THE PORT ATTRACTIVENESS INDEX: APPLICATION ON AFRICAN PORTS

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***Abstract** - The overall operational reputation of a port is based on objective factors, including infrastructure endowments and efficiency in the logistics chain as well as on perceived subjective factors such as reliability, and level of corruption. In this work we analyze the concept of port attractiveness, starting with the hypothesis that subjective port determinants (i.e., user perception) and objective/endogenous and exogenous factors can be quantified together. We thus determine the Port Attractiveness Index and test it using 41 container ports of 23 African countries for the period 2006-2010. We apply a bottom-up approach to investigate the structural relationships among the three sets of determinants (endogenous, exogenous and subjective) that impact on port attractiveness. Our methodological approach employs structural equation modeling. Results indicate that subjective factors are indeed influential variables for port attractiveness. Moreover, when examining port attractiveness and investment strategies, we demonstrate that in many cases in African ports governments should implement soft infrastructure as a first step rather than investing in hard infrastructures.*

***Key-words* -** SHIPPING, MARITIME TRADE, PORT REPUTATION, AFRICA, STRUCTURAL EQUATION MODELING

***JEL Classification* -** C49, F14, R40

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1. INTRODUCTION

Maritime ports, and investments to target their expansion, are often deemed by governments not only as an important enhancement of their national assets but also as a means of establishing a gateway to the global shipping network. International trade at present comprises 80% of goods transported via seagoing routes; in the last two decades, ports have grown rapidly to become increasingly specialized, highly capital intensive, and able to carry out a wide range of value-added activities. The recent financial crisis and the consequent restricted availability to credit highlights a major long-term challenge for port investment, which is how to attract the private sector in the financing of port developments in order to maintain and increase market share while achieving profit margins. Foreign direct investment (FDI) in ports is generally very successful; and effective strategies, particularly in developing countries, where international terminal operators (ITOs) in Africa and South Asia are responsible for over 75% of privately-handled containers and cargo (Drewry, 2010), are proof positive of this success. But as observed by UNCTAD (2011), although an attractive option, FDIs are not always simple to implement.

One of the main difficulties of FDIs is that the flow of private investment, as by ITOs, is often decided on the basis of available information and data. This information not only describes the features of the ports, such as possible market size, emergence of inland trade, and transshipment capability, but may also refer to the economic and policy environment of the host country and may include policy stability, regulatory transparency, support for the investment, and so forth. However, it is important to stress that, in developing countries especially, this information is often unreliable and disputable due to ineffective data collection practices, corruption aimed to inflate or deflate the significance of the data, and underinvestment by administrative agencies. Nonetheless, a combination of perceived and actual robust information undeniably provides investors with a financial picture of the level of attractiveness of a port when considering potential investment. From this perspective, port attractiveness is pivotal to the financial decisions of investors and should not be underestimated in scholar and practitioner analyses.

Although port attractiveness is not a new topic, the literature on the subject is still rather limited (Ng, 2006). Most authors have studied port attractiveness through survey methodologies which apply shippers' perspectives based on their selection of ports during cargo route planning (Tongzon, 2009). Scholars have analyzed a wide range of determinants for port attractiveness, and these tend to vary according to survey sample (i.e., shipping lines, freight forwarders or independent shippers), and study area (i.e., North America, Europe, South-east Asia). Port attractiveness determinants can generally be grouped into three categories: endogenous, exogenous and subjective. Endogenous factors regard the port directly: port infrastructure endowment (Murphy et al., 1994; Slack, 1985; Tiwari et al., 2003; Tongzon, 2002; Ha, 2003), monetary costs (Murphy et al., 1994; Ha, 2003; Foster, 1978; Tongzon, 2002; Tiwari et al., 2003; Foster, 1978; Lirn et al., 2003), logistic efficiency (Murphy et al., 1994; Slack, 1985;

Tiwari et al., 2003; Tongzon, 2002 and 2009; Ha, 2003), and port accessibility (Huybrechts et al., 2002).

On the other hand, exogenous factors include a number of external determinants that influence port throughput indirectly: national and local economic competitiveness (Przybyłowski, 2008; OECD, 2008), geographic location (Tiwari et al., 2003; Tongzon, 2002; Lirn et al., 2003; Ha, 2003), and shipping line characteristics (Noteboom, 2009; Slack, 1985; Tiwari et al., 2003). The third category, subjective factors, leverage port attractiveness and above all refers to the reputation of a port among sector operators (Lirn et al., 2003; Ng, 2006; Tongzon, 2002; Daya et al., 2006; Bird and Bland, 1988).

Whereas, subjective factors consider assistance, flexibility, and communication with customers (Murphy et al., 1994; Ha, 2003; Tongzon, 2002; Slack, 1985), shippers' experience (Slack, 1985; Noteboom, 2009), and tradition, personal contacts, and level of cooperation among shippers (Tongzon, 2009). According to some authors (inter alia Foster, 1978 and Lirn et al., 2003), endogenous factors are the most significant determinants of port attractiveness. Although a number of authors recognize that exogenous and subjective determinants are also influential, to the best of our knowledge, no study has yet attempted to propose an analytical model to consider endogenous, exogenous and subjective determinants altogether in the evaluation of port attractiveness.

Against this background we contribute to existing literature by setting out a quantitative approach to assess port attractiveness. Our aim is to construct a synoptic index which can be used by various stakeholders (i.e. government bodies, investors and researchers) to evaluate and compare qualitative and quantitative characteristics of ports in a region (i.e., attractiveness of ports). We construct the Port Attractiveness Index and apply it to the case of African ports. Our methodology exploits a bottom-up statistical approach (structural equation modeling, SEM) which allows one to investigate and combine causal relationships among exogenous, endogenous and subjective determinants and to measure their significance. The advantage in the use of SEM methodology resides in modeling exogenous, endogenous and subjective determinants as latent variables. With this approach we achieve two goals: 1) we relate observed variables to the selected polytomous factors (latent structural determinants) and we evaluate their impacts, and 2) we scrutinize the effect of each latent structural determinant on port attractiveness. By means of the research framework illustrated thus far, we structure the analysis in a framework of step-by-step research questions as follows:

1: What is the attractiveness of ports and how we can measure it?

2: How do we construct the Port Attractiveness Index by combining endogenous, exogenous and subjective variables?

3: Is it possible to construct a synoptic index that estimates the relative importance of the attractiveness of a port, given its endogenous, exogenous and subjective variables? In particular, we also want to test the following assumption that soft infrastructure consisting of three components – port reputation, economic development of port hinterlands, and quality of port facilities – is a major determinant of port attractiveness.

4: Is the Port Attractiveness Index suitable to benchmark ports' characteristics and performances?

In our discussion of the Port Attractiveness Index, we have decided to test the index on Africa ports, but this choice is not a fortuitous one. As data on the Africa maritime industry and its trade growth is scant, the data which is available is often biased towards an oversimplified perception of the entire continent which tends to perpetuate false and partial opinions of African countries (Adichie, 2009). Scholars have quantitatively assessed 'perception' through the use of such indicators as country corruption[3] and logistics performance index.[4] The aforementioned indices have been constructed on the basis of surveys with experts, companies and individuals. In particular, Refas and Cantens (2011) have studied the perception of cargo dwell time in the port of Douala and Cameroon. Daya et al. (2006) have shown that corruption and the perception of corruption are impediments to trade, because they increase both the risk and the cost of conducting business in African countries. An Ernst & Young survey (2011) has investigated the perception of investments in Africa, and findings yield generally positive perceptions over the medium to long-term.

In this work we will address the subjective variable 'perception' by examining 41 container ports in 23 different countries and show through the use of observed macro-economic, socio-economic and infrastructure variables how very different economic and financial opportunities coexist on the African continent. This objective is partially the inspiration for this new Index, since for the case of African ports a positive perception and reputation is critical to the long-term growth of the continent. In fact, the Minister of Trade, Industry, Private Sector Development of Ghana has observed that "the issue of negative perception of Africa by the European and other business communities has played a major role in impeding efforts at attracting much needed level of Foreign Direct Investment."[5]

The structure of the analysis is as follows. In the next section we discuss the methodology applied to study port attractiveness and subsequently construct the Port Attractiveness Index. In Section 3 we present the data set used for the case study of 41 container ports in Africa. In Section 4 we show the results of our case study, and round out the paper in Section 5 by restating our conclusions and discussing future research.

2. METHODOLOGY

Our literature review on port attractiveness in the previous section highlights the limited attention given to the notion of port attractiveness in maritime studies. As stated in our first research question, it is necessary to provide an unam-

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[3] http://www.transparency.org/cpi2011/results
[4] http://data.worldbank.org/data-catalog/logistics-performance-index
[5] Source: www.ghananewsagency.org

biguous definition of port attractiveness as the cornerstone of the Port Attractiveness Index. We define port attractiveness as the *combination of the productive capacity of a port and its level of international competitiveness which provides direct and indirect economic benefits*. A port generates freight traffic through its interconnectedness with inland trade routes and with other regional and international ports. Thus, in order to be attractive and competitive, ports often need to be integrated vertically, i.e., secure maritime routes and landside operations; and integrated horizontally, i.e., highly specialized with a wide geographical market share. The implication here is that a port must be equipped with effective facilities, it must provide reliable services at the lowest price, and it needs to have an efficient productivity level. These characteristics altogether comprise the reputation of a port as an intricate network of operators, investors and maritime brokers.

As discussed in the Introduction, three main categories of key variables are influential in port attractiveness. These variables, i.e., endogenous, exogenous and subjective variables, and in particular the subjective variables, are often collected via surveys (Sequeira, 2012). However, survey methodologies are expensive to carry out and are also time consuming, therefore as an alternative method in this study we consider the copious data collected from third-party organizations (i.e., World Bank, Containerisation International, UNCTAD, internet flows, crowd sourcing data etc.) in order to increase the scale and volume of the examined data as well as variety of the data. After having collected a significant volume of multivariate data, our next step in the analysis is to select a methodology that best supports our objectives: to construct a synoptic index that defines and assesses port attractiveness by means of port variables that are not directly observable (latent variables). Structural Equation Modeling (SEM) is a robust statistical methodology perfectly suited to our calculation of the causal relationships between the variables influencing port attractiveness (Ullman and Bentler, 2012).

SEM is a method similar to multiple regression analyses of factors in the case of multivariate data. However, when compared to multiple linear regression, SEM has many advantages which, as observed by Kline (2011), include greater flexibility in assumption definitions (particularly in cases of multicollinearity), the capacity to structure confirmatory factor analysis, the use of latent variables (i.e., predictors not directly observable), the ability to model error terms and test coefficients across multiple and between-subjects groups, and to handle time series with auto correlated errors, non-normal and incomplete data. In general, Structural Equation Modeling has been applied with one of the following approaches (Ullman and Bentler, 2012):

1. Strictly confirmatory approach: a model is tested using SEM goodness-of-fit tests to determine if variance and covariance in the data are consistent with a model specified by the analyst.

