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Abstract: - The purpose of this study is to analyze the performance of a port through its characterizing factors and understand their importance. Both Data Envelopment Analysis (DEA) and statistics of factor analysis were used, as well as linear regression. Based on a sample of 43 European ports, the results of this study indicate the existence of a relationship between performance and several variables that characterize the port. Additionally, they also confirm the impact of location, governance, size, infrastructure, specialization, logistic integration and maritime services in the ports operational and financial performance and efficiency.

Key-Words: - Ports, performance, characterizing factors.

1 Introduction

Ports have always had an important role in the development of national and international trade of countries, currently challenged by globalization, with implications for sustained economic development of their regions (Gaur, 2005)[17]. Globalization, emerged from trade growth between continents, regions and countries, has led to an expansion of global seatrade with huge impacts for ports. Increasing competition between transport modes and growing capacity per unit of transport demand for higher performance level in ports, which largely depend on their characteristics, such as infrastructure, equipment, governance structure and integration in logistic networks.

Ports have become an intersection node in logistic chains, in which goods engage in additional operations taking advantage of proximity or their stay in transit to other places (Estrada, 2007)[14]. These conditions affect their efficiency and performance and can provide international competitive advantages (Tongzon, 2002)[38]. In this sense, according to Cullinane et al. (2005)[9], containerization and the effect of globalization of services have involved changes in ports due to the possibility of offering integrated logistic services in transport chains involving the industry of regular lines. Therefore, the development of transport infrastructure, the construction of interconnected logistic parks, the increase in vessel size and the investment on “hub-ports” serving larger “hinterlands" led to increased competition between ports (Wang and Cullinane, 2006) [44]. In the same context, ports are a major determinant of shipping costs (Sanchez et al., 2003)[36], proving the importance and the strong impact of efficiency on unit costs and competitiveness (Notteboom and Winkemans, 2001; Robinson, 2002)[31][35]. Consequently, by virtue of the competition, ports feel the need to increase traffic beyond its economic development (Haralambides, 2002; Notteboom and Rodrigue, 2005)[20][30].

Few studies have analyzed efficiency, productivity and performance of ports (Gonzalez and Tujillo, 2007)[18]. Chang and Lee (2007)[5] made an extensive review on numerous studies on port performance and inter-port competition and draw attention to several unanswered questions, such as the influence of privatization on port performance and competitiveness and how to measure differences in relative efficiency between competing ports. Almost all authors studied the issue of port performance merely comparing ports and terminals, without explaining their differences or understanding the reasons why some ports are more efficient and have better performance than others. Trujillo and Tovar (2007)[40] compared the efficiency of ports in Europe and concluded that their study could not explain the factors that determined the level of port efficiency.

Estache et al. (2005)[13] observed the relationship between efficiency and port ownership and identified efficiency rankings, but recognized the need to further research on the influence of characteristics in port efficiency. Another gap in recent studies refers to the fact that few authors have attempted to use port efficiency indexes (DEA) as a output variable of explanatory models of the factors that influence port performance, in a second stage analysis, as illustrated by Turner, Windle and Dresner (2004)[41]. This study focuses on analyzing the impact of characterizing factors on the port performance, using operational, financial and efficiency indicators. Considering the multidimensional nature of port performance, the study aims to analyze which characterizing factors are relevant and what measure the relationships. The study of these characteristics and their influence have an increasingly interest and importance when considering building a new port or upgrading an existing one and for achieving higher levels of competitiveness. This paper has been organized in nine parts: following the introduction, the literature review is presented and hypotheses are formulated. The next section describes the research methods, including model and variables, as well as data collection and instruments used. Then, results are presented followed by discussion. After conclusions, implications for management and directions for future research are proposed.

2 Literature Review and Hypothesis

In the nineties, new methodologies for measuring efficiency were introduced in the port studies, but there was an enormous discussion about which method best identified the complex interactions among players within the port industry. The studies have focused on the relationship between efficiency and port reforms, port ownership, size, transhipment, investment, hub ports (Notteboom et al., 2000)[32] and efficiency over the years (Cullinane et al., 2004)[10]. Therefore, evidence suggests that several performance indicators have been used to evaluate port performance. Among the key performance indicators used in several studies, port total throughput in tonnes or TEU (Twenty-feet Equivalent Unit) and the number of vessels calling a port by type of cargo, roll-on roll-off, break-bulk, containerized cargo, dry bulk and liquid bulk stand out, since all ports aim to move more cargo and more vessels.

Several authors used port total throughput in absolute value as an output variable for models of performance analysis, such as Song and Yeo (2004), Poitras, Tongzon and Li (1996), Barros (2003), Trujillo and Tovar (2007), Garcia-Alonso and Martin-Bofarull (2007), Park and De (2004) and Herrera and Pang (2006)[37][34][2][40][33][22]. Another performance indicator is the level of revenue per tonne or employee of the Port Authority, assuming a public perspective. This reflects the value of the services offered and what customers are willing to pay in terms of rates for calling a port, regarding the infrastructure conditions or location (Barros, 2003; Park and De, 2004; Gonzalez and Trujillo, 2007, Turner et al, 2004) [2][33][18][41]. The performance of a port has a multivariable behaviour, which suggests the use of operational performance indicators, such as the number of vessel calls and cargo handled per year, and also financial performance indicators of port authorities and port efficiency DEA index to measure the relationship between outputs and inputs.

