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Shifting proximities. Visualizing changes in the maritime connectivity of African countries (2006/2016)

David Guerrero⁺¹, Patrick Niérat⁺, Jean-Claude Thill[‡] & Emmanuel Cohen⁺

⁺Université Gustave Eiffel, IFSTTAR, AME-SPLOTT

[‡]University of North Carolina at Charlotte, Department of Geography & Earth Sciences

Abstract

As a process, containerization in Africa is still on-going. In the last decades, a number of new port projects have emerged in parallel with the reorganization of services by shipping companies. To reflect these changes, this paper studies several questions on the geographic differentiation of maritime connectivities across the continent as well as on the longitudinal trends in maritime connectivities in relation to evolving economic, trade and logistical contexts. To this end, we propose a synthetic visualization of the country-level containerized links using the Liner Shipping Bilateral Connectivity Indicator (LSBCI). The resulting graph, obtained through Multidimensional Scaling (MDS), shows that West Africa and East Africa appear as relatively separated subsystems, mediated by several countries in the Northern and the Southern parts of Africa. Between 2006 and 2016, West Africa, initially tied to Europe and America, is increasingly tied to Asia. Our results show major improvements in the maritime connectivity of Morocco, Djibouti and several West African ports. Conversely, most of mainland East African countries stagnate or decline. Connectivities have not converged across the continent. In some cases changes in maritime connectivity mostly result from variations in vessel size. We explore a method to identify these situations.

Keywords: *Containerization, Connectivity, Africa, Development, LSBCI, Vessel size.*

¹ Corresponding author (david.guerrero@univ-eiffel.fr)

1. Introduction

The shift from general cargo to container shipping is still on-going in Africa. Until recently, general cargo vessels dominated the regional trade of manufactured goods. For shipping companies, Africa was considered as a niche market, characterized by low and uncertain demand. For shippers, poor infrastructure and ineffective ports resulted in such a transport-cost disadvantage that even low labor costs would fail to attract investment in manufacturing (Levinson, 2016). After unsuccessful attempts in the 1960s, Africa started its first wave of containerization in the late 1970s, a process mainly driven by overseas exporters aiming to protect their high-value manufactured goods from theft and bad weather conditions (Pedersen, 2003). Furthermore, shipping companies aiming to reduce the rate of empty containers, encouraged the containerization of the exports of agricultural goods. However, the container was not well suited to African economies. The overall low value of goods, the abundant and cheap labor at ports and the lack of handling equipment of most shippers did not favor the expansion of containerization. Furthermore, the structural crises of African countries during the 1970s and 1980s heavily hampered the much needed investments in port infrastructure (Castillo-Hidalgo and Ducruet, 2020).

The conditions for containerization became more favorable in the late 1990s and early 2000s. The inflow of large foreign investments and the deployment of services by shipping lines resulted in a dramatic increase in the maritime connectivity of the region. There is some debate among scholars about the ways in which maritime shipping connectivity has improved in Africa (Mboya, 2021). Some argue that connectivity improvements have mainly affected the connections of Africa with Asia, but without significantly changing the connectivity within Africa and with other world regions. Others offer the counter-argument that the enhancement of maritime connectivity of Africa with Asia also leads to an improvement of connectivity among African countries as well as with other regions (Kuo, 2017, cited by Mboya, 2021). This research aims to shed light on this debate by proposing a synthetic approach to bilateral connectivity of African countries and associated visualization forms, and on how it has changed in recent years. Recent work on African ports has emphasized the need for more research in this area to understand what specific regions of Africa are linked to certain parts of the world; other issues of interest concern the emergence of preferential linkages, and their evolution over time (Olukoju and Castillo-Hidalgo, 2020). Furthermore, within the field of port geography, there are still few studies seeking to understand the ways in which containerization has reshaped Africa's connectivity during the last two decades. This paucity of port geography research is all

the more striking in view of the number of works devoted to Africa in former periods, such as in the 1950s-1970s (Ng and Ducruet, 2014).

This paper uses the Liner Shipping Bilateral Connectivity Index (LSBCI) published by UNCTAD, as a way to synthetically apprehend the linkages of African countries among each other, but also between them and the rest of the World. To improve the readability of the visualization forms produced through this process, we propose a grouping of non-African countries. In the context laid out above, our specific research questions include the following: Is maritime connectivity uneven across African countries; Is there a regional dimension in the quality of maritime connectivities across Africa; Is maritime connectivity with regions outside the African continent similar to connectivities internal to the continent; Has maritime connectivity evolved towards a convergence or a divergence during the decade of 2006-2016; Can changes in maritime connectivities be ascribed to technological and operational changes (like the increase in vessel capacity) and to China's ambitious infrastructure investments.

The rest of the paper is organized as follows. The next section presents a review of the extant literature. Then, we introduce some background on African freight ports and the methodology for the analysis of LSBCI data used in this study. Next, we present an overview of our results, and we finally draw the conclusions of this research.

2. Literature review

2.1 Maritime connectivity and port systems

Dating back to the pioneering work of Robinson (1970), Vigarié (1979), Bird (1980), Charlier (1992), and others, it has been well recognized that ports do not operate in isolation from each other, and exhibit close operational and structural connections both with their hinterland and their foreland. They are nodes where vessels call between voyages to and from other sea ports, which constitute maritime networks that span regional and global scales. The quality of the maritime services that operate between ports is what make these networks true systems that function with a strong degree of interdependence. This quality encompasses various aspects, including the frequency of services, the number and variety of operators, and the capacity of shipping vessels that are deployed on various routes. These various aspects are commonly referred as measures of the maritime connectivity. There is a direct correspondence with the node-based measures of centrality and connectivity used in network science (Taaffe et al, 1996,

Rodrigue, 2020). The LSBCI metrics constitute a recent comprehensive effort at depicting maritime connectivity across the globe at the granularity of countries.

The study of maritime connectivities has become one of the well-established traditions in maritime economics and maritime geography, with the recognized aims to identify spatio-temporal structures in maritime networks locally and globally, to identify how they respond to broader economic and trade trends such as globalization and technological and organizational changes, and to articulate theories on how spatial economies evolve. Some of the notable recent literature along this line of scientific inquiry includes Notteboom and Rodrigue (2005), Ducruet et al (2010), Hesse (2010), Ducruet and Notteboom (2012), Ducruet et al (2018), Jung et al (2018), Jung and Thill (2022), and others.

2.2 The path dependency of the colonial networks

African ports were initially created for exploitation by foreign powers. As early as the 17th century, the ports of the region were purposed primarily for the slave trade as well as the evacuation of the continent's natural resources to the colonial powers. Later on, during the colonization, the development of port infrastructure served by railroads and a network of trails allowed competing colonial powers to carry out their extractive and export activities (Debie, 2010). Infrastructure networks were typically built from the resource sources to port gateways and there was no incentive for colonists to integrate infrastructure in a manner that would increase self-reliance and intra-regional trade (Oliete and Magrinya, 2018), especially given the overt rivalry between colonial powers. Taaffe et al (1963) envisioned the post-colonial evolution of transport connections from an initial setting of weakly interconnected ports to an integrated sea-land network. However, after more than half a century, the logistical integration of Africa remains far from achieved (Debie, 2010, Oliete and Magrinya, 2018).

This extraverted structure of African transport networks favored a certain hierarchy of ports, which has remained remarkably stable in the long term. Using an impressive dataset containing port throughput and vessel calls from 1880 to recent times, Castillo-Hidalgo and Ducruet (2020) showed that ports from Morocco, Egypt and South Africa were already prominent at the turn of the 19th Century. They also found that, with few exceptions, most of the ports built during the colonial era survived and even became major gateways in the age of containerization, such as Tema, Ghana. Alternatively, the authors also brought up examples of successful hub development such as Tangier-Med in Morocco, but reminded us that the 'old' Casablanca remains the main gateway of the country. Hence, despite the technical and organizational changes in

land and maritime transport, the port calls and throughputs have remained concentrated on the dominant ports, with few signs of spread down the ranks of lesser ports.

2.3 The container: a tool for economic decolonization?

There is an open debate on the ways in which containerization has affected African economies. While the most optimistic view underscores the power of the container as a way to reduce Africa's economic dependence on former colonial powers, others stress its high costs and the risks of heightened dependence of local economies through the compounded effect of debt trap and focused international connectivity.