2. Alternative modeling approach: two or more causal models are tested to determine which has the best fit.

3. Model development approach: SEM application usually combines confirmatory and exploratory purposes. When a model is tested using SEM procedures, if it is found to be unsatisfactory, an alternative model is tested based on changes suggested by SEM modification indexes.

In our study we apply the model development approach (3); in this case the statistical properties and applications of SEM are well developed and the approach has been implemented across several research fields, including education (Timothy and Myint, 2009), psychology (MacCallum and Austin, 2000; Agho et al., 1992), sociology (Bielby and Hauser, 1977), econometrics (Dell'Anno and Schneider, 2009; Amemiya 1985), and logistics (Stank et al., 2001; Dunn et al., 1994). SEM has been applied in maritime industry studies in order to analyze liner service capacity (Venus Lun et al., 2011), vertical integration between shipping lines and ports (Bichou and Bell, 2007), linkages between inter-organizational culture, trust, knowledge sharing, collaboration, and performance in the maritime supply chain (Nir et al., 2012), influence of relationship orientation in third-party logistics (Panayide and So, 2005), and the propensity for shippers to use Internet services in liner shipping (Lu et al., 2007). Guo et al. (2009) used path analysis and structural equation modeling to examine influential factors for the dry bulk shipping market. Beyond specific applications in the maritime industry but pertinent to our interest in this work, SEM has also been applied to the analysis of user perception, in for example, the ease to use technology (Fishbein and Ajzen, 1975; Davis, 1989; Ajzen, 1991) and the perception of security protection and satisfaction of e-commerce users (Glover and Benbasat, 2010). Given this backdrop, in the next sections we will discuss the two additional questions (Q2 and Q3) initially posed: how to build the Port Attractiveness Index and how to estimate the different parameters of the three categories of variables: endogenous, exogenous and subjective.

2.1. Port Attractiveness Index

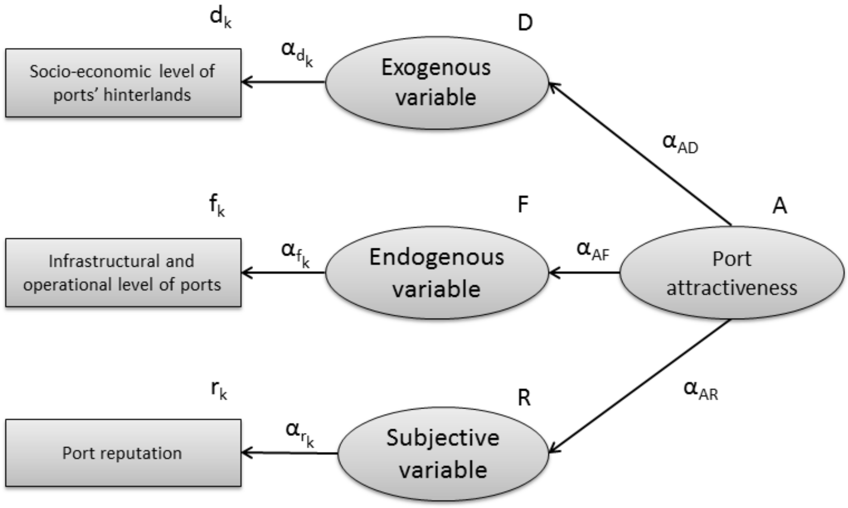
In order to construct the Port Attractiveness Index, we assume that the higher the value of endogenous, exogenous and subjective variables (hereafter called key constructs) the higher the Port Attractiveness Index (Figure 1).

To validate the structural models of port attractiveness, we need to test the structural causal relationships between the three key constructs: endogenous variables (F), exogenous variables (D) and subjective variables (R). The three key constructs are latent variables that determine the attractiveness of a port (A). The exogenous latent variables D are meant to represent the socio-economic level of port hinterlands and the quality of their governance. D can be dependent on several variables such as economic development (Mazumdar, 1996), quality of telecommunication infrastructure (Oyelaran-Oyeyinka and Lal, 2005), and integrity level (i.e., level of corruption, accountability in governance, etc.) (Montinola and Jackman, 2002).

Key construct F refers to the infrastructural and operational level of the port (endogenous variables). F is usually dependent on variables such as port facilities (Slack, 1985; Tongzon, 2002), logistic efficiency (Murphy et al., 19994;

Ha, 2003; Foster, 1978; Tongzon, 2009) and port productivity (the higher the port throughput, the higher the infrastructure level of a port). The most innovative part of our study through the use of SEM is to quantitatively evaluate port reputation represented by the subjective key construct R. In this case, we assume that R is dependent on variables such as port quality (from shippers' point of view), centrality in the international shipping network (the higher the interconnectivity of a port in the global shipping network, the higher its reputation in the industry), level of reliability, security level (i.e., piracy attacks in Africa, (the higher the level of piracy risk closer to a port, the lower its reputation will be).

Figure 1. Structural equation model of causal relationships between factors in port attractiveness



Source: Authors elaboration.

We linearly combine the causal relationships obtained from the SEM to build the Port Attractiveness Index Φ. The index Φ_i^j for port i in the j^{th} year can be written in mathematical terms as follows:

$$\Phi_i^j = \alpha_{AR} * R_i^j + \alpha_{AF} * F_i^j + \alpha_{AD} * D_i^j \quad (1)$$

where:

$$R_i^j = \sum_{k=1}^{n} \alpha_{r_k} * r_{i,k}^j \quad (2)$$

$$F_i^j = \sum_{k=1}^{n} \alpha_{f_k} * f_{i,k}^j \quad (3)$$

$$D_i^j = \sum_{k=1}^{n} \alpha_{d_k} * d_{i,k}^j \quad (4)$$

α_{AR}, α_{AF}, α_{AD}, α_{r_k}, α_{f_k} and α_{d_k} are the path loadings obtained from the SEM and represent the relative importance of each key construct and measured variable; $r^j_{i,k}$, $f^j_{i,k}$ and $d^j_{i,k}$ are the k^{th} observed variables for port i in the j^{th} year.

In Annex 1 we present a brief overview of SEM for readers not familiar with this methodology.

3. CASE STUDY: ATTRACTIVENESS OF AFRICAN PORTS

After the 2008 financial crisis, the container industry, although growing steadily until that time, recorded global losses of around USD 1.5 billion in 2009 (Beddow, 2010). The economic turbulence generated by the 2008 downturn had forced carriers to reorganise liner services. For instance, inter-carrier cooperation (i.e., vessel sharing) has become an unavoidable option for most container liners in order to share investment risk and reduce financial losses (Notteboom et al., 2010; Caschili et al., 2014). It has been argued that such stark economic events could shock the global system and force leading manufacturing suppliers to search for new trading partners (Sturgeon and Kawakami, 2010). While western countries and specifically countries within the Euro monetary zone are still coping with weak economies, Africa is experiencing its biggest economic boom in 30 years. During the period 1980-2000, the rest of the world grew at an average rate of 5% per annum faster than Africa. However, since the early 2000s the growth rate in Africa has accelerated, and countries such as Ethiopia, Mozambique, Tanzania, Ghana, Zambia, and Nigeria are expected to grow at a rate of between 7 and 8% by 2015 (IMF, 2011). In this period, new trends are emerging in the trading market; the US and EU are still the leading commercial partners in Africa, but in recent years countries in East Asia and South America have rapidly been gaining new market share in Africa (Afribiz.info., 2011). At present, most of the inbound container traffic in African ports comes from Asia; approximately 60% of Western African containers come directly from China, the leading commercial partner for countries such as the Republic of Congo (40%) and Nigeria (50%). Trade between China and Africa has increased from USD10 billion in 2000 – to USD127 billion in 2010 – while all trade between Asia and Africa has climbed to USD304 billion in 2010. The total trade of Asia-Africa is forecast to soar to over USD1.5 trillion by 2020 (Jagtiani and Krishnan, 2011).

However, structural problems still hinder the growth of most African maritime trade. A lack of modern ports and underdeveloped inland transportation and logistics limits their efficiency and thus their capacity to grow (Mbekeani, 2010). Some ports experience high levels of inland congestion; for example, in Apapa (Nigeria), truck drivers must wait four to five days merely to gain access to the port. In some countries problems are worsened by customs requirements. In the Democratic Republic of Congo exports need 18 days on average to clear the customs controls, and in Mozambique the waiting period is approximately 10 days.[6] Despite the long waiting times, between 2006 and 2010 a noticeable

[6] Source: Catalog Sources World Development Indicators (World Bank data set).

increase in container traffic was recorded at some African ports, such as Toamasina (Madagascar) with a 34% rise, Port Said (Egypt) 26%, Maputo (Mozambique) 24%, and Durban (South Africa) 8%.[7]

According to Zafar (2007), several factors have stimulated the growth of container traffic in Africa, and by so doing have cultivated a positive cyclical effect: steady economic growth, lower political instability and criminality, and increased foreign investment. The distribution of Foreign Direct Investment (FDI) is, however, still uneven on the African continent: Morocco, Angola, Equatorial Guinea, Nigeria, and Sudan absorb about 50% of the total inflows to Africa (Dupasquier and Osakwe, 2005). We observe however, that since 2008 there have been a number of major investments dedicated to the construction and upgrade of ports in Guinea (Conakry's port: EU500 million); Togo (Lome port: new container terminal for 7000+ TEU containerships – EU60 million); Cameroon (deep water port in Kribi: USD489 million); Kenya (construction of a second container terminal in Mombasa port: USD180 million – and a new port in Lamu costing USD3.5 billion); Tanzania (construction of two container terminals in the port of Dar Es Salam: USD460 million); South Africa (expansion of the port of Durban for USD4.3 billion and construction of a new port in Ngqura amounting to USD1.3 billion); Cote D'Ivoire (investments in terminal capacity, road and rail upgrades on hinterland linkages of the Abidjan port: USD90 million); Morocco (Tangier-Med I, concluded in 2007 and its expansion Tangier-Med II started in 2009: EU200 million). Nonetheless, investment in African ports remains comparatively low and more financial private intervention is needed to improve port infrastructure and logistics and links with hinterlands (Mafusire et al., 2010).