The port geographical location seems to be another determining factor of performance (Liu, 1995)[28] and perhaps the most important one, since the port does not exist by itself, with the exception of ports exclusively dedicated to transhipment. Evidence shows that the volume of cargo handled at a port has a strong relation with its geographical location, which is usually unchangeable (Song and Yeo,

2004)[37]. In fact, this was one of the main reasons why shipping companies have chosen the port of Bangkok. Some studies have concluded that the proximity to small economies negatively affects the total throughput and port performance and also that the demand for port services is driven by the traffic generation and consumption volumes of the region where the port is located (Tongzon, 2002)[38]. This indicates that the region's economic performance has influence on port performance (Cheo, 2007)[7], although port characteristics may interfere in that relationship. Furthermore, it has been recognized that the proximity to a developed region influences the port characteristics, namely the level of investments in infrastructure, equipment and accessibilities, thus, having an impact on the port performance. The following hypotheses are established:
Hypothesis 1: The geographical location influences the port's operational and financial performance.
Hypothesis 2: The proximity to a developed region has a positive impact on port performance.

For many years, it has been considered that port size has influence on its performance (Liu, 1995; Wingmans, 2003)[27][45] and, in fact, it is one of the key variables, because this is one sector that seems to be affected by economies of scale and agglomeration economies, requiring high initial investments. Evidence has shown that productivity increases with port size driven by significant economies of scale, which suggests that higher investments should be concentrated in ports with larger size rather than in smaller ones (De Neufville and Tsunokawa, 1981)[11]. Results from other studies indicated that there seems to be a learning effect in ports with larger size which contribute to improve both performance (Estache et al. 2005; Turner, Windle and Dresner, 2004; Gonzalez and Trujillo, 2007)[13][41][18] and efficiency, which has led Herrera and Pang (2006)[22] to conclude that the size is an instrumental variable of efficiency.
However, other authors have argued that dimensional factors such as economies of scale and economies of scope, location and regional concentration can lead some ports to operate below their capacity (Barros and Peypoch, 2007)[4], which undermines the implementation of size with infrastructure as a proxy. Others have considered that the size of port terminals does not influence its efficiency, which is instead a result of an increasingly competitive environment (Cullinane et al., 2004)[10]. The hypothesis is defined as follows:

Hypothesis 3: The size of a port influences the operational and financial performance and efficiency.

According to Liu (1995)[28], both investment in port infrastructure and the capital-intensity level are other factors that can explain the differences in performance and efficiency between ports, because without infrastructures or the ability to offer services, a port could not be able to handle an increasing number of vessels or cargo. It has been observed that the capacity of the quay is an input variable that strongly influences the efficiency and a production factor related to the model's outputs, as proposed by Park and De (2004)[33]. In a study about the evolution of the relative efficiency and hinterlands of the ports of Bilbao and Valencia, Garcia-Alonso and Martin-Bofarull (2007)[16] took a period of large investments as a reference and concluded that not always the same amount of investment in infrastructure leads to equivalent improvements in performance. This indicates that further study of other factors, such as location, integration in supply chains and hinterlands, among others, is required.
Accessibilities have a significant influence on port efficiency (Wiegmans, 2003)[45]. In the case of maritime accesses, they can even determine which segment of market a port can access and offer economies of scale to its customers, resulting in substantially lower freight costs. Turner et al. (2004)[41] studied the impact of land and sea accesses and Gaur (2005)[17] identified factors that affect port performance, such as access by sea, quay, terminal, storage, value added services and connectivity to the hinterland. The hypothesis is as follows:
Hypothesis 4: Better infrastructures in ports influence port performance and efficiency with constant returns.

Port specialization such as the containerization rate was reported by Trujillo and Tovar (2007); Medda and Carbonaro (2007) and also by Laxe (2005)[40][29][25]. The weight of general cargo in total throughput, named "unitization rate", is also important because it reflects the development stage of a port, from industrial to modern commercial port. Tongzon (2002)[38] concluded that an increasing number of vessels calling a port allow a wider range of choices for shippers, greater flexibility and smaller transit times, improving port performance. The author also highlighted factors such as direct-call liner services productivity, port handling charges and waiting times as determinant

for port performance and in port selection preferences of shipping companies. Moreover, port selection preferences of shipping companies are also based on their global partnerships and logistic networks (Tongzon and Heng, 2005)[39], which is why it is of utmost importance for ports to be integrated not only in the maritime services of existing global shipping companies networks with the world's main ports, but also in their inland global logistic chains. Veldman and Buckmann (2003)[43] attempted to explain the market shares of Northern Europe ports and their performance using factors such as frequency and transit time of vessels, freight prices, the terminal handling prices and inland transport prices. Turner et al. (2004)[41] studied the impact of shipping services and port equipment on the performance of ports. The hypotheses are:
Hypothesis 5: The more specialized ports have better performance.
Hypothesis 6: Ports with a wider range and better maritime services have better operational and financial performance and efficiency than others.
Hypothesis 7: Ports with higher number of direct-call liner services of global carriers and higher logistic integration have better efficiency.