Recent analysis by historians has brought new insights into this debate by suggesting a strong link between containerization and the effective economic decolonization of countries. In recent work centered on the case of a British shipping company, White (2019) examined how the container was progressively adopted in the 1970s for maritime connections between Britain and the Dominions. On the one hand, British shipping companies used containerization as a strategic tool to save their core business and preserve Commonwealth links which were threatened by post-colonial globalization. On the other hand, Dominions such Australia and New Zealand used the container to diversify their trade links and to reduce transport costs, especially when the integration of the United Kingdom within the European Community threatened the loss of Commonwealth preference (White, 2019). Other newly independent countries, such Malaysia/Singapore and Sri Lanka also granted a central role to the container as a tool for the implementation of export-oriented policies (Levinson, 2006).

Although containerization in Africa was slower to materialize, it also greatly contributed to economic decolonization. This trend was confirmed by Ducruet and Tsubota (2020) who showed how African trade shifted to non-European regions starting in the late twentieth century. However, there are significant differences within Africa, the South and the East being more tightly connected with Asia than the rest of the continent (Ducruet and Notteboom, 2012, Niérat and Guerrero, 2019). The increasing orientation of African trade towards China has been examined by Mboya (2021), who highlighted the alarming trade imbalance between China and African countries. This author claimed that the investments made by China in African countries have connected them to China rather than to their regional neighbors. In such a context, he called into question the true beneficiaries of connectivity improvements in the region.

As evidenced by the cases discussed above, containerization in Africa has essentially been driven from the outside. The bulk of African containerized trade was carried by foreign shipping companies and main investments in port infrastructure came from foreign countries. This could be problematic for the resilience and stability of Africa's economic development. The credit terms could function as debt traps that may bring African economies under stronger political control of foreign countries external to the continent. For instance, the fast incorporation of Djibouti in the Maritime Silk Road framework raises questions about the sustainability of the loans that Djibouti contracted with China (Styan, 2020). If containerization unquestionably contributes to decolonization, it also involves a high risk of heightened dependence.

This paper adds to the existing literature by investigating how strongly the different African countries are logistically linked to other parts of the world and how these links have evolved over the 2006-2016 period.

3. General background of African ports

The economies of most of African countries are small and highly reliant on the export of raw materials, which make them particularly dependent on maritime transport. Although bulk throughput is very important in the region, the focus of the present paper is on containerized trade and logistics. Since its early development in the 1970s and its generalization in the 2000s, containerization has contributed to improve the reliability of maritime connections. Africa however remains a minor contributor to the container market (5-6% of global throughput, Drewry's, 2017). Overall, large container ports in the region are very scarce, only nine exceed 1 M TEUs, and 3 exceed 2M TEUs (Deiss, 2022). Two of them are pure hubs: Tangier (Morocco) and Port-Said (Egypt), with transshipment ratios over 90 %. Durban (South Africa) is also a very special case because it provides access to the most advanced regional economy, the Gauteng province, which concentrates 7% of Africa's GDP on 0.6% of its land. Beyond these exceptional cases only Tema (Ghana), Lomé (Togo), Lagos (Nigeria), Pointe Noire (Congo), Damietta (Egypt) and Mombasa (Kenya) reach the annual throughput threshold of 1 M TEUs.

To understand the changes in the maritime connectivity of African countries, at least four processes seem particularly crucial: (1) the investments of foreign terminal operators, (2) the process of vertical integration in ports by certain shipping companies, (3) the establishment of Special Economic Zones (SEZ), and (4) the transshipment patterns varying across the different port ranges.

3.1 Investments of foreign terminal operators in Africa

During the 2000s, the port reforms enacted in African countries have enabled an increased private sector participation in terminal operations. In many cases, the terminals have been transferred to private operators for 20-25 years, although the concession length can be shorter (15 years, San Pedro, Côte d'Ivoire) or longer (35 years, Lomé, Togo), (Farrell, 2014). These concessions are awarded through competitive tendering, which have often been won by foreign operators, usually under partnerships with some local operators. Foreign terminal operators are playing a key role in the containerization of African ports, since they bring with them investments and know-how, which are crucial for connectivity improvements.

Amongst the main foreign terminal operators, Bolloré has a strong position in West Africa, especially in the largest ports of Tema (Ghana) Cotonou, (Benin) Abidjan (Côte d'Ivoire), Lagos (Nigeria) and Pointe Noire (Congo). It is worthwhile noting that the activities of Bolloré in Africa go far beyond the management of port terminals, and also involve freight forwarding and rail transport (Debie, 2014) Another important player is DP World, which operates facilities in North Africa (Djendjen and Algiers, Algeria), Sokhna in Egypt and East Africa (Djibouti, and Maputo, Mozambique). For DP World, the African experience seems overall less positive than for Bolloré, with the abrupt ending of the concession of Doraleh Container Terminal in Djibouti (Barton, 2021) and the more or less successful experiences in Algeria (Mohamed-Cherif and Ducruet, 2016).

3.2 The process of vertical integration in ports by some shipping companies

For top global shipping lines -such as Maersk, CMA-CGM or MSC- Africa makes a fairly low contribution to their activities compared to other regions. Margins are usually higher than in other regions, but they tend to diminish as the number of competitors has increased in recent years. Chen et al (2013) provided evidence of overcharging practices by shipping lines on the Far East-South African sailing route. Reasons cited for the overcharge relate to vessel imbalance factors, load factors (particularly the inability to exploit new generation vessel capacity) and business risks associated with a regional setting that is generally underdeveloped and poorly connected through infrastructure. One means to limit these risks and acquire a competitive advantage over other shipping companies has been vertical integration (Frémont, 2009). Therefore, shipping lines take on the functions of a terminal handling company or an inland transport provider. In Africa, APMT, which belongs to the Maersk group, operates terminals in Tanger Med (Morocco), San Pedro (Côte d'Ivoire), Tema (Ghana) and Onne

(Nigeria). MSC operates terminals in Lomé (Togo), San Pedro (Côte d'Ivoire), Tanger Med (Morocco) and Tin Can (Nigeria). In March 2022, MSC reached a deal with Bolloré Group for the acquisition of Bolloré Africa Logistics for 5.7 billion euros². If this agreement is approved by competition authorities, MSC will become, by far, the largest terminal operator in Africa in terms of handling capacity.

3.3 Establishment of Special Economic Zones (SEZ)

In the Special Economic Zones (SEZ), private firms are exempt from the tax regime applicable in the host country, in particular with regard to customs. In return for this concession and other benefits, host countries expect these firms to create employment, stimulate exports and contribute to the diversification of their economies (Bost, 2019). SEZ were introduced relatively late in Africa as compared to other regions. Some of them are located at seaports, where firms can unload cargo without customs duties and taxes and with minimal formalities, pending re-export to a third country. In Africa, although their impacts on local development seem modest (Bost, 2011), SEZs have contributed to develop trade. Therefore, SEZs may have played an important role in the improvement of the maritime connectivity of the hosting economies.

In the recent years, China has invested heavily in the development of SEZs in Africa in combination with large transport infrastructure projects. This is part of a broader policy of the Maritime Silk Road or Belt Road Initiative (Ferrari and Tei, 2020). For China, this strategy allows Chinese companies to enter African markets. The recent SEZ developments in Tanzania, Kenya, Morocco and Egypt are good examples of Chinese engagement on the African continent. Moreover, the joint investments of China in neighboring countries, such as Djibouti and Ethiopia (port infrastructure, railways, SEZs), may encourage intra-regional cooperation for the management of the shared transport infrastructures (Demissie, 2018).

3.4 Evolution of transshipment patterns across various port ranges

In African ports, the shipping demand is generally low and unstable. To cope with these conditions, shipping companies frequently adopt transshipment strategies, consisting in consolidating container throughput at certain ports to better adjust the capacities of vessels to the density of demand at ports (Rodrigue, Ashar, 2016). This allows shipping companies to increase the number of connections between ports, at the cost of one or more transshipments at

² MSC moves ahead with \$6.3bn Bolloré Africa Logistics acquisition, [Splash247.com](https://splash247.com/msc-moves-ahead-with-6-3bn-bollore-africa-logistics-acquisition/)
<https://splash247.com/msc-moves-ahead-with-6-3bn-bollore-africa-logistics-acquisition/>

hub facilities. When there is transshipment, the container is just in transit, between two trips by sea. There are several types of transshipment schemes: the most frequent in Africa is hub-and-spokes network. It consists in deploying large (mother) vessels in the main routes, and small (feeder) vessels to ensure the connections with smaller ports through the hubs.

