.00	32.50	15.69	19.81	28.31	26.23	33.92	26.12	24.88	23.62	34.69	29.15	35.00	24.50	8.58	20.69	18.42
3	11	17.73	27.73	22.14	21.73	27.50	19.86	25.27	19.59	23.95	28.18	24.32	21.09	20.82	20.05	25.64	24.27	27.73	29.64	23.77	24.18	29.64	24.77	27.73
4	15	25.63	22.57	23.70	21.83	12.03	20.80	17.73	17.93	22.77	21.17	17.13	19.67	15.00	21.23	20.03	20.87	10.47	12.07	13.17	20.87	31.13	20.77	20.77
Total	43																							
Chi-square		7.283	4.339	1.457	0.057	18.342	1.194	9.412	14.913	7.411	4.379	7.894	2.211	18.651	3.062	7.605	2.145	33.023	18.919	26.552	3.445	30.328	0.881	3.504
df		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Asymp. sig.		0.063	0.227	0.692	0.996	0.000	0.755	0.024	0.002	0.060	0.223	0.048	0.530	0.000	0.382	0.055	0.543	0.000	0.000	0.000	0.328	0.000	0.830	0.320

Table A10. Kruskal–Wallis tests applied for each group of ports (BULKTON20 vs. GENERALTON19).

Group BULKTON GENERALTON	*N*	DROTERD2	DMEDIT3	SEAPORT4	DCITY5	QUAYL6	CRAINSKM7	TERMSIZE8	MAXDRAFT9	TXUNIT10	TXHORIZ11	TXCONT12	REGULARLSHIPS13	SHIPSIZE14	BIGSHIPO15	PORTPRIV16	GDPCAP17	TOTALTON18	GENERALTON19	BULKTON20	EURPERSON21	EURTON22	DEABCC23	DEACCR24
1	19	27.29	21.95	22.34	22.16	12.97	21.21	16.00	16.21	25.18	19.92	16.34	19.63	14.53	20.32	17.92	19.58	10.00	12.68	12.08	19.03	26.76	21.29	21.13
2	7	21.57	11.14	24.93	22.57	25.21	21.71	24.14	33.43	5.57	17.07	27.00	29.14	36.43	23.93	22.29	20.71	29.29	15.71	32.14	24.36	13.00	22.71	23.93
3	11	14.18	27.00	18.23	21.73	33.55	25.68	27.73	27.23	20.91	23.45	26.55	21.95	29.55	25.23	29.55	24.14	37.00	35.91	36.00	24.73	13.41	22.36	20.68
4	6	20.08	25.67	24.42	21.33	25.67	18.08	28.00	17.42	33.08	31.67	25.75	21.25	15.00	19.17	20.75	27.25	24.00	33.33	15.92	23.67	33.17	22.75	24.92
Total	43																							
Chi-square		7.786	7.492	2.666	0.041	20.091	1.609	8.201	12.575	17.964	5.420	7.032	2.964	21.811	1.976	8.160	2.267	35.560	30.598	31.514	1.938	16.245	0.117	0.703
df		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Asymp. sig.		0.051	0.058	0.446	0.998	0.000	0.657	0.042	0.006	0.000	0.144	0.071	0.397	0.000	0.577	0.043	0.519	0.000	0.000	0.000	0.585	0.001	0.990	0.873