According to Liu (1995)[28], governance, meaning port ownership and management, is one of the characterizing factors that influences port performance and efficiency. The author also considered that private ownership or management should be more efficient when compared with public one, because the first has profit-driven objectives, while in public management there are not enough incentives to improve performance. For example, port reforms undertaken in Mexico resulted in efficiency gains (Estache et al., 2001)[12], which suggests that privatization has enhanced efficiency in ports (Barros and Athanassiou, 2004)[3]. However, Cheon (2007)[7] raised the question of whether governance reforms had the same successful result everywhere. He also emphasized the fact that most studies only distinguished between private and public management and did not consider the complexity and differences between port ownership and management.
Lui et al. (2005)[29] reported that the Chinese port terminals with sino-foreign private partnerships have higher levels of performance and that terminals with inter-continental liner services are also more efficient than those only operating regional routes. Notteboom et al. (2000)[32] demonstrated that efficiency is higher on hub ports when compared with feeder ones, because these are, in many cases, managed by local authorities and are not linked to global operators. Nevertheless, it cannot be proven that there is a direct causal link between port ownership or management and efficiency (Gonzalez and Trujillo, 2007)[18]. As a result, the following hypothesis is formulated:
Hypothesis 8: Ports with a higher number of terminals managed by private operators have better performance levels.

3 Research Methods

3.1 Research model

The research model is based on the relationship between the characteristics of the port and its performance. The characteristics of the port are identified by the port location, size, infrastructure, specialization, maritime services, integration on global logistics and governance. The port's performance is evaluated by operating performance, financial performance and efficiency of the port.

3.2 Variables

Port location refers to the geographical position relative to Europe and to the main transport axes and global trade lanes. It is defined by the distance to Rotterdam port (DROTERD2) is calculated by drawing a straight line between the chosen port, taken from the sample, and the maritime entrance of Rotterdam port in kilometers. It is a continuous variable greater than zero. The distance to the central axis of the Mediterranean Sea (DMEDIT3) covers the shortest distance in kilometers, measured on the meridian of the sample port, from the port to the central point between the shores of the Mediterranean Sea which cross the same meridian. It is a continuous variable greater than zero. Different authors have used the distance variable (Song and Yeo, 2004; Ugboma et al. (2006) Tongzon (2002), Lui (1995) and Estache et al. (2001)[37][42][38][28][.12] The distinction between sea port or estuary/inland port (SEAPORT4) is defined by a dummy variable that assigns value 1 for ports located on the coast and value 0 for those located in estuaries or rivers. The geographical location and transport network are reported by Gonzalez and Trujillo (2007)[18] as environmental variables. The distance to the nearest city (DCITY5), in kilometers, is determined by drawing a straight line between the sample port and the urban centre nearby. This kind of variable is referred by various authors (Notteboom and Rodrigue, 2005; Tongzon, 2002, Fleming and Baird, 1999)[30][38][15].

The total quay length in meters refers to the size of the port-based infrastructure built (QUAYL6). It is defined by the sum of the total length of all the operating quays with more than four meters of depth. Coto-Millan et al. (2000)[8] used the length of the quay to measure the size of a port with depths above 4 meters and Liu (1995)[28] as a factor that influences port performance.

Infrastructures are characterized based on the intensity and level of operational infrastructure and measured by the number of cranes per kilometer of berth (CRAINSKM7) is defined by the total number of quay cranes of operational terminals, regardless its type or function, divided by the sum of terminals quay length in kilometers. The average size of terminals (TERMSIZE8), in tones, is determined by the total port throughput divided by the number of port terminals, physically separated and with different management, resulting in the average cargo volume per terminal. The quay depth (MAXDRAFT9), in meters, is defined by the distance between maximum depth and the hydrographic zero. It is a continuous variable, greater than zero, used by authors such as Wang and Cullinane (2006), Guy and Urli (2006) and Tongzon (2002)[44][19][38].

Port specialization refers to the way a port is specialized in handling specific cargos and it is identified by the "unitization rate" (TXUNIT10) accounts for the weight of general cargo volume in the total throughput, in tonnes. General cargo includes break-bulk cargo, containerized cargo and roll-on roll-off cargo. The "horizontalization rate" (TXHORIZO11) is determined by the weight of roll-on roll-off cargo in the general cargo volume. When the value tends to 1, it means the port is specialized in roll-on roll-off cargo, as a part of general cargo. The containerization rate (TXCONT12) is the percentage of general cargo transported by containers, in terms of tonnes. It is a continuous variable between zero and one and has been used by Trujillo and Trova (2007), Hui (2004) and Laxe (2005)[40][23][25].