Given their geographical characteristics and the uneven density of demand and capacity limitations, many West African ports are serviced through several hubs in Europe (Algeiras, Las Palmas, Antwerp), North Africa (Tanger-Med), or South Africa (Ngqura, Durban). In East Africa, Mauritius and Reunion act as hubs for part of the ports in the region. However, they compete with the ports in Malacca strait (Tanjung Pelepas, Port Klang, Singapore), the Indian subcontinent (Colombo) and the Middle East (Djebel Ali), which also have direct connections with many of the East African ports. As compared to hinterland throughput, transshipment throughput is highly volatile and cargo can easily shift from one hub to another (Notteboom et al, 2019). Therefore, the connectivity of countries such Morocco, Egypt, Togo, Congo or South Africa may change considerably depending on the hub strategies of shipping companies. Furthermore, with the development of direct connections to China of many West African countries, the mediating role of the former may become weaker (Guerrero et al, 2022).

3. Data and method

The Liner Shipping Bilateral Connectivity Index (LSBCI) is freely available on-line on the UNCTAD website³. These data have been provided to us as a courtesy of UNCTAD. LSBCI is designed to measure the quality of container transport connections between pairs of countries. For each country pair, the LSBCI is the average of five normalized components (Fugazza and Hoffmann, 2017): (a) the number of transshipments required to get from country A to country B; (b) the number of direct service connections common to both countries A and B; (c) the number of common service connections by country pair with one transshipment; (d) the level of competition on services that connect country A and country B; (e) the size of the largest ship on the weakest route connecting countries A and B. The LSBCI is a symmetrical indicator published annually, whose value range between 0 (minimal connectivity) to 1 (maximal connectivity).

For this study, we use a complete dataset of LSBCI and its individual components for 2006 and 2016. These two years are important as they bracket the changes that occurred during a decade

³ <https://unctadstat.unctad.org>

rich in significant events affecting the global economy and trade patterns around the globe, and in Africa in particular. Specifically, the Great Recession of 2007-2009 affected all countries of the world and disrupted global trade quite deeply. Also, China's Belt and Road Initiative was formally launched in 2013 with targeted investments in nearly 70 countries and international organization, with the aim of spurring development through trade centered on the People's Republic of China.

In this study, we analyze the LSBCI links of 39 African countries and five geographical groupings of countries outside of Africa. Summarizing the links for these groupings enables us to tease out some of the most salient relationships, leaving aside more localized detail. The LSBCI between each geographical group and each African country is computed on the basis of the original LSBCI statistic as follows. The LSBCI between a country group and any African country is derived from the country-based LSBCIs as the maximum LSBCI link of all the countries in the group and the country under consideration. These derived values are therefore consistent with the principle of the original LSBCI as a depiction of the best connectivities between territorial entities.

Please insert Figure 1 and Table 1 about here

To facilitate the visualization, Africa is partitioned into four sub-regions that are geographically contiguous and compact (Figure 1). These sub-regions are based on the United Nations geoscheme⁴. The maximum LSBCI is in North Africa (0.39 in 2006 and 0.47 in 2016) while the highest average is in the Southern part of Africa (0.21 in 2006 and 0.23 in 2016) (Table 1). The values for the West and East regions are very similar. We also note that average and median values have remained stable between 2006 and 2016, but the maximum values jumped significantly overall and for each of the four African study regions. In line with this trend, we find the range of LSBCI values has increased during the study period in all African regions as a few countries increasingly stand out of the pack, while the rest show little or no change. Hence, there is no evidence of convergence in international maritime connectivity in Africa; instead divergence has been the dominant trend

Of all the sub-regions, North Africa has the highest maximum LSBCI in both 2006 and 2016 (Table 1 and Figure 1). In terms of connectivity with country groups outside of Africa, the

⁴ https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:African_regions_according_to_the_United_Nations_geoscheme.png. Central and West Africa were merged for the sake of simplicity.

performance of Northern Africa exhibits some differences between 2006 and 2016. In 2016, its highest LSBCI scores were with Europe (0.47), China (0.44), Indian Ocean (0.40) and Far East (0.39), while in 2006, it was with China (0.39), Europe (0.38) and Indian Ocean and Far East (0.36 each). In 2006, these high scores result from the good connections of Egypt specifically, and also Morocco in 2016. Both countries are strategically situated on the main East-West trade corridor.

The method used to synthetically visualize the positions of countries and regions within the LSBCI space is Multi-dimensional scaling (MDS). This so-called ordination technique defines a multidimensional space based on the pairwise distances (or dissimilarities) between these entities (Kruskal and Wish, 1978). The generated space is an abstract Cartesian space of n dimensions within which entities are positioned. It represents the hidden structures of the data. In the process of generating this space, parsimony is a driving consideration so that MDS is also a dimension reduction technique. The metric used in this study for this purpose is the inverse of LSBCI ($1/LSBCI$), varying between 1 for entities that are very close, and infinite for very distant ones. MDS provides a synthetic visualization of a dataset such as ours in the form of a space of lower dimensionality, typically one, two or three dimensions. Readers are referred to Guerrero et al. (2021) for a more detailed methodological discussion of MDS applied to LSBCI data and to Kashiha et al (2013) for some other applications in the freight transportation domain.

The MDS algorithm makes use of an iterative fitting process to generate its output “map” solution whose configuration of entities best fits the original data. The quality of the output of MDS is measured by so-called stress measures, which quantify the goodness-of-fit between the pattern of entities in the space of reduced dimensionality and the original data (as measured by the LSBCI in this study). This value depends on the number of numerical iterations and on the number of dimensions in the output solution. The result is considered to be acceptable when the stress is below 0.20 (Borgatti et al, 2013). The stress values obtained in this work are presented in Appendix 1. For 2 dimensions, the stress is around 0.28, which is marginally acceptable, but highlights the need for taking into account a third dimension to provide a more complete representation of covariances embedded in the LSBCI matrix and a richer interpretation of the patterns depicted by the MDS visualization results. The results for 2006 and 2016 are very similar. For the sake of simplicity, in this paper we only interpret two dimensions for each year: 1 and 2 for 2016 and 2 and 3 for 2006. We focus on the dimensions

which seem to better reflect the geographical positions of countries. The visualization of the other dimensions are contained in Appendices 2 and 3.

Aside from the software used to run the MDS (Xlstat), these graphs were built using Qgis. MDS is available in many of statistical software, including open-source platforms such as R.

4. Connectivities in 2016

Please insert Figure 2 about here

Figure 2 presents the positions of countries within the MDS output space, based on the inverse of LSBCI. Countries and country groupings are represented by a circle whose surface is proportional to their largest LSBCI value with any other entity in the dataset. The position of countries and country groupings in the MDS space has two complementary interpretations. First, we can look at their centrality versus peripherality within the frame set by the MDS space itself. This is indicative of the degree of similarities or affinities of a specific entity with respect to the overall set of entities in the dataset. A centrally positioned entity would be an entity with strong similarities with a large number of other entities. Given the data we work with here, such an entity would exhibit strong overall maritime connectivity across the maritime system. A peripheral entity, on the contrary, would have weak connectivity on the whole. Second, we can focus on localized clusters of entities in the MDS space. Such local clusters encompass entities that are similar (i.e., well connected) to each other, but quite dissimilar (i.e., less well connected) to entities that do not belong to the same cluster. This is further discussed in relation to the specific results depicted in Figure 2.

Countries and regions that are best connected overall are situated towards the center of the graph. This includes Europe and the Asian geographical groupings, most of the North African countries, South Africa (ZAF), and several countries from West and East Africa. The fact that Europe and Asia are well connected is certainly consistent with the fact that these regions form the hubs of global trade and of the supporting logistical networks. African countries that are positioned in this core fulfill the same function within the African context. At the periphery of the graph, there is a large number of countries with lower overall connectivity levels. Amongst the latter, some are islands, which tend to have smaller economies and therefore to be less sought after by shipping lines as they generate less cargo to be hauled.