Having set the background for our analysis, we next apply the Port Attractiveness Index for the case of 41 ports in Africa. We argue that successful investments need to be supported both by hard infrastructures (efficient and well-equipped port facilities) and soft infrastructures (i.e., productive hinterlands and positive port reputation among shipping liners and brokers). If a port host country considers the maritime industry as an important multiplier for competitive economic growth and therefore sea ports as gateways to the global trade networks, then investment in ports should become more attractive. We verify in Figure 2 the correlation among Foreign Direct Investments (FDI), Gross Domestic Product (GDP) and Logistics Performance Index for 120 countries worldwide.[8]

Figure 2 shows a correlation between FDI and GDP (correlation coefficient 0.69) and a very heterogeneous range of values (six degrees of magnitude between minimum and maximum values). Most African countries are depicted in the bottom area of the graph. Only North African countries and South Africa position themselves in the upper middle part of the graph. It is interesting to note that the relationship between FDI and GDP is not linear but instead follows

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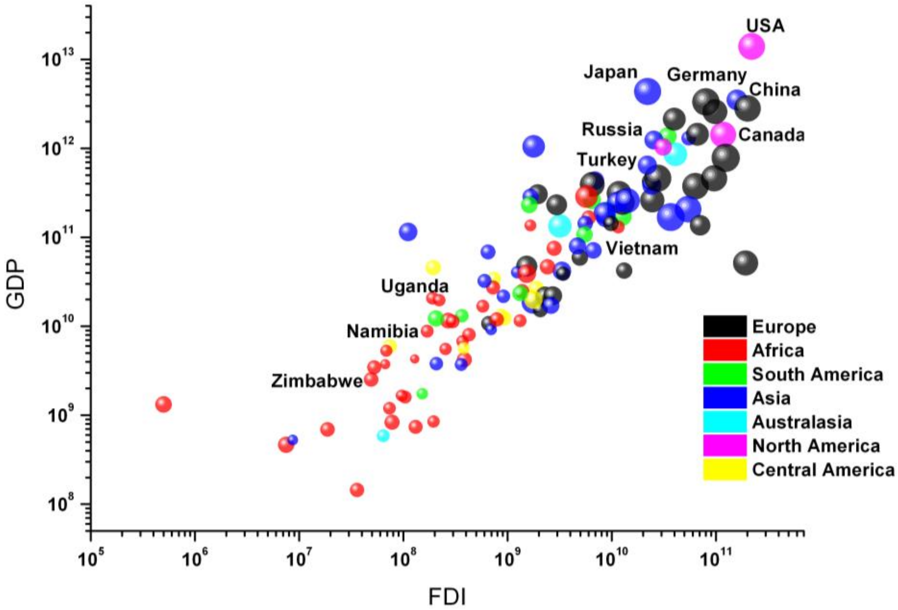
[7] Authors' elaboration on Containerisation International data set.
[8] The information is extracted from the World Bank data set.

a power law,[9] which means that richer countries are able to attract higher foreign investments. We also observe that the Logistic Performance Index grows as GDP and FDI increase. Thus, as already discussed in the literature (Mohey-ud-din, 2007; Hong, 1997; Bhandari et al., 2007; Moshirian, 2008), our preliminary investigation confirms that FDI may act as a multiplier in the economic growth of a country.

Figure 2. Log-log scatter plot of FDI versus GDP for 120 countries in 2007



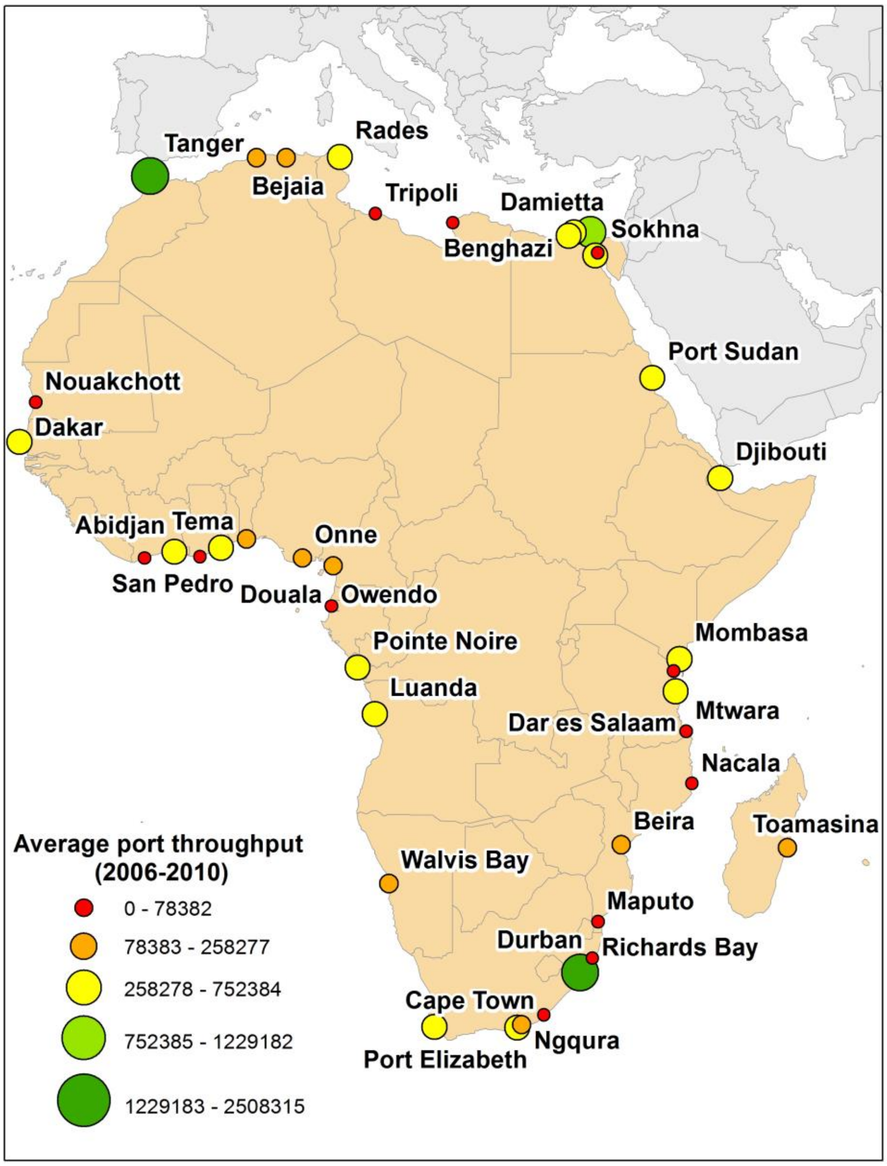
Legend: Country circle size is proportional to the Logistic performance index and colours identify country membership in continents.
Source: Authors elaboration on World Bank data set.

3.1. Data set

In this study as previously discussed we collect data from a large variety of sources in relation to 41 container ports in 23 African countries (Figure 3 and Annex 2). We have selected the 41 ports on the basis of an opportunistic data collection: our data set contains information over the 2006 to 2010 time period for container ports whose yearly throughput was available in the Containerisation International data set at the date of collection (January 2012). More than 75% of our sample covers information for at least four years. The ports are evenly distributed along the coast of Africa. The data set provides information over a very heterogeneous sample of ports, ranging from hub ports in South Africa and Egypt, to minor ports in Mozambique and West Africa. We have decided to omit the ports in North Africa that belong to European countries (i.e., The Canary Islands and Madeira Islands).

[9] Curve fitting $Y=bX^a$, with a=1.8 and $b=4.7E^{-9}$, Adjusted R-square 0.47.

Figure 3. Visualization of the 41 African ports considered

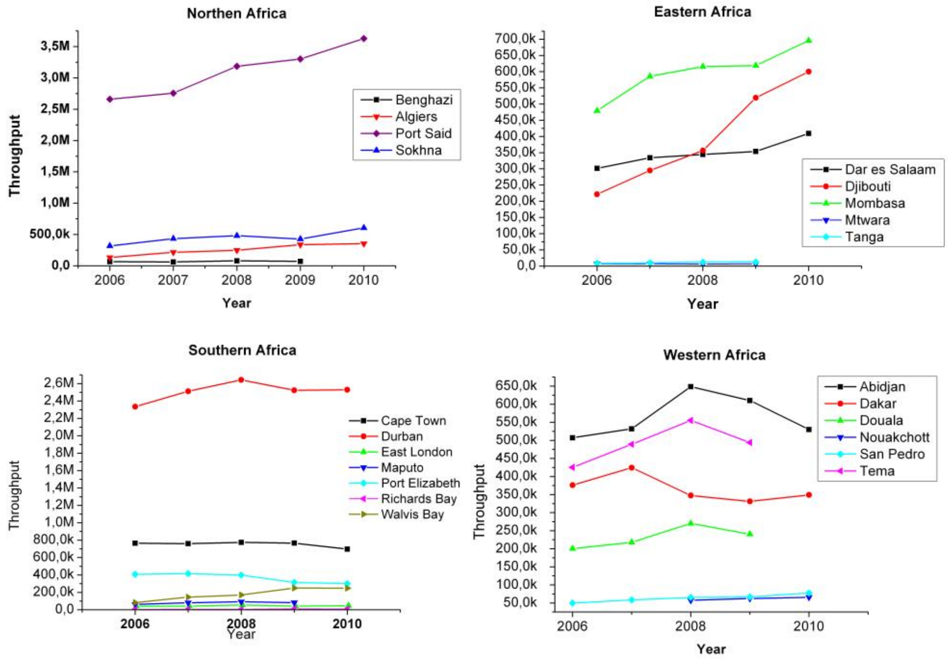


Legend: Size and color of ports are visualized according to the average throughput recorded over the 2006 to 2010 time period.
Source: Authors elaboration on Contenarisation International data set.

The average value of port throughput is 455,872 TEUs per year, with a standard deviation of 675,649, indicating a wide range of throughputs in our sample; the maximum value is 3.6 million TEUs for Port Said (Egypt) in 2010. We have recorded the minimum volume of TEU (3,332) in Richard Bay (South

Africa) in 2006. A few ports in geographically-strategic locations (i.e., Egypt because of the Suez Canal, Morocco because of the Strait of Gibraltar, and South Africa because of the Cape Town route) dominate the market, while the remaining ports are growing steadily but with low annual throughputs. In Figure 4 we visualise port throughput trends by region for ports where information is available for at least three years in the observed time period 2006 to 2010.

Figure 4. Port throughput trends between 2006 and 2010



Source: Authors elaboration on Contenarisation International data set.