Maritime services are defined by the ratio of the number of direct-call liner services in the total of port calls (REGULARSHIPS13). It is a continuous variable between zero and one, which emphasizes the importance of liner services. Maritime services as been used by Ugboma et al. (2006), Poitras et al. (2005), Yanbing and Zhongzhen (2005), Tongzon (2002), Lee and Kim (2006), Turner et al. (2004)[42][34][46][38][26][41]. The average size of vessels calling a port (SHIPSIZE14), measured in tones of gross tonnage is a continuous variable, greater than zero and has been used by Turner et al. (2004)[41].

Integration into the global logistic networks (BIGSHIPO15) is determined by the ratio of the number of liner services of the seven main global carriers to the total number of shipping lines that call the port weekly, every two weeks or monthly. It is a continuous variable between zero and one.

Logistic integration has been used by Song and Yeo (2004)[37]. The seven largest shipping companies were considered APM, MSC, CMA CGM, Evergreen, Hapag-Lloyd, CSCL and APL.

Port governance (PORTPRIV16) is defined by the weight of the cargo volume handled by private management terminals in the total port throughput, in terms of tones. Because it assumed an inverted U-shape, not following a normal distribution, a dummy variable was preferred, taking the value of 1 for ports with a percentage of cargo handled at private terminals greater than or equal to 50% and 0 otherwise. Governance variable has been used by Notteboom et al. (2000) and Tongzon and Heng (2005)[32][39].

The region's economic performance (GDPCAP17) is a control variable used and it is measured by the ratio between the region's GDP (NUTS II1 considered)1 and population, as a percentage of average European Union (EU27 = 100).

Port operational performance variables chosen are total throughput (TOTALTON18), general cargo (GENERALTON19) and both solid and liquid bulk cargos (BULKTON20), which are measured in absolute value in terms of tones. Port financial performance is defined by the variables: port authority gross revenues per employee (EURPERSON21) and port authority gross revenues per ton, both measured in Euros (EURTON22). The efficiency performance is determined by efficiency indexes DEA-BCC (DEABCC23), which stands for Banker, Charnes and Cooper (1984)[1], with increasing returns-to-scale model and DEA-CCR (DEACCR24), which stands for Charnes, Cooper and Rhodes (1978)[6], with constant returns-to-scale model.

4 Data Collection and Instruments

Based on a data universe of 230 largest European ports in terms of annual throughput (ESPO Report, 2007), a valid sample of 43 ports was taken. For each port of the sample, the distance to Rotterdam

[1] According to level 2 of Nomenclature of Units for Territorial Statistics (NUTS) of a total of three levels defined by the European Union for statistical purposes.

port was calculated, as well as the distance to the central axis of Mediterranean Sea, by drawing a straight line with reference to the geographical meridian, using Google Earth software. Regional GDP per capita is used for each port according to the average classification of NUT 2 where the port is located (Regional Yearbook, 2008, Eurostat). This study uses the non-parametric data envelopment analysis (DEA) method and the statistical factor analysis and linear regression.

5 Results

The study shows that the European port activity is concentrated in few main ports or hub ports and there are many small and medium-sized ports, which influences the distribution of the variables. The Pearson correlation indexes are significant (p = 0,001) with the exception of the variables DMEDIT3, DCITY5, TERMSIZE8, and BIGSHIPO15 PORTPRV16 (Appendix I, Table 1). There is a significant correlation between the dependent variables TOTALTON18, GENERALTON19, BULKTON20 and EURTON22, as well as among the variables DEABCC23 and DEACCR24, which was to be expected, considering that these are performance variables resulting from port activity or efficiency. Factor analysis resulted in a model with seven variables (KMO = 0,658, p = 0,000, Tables 2 and 3) and two components that are associated with port specialization in bulk cargo and general cargo.

Port size explained by bulk cargo volume is associated with the variables TXUNIT10 (-), SHIPSIZE14, MAXDRAFT9, BULKTON20 and EURTON22 (-), while the general cargo volume is associated with variables GENERALTON19, BULKTON20 SEAPORT4 (-). Ports with higher general cargo volumes seem to handle high bulk cargo volumes, although they are not specialized in bulk. Multiple linear regressions have been applied in phases for each dependent variable and all explanatory factors included in the model were embodied in the variables. The results were very significant for TOTALTON18, GENERALTON19 and EURPERSON20 using variables in natural logarithm form and the results obtained were significant for the dependent variables BULKTON20, EURTON22 and DEACCR24. The assumptions of normality, homogeneity and errors were tested again and no serious problems of multicollinearity (VIF) were found.

Overall, the results suggest that the port operational performance is influenced by location, size, infrastructure, specialization and maritime services (Appendix II). The financial performance is affected by location, infrastructure, specialization, maritime services and governance. Finally, the port efficiency is influenced by infrastructure, specialization, maritime services, logistic integration and governance. Therefore, these findings imply that port performance can be largely explained by the following factors: location, size, infrastructure, specialization, maritime services and logistic integration of the port, as well as by the economic performance of the region in which the port is located, particularly in what concerns the financial performance and efficiency of the port, although in a indirectly way. Based on the obtained results, Fig. 1 presents a relationship model between port characteristics and performance.