In Figure 2, the positions of the African sub-regions (color-coded as such) roughly correspond to their geographical positions (West African ports on the left, etc.), which facilitates the

reading and interpretation of the MDS visualization. More importantly, however, we find that countries in the same sub-region tend to be found in close proximity to each other on the MDS map. This conveys the strong effect of geography on containerized cargo connectivity and on the logistics and trade relationships that are woven internationally. It is worth reemphasizing that geographic locations are not used as input in the creation of the MDS visualizations. Maritime connectivities suggest that these port clusters may *complement* each other at the global scale of trade relationships as they each serve different hinterlands formed of multiple African countries; on the other hand, evidence on connectivities leads us to argue that countries in the same cluster display some degree of *substitution* with each other, as they have geographically contiguous and overlapping hinterlands. These substitution effects may be aligned with incipient regional economic communities such as the Economic Community of West African States (ECOWAS) and the East African Community (EAC). East and West African sub-regions in particular occupy fairly distinct portions of the MDS space, while North and South African countries intermingle with each other, as well as with several country groupings from outside of Africa.

Finally, Figure 2 reveals the existence of smaller clusters of countries (often consisting of 2 countries only), including Nigeria and Congo, Togo and Ghana, South Africa and Reunion, Egypt, Mauritius and Djibouti, and some others. These smaller clusters are often embedded within larger sub-regions, which suggest that they may play complementary roles regionally, but also that their constituting countries may be seen and used as substitute locally by shipping companies.

Please insert Figure 3 about here

5. Changes in 2006-2016: West Africa goes East, East Africa stagnates?

The MDS visualization produced on the basis of 2006 LSBCIs is shown in Figure 3. The comparison of Figures 3 and 2 raises several interesting points of difference:

- a) The geographical groupings (non-Africa) become closer together, at the core. The only exceptions concern Pacific and Europe which remain separated.
- b) West Africa and East Africa remain separate, at opposite sides of the graph.
- c) Within West Africa, some countries move towards the core (Congo [CGO], Togo [TGO], Ghana [GHA], Nigeria [NGA]) and distance themselves from the other

countries in the region, a sign that over the 2006-2016 period they have gained significant connectivity compared to others.

- d) Morocco [MAR] becomes the main maritime country in North Africa, and joins Egypt [EGY] at the core. However Morocco remains closer to Europe and West Africa, and Egypt seems more oriented to East Africa and the Indian Ocean.
- e) South Africa and Egypt were the only interregional hubs in 2006, in intermediate positions between West Africa and East Africa. Both were closer to East Africa and Asian geographical groupings. In 2016, while Egypt remains embedded in East Africa and Asian groupings, South Africa gets closer to Europe and West Africa.
- f) China has considerably strengthened its business and economic ties with many African countries during the 2006-2016 period as part of their push consistent with the One Belt-One Road Initiative. The connectivity of African countries with respect with America stagnates during this period.

From a methodological point of view, MDS offers a simplified representation of the interactions between countries, and consequently some of the apparent proximities are not always synonymous with strong interdependence between the countries concerned. To clarify this point it is useful to look at the positions of countries in the space formed by dimensions 3 and 1 (Appendices 2 and 3) when a 3-dimension MDS solution is retained.

Let us take the example of Algeria (DZA, blue) and China. On dimensions 1 and 2, their respective projections have very close coordinates for 2016 (Figure 2), in contrast to 2006 where the points are far apart (Figure 3). One might therefore assume that a significant link between the two countries or similarities in their interactions with the rest of the world have emerged during this period. However, if we look at LSBCI for the pair in question, we notice that it remains stable between these two years, which actually implies that two dimensions are not sufficient to analyze the projections of these points. The fact that a third dimension that has been chosen allows us to correct this bias, as can be seen in Appendices 2 and 3, where the countries are relatively far apart, with Algeria at the extreme end of the plane, and China closer to the center of gravity for both 2006 and 2016. Moreover, the graph indicates that China's interactions with the rest of the world are more important than those of Algeria (Figures 2 & 3), as the two points do not have the same circumference, which proves that other parameters than the coordinates of the projections should be taken into account in the analysis.

Another interesting aspect concerns the points for which we detect a greater proximity to the center of gravity compared to 2006. This is the case for Djibouti (DJI, yellow, Figures 2 & 3), whose LSBCI with China has skyrocketed by 40% between these two years. Nevertheless, we can see this rapprochement is also conditioned by the links of other countries with the rest of the world (Figures 2 & 3), creating a sort of suction effect from which Djibouti benefits in particular because of its strong link with Egypt (EGY, blue), whose strategic location allows multiple accesses to different regions such as Mediterranean Europe, part of the Middle East and indirectly Asia, for which Djibouti is precisely a crossing point. It is worth noting that for 2006, on the plane formed by dimensions 2 and 3 (Figure 3), Djibouti remains close to Egypt, but its size and proximity to the center of gravity are smaller than for 2016 (Appendix 2), unlike the plan formed by dimensions 1 and 2, which offers a better representation of these two points for 2016, thus reflecting a significant change during this period.

To sum, the maps comparing the connectivities between 2006 and 2016 (Figures 2 and 3) clearly show that the African continent is changing and the connectivities of the constituting countries have shown diverse trends during this period. This point is further emphasized by the series of maps in Appendices 4 and 5. Certain countries have fared quite well in terms of connectivity (ex. Morocco, Djibouti, Togo, Angola, Congo, Mauritius) strengthening their shipping links with the rest of the global economy, while others show much less progress (inland countries of East Africa, Tunisia) in this respect. Hence, the growing divergence in connectivities that was mentioned earlier. Clearly, the African continent is increasingly differentiated. Some parts of Africa are better positioned to take advantage of global trade over the coming decades as the geographic and infrastructure handicaps of the past are overcome.

The LSBCI is a normalized indicator. By design, it uses the size of the largest vessels calling at a country's ports in the year, in relation to the largest vessels in the world that year. Comparisons over time are therefore difficult because the trends in the index are tied to each of the five components, which may run contrary or together. The evolution of South Africa seems to show a decline of its role between West Africa and Asia. However, this role probably overlaps with other trends that reinforce the connections of South Africa with large countries. The latter connections are probably stronger than the former so that the phenomenon is hidden.

6. An exploration on the role of vessel size on connectivity change

Between 2006 and 2016, the average size of vessels deployed on African routes doubled. This has pulled the LSBCI up. However it is not clear that the changes in vessel size resulted in an advantage for shippers. The reasons behind this ambiguity are both statistical and operational. Statistically, as recently discussed by Hoffmann et al. (2020), all of the LSBCI components are correlated with trade except the *variable maximum vessel size*. From an operational point of view, shippers may well consider the vessel frequency and the variety of shipping companies as part of their decision process, but they are not directly affected by vessel size. Moreover, during the 2006-2020 period, the increase in vessel size went hand in hand with the reduction in the number of calls and in the number shipping companies (Hoffmann and Hoffmann, 2021). Therefore, it is important to distinguish the variations in LSBCI mainly resulting from variations in vessel size, from other variations which also concern the frequency of services or the number of shipping lines.

To do so, we have recalculated the LSBCI using the individual components, but without including vessel size. This allowed us to compare variations in vessel size, on one hand, and variations in the other four components, on the other hand.

Please insert Figure 4 about here

The plot of longitudinal change in vessel size against change in other LSBCI components (Figure 4) shows that the former is only weakly correlated overall with the other components of the LSBCI. Also, while the plot of pooled data depicts the overall picture on the continent, it hides large disparities between country pairs. We now proceed to a discussion of this point.

Please insert Figure 5 about here

Figure 5 reproduces the same scatter plot as Figure 4, but highlighting the links of select African countries in each of its panels to better tease out differences between countries. Different types of situations can be identified among these countries depending on the directionality of the relationship between components and on the relative variability of the maximum vessel size. For Angola, Djibouti and Morocco, we observe overall a positive relationship between component changes over the decade of study. For the two former countries, a substantial part of the LSBCI variations comes from vessel size increase. For the latter, the relationship between vessel size and the other components is even much stronger, in line with the tremendous increase in vessel sizes, as can be detected in the upper portion of the Morocco panel. These countries have seen their regional significance in maritime trade increase, with the

strengthening of the hub function of ports within their borders that have more effectively articulated regional shipping services with linehaul services between continents, where much large vessels have been deployed over the study period. The countries of Sierra Leone, Liberia and Tunisia have experienced stagnation and even decline in their connectivity measures, both vessel size and others. In the case of the two former countries, there have been important decreases in maximum vessel size for a number of their LSBCI links. In Tunisia, on the other hand, vessel sizes have remained rather similar (although a tendency towards a drop can be detected in line with a greater emphasis on regional services, and most the change on the overall LSBCI of Tunisia links can be attributed to other connectivity components.