With the exception of a few unstable trends in the ports of Abidjan and Dakar, the other ports have positive or stable trends. Northern Africa is dominated by Port Said, which is located on the Suez Canal and works mainly as a transhipment point. Ports in Eastern Africa have all increased their throughput between 2006 and 2010. The Southern Africa region handles the highest volumes of TEU, although ports in Southern Africa have experienced a slight decrease of container throughput since 2008. Finally, Eastern Africa had the highest boom in containerisation: the ports of Dar es Salaam, Djibouti and Mombasa clearly increased container volumes during the reference period.

In the remainder of this section we provide a description of the observed variables used in the SEM. Table 2 summarizes and provides references for each variable. It is worth mentioning that some of the variables described below were not used in the final configuration of the Port Attractiveness Index. The exclusion of some variables has been due to goodness-of-fit reasons of the SEM.

1) **Endogenous variables** (key construct F) are the characteristics of a port's facilities. We assume that the higher the infrastructural endowment of a port, the higher its attractiveness will be. We have collected the following information on port infrastructures:

- total land area (in square metres);
- number of quays;
- berth size (in metres);
- average water depth (in metres);
- average time to clear customs.

The infrastructural characteristics considered in this study do not change over the observation time period. In Table 1 we depict their linear correlation (Pearson correlation matrix). Port area, number of quays and berth size are linearly correlated, while water depth is correlated only with berth size.

Table 1. Pearson's correlation matrix

	Total Port Area	Number of quays	Berth size	Water depth
Total Port Area	1	.231**	.272**	-.087
Number of quays		1	.804**	-.233**
Berth size			1	.039
Water depth				1

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

Logistic efficiency and cost are problematic variables of our study because African ports do not publish official information on monetary costs and statistics on logistic and production efficiency, such as time taken to load/unload containers, waiting time for carriers and lorries, etc. For this reason, we assume that the variable average time to clear customs is an effective proxy for measuring the logistic efficiency of a port. Average time to clear customs information is issued by the World Bank and measures the average number of days to clear direct imports through customs.

2) **Exogenous variables** (key construct D) aim to evaluate the level of socio-economic development of the port host country. Due to the lack of information at the local scale, we assume that the exogenous variables are evenly distributed across a country. We are aware that we introduce a disputable assumption here that cannot be indiscriminately applied to every geographic setting/case study. We assume that this simplification is valid for our case study for the following reasons: 14 out of 23 countries are represented by only one port which is usually the biggest national container port. Four countries (Algeria, Cote d'Ivoire, Ghana and Tunisia) have two ports in our data set, of which one of them is located in the capital while the second one has been developed to compensate congestion in the major port. These four countries are small or their ports are located relatively closed to each other. The five ports in Egypt are located

around the Suez Canal. Finally we are conscious that some problems might exist for ports in three countries: Mozambique, South Africa and Tanzania. In these cases ports are spread across their coastline and are used as gateways by different regions/hinterlands. We will pay special attention in the interpretation of the results keeping in mind the discussed limitation of our case study.

We assume a positive correlation between port attractiveness and socio-economic factors while poor quality governance is expected to negatively influence port attractiveness.

• GDP is the yearly market value of all officially recognised final goods and services produced within a country.

• Total investments per year (% GDP) are expressed as a ratio of total investment in current local currency and GDP in current local currency. Investment or gross capital formation is measured by the total value of the gross fixed capital formation and changes in inventories and acquisitions, less disposals of valuables for a unit or sector.

• Consumer price index measures changes in the price level of consumer goods and services purchased by households.

• Goods import (and export) refers to all movable goods (including non-monetary gold) involved in a change of ownership from non-residents to residents. The category includes goods previously included in services: goods received or sent for processing and their subsequent export or import in the form of processed goods, repairs of goods, and goods procured in ports by carriers. Goods import and export do not completely cover the set of countries in our dataset.

• Number of Internet users measures the number of people with access to the worldwide network. According to Birba and Diagne (2012), Internet users in the sub-Sahara are mostly young and well-educated people. Our hypothesis is that the variable of the number of Internet users is an affective proxy variable to evaluate the presence of a middle class in a country. As a consequence, the higher the number of people using the Internet, the larger is the middle class. We conjecture that the middle class is likely to have the highest purchasing power, which subsequently encourages trade of manufactured goods, which are moved mostly via containers.

• Corruption Perception Index (CPI) ranks countries by their perceived levels of corruption, as determined by expert assessments and opinion surveys. The CPI generally defines corruption as the misuse of public power for private benefit.

3) **Subjective factors** (key construct R): this set of variables measures the reputation of ports among stakeholders (investors, operators, shipping companies, trade facilitators, and so on).

• Port Quality index measures business executives' perception of countries' port facilities. Data are provided by the World Economic Forum's Executive Opinion Survey and collected online or through in-person interviews. The

World Bank provides scores in the range from 1 (port infrastructure considered extremely underdeveloped) to 7 (port infrastructure considered efficient by international standards). To ease the interpretation of the results we invert this classification by assigning the highest value to the port with the highest efficiency.

• Liner Shipping Connectivity Index (LSCI) indicates how well countries are connected to the global shipping network based on the status of their maritime transport sector. The Index is computed based on five components of the maritime transport sector: number of ships, container-carrying capacity, maximum vessel size, number of services, and number of companies that deploy container ships in a country's ports.

• Piracy attack. The past decade has witnessed an unprecedented increase of piracy, especially between the Red Sea and Indian Ocean, near the Somali coast, in the Strait of Malacca, and in the Gulf of Guinea. We consider the impact of piracy on the reputation of each port by calculating the number of piracy attacks that occurred in a buffer zone of 500 miles from each port every year (Annex 5).

The values of the considered variables are scattered over a large spectrum with standard deviation greater than mean values. A number of variables are not normal distributed, as shown by values of skewness and kurtosis (Annex 3).

Table 2. List of variables

Variable	Source
Throughput [TEU] (2006-2010)	CI[1]
Total area [m2]	CI
Number of quays	CI
Berth [m]	CI
Depth [m]	CI
Port quality index (2007-2010)	World Bank
Corruption perception index (2006-2010)	Transparency International
GDP (2006-2010)	World Bank

Variable	Source
Average time to clear imports customs	World Bank and various sources
Liner Shipping Connectivity Index (LSCI)	UNCTAD
Goods imports	World Bank
Goods exports	World Bank
Internet users	World Bank
Consumer price index	World Bank
Number of piracy attacks per year in a buffer zone of 500 miles from each port	Own elaboration on U.S. National Geo-spatial-Intelligence Agency data set

[1] Containerisation International.

3.2. Limitation of the data set and normalisation

There are some limitations in our collected data set. The first limitation relates to the heterogeneity of variables, which have been collected with different units and scales of measurement. In fact, they measure very different features, ranging from port throughput (in TEU) and berth length (in metres) to piracy attacks (total number) and GDP (in US dollars). For this reason we have applied a logarithmic transformation in order to normalise our data set and lessen the impact of highly skewed distributions. A second limitation regards the number of entry points in our data set. SEM is largely affected by the size of data samples. Jackson (2003) suggests that an ideal sample size compared to the number of parameters to be estimated should be 20:1 or at least 10:1. Our variables have 165 data entries (restricted to 153 in two cases: 'Goods Import' and 'Goods Export'). Moreover, the set of information collected for the 41 ports does not cover every port over the five years of observation (2006-2010), thus resulting in the 165 data entries of our sample.

4. PORT ATTRACTIVENESS IN AFRICA

Based on the model presented in Section 2.1, we validate and compare the factors that affect port attractiveness using a three-step goodness-of-fit test approach (among other tests, we apply RMSEA, RMR, NFI, etc., see Table 5). We first examine several models and reject or confirm them based on the results of fitting tests. In the second step we develop alternative models based on changes suggested by the fitting tests. Finally, we choose the best model among those that have passed the goodness-of-fit tests and coherence of results with our hypotheses (see Section 3.1). More than 30 models have been tested before finding the optimal configuration (Figure 5). As discussed in Annex 1, methods of estimation for SEMs assume multivariate normality of variables, that is, each variable is assumed normal distributed and any pair of variables is bivariate normal distributed. In order to verify the hypothesis of multivariate normality, we check for skewness and kurtosis of the considered variables (Table 3).

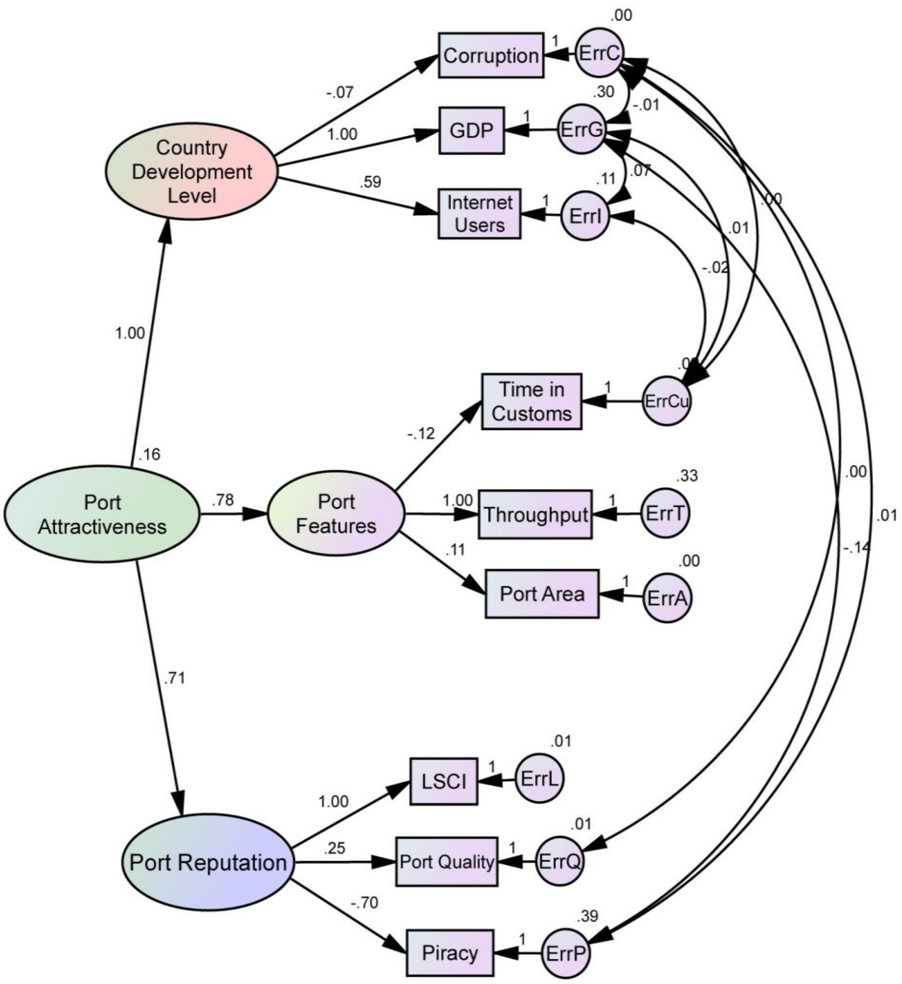
Table 3. Assessment of multivariate normality

Variable	Skew	Kurtosis
Depth	.144	-.412
Corruption	-.849	-.418
Throughput	-.522	-.096
GDP	-.405	-.610
LSCI	.307	-1.262
Time in customs	-.456	-.213
Internet users	-.623	-.123
Piracy	.621	-1.001
Port Quality	-.076	-1.070
Multivariate		4.742

Table 4. Fit indices with recommended values

Statistic	Recommended Value	Obtained Value
$\chi2$		20.88
d.f.		19
$\chi2$ / d.f.	<2.0	1.099
RMR	<0.01	0.009
GFI	>0.9	0.973
AGFI	>0.9	0.936
RMSEA	<0.06	0.025
NFI	>0.9	0.960
RFI	>0.9	0.925
IFI	>0.9	0.996
CFI	>0.9	0.996
TLI	>0.9	0.993

Figure 5. Casual SEM diagram with assessment of un-standardised path loading



Source: Authors elaboration.