Linear regression tests have confirmed the relationship between location, size, infrastructure, specialization and maritime services with port performance, has the most significant factors. Factor analysis tests not only confirmed the relationship between port specialization and infrastructure, but also between specialization and maritime services (Tables 2 and 3). Differences in port infrastructure could be found between ports specialized in general cargo and those specialized in bulk cargo: the former having a large number of cranes per kilometer of quay and larger terminal areas, while the latter seemed to have deeper maritime accesses. The study also examined the relationship between port size and infrastructure and between port size and maritime services. Port specialization in general cargo calls for liner services, while specialization in bulk cargo attracts tramping services, by time or voyage charter, with no regular scheduled itineraries and using vessels with a deeper draughts. A relationship between port infrastructure and maritime services was also found. It was observed that port size affects performance, mainly because ports with larger terminal areas can accommodate cargo growth, resulting in higher quay occupancy rates, which in turn will progressively lead to increasing demand for cargo-handling. The tests also found that there is a relationship between location and port size, which is consistent with the fact that the largest European ports are located in Northern Europe and Mediterranean Sea, both with privileged access to the main European trade routes.

6 Discussion

This study confirms that not only port activity is a multidimensional factor, but also that port characteristics determine performance, which is consistent with the results of Gonzalez and Trujillo (2007)[18]. Port size, location, infrastructure and maritime services were identified as the main determinants of port performance, also taking into account the importance of port specialization. If logistic integration and governance influence port performance, they do so through size and maritime services. All explanatory models show that size is the most significant attribute when explaining port performance at operational level. In other words, ports with insufficient terminal surface or quay length cannot accommodate increasing traffic growth. However, it is not possible to know whether size enhances high growth rates or if it is the other way around. As a result, this raises some questions: are there other factors that can contribute to port growth? For example, do larger ports have greater diversity of cargo?

Following port size, the results show that the port‘s geographical location is another significant factor when determining port performance as proposed by Estache et al. (2001) and Liu (1995)[12][28], since it is driven by the development and performance of the hinterland, regardless its dimension or economic importance. The proximity to Rotterdam port and to Europe’s logistic and economic centres is of great importance for port‘s operational performance, expressed in tonnes of cargo, but was not proven that the importance of proximity to the central axis of the Mediterranean Sea, where the main global seaborne traffic flows in round-the–world routes. The study shows that distance from urban centres has relationship with port financial performance and that ports situated close to urban areas have better financial performance. But port location near the sea or the city is not significant when trying to explain port operational performance and the port efficiency. Nevertheless, location is an important characterizing factor of port performance and there is no doubt that two ports with similar characteristics have different performance levels whether they are or not strategically close to main consumption and production centres or to main trade routes. The region’s economic development has a significant impact in port performance, as it is largely responsible for port expansion. Hypothesis 1 is confirmed to the extent that seaports close to central Europe have better performance levels. Hypothesis 2 is also confirmed, although the region’s influence has an indirect effect on performance through port characteristics.

The results confirm that port operational and financial performance increases with size, taking advantage of significant economies of scale at seaport level, which is consistent with the recommendation that ports with larger size should benefit from higher investments over smaller ones as they have performance advantages (De Neufville and Tsunokawa, 1981)[11]. Nevertheless, smaller ports have an important role in the region generating relevant economic impacts, despite their lower performance in absolute value. Equally important is the size of port terminals. There seems to be a learning effect from ports with larger size that enhances performance improvement, as argued by Estache et al. (2001, 2005), Turner, Windle and Dresner (2004), Gonzalez and Trujillo (2007)[12][13][41][18]. Port size is determinant of the port operational performance, either due to economies of scale or due to the learning effect from hub port attractiveness (from port user’s perspective). Thus, hypothesis 3 is confirmed.

Port infrastructure investment level is another factor that explains differences in performance and efficiency between ports, as illustrated by Liu (1995)[28], since the quality of the infrastructure is essential to explain the productivity and adaptability to increasing port user’s demands, thereby contributing to port performance. The higher the productivity levels and adaptability to port user’s requirements, in cargo handling and vessel’s demands, the more competitive is the port infrastructure, enhancing high performance standards in operational services. The terminal’s average size seems to contribute to port performance and efficiency, by allowing, with the same length of quay, higher cargo volumes handled per year, because of the possibility of having higher intensive-use of equipment, with an optimum balance between terminal storage and berth capacities. Port infrastructure is a necessary but not a sufficient condition when explaining performance; therefore it should be combined with other variables. Both maritime and inland accessibilities are significant determining port efficiency, since the deeper the maritime access, the larger the vessels that can call the port, experiencing higher berth productivity rates and rising cargo volume, for the same quay length.

The greatest water depth influences the port’s financial performance, since upgrading maritime access channels requires large investment levels in dredging or building breakwaters, but generates additional revenues per tonne and per employee to the port authority. The world fleet has been experiencing a continuous growth in the average size of vessels with bigger drafts and increasingly large tonnage capacity, leading to a significant reduction in transport costs per tonne and faster turnaround times at the ports. Larger vessels tend to call fewer ports and to select those with deeper maritime access, which becomes a crucial issue in terms of port performance. Therefore, the deeper the navigation accesses, the more large vessels are likely to call the port, raising the amount of total throughput. Insufficient water depth is an important limitation preventing a port from growing, further aggravating transport costs, calling for less competitive vessels, shrinking its influence to a limited area, negatively affecting port services evolution and efficiency. Therefore, hypothesis 4 is confirmed.