Please insert Tables 2 and 3 about here

The evidence reported above points to significant disparities between African countries in terms of how their maritime connectivities were affected by the evolution of vessel sizes. In addition, there are dramatic deviations between links in the evolution of vessel sizes and that of the other LSBCI components. Tables 2 and 3 show a selection of links for which this is particularly notable. Table 2 shows that some of the LSBCI gains on links of Djibouti, South Africa, Congo and Angola result from increase in the maximum vessel size. Table 3 shows cases where the opposite can be observed, that is there is a decrease in vessel size but without a substantial decline in the other LSBCI components. Some countries appear in both tables, such South Africa and Angola. Egypt is involved in many of these links.

All in all, the plot of Figure 5 shows that the trends of vessel size on the one hand, and of the other dimensions of connectivity, on the other hand, may follow different pathways between countries, but also between different country-to-country links, as the local and global contexts may be quite different. This stresses the need to rethink the role of vessel size within connectivity indicators in future research, particularly in relation to the dynamical changes in local and global contexts.

7. Conclusions

This paper emphasized the geographical dimensions of maritime connectivity, by suggesting new representations for African countries. The resulting graphs convey the strong effect of geography on containerized cargo connectivity and on the logistics and trade relationships that are woven internationally. We found that countries in the same sub-region tend to be in close proximity to each other on the MDS output map. It is worth recalling that geographic locations are not used as input in the creation of the MDS visualizations.

The visualizations of the maritime network showed that Morocco, Egypt and South Africa are, by far, the best connected countries. We found a major improvement in the connectivity of Morocco, Djibouti and several West African countries, with most of the non-African regions. Conversely, the connections of most of mainland East African countries stagnate or decline. Previous works have also highlighted the increasing importance of non-European connections for ports in East Africa and South Africa (Notteboom and Ducruet, 2012, Niérat and Guerrero, 2019). In addition to this trend, the present work showed a fast development of the links of several West African countries to the Indian Ocean and the rest of Asia. Some of the latter seem to become less dependent on South African hubs for their interregional connections.

When we started this work we expected that the comparison of the 2006 and 2016 graphs would raise a clear change on the positions of African countries with regard to Europe and Asia. This trend, which was suggested by studies conducted by other scholars, does not appear clearly in the MDS analysis of the LSBCI. However, we detected some differentiation among countries, a small number of which succeeding in enhancing their connectivity to the global economy. To overcome this issue that we believe to be linked to the lack of discriminating power of LSBCI, we analyzed separately one of the dimensions of LSBCI: the maximum vessel size. This analysis revealed that part of the variations in connectivity results from the sole variations on the vessel size component. Given the strong upward trend of vessel size during the period under study, it is therefore important to assess how balanced is the growth of connectivity between the different LSBCI components. For instance, our analysis showed that the links of the most dynamic countries, Morocco, Djibouti and Angola, have been affected differently by vessel size growth. On the other end of the spectrum, there are countries such Tunisia with a decrease in the vessel size but with positive trends for the average of the other four components. Future studies is warranted to take into account divergences between connectivity and vessel size, eventually showing which foreign regions are the more affected.

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Tables

Table 1. Descriptive statistics of the LSBCI in Africa

	Max		Min		Average		Median		Std Dev	
	2006	2016	2006	2016	2006	2016	2006	2016	2006	2016
North	0.39	0.47	0.11	0.11	0.18	0.20	0.17	0.19	0.04	0.06
West	0.30	0.34	0.10	0.10	0.19	0.20	0.17	0.18	0.04	0.05
South	0.33	0.39	0.16	0.16	0.21	0.23	0.22	0.22	0.05	0.06
East	0.28	0.36	0.10	0.10	0.18	0.20	0.17	0.19	0.04	0.05
Africa	0.39	0.47	0.10	0.10	0.19	0.20	0.17	0.18	0.04	0.05
Non-Africa	0.57	0.62	0.16	0.16	0.24	0.27	0.23	0.24	0.08	0.10

Source: UNCTAD

Table 2. Selection of links with divergent trends for vessel size and the other LSBCI components (1/2). Increase in the maximum vessel size

A. Increase in the maximum vessel size			2006-2016 Variation	
Country 1	Country 2	LSBCI 2016 (Including Max Vessel Size)	Max Vessel Size	LSBCI without Max Vessel Size
South Africa	Canada	0.42	0.49	0.04
South Africa	Israel	0.41	0.48	0.05
Congo	United States	0.40	0.47	0.02
Angola	Mexico	0.36	0.47	0
Djibouti	Israel	0.37	0.46	0.05
Morocco	Chile	0.37	0.46	0.09
Djibouti	Croatia	0.31	0.45	-0.01
South Africa	Angola	0.46	0.45	0.09
South Africa	Congo	0.44	0.45	0.08
Congo	Netherlands	0.40	0.44	0
South Africa	Vietnam	0.40	0.43	0.08
Congo	Vietnam	0.33	0.43	0.06
Togo	Poland	0.34	0.41	0.08

Table 3. Selection of links with divergent trends for vessel size and the other LSBCI components (2/2). Decrease in the maximum vessel size

B. Decrease in the maximum vessel size			2006-2016 Variation	
Country 1	Country 2	LSBCI 2016 (Including Max Vessel Size)	Max Vessel Size	LSBCI without Max Vessel Size
Liberia	United Kingdom	0.27	-0.33	0.01
Angola	United Kingdom	0.38	-0.31	0.08
Liberia	Thailand	0.17	-0.28	-0.04
Egypt	Panama	0.39	-0.22	0.12
Liberia	Germany	0.24	-0.22	-0.07
Liberia	China	0.23	-0.22	-0.07
South Africa	Egypt	0.38	-0.2	0.08
Egypt	Guatemala	0.33	-0.17	0.08
South Africa	Haiti	0.24	-0.17	0.03
Angola	France	0.42	-0.16	0.03
Egypt	Belgium	0.55	-0.14	0.02
South Africa	Turkey	0.38	-0.14	0.11
Senegal	United States	0.35	-0.14	0.11

Figures

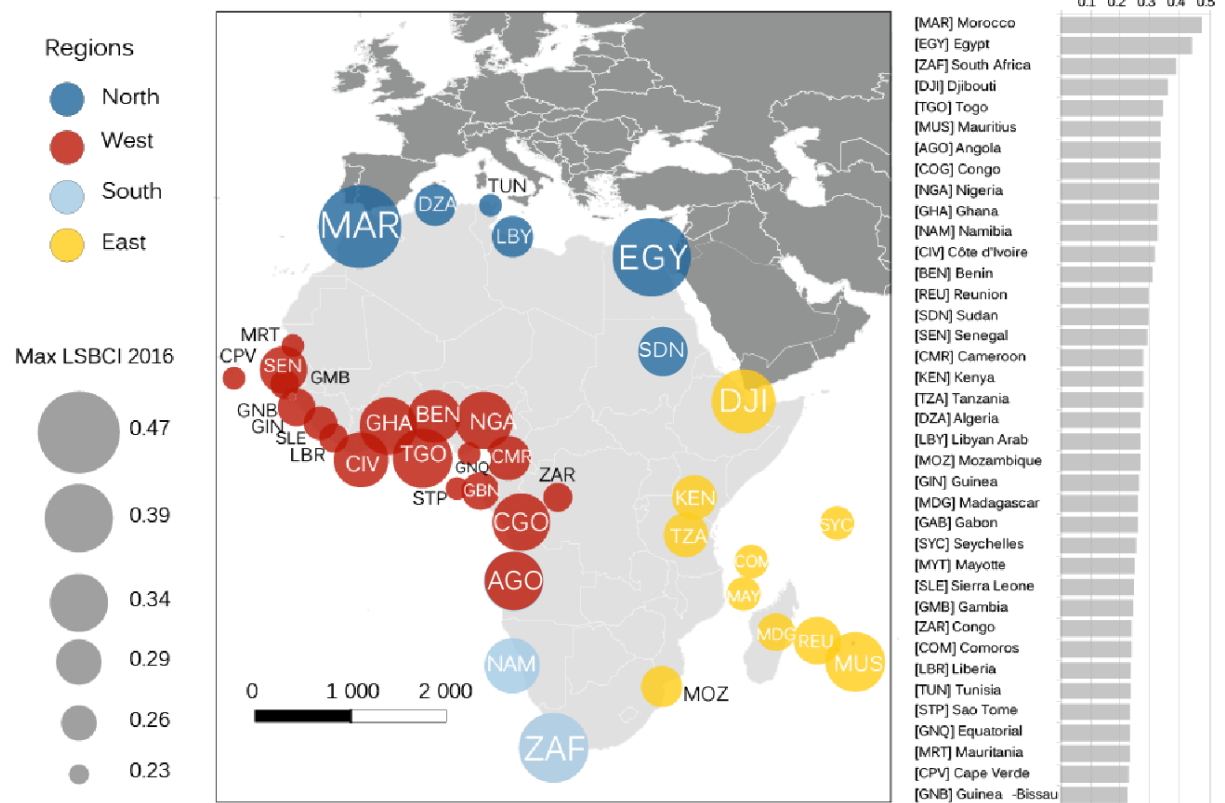


Figure 1. Regional partitioning and geographic and statistical distribution of LSBCI