Except for the variable LSCI, for all other variables skewness and kurtosis fall in the range between -1.00 and +1.00. These variables are therefore normal distributed. We also test Mardia's index of relative multivariate kurtosis (Mardia, 1970), which must vary between -1.96 and +1.96 to support multivariate normality of data distribution. The variables reported in Table 4 have not passed the Mardia's index test (4.74), so the hypothesis of multivariate normality is rejected for our data set. Because the multivariate normality prerequisite is not satisfied, we use the Asymptotically Distribution-Free estimator (ADF), which assumes a no-normal distribution of variables, to estimate the path loadings of our structural model. The goodness-of-fit indices (Table 4) demonstrate that the chosen structural model is consistent with the data. All fitting indices have surpassed their recommended values. In terms of hypothesised links between the measured and latent variables and their statistical significance, all links showed significance paths at p-value < 0.001 (Annex 4). In other words, territorial development level (exogenous key construct), port assets (endogenous key construct), and port reputation (subjective key construct) all influence the attractiveness of a port.

Figure 5 provides the path loading diagram along with estimated unstandardised coefficients for the estimation of port attractiveness. Errors covariances were established through exploratory approach. The SEM analysis has suggested the introduction of a number of correlated errors which were accepted if the model's fit improved and the correlated error was supported by observed circumstances. For example in Figure 5 we establish a correlated error between Corruption and Time in Customs because we expect that bureaucratic countries, where time in customs are longer due to the number of documents required and inefficient systems, have higher levels of corruption (Martini, 2013).

Annex 4 reports on the path parameters and error co-variances. All parameter signs are consistent with the expected values.

We can now evaluate for our case study of the Africa ports the relative importance of each key factor and measured variable. The territorial development surrounding an African port is the major factor for determining port attractiveness (path coefficient 1.00). Port assets are as important as port reputation (path coefficients of 0.78 and 0.71, respectively). In the case of the key determinant, port reputation, the capacity of a port to be integrated in the international shipping network (LSCI) is four times more important than port quality. Thus, in order to increase port attractiveness, port operators need to develop a wide network of commercial relationships with other ports. Providing effective services (port quality coefficient = 0.25), ports can also benefit from the positive word-of-mouth effect: ports become more attractive when they function as hubs (i.e., carriers can exploit cooperative schemes in those ports), and they benefit from tacitly being promoted in the industry through a multiplier networking mechanism (Huck and Tyran, 2003). On the other hand, piracy is clearly a negative factor for the reputation of African ports (path coefficient = -0.70). Ship owners try to avoid areas and ports that are risky with regard to piracy attacks (high density of incidents); they also consider rerouting in order to avoid hijacks and high insurance premiums (Parmar, 2012). We mentioned in the Introduction that scholars have considered port infrastructure assets as a main determinant of port attractiveness. An interesting finding emerges from our study: port assets count as much as port efficiency (in our case the path loading is negative because the longer a good is held in customs the worse is its efficiency). This is not surprising; ports with good infrastructure assets (storage area, berths, cranes, etc.) but inefficient operations are less productive and thus able to handle less container traffic. Finally, territorial development is mainly assessed through GDP and number of Internet users. The level of corruption, although significant, does not have a major impact on territorial development (path coefficient -0.07). This finding is in accordance with a recent research, which points out that 'corruption may have little average effect on the growth rate of GDP per capita,' although it limits the capacity of a country to grow (Aidt, 2009).

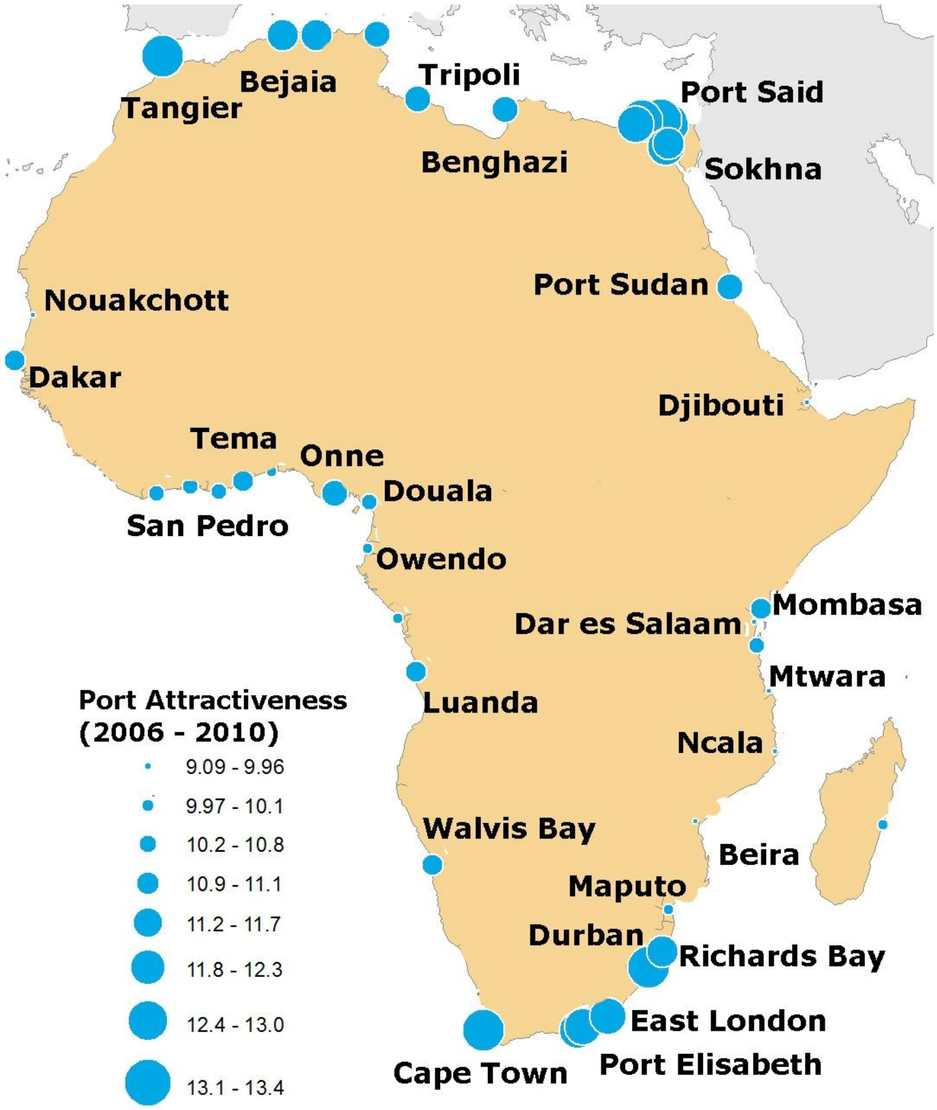
4.1. Results of Port Attractiveness Index in Africa

The Port Attractiveness Index (Φ) expressed by equation 1 has been rooted to the causality relationships among the determinants of Africa port attractiveness that we have scrutinised through SEM. Figure 6 depicts the average value of the Port Attractiveness Index for the time period 2006-2010, and each blue circle is proportional to the value of the Index. We observe that the main ports in Africa are clearly situated in North and South areas of the continent. Such an obvious dichotomy is primarily due to the strategic positions of these ports along the main transatlantic shipping corridors. But their geographically advantageous positions have been augmented by the implementation of strategic investments for advanced logistics infrastructures and fixed capital investments, as can be witnessed for the ports of Sudan, Dakar and Onne. Ports in central Africa (both west and east coast) suffer low levels of attractiveness, and if we compare this result with level of piracy activity, we observe that the less attractive ports are also situated near areas of higher piracy activity (Annex 5).

The ranking and relative change in the Port Attractiveness Index between 2006 and 2010 is reported in Figure 7 for 25 ports that cover the observation period 2006-2010 (we have reported the complete ranking for all ports included in our study in Annex 6). Although the main ports in Egypt and South Africa occupy the first five positions in the ranking, we can nevertheless observe that a few North African ports show negative performances. Algier has moved from the 8th position in 2006 to 13th in 2009 (11th in 2010); Rades from 15th in 2006 to 20th in 2009. This trend is certainly related to the opening of the new port of Tangier in Morocco, which launched its operations in July 2007 and has been able to take relevant container market share from the other ports. The new port of Tangier in Morocco is already positioned in the middle-upper part of the ranking.

Other ports have lost their positions in the ranking, including East London (South Africa), Dakar (Senegal) and Abidjan (Ivory Coast). As discussed in section 3.1, South Africa is a special case in our study because we assume that the national GDP can be used as indicator of the hinterland economic development of South African ports. In the case of South Africa the National Institute for Statistics (Statistics South Africa, 2011) provides us with the GDP of each province. Because of lack of detailed information on the hinterland and catchment areas of each South Africa port, we have assumed that the hinterland of each port corresponds to the province where the port is located. Corruption and level of Internet access are assumed to be unvarying across South Africa. Figure 8 reports the values of Port Attractiveness Index (in 2010) which have been calculated by using the same path loadings obtained from the SEM analysis in Figure 5.