The results show that another important factor affecting the port performance is specialization. This study demonstrate the influence of containerization rate on port efficiency as reported by Trujillo and Tovar (2007), Medda and Carbonaro (2007) and Laxe (2005)[40][29][25]. Moreover, ports with higher specialization in handling general and roll-on roll-off cargo generally achieve higher performance levels in total cargo and general cargo handling, and affects financial performance. The "horizontalization rate" can explain much of the port operational and financial performance both in terms of port authority's revenues per tonne generated and efficiency index, because roll-on roll-off traffic yields higher revenues and lower needs for investment in cranes, allowing more value-added services to be developed. Thus, hypothesis 5 is demonstrated.

This study equally illustrates the importance of liner services frequency in determining port overall efficiency level, which is consistent with the results of Tongzon (2002)[38]. This author argued that a high number of direct-call liner services increasingly offers shippers more options, greater flexibility and faster turnaround times, enhancing a better use of port infrastructure and a higher performance. As denoted by Veldmen and Buckmann (2003); Turner, Windle and Dresner (2004)[43][41], the number of direct-call liner services and the size of vessels that call a port are of utmost importance when determining port performance and efficiency, as port aim to meet the specific liner shipping needs offering tailored services to port users, as well as added-value services.

The results also show that vessels size and the number of liner services calling the port, due in part to the existing maritime accesses, determine not only the level of freight rates charged to the port users, but also the maritime routes connected to the port. Therefore, they have become key factors of port performance in terms of cargo throughput, as well as and in terms of port authority revenues per employee and per tonne. Vessels size is a main factor explaining the reduction of maritime transport costs per tonne of cargo and in the port, with influence on port performance. This study has identified that vessels size and the number of lines calling a port determines the port's operational and financial performance and efficiency. Hypothesis 6 is confirmed.

Moreover, port logistics integration in global liner shipping networks also allows the port to offer a wider range of global services with higher quality and often more competitive. This relationship was proven for port performance in terms of efficiency index, in which some of the tested models showed the significance of this factor. There is a controversy about whether the importance of port logistic integration is a characteristic of the port or if it is only an external factor or even if it should be taken as an indicator of port performance. It seems that it must be regarded as part of the port services package offered and one of the characteristics that explain port performance in terms of efficiency. The results suggest that the port integration in global maritime logistic chains connected to international companies has triggered port operators to improve their technical knowledge, thereby eliminating non-productive costs, increasing efficiency and customer satisfaction and, thus, performance levels. In fact, shipping liners have often control over terminal operations or form partnerships with global terminal operators, which in both cases requires terminal managers the ability to meet highly demanding liner shipping needs and also to accommodate larger vessels, thus, achieving higher port performance levels. Strategic partnerships with global carriers has forced terminal operators to adapt their facilities layout, infrastructure, equipment, information systems, management and know-how in order to accommodate their specific needs, which in turn have led to substantial efficiency improvements when compared with others that have not been subjected to such demanding challenges. Hypothesis 7 is confirmed.

It becomes clear for governance purposes that private sector participation in the port industry is determining for performance as the port benefits from technical know-how and challenging demands deriving from a logistic integration in global networks, whether through terminal operators or shipping liners. However, Tongzon and Heng (2005)[38] have concluded that full port privatization does not necessarily guarantee higher efficiency levels. Only a combined "mix" of public ownership and private management is an effective way to obtain maximum performance in using port inputs, considering the complex interactions among players in the port and maritime industry and institutional entities. The results obtained

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demonstrate this. Further study should try to identify the best extent of private sector participation that maximises port efficiency, which is an important policy issue, since full privatization can even be counter-productive and lead to lower performance levels. The institutional context as well as the increasing role of port authorities, dealing with other public bodies, promoting better integration in transport networks, helping trade facilitation process, assisting the private sector to obtain construction licenses and operation permits, among others, can be often determinant to achieve the desired levels of port performance. The results of the study do not confirm the idea argued by Gonzalez and Trujillo (2007)[18] that ownership and management structures are not determinant for port efficiency, due to the fact that using representative sample ports of various sizes and types the contrary has been found. This result is also opposite to the one identified by Cheon (2007)[7], who considered that the only reason why port ownership had influence on efficiency was because the sample used only included ports with successful concessions. However, according to some results, it was observed that port governance model influences port performance in terms of port efficiency (+). Therefore, these findings could not support the idea that privatization is the best way to dramatically increase the port efficiency, as illustrated by Barros and Athanassiou (2004)[3], but just one way. The Hypothesis 8 is, thus, demonstrated.