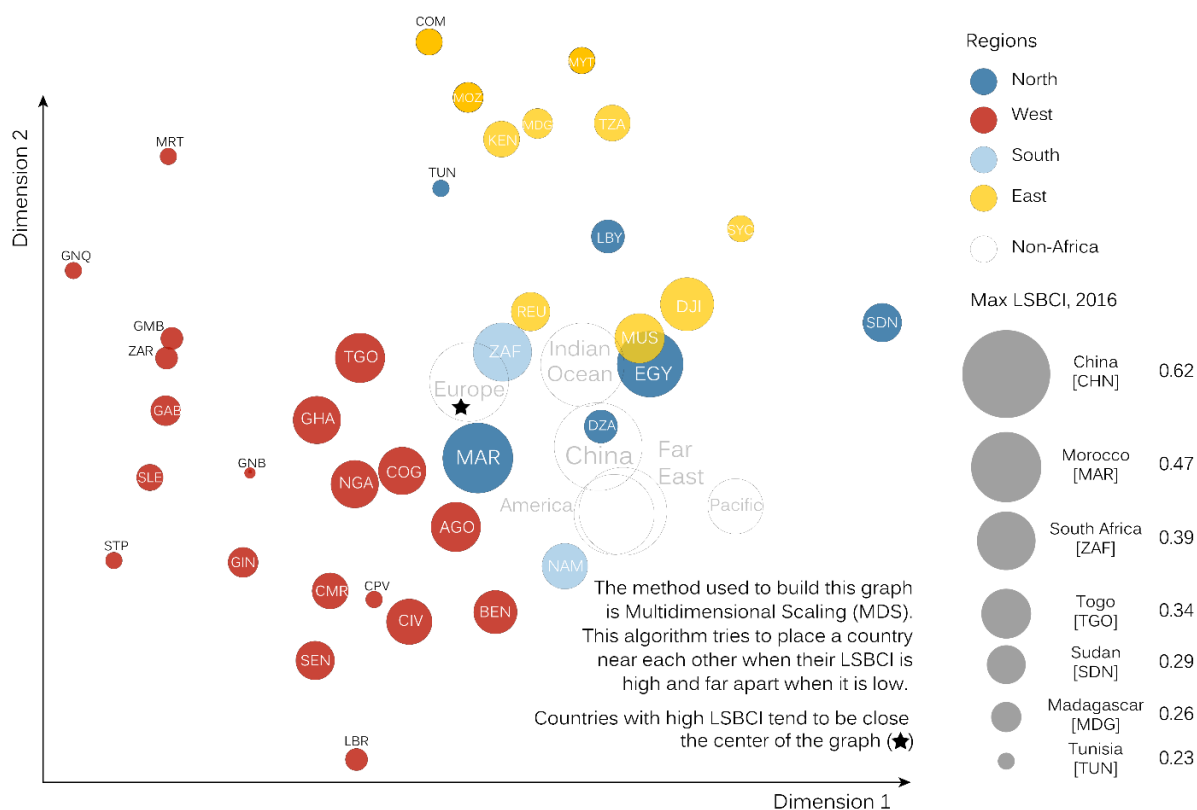


Figure 2. MDS results for 2016 LSBCI links between African countries and the rest of the world in country groupings. Dimensions 1 and 2. Source: UNCTAD

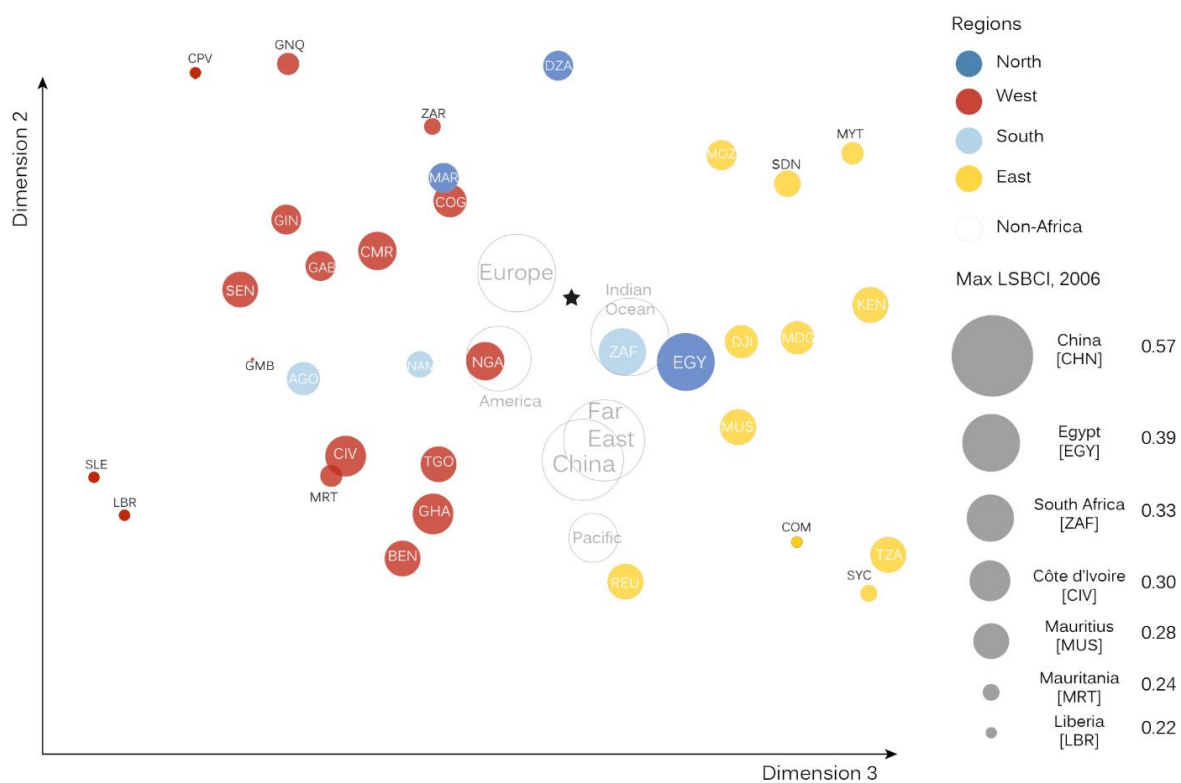


Figure 3. MDS results for 2006. LSBCI links between African countries and the rest of the World in country groupings. Dimensions 3 and 2. Source: UNCTAD, 2016