Figure 6. Geo-referred visualization of port attractiveness index

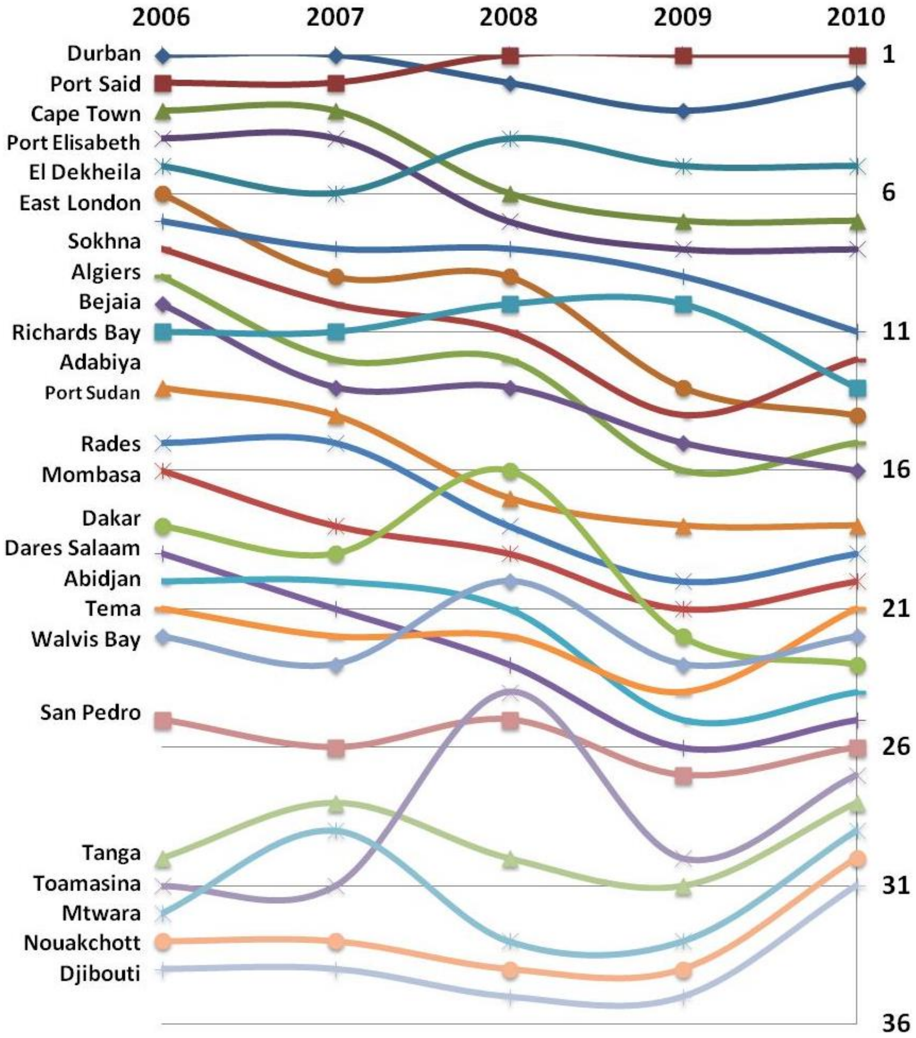


Source: Authors elaboration.

Comparing the results in Figures 7 and 8, the latter analysis provides more reliable results. For example the port of East London appears less attractive with the new calculations. According to Eastern Cape Province,[10] the East London port infrastructure has been receiving less and less foreign investment, and many of the containers destined for East London are often diverted to Port Elizabeth, Durban and Cape Town which are the major gateways of South Africa.

[10] Source retrieved from: www.dedea.gov.za

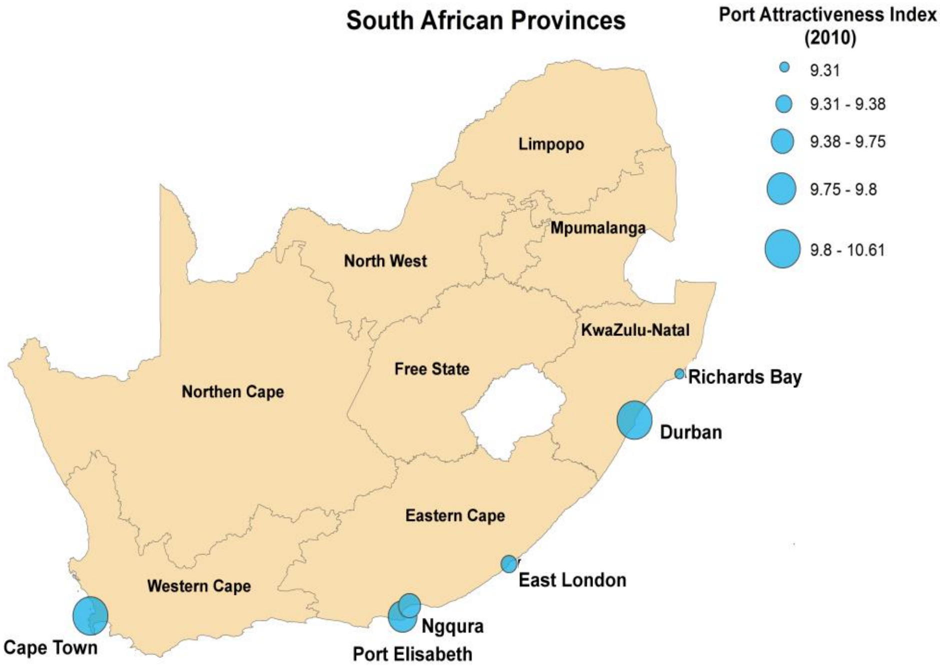
Figure 7. Ranking of Port Attractiveness Index



Source: Authors elaboration.

In West Africa, Dakar is the most congested port due to its strategic geographic position. The African Development Bank recently loaned EU47.5 million for the upgrade of Dakar's container terminal. In the case of Abidjan, its loss in port attractiveness is generated by internal civil conflict. After the November 2010 presidential election, the UN stationed 9,000 peacekeeping personnel on the Ivory Coast. This political instability is worsened by neighbouring conflicts in Sierra Leone and Liberia. When we examined the performance of other regions, an interesting case is the port of Nacala, which has jumped from 32nd position in 2006 and 2007 to 10th and 8th in 2009 and 2010, respectively. Nacala's rise in the Port Attractiveness Index is due to significant investment of the Mozambique government towards developing efficient national multimodal transport networks. The strategic position of ports in Mozambique indicates that transport costs are 60% cheaper than average Sub-Saharan countries, and logistics efficiency is 70% faster than average Sub-Saharan countries. These ports are rapidly emerging as major gateways for the corridors connected to land-locked countries, such as Zimbabwe, Zambia and Malawi, and therefore increasing in influence within the global trade market (Domeniguez-Torres and Briceño-Garmendia, 2011).

Figure 8. Port Attractiveness Index in South Africa considering the economic characteristics of ports' hinterland

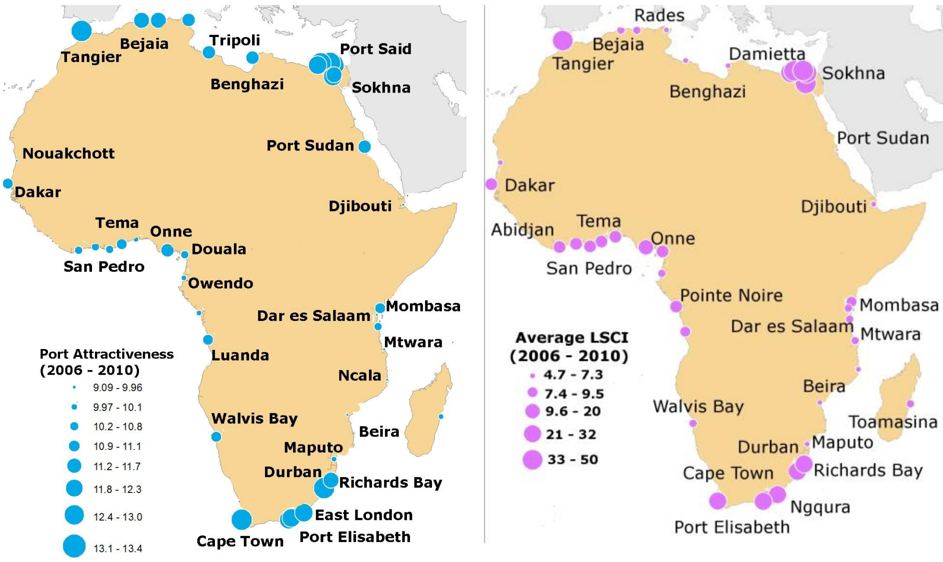


Source: Authors elaboration.

4.2. Comparison of Port Attractiveness Index with antagonistic approaches and indicators

One of the innovative characteristics of the Port Attractiveness Index is that it allows for the introduction of quantitative variables related to the ports and their hinterlands and also subjective variables (i.e., accountability, corruption, etc.). By combining these two types of information and data we are able to overcome the problems of partial overviews of the ports, as in the cases of strictly quantitative methods and also avoid expensive and time consuming field survey analyses. For instance, using a survey methodology, Sequeira and Djankov (2010) have studied the impacts of corruption in the competing ports of Durban and Maputo. Although both ports have similar infrastructural facilities and are equidistant from the booming South African provinces of Gauteng, Kwazulu-Natal and Mpumalanga, the port of Durban has a much higher yearly throughput than Maputo. Sequeira and Djankov (2010) note from the survey analysis that some firms prefer to travel, on average, an additional 322 kms in order to avoid 'coercitive' and 'collusive' corruptions in the port of Maputo. Conversely, Sequeira and Djankov (2010) reckon that the port of Durban, with its large hinterland catchment area, therefore has greater attractiveness than Maputo. When we compare the results of Sequeira and Djankov with our Port Attractiveness Index, we observe that our results are in line with theirs, but in our case we did not have to collect data in the field. Between 2006 and 2009, Durban ranks between first and third position in the general ranking, while Maputo between 27th and 29th position (Figure 7 and table E1).

Figure 9. Comparison between Port Attractiveness Index (on the left) and Liner Shipping Connectivity Index (on the right)



Source: Authors elaboration.

This is an important outcome for analysts and operators, particularly in developing countries, where the collection of survey data is an often troublesome operation. If we now compare the Port Attractiveness Index with the commonly and widely used Liner Shipping Connectivity Index (LSCI) developed by UNCTAD, we again notice a very similar behaviour between LSCI and Port Attractiveness Index for the ports of Durban and Maputo (Figure 9, we assume our comparison based on the concept that the more a port is connected with the international trade network, the higher is its attractiveness). However, we observe some discrepancies between the Port Attractiveness Index and LSCI. In particular, for West African countries the LSCI values are homogenous, whereas the Port Attractiveness Index is able to better differentiate among the different characteristics of the ports of this area. Dakar, Tema, Onne and Luanda are the most ‘attractive’ ports of the area (2006-2010). In North Africa we have similar results; the LSCI index is quite homogeneous in this area. However, the Port Attractiveness Index allows us to verify that the ports in Egypt and Morocco dominate the area, while ports in Algeria, Tunisia and Libya show a much lower attractiveness performance. The Port Attractiveness Index is therefore able to discriminate more clearly among the various characteristics of each port in order to provide a more comprehensive overview of the port characteristics.

