10-31-2021

Container trade and demand for the west coast of Africa: determining the competition and collaboration between six major ports in the region

Ngouye Sougoufara

WORLD MARITIME UNIVERSITY
Malmö, Sweden

CONTAINER TRADE AND DEMAND FOR THE WEST COAST OF AFRICA:

DETERMINING THE COMPETITION AND COLLABORATION BETWEEN SIX MAJOR PORTS IN THE REGION

By

NGOUYE SOUGOUFARA
(Senegal)

A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of

MASTER OF SCIENCE
in
MARITIME AFFAIRS

(PORT MANAGEMENT)

2021

Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

(Signature): ....
(Ngouye SOUGOUFARA)

(Date): 20- 09- 2021

Supervised by: Dr. Satya Sahoo

Supervisor's affiliation: Professor, Shipping and Port Management
World Maritime University, Malmo, Sweden

Acknowledgment

I am grateful to ITF Foundation for granting me a fellowship but giving me the opportunity to pursue the MSc program at World Maritime University.

I would like to express my sincere gratitude to my supervisor Professor Satya Sahoo for his extensive knowledge, precious guidance, and support all along this process.

I recognize with deep gratitude to Professor Dong-Wook Song, head of shipping and ports management, Professor George Theocharidis, Professor Gang Chen for their guidance and encouragement before and throughout my dissertation period.

I am deeply obliged to my parents Mr. Mamadou SOUGOUFARA and Mrs. Fatou S. DIOP, my brothers Ibrahima, Djibril, and sisters Sokhna, Fatma, for raising me up for their supports and inspiration throughout my study. Equally, I am indebted to my lovely wife, Mame Fatou, my son Ibou and daughter Dina for their constant support and love, which was helpful throughout this program.

Abstract

Title of Dissertation: Container trade and demand for the west coast of Africa: Determining the competition and collaboration between six major ports in the region

Degree: **Master of Science**

Following the globalization of trade, a regionalization process started. The network of ports mainly endorses this process. In the Atlantic facet of Africa, many major ports are interacting. As the ports are in different levels of development, they can achieve their infrastructure development and capacity building through strategic Alliance. The research examines the intensity and the type of relationship that exists between the six major ports (Tanger, Dakar, Abidjan, Tema, Lome, Lagos) in the region. That identification of the characteristics of the network can help to support the strategic decision that can be implemented by Port Authorities to develop their throughputs. A dependency ratio model has been applied to determine the type of throughput generated by each port through its bilateral relationship with the others.

The research has been designed to conduct an empirical analysis based on four models (Dependence Ratio, Multiple linear regression, Cointegration Model, and ARMA) to determine the volume of container throughputs exchange between the group of ports and their impact on their productivity. A set of data covering the period of 2013 to 2021 is used on a quarterly basis.

The results highlight the existence of collaboration between pair ports and competition as well due to Hinterland disputes. This study also looks at the joint venture made in those ports.

The study can positively assist the port management authorities in choosing their strategic alliance to generate more throughput. The region captivates more port investment. It also supports efficient investment decisions. Furthermore, it can help build the Hub and feeder ports network, supporting the increase of trade between neighboring countries.

KEYWORDS : competition; co-operation; Tanger; Dakar; Abidjan; Tema; Lome; Lagos

Table of Contents

List of Tables

List of Figures

List of Abbreviations