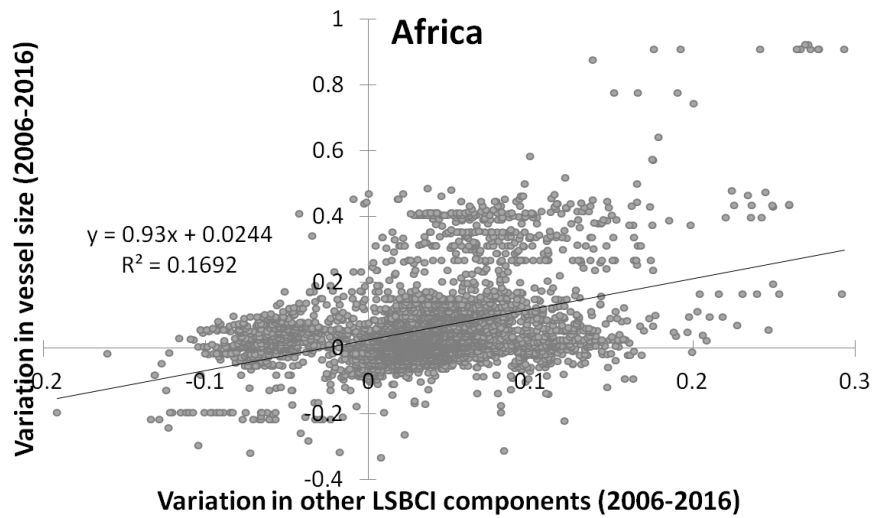


Figure 4. Maximum vessel size vs Other LSBCI Components. Variation 2006-2016.
Source: UNCTAD

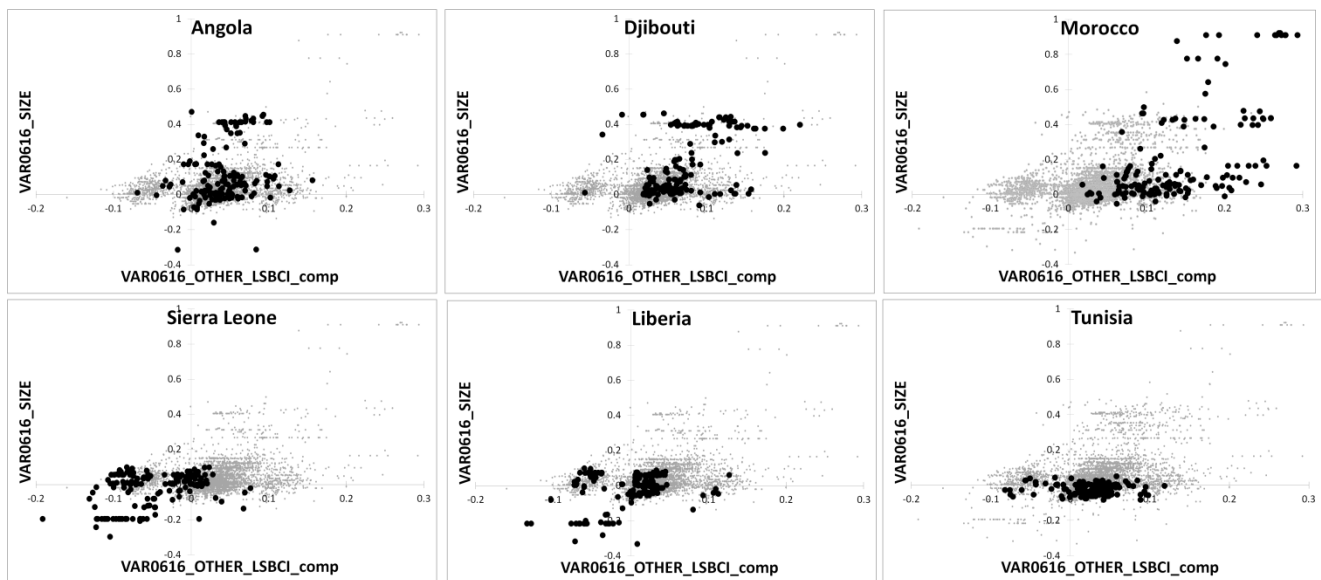
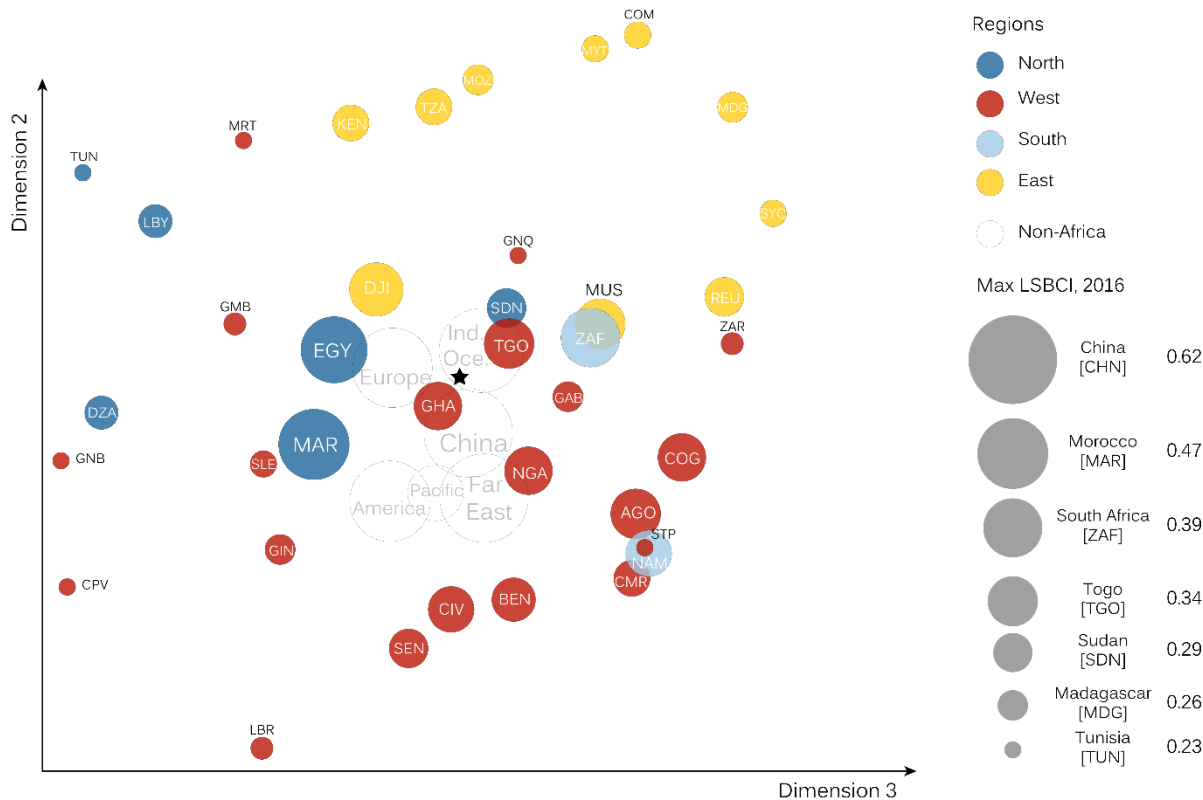


Figure 5. Maximum vessel size vs Other LSBCI Components. Variation 2006-2016 for a selection of countries. Source: UNCTAD