In Figure 10 we summarize port characteristics and Port Attractiveness Index for the ports of Dar Es Salaam, Durban and Mombasa. We use these three cases to compare the benchmark of Port Attractiveness Index versus LSCI. Durban has highest values in both indices due to better infrastructure and economic conditions. Dar Es Salaam and Mombasa are very similar in terms of infrastructural endowment, national economic conditions and characteristics ascribable to port reputation. This characteristics are concisely represented in the Port Attractiveness Index and the figures are confirmed in the LSCI.

Figure 10. Summary of port characteristics for three ports in South-Eastern Africa

DAR ES SALAAM	DURBAN	MOMBASA
Throughput: 348,700	Throughput: 2,508,000	Throughput: 599,050
Area: 180,000 m^2	Area: 1,960,000 m^2	Area: 220,000 m^2
Quays: 1	Quays: 9	Quays: 5
Tot length berths: 549 m	Tot length berths: 2,651 m	Tot length berths: 596 m
Time in customs: 31 days	Time in customs: 35 days	Time in customs: 30 days
Corruption index: 2.88	Corruption index: 5.2	Corruption index: 7.8
National GDP: 19,259,000 US$	National GDP : 293,782,000 US$	National GDP : 28,098,000 US$
Internet users: 8.6 %	Internet users: 9 %	Internet users: 12 %
LSCI: 9.98	LSCI: 29	LSCI: 11
Port quality index: 3.01	Port quality index: 4.5	Port quality index: 3.6
Piracy attacks: 2	Piracy attacks: 0	Piracy attacks: 33
Attractiveness index: 10.6	Attractiveness index: 13.34	Attractiveness index: 11.06

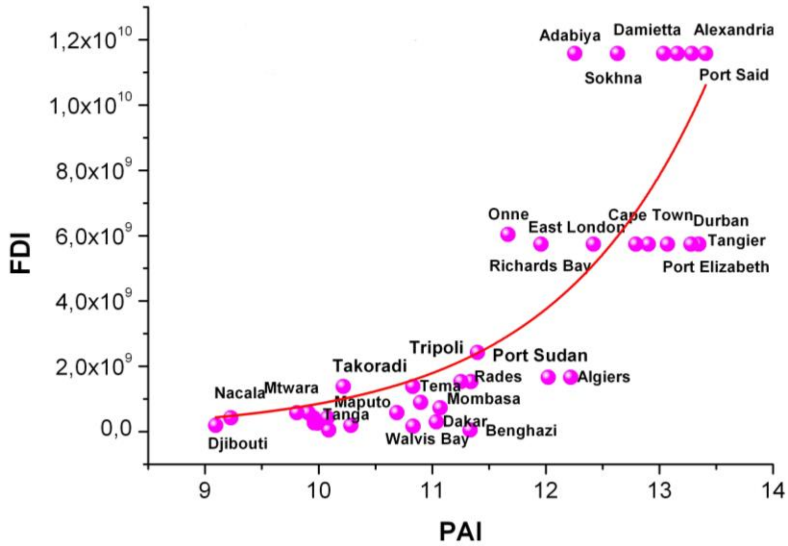
Source: Authors elaboration.

4.3. Port Attractiveness Index and Foreign Direct Investments

Finally, we want to conclude by examining the possible correlation between the Port Attractiveness Index and financial investment in ports. To conduct this analysis, we consider the World Bank Foreign Direct Investment (FDI) data and the evaluated Port Attractiveness Indices. In Figure 11 we plot our results.

There is an exponential positive correlation between the two variables (Pearson’s correlation coefficient = 0.81) which indicates that higher values of the Port Attractiveness Index stimulate foreign direct investment. In other words, investors will prefer to invest in ports where the financial risks are leveraged by good “hard and soft” infrastructure, as indicated by the high values of the Port Attractiveness Index.

Figure 11. Correlation between average Port Attractiveness Index (PAI) and average Foreign Direct Investment (FDI)



Adjusted R^2 *= 0.67. Regression curve:* $Y = 5.3e^{5.2} * 2.09^{X}$
Source: Authors based on World Bank data base).

The proposed approach of the Port Attractiveness Index demonstrates that, not only is it possible to develop a robust methodology able to combine different forms of data in order to evaluate and weigh the different determinants influencing port attractiveness in a more comprehensive way, but it also proves that the Index can be used as a practical tool for operators and investors when they make financial decisions and investments.

5. CONCLUSION

Port attractiveness is often described as a combination of different sources of information and experiences in the assessment of port operations and investment potentiality. We have proposed here a new method to evaluate the attractiveness of a port by applying structural equation modelling (SEM). We have examined port attractiveness as a function of endogenous, exogenous and subjective variables. We have tested the hypothesis that port attractiveness not only depends on port infrastructural characteristics but also on a number of subjective determinants such as user perception of a port (i.e., reliability and safety). Several authors have already studied the influence of port perception on users' choice through surveys. The novelty that we have introduced in this analysis has consisted of an examination of the structural relationships among three classes of variables (endogenous, exogenous and subjective) collected from different data sources, i.e., World Bank, Containerisation International and UNCTAD. The parameters obtained from the SEM analysis were then used to generate the Port Attractiveness Index. We have applied this methodological approach to a set of 41 container ports in 23 African countries for the period 2006-2010. Results have shown that endogenous, exogenous and subjective variables can be used to estimate a population of covariance matrix that is highly similar to the sample covariance matrix. In other words, we have demonstrated that the three classes of determinants (modelled as latent variables) are suitable in the measurement of port attractiveness and can be used to build a quantitative indicator. Among the three latent variables, exogenous variables (which represent the level of development of ports' hinterlands) are the most influential; this means that in order to be economically successful a port has to strengthen the freight traffic and business from its catchment area (hinterland). As a consequence, the ports with close ties to their hinterlands will not merely develop and operate as transhipment ports. In the evaluation of the index, endogenous and subjective variables have shown a similar importance, which indicates that if we consider the combined cumulative relevance of exogenous and subjective variables, they count more than the infrastructural endowment of a port (i.e., endogenous key construct in our model). This finding leads us to the following policy recommendations for stakeholders, policy makers and planners: to increase the attractiveness of a port, governments should first address the implementation of soft infrastructures rather than hard ones. The Port Attractiveness Index calculated for the 41 container ports of our study, shows that ports in Egypt and South Africa always occupy the first five positions. A few North African ports have shown negative performance within the time frame of this research. When we have examined the performance of other regions, however, we have spotted some interesting cases. Nacala port jumped from 32nd position in 2006 and 2007 to 10th and 8th in 2009 and 2010, respectively. This finding can be explained by the strategic positioning of Nacala port within the recently improved multimodal infrastructure corridors which connect landlocked neighbours such as Zimbabwe, Zambia and Malawi. We have also argued the significance of the Port Attractiveness Index in relation to investment decisions and strategies, for instance, Foreign Direct Investments correlates positively with port attractiveness.

Beneficial future research would be to evaluate the Port Attractiveness Index and extend the analysis worldwide to a larger set of ports which considers industrialised, developing and lagging countries. Furthermore, due to the similarities between the maritime and aviation industries, we also plan to extend the application of the Port Attractiveness Index to study airport attractiveness.

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ANNEX 1.
Structural Equation Modeling (SEM)

SEM consists of two processes: validation of the model measurements (factor analysis) and fitting the structural model (path analysis with latent variables). The core of SEM methodology is parameter estimation, which consists of the comparison of the covariance matrices of observed variables with the estimated covariance matrices of the best fitting model. Up to three sets of simultaneous equations can be evaluated in the estimation of the model's path loadings:

- a measurement model for the dependent variables;
- a measurement model for the independent variables;
- a structural model.

The combination of a measurement model and a structural model is applied in SEMs with latent variables. In the case of observed variables, the SEM is composed of a structural model without any measurement models. Confirmatory factor analysis is implemented through a measurement model. In general, there are no constraints on the number of dependent and independent variables that a SEM can incorporate. In the measurement model the dependent variable y_i is related to the vector of latent variable η_i as follows:

$$y_i = v + \Lambda\eta_i + Kz_i + \varepsilon_i \qquad \text{(A1)}$$

where v is a vector of intercepts; Λ is a $n \times m$ matrix of so-called factor loadings (the correlation coefficients between the variables and unobserved factors); z_i is the vector of observed covariates; and ε_i is a vector of measurement errors which follows a normal distribution. The matrix K contains regression coefficients that describe direct effects of the independent variables (z_i) on the latent variables.

The structural part of the model describes the relation between the latent variables (η_i) and the independent variables z_i:

$$\eta_i = \alpha + B\eta_i + \Gamma z_i + \zeta_i \qquad \text{(A2)}$$

Here α is the intercept and B is an $m \times m$ matrix of regression coefficients describing the relation between the latent variables. The diagonal elements of this matrix are zero and I - B is non-singular. Independent variable coefficients are given by the $m \times q$ matrix Γ. Finally, ζ_i is an m-dimensional vector of residuals, which is assumed to be independent from the error vector ε_i.

Equations A1 and A2 are resolved interactively through the minimisation of the differences between the sample variance-covariance matrix and the model replicated matrix. The minimisation is achieved through methods such as maximum likelihood, generalised least squares or weighted least squares.

A number of tests are used in our analysis to evaluate whether a structural model is consistent with the data. Kline (2011) identifies two categories of tests: (1) Model test statistic (i.e., Chi-Square); (2) Approximate fit indexes (i.e., RMSEA, GFI, CFI and SRMR).

It is beyond the scope of this paper to discuss each of the tests in the two categories. Readers who are unfamiliar with SEM fitting tests can find appropriate references in Kline (2011) and in articles published in specialised scientific media, particularly Structural Equation Modelling: A Multidisciplinary Journal.

Finally, one can find several software and statistical packages already developed for implementing SEM (i.e., EQS, LISREL, MPlus. etc.). In this study we use SPSS Amos version 20.