7 Conclusions

As port characteristics can influence its overall performance in various ways, their understanding is essential not only for developing a new port or for the purpose of expanding existing ones, but also for adopting strategic port policies moving towards a more competitive port industry. This means that competition between transport modes and higher vessel capacity per unit of transport demand for higher port performance levels, which in turn depend on port characteristics. In fact, they have significant impacts not only on efficiency, performance and port competitiveness, but also on the region‘s economic growth. The study confirms that port's operational performance strongly depends on the geographical location and economic characteristics of the region, particularly those located in Europe, which in turn influence port size. Moreover, port size has considerable impact on port performance, also affecting infrastructure and maritime services. The amount of port infrastructure investment can explain the differences in performance and efficiency among ports, which in the case of maritime accesses investments are decisive, not only in terms of the level of market a port can achieve, but also in providing better maritime services to port users. Port specialization also affects the performance levels through the maritime services offered and infrastructure. A wider range of maritime services and larger number of vessels calling a port increasingly offer shippers more alternatives. In the same way, the presence of global carriers calling the port improves the port logistic integration in global shipping networks enhancing positive effects on performance.

8 Implications for Management

These findings have significant implications for port management, specifically due to a better understanding of the role of port authorities and their influence on governments and port terminal operators, leading to a positive effect on investment options, as in the case of building a new port or terminal, and also inducing a better adequacy of the governance model. Further knowledge of port characteristics and their effects on performance can provide a better investment selection option and commercial decisions.

9 Directions for Future Research

The study has also raised a number of other questions for future research. Firstly, it would be interesting to know whether ports characteristics influence the performance or it is the opposite due to their dialectical relationship over time. Secondly, further investigations could also try to define at to what extent port characteristics are determined by each other, how they relate themselves and how they can contribute directly or indirectly to port performance. Finally, future studies should try to clarify whether it is the type of port and terminal management or its characteristics that determine performance.

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Appendix

Table 1 – Pearson correlation

Pearson Correlations

	DROTERD2	DMEDIT3	SEAPORT4	DCITY5	QUAYL6	CRAINSKM7	TERMSIZE8	MAXDRAFT9	TXUNIT10	TXHORIZ11	TXCONT12	REGULARLSHIPS13	SHIPSIZE14	BIGSHIPO15	PORTPRIV16	GDPCAP17	TOTALTON18	GENERALTON19	BULKTON20	EURPERSON21	EURTON22	DEABCC23	DEACCR24
DROTERD2	1	-,372*	0,079	-0,014	-,335*	-0,001	-0,099	0,023	0,108	-0,253	0,053	0,117	-0,091	0,019	-,391**	-,464**	-,420**	-,379*	-,354*	-0,03	-0,07	-0,119	-0,129
DMEDIT3	-,372*	1	-0,093	-0,01	0,126	0,09	0,192	-,363*	0,214	,306*	-0,26	-,311*	-0,24	0,043	-0,04	0,274	0,043	0,129	-0,075	0,185	0,256	-0,049	-0,041
SEAPORT4	0,079	-0,093	1	-0,098	-,351*	-,321*	0,066	0,232	-0,08	0,256	-0,073	-0,109	0,048	0,084	-0,24	0,044	-,320*	-,335*	-0,215	0,283	0,149	-0,126	0,006
DCITY5	-0,014	-0,01	-0,098	1	-0,012	0,072	-0,105	0,283	-0,208	0,004	-0,037	-0,006	0,257	0,031	0,238	0,031	0,083	-0,047	0,22	0,273	-0,233	0,093	-0,025
QUAYL6	-,335*	0,126	-,351*	-0,012	1	0,004	0,121	0,23	0,088	-0,111	,328*	,312*	0,219	-0,011	,309*	,303*	,829**	,889**	,528**	0,062	-0,212	0,18	-0,035
CRAINSKM7	-0,001	0,09	-,321*	0,072	0,004	1	0,217	0,076	-,353*	-,420**	0,277	0,136	0,177	,352*	0,019	-,385*	0,173	0,069	0,254	-0,144	-,342*	-0,061	-0,186
TERMSIZE8	-0,099	0,192	0,066	-0,105	0,121	0,217	1	0,021	-0,033	0,11	0,063	-0,169	0,089	0,176	0,196	-0,057	0,164	0,131	0,161	-0,055	-0,032	0,076	0,232
MAXDRAFT9	0,023	-,363*	0,232	0,283	0,23	0,076	0,021	1	-,430**	-0,241	,391**	0,264	,703**	0,17	,364*	0,069	,319*	0,18	,403**	,384*	-0,295	-0,045	-0,064
TXUNIT10	0,108	0,214	-0,08	-0,208	0,088	-,353*	-0,033	-,430**	1	,544**	-0,199	-0,068	-,580**	-,435**	-0,153	0,198	-0,038	0,23	-,358*	-0,054	0,258	-0,053	-0,096
TXHORIZ11	-0,253	,306*	0,256	0,004	-0,111	-,420**	0,11	-0,241	,544**	1	-0,297	-,315*	-,373*	-0,221	0,008	,371*	-0,119	-0,014	-0,216	0,119	,533**	0,018	0,023
TXCONT12	0,053	-0,26	-0,073	-0,037	,328*	0,277	0,063	,391**	-0,199	-0,297	1	,619**	,321*	0,285	0,109	0,04	,435**	,375*	,391**	-0,054	-0,225	0,039	-0,122
REGULARLSHIPS13	0,117	-,311*	-0,109	-0,006	,312*	0,136	-0,169	0,264	-0,068	-,315*	,619**	1	,312*	-0,047	0,015	0,239	,399**	,384*	,309*	0,002	-0,278	0,156	0,031
SHIPSIZE14	-0,091	-0,24	0,048	0,257	0,219	0,177	0,089	,703**	-,580**	-,373*	,321*	,312*	1	0,182	0,208	0,025	,438**	0,217	,591**	,403**	-,468**	-0,009	-0,024
BIGSHIPO15	0,019	0,043	0,084	0,031	-0,011	,352*	0,176	0,17	-,435**	-0,221	0,285	-0,047	0,182	1	-0,164	-0,276	0,062	-0,052	0,186	-0,043	-0,209	0,184	0,142
PORTPRIV16	-,391**	-0,04	-0,24	0,238	,309*	0,019	0,196	,364*	-0,153	0,008	0,109	0,015	0,208	-0,164	1	,328*	0,287	0,256	0,247	-0,04	-0,061	0,13	0,25
GDPCAP17	-,464**	0,274	0,044	0,031	,303*	-,385*	-0,057	0,069	0,198	,371*	0,04	0,239	0,025	-0,276	,328*	1	,313*	,376*	0,149	0,122	0,186	0,208	0,188
TOTALTON18	-,420**	0,043	-,320*	0,083	,829**	0,173	0,164	,319*	-0,038	-0,119	,435**	,399**	,438**	0,062	0,287	,313*	1	,903**	,847**	0,092	-,314*	0,129	-0,079
GENERALTON19	-,379*	0,129	-,335*	-0,047	,889**	0,069	0,131	0,18	0,23	-0,014	,375*	,384*	0,217	-0,052	0,256	,376*	,903**	1	,537**	0,048	-0,186	0,154	-0,04
BULKTON20	-,354*	-0,075	-0,215	0,22	,528**	0,254	0,161	,403**	-,358*	-0,216	,391**	,309*	,591**	0,186	0,247	0,149	,847**	,537**	1	0,12	-,387*	0,063	-0,106
EURPERSON21	-0,03	0,185	0,283	0,273	0,062	-0,144	-0,055	,384*	-0,054	0,119	-0,054	0,002	,403**	-0,043	-0,04	0,122	0,092	0,048	0,12	1	-0,094	-0,099	-0,099
EURTON22	-0,07	0,256	0,149	-0,233	-0,212	-,342*	-0,032	-0,295	0,258	,533**	-0,225	-0,278	-,468**	-0,209	-0,061	0,186	-,314*	-0,186	-,387*	-0,094	1	-0,012	0,084
DEABCC23	-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	1	,791**
DEACCR24	-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	,791**	1