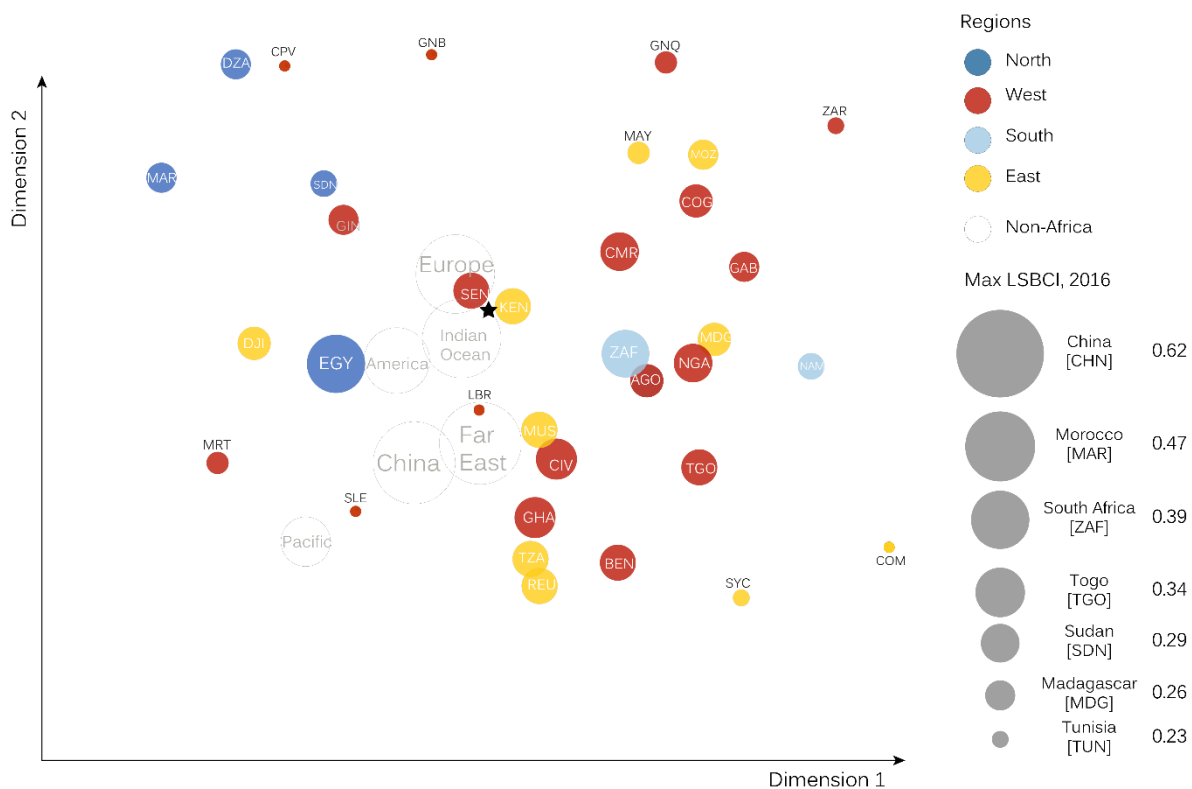
Appendices

Appendix 1. MDS results for LSBCI links between African countries and the rest of the World (aggregates).

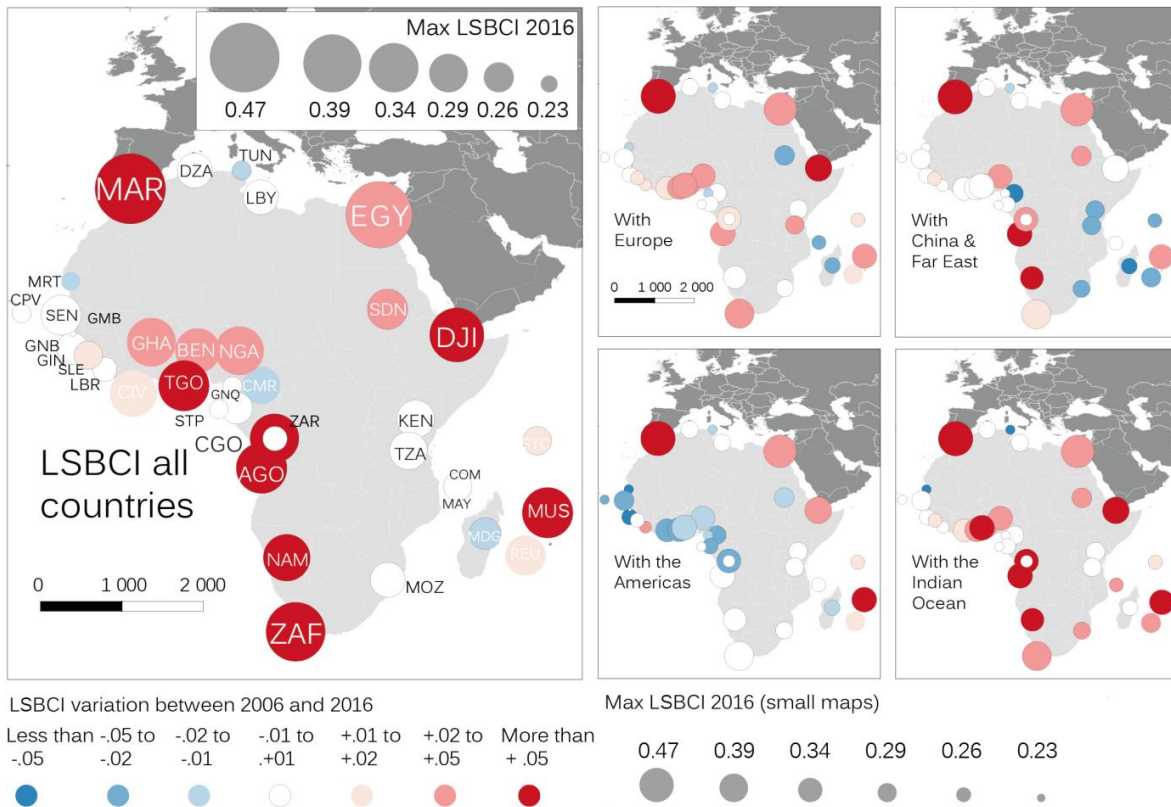
		Number of dimensions		
Year		1	2	3
2016	Kruskal's stress	0.610	0.280	0.197
	Iterations	18	103	367
2006	Kruskal's stress	0.625	0.276	0.199
	Iterations	12	156	244



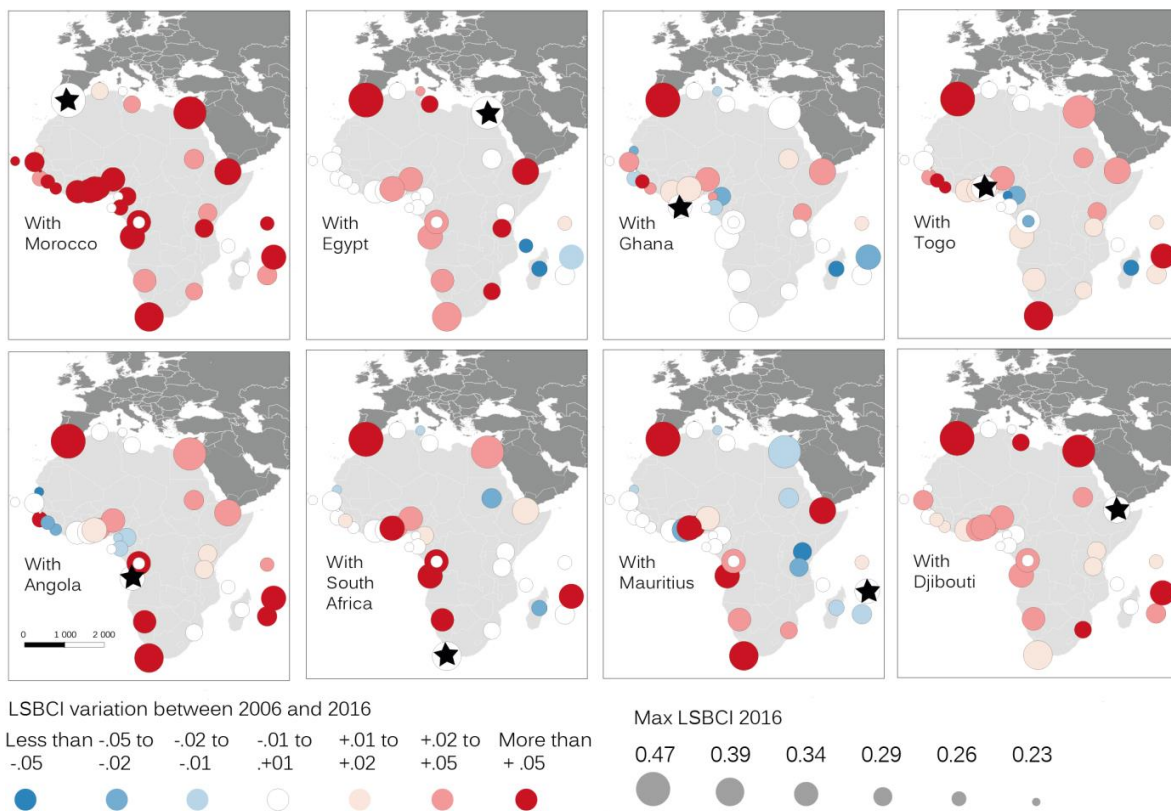
Appendix 2. MDS results for 2016 LSBCI links between African countries and the rest of the world in country groupings. Dimensions 3 and 2. Source: UNCTAD



Appendix 3. MDS results for 2006. LSBCI links between African countries and the rest of the World in country groupings. Dimensions 1 and 2. Source: UNCTAD, 2016



Appendix 4. LSBCI variation 2006- 2016 (Total, non-Africa). Source: UNCTAD, 2016



Appendix 5. LSBCI variation 2006-2016. Selection of countries. Source: UNCTAD, 2016