ANNEX 2.
List of the 41 ports used in the study

Country	Port
Algeria	Algiers, Bejaia
Angola	Luanda
Benin	Cotonou
Cameroon	Douala
Congo	Pointe Noire
Cote d'Ivoire	Abidjan, San Pedro
Djibouti	Djibouti
Egypt	Adabiyah, Alexandria, Damietta, El Dekheila, Port Said, Sokhna
Gabon	Owendo
Ghana	Takoradi, Tema
Kenya	Mombasa
Libya	Benghazi
Madagascar	Toamasina
Mauritania	Nouakchott
Morocco	Tangier
Mozambique	Beira, Maputo, Nacala
Namibia	Walvis Bay
Nigeria	Onne
Senegal	Dakar
South Africa	Cape Town, Durban, East London, Ngqura, Port Elizabeth, Richards Bay
Sudan	Port Sudan
Tanzania	Dar es Salaam, Mtwara, Tanga
Tunisia	Rades, Tripoli

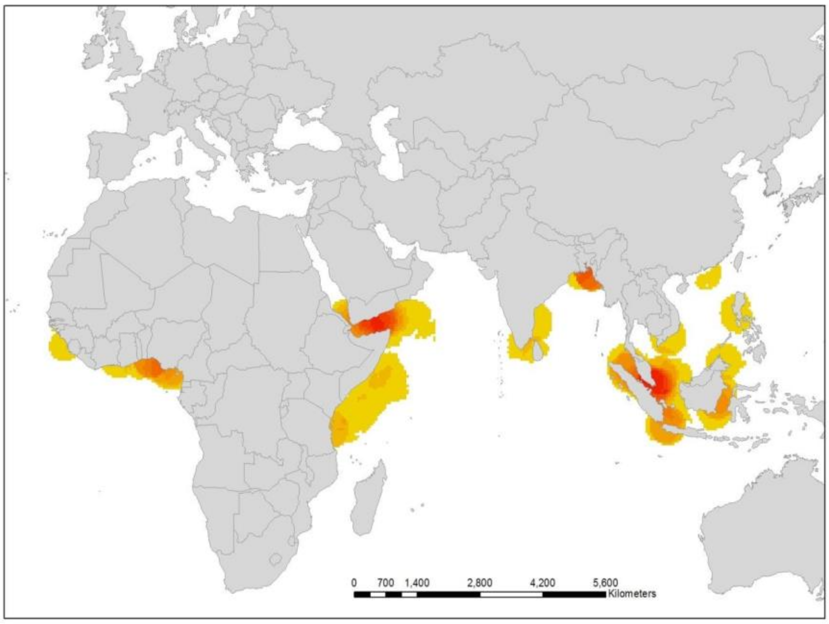
ANNEX 3.
Relevant statistics of variables

	N	Min	Max	Mean	Std. Devia-tion	Vari-ance	Skew	Kurto-sis
Throughput	165	3,332	3.6E6	455,872	675,649	4.565E11	2.742	7.466
Port area	165	5,000	4.4E6	435,868	766520	5.876E11	3.561	14.390
Number of quays	165	1	15	4.04	3.48	12.12	1.562	1.929
Berth size	165	150	3,461	996.90	817.76	668,74	1.239	0.342
Water depth	165	8.5	17	12.03	2.11	4.44	0.574	-0.091
Time in customs	165	12	66	29.32	9.742	94.90	0.475	0.796
Corruption	165	1.6	5.1	3.193	0.897	0.805	-0.596	-0.750
LSCI	165	4.709	52.534	21.037	15.445	238.548	0.861	-0.720
Port Quality	165	2	5.64	3.690	0.820	0.671	0.195	-1.166
GDP	165	768,874	3.6E8	1.008E8	1.078E8	1.162E16	0.852	-0.591
Piracy	165	0	158	11.96	23.59	556.657	3.311	13.142
Total Invest	165	8.685	50.027	23.198	7.912	62.60	0.967	2.001
Consumer price index	165	8.957	2,093	206.81	219.688	48,262.81	5.709	41.599
Imports goods	153	1.6E8	9.057E10	2.77E10	2.778E10	7.718E20	0.904	-0.471
Exports goods	153	5.517E7	8.612E10	2.673E10	2.871E10	8.201E20	0.935	-0.604

ANNEX 4. Model estimates

			Estimate	S.E.	C.R.	P
Port assets	<---	Port attractiveness	.777	.107	7.287	***
Territorial Development	<---	Port attractiveness	1.000			
Port reputation	<---	Port attractiveness	.705	.049	14.269	***
GDP	<---	Territorial Development	1.000			
LSCI	<---	Port reputation	1.000			
Piracy	<---	Port reputation	-.696	.155	-4.478	***
Port Quality	<---	Port reputation	.247	.020	12.572	***
Internet users	<---	Territorial Development	.586	.048	12.139	***
Time in customs	<---	Port assets	-.116	.034	-3.372	***
Throughput	<---	Port assets	1.000			
Corruption inverted	<---	Territorial Development	-.069	.010	-6.570	***
Port Area	<---	Port assets	.113	.020	5.811	***
ErrQ	<-->	ErrC	-.002	.000	-5.608	***
ErrP	<-->	ErrG	-.143	.017	-8.215	***
ErrI	<-->	ErrG	.075	.010	7.492	***
ErrP	<-->	ErrC	.009	.002	5.448	***
ErrCu	<-->	ErrG	.013	.004	3.430	***
ErrG	<-->	ErrC	-.008	.001	-6.227	***
ErrCu	<-->	ErrC	-.001	.000	-3.476	***
ErrI	<-->	ErrCu	-.020	.003	-7.254	***

ANNEX 5. Density map of piracy attacks



Legend: Lighter to darker areas correspond to denser zone of attacks.
Source: Authors elaboration on U.S. National Geospatial-Intelligence Agency data set.

ANNEX 6.
Port Attractiveness index ranking

2006	2007	2008	2009	2010
Durban	Durban (=)	Port Said (+)	Port Said (=)	Port Said (=)
Port Said	Port Said (=)	Durban (=-)	Damietta (=+)	Durban (=+)
Cape Town	Cape Town (=)	Damietta (+)	Durban (=-)	Damietta (=-)
Port Elizabeth	Port Elizabeth (=)	El Dekheila (+)	Alexandria (=+)	Alexandria (=)
El Dekheila	Damietta	Alexandria (+)	El Dekheila (=-)	El Dekheila (=)
East London	El Dekheila (=-)	Cape Town (-)	Tangier	Tangier (=)
Sokhna	Alexandria	Port Elizabeth (-)	Cape Town (=)	Cape Town (=)
Algiers	Sokhna (=-)	Sokhna (=)	Port Elizabeth (=)	Port Elizabeth (=)
Bejaia	East London (-)	East London (=)	Sokhna (=)	Nacala (+)
Richards Bay	Algiers (-)	Adabiya (=+)	Adabiya (=+)	Ngqura (+)
Adabiya	Adabiya (=)	Algiers (=-)	Nacala (++)	Sokhna (-)
Onne	Bejaia (-)	Bejaia (=)	Ngqura	Algiers(+)
Port Sudan	Richards Bay (-)	Richards Bay (=)	East London (-)	Adabiya (++)
Benghazi	Port Sudan(=-)	Tripoli (+)	Algiers (-)	East London (=-)
Rades	Rades (=)	Benghazi (+)	Richards Bay (=-)	Bejaia(=+)
Mombasa	Tripoli	Dakar (+)	Bejaia (-)	Richards Bay (=-)
Luanda	Benghazi (-)	Port Sudan (-)	Benghazi (-)	Onne (+)
Dakar	Mombasa (-)	Rades (-)	Port Sudan (=-)	Port Sudan (=)
Dar es Salaam	Dakar (=-)	Mombasa (=-)	Onne (--)	Rades (=+)
Abidjan	Abidjan (=)	Walvis Bay (+)	Rades (-)	Mombasa (=+)
Tema	Dar es Salaam (-)	Abidjan (=-)	Mombasa (-)	Tema (=+)
Walvis Bay	Tema (=-)	Tema (=)	Dakar (--)	Walvis Bay (=+)
Douala	Walvis Bay (=-)	Dar es Salaam (-)	Walvis Bay (-)	Dakar (=-)
Takoradi	Takoradi (=)	Toamasina (+)	Tema (-)	Abidjan (=+)
San Pedro	Douala (-)	San Pedro (=+)	Abidjan (-)	Dar es Salaam (=+)
Pointe Noire	San Pedro (=-)	Douala (=-)	Dar es Salaam (-)	San Pedro (=)
Owendo	Maputo (+)	Maputo (=)	San Pedro (-)	Toamasina (=)
Cotonou	Tanga (+)	Beira (+)	Maputo (=-)	Tanga (=)
Maputo	Mtwara (+)	Cotonou (=-)	Douala (-)	Mtwara (=)
Tanga	Beira	Tanga (-)	Toamasina (--)	Nouakchott (=)
Toamasina	Toamasina (=)	Owendo (-)	Tanga (=-)	Djibouti (=)
Mtwara	Nacala	Nacala (=)	Owendo (=-)	
Nouakchott	Nouakchott (=)	Mtwara (-)	Mtwara (=)	
Djibouti	Djibouti (=)	Nouakchott (=)	Nouakchott (=)	
		Djibouti (=)	Djibouti (=)	

Legend. Trends: extremely positive ++, positive +,stable =, negative -, extremely negative --

L'INDICE D'ATTRACTIVITÉ PORTUAIRE : UNE APPLICATION AUX PORTS AFRICAINS

Résumé - *La réputation d'un port est fondée sur des facteurs objectifs, tels que son niveau d'infrastructures et l'efficience de la chaîne logistique, ainsi que sur des facteurs subjectifs comme la fiabilité et le niveau de corruption perçus par les utilisateurs. Dans ce travail, nous avons analysé la notion d'attractivité portuaire en partant de l'hypothèse que les déterminants subjectifs et les facteurs objectifs – endogènes (longueur et nombre de quais...) et exogènes (PIB...) – peuvent être quantifiés ensemble. Nous avons déterminé l'indice d'attractivité portuaire à partir d'un échantillon de 41 ports à conteneur de 23 pays africains, pour la période 2006-2010. Pour cela nous avons appliqué une approche ascendante* (bottom-up) *pour étudier les relations structurelles entre les trois ensembles de déterminants (endogènes, exogènes et subjectifs) qui ont un impact sur l'attractivité portuaire. Les résultats obtenus du modèle indiquent que les facteurs subjectifs ont une influence importante sur l'attractivité portuaire. Il apparaît alors que dans de nombreux ports africains, les gouvernements devraient d'abord développer des infrastructures « soft » plutôt que d'investir dans des infrastructures « hard ».*

Mots-clés - TRANSPORT, COMMERCE MARITIME, RÉPUTATION PORTUAIRE, AFRIQUE, MODÉLISATION PAR ÉQUATION STRUCTURELLE