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

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

Table 2 – Rotated component matrix

Rotated Component Matrix[a]

	Component	
	1	2
SHIPSIZE14	,908	,112
MAXDRAFT9	,813	-,059
TXUNIT10	-,742	,279
BULKTON20	,646	,568
EURTON22	-,547	-,317
GENERALTON19	,136	,842
SEAPORT4	,168	-,726

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Table 3 – KMO

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,658
Bartlett's Test of Sphericity	Approx. Chi-Square	108,855
	df	21
	Sig.	,000

Table 4 – Regression models summary

	LN TOTALTON18	LN GENERALTON19	BULKTON20	LN EURPERSON21	EURTON22	DEACCR24
Adjusted R Square	0.887	.886	.514	.682	.388	.218
Durbin-Watson	1.825	1.329	1.866	2.008	1.953	2,267
ANOVA Sig.	.000	.000	.000	.000	.000	.019

	LN TOTALTON18		LN GENERALTON19		BULKTON20		LN EURPERSON21		EURTON22		DEACCR24	
	St. Beta	Sig.	St. Beta	Sig.	St. Beta	Sig.	St. Beta	Sig.	St. Beta	Sig.	St. Beta	Sig.
(Constant)		.017		.024		.278		.857		.000		.105
DROTERD2	-.160	.007	-.157	.009	-.190	.104						
DMEDIT3							.393	.000				
DCITY5									-.201	.122		
QUAYL6	.309	.000	.303	.000	.356	.004	-.252	.025				
CRAINSKM7							-.409	.001			-.324	.039
TERMSIZE8	.265	.000	.263	.000							.268	.079
MAXDRAF9							.474	.001				
TXUNIT10			.612	.000			.270	.075	-.314	.066		
TXHORIZ11	.211	.000	.203	.001			.271	.016	.560	.000		
TXCONT12											-.462	.024
REGULARLSHIPS13											.421	.032
SHIPSIZE14	.556	.000	.563	.000	.496	.000	.801	.000	-.390	.014		
BIGSHIPO15											.412	.015
PORTPRIV16							-.281	.015			.316	.036

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Figure 1 – Relationship model between port characteristics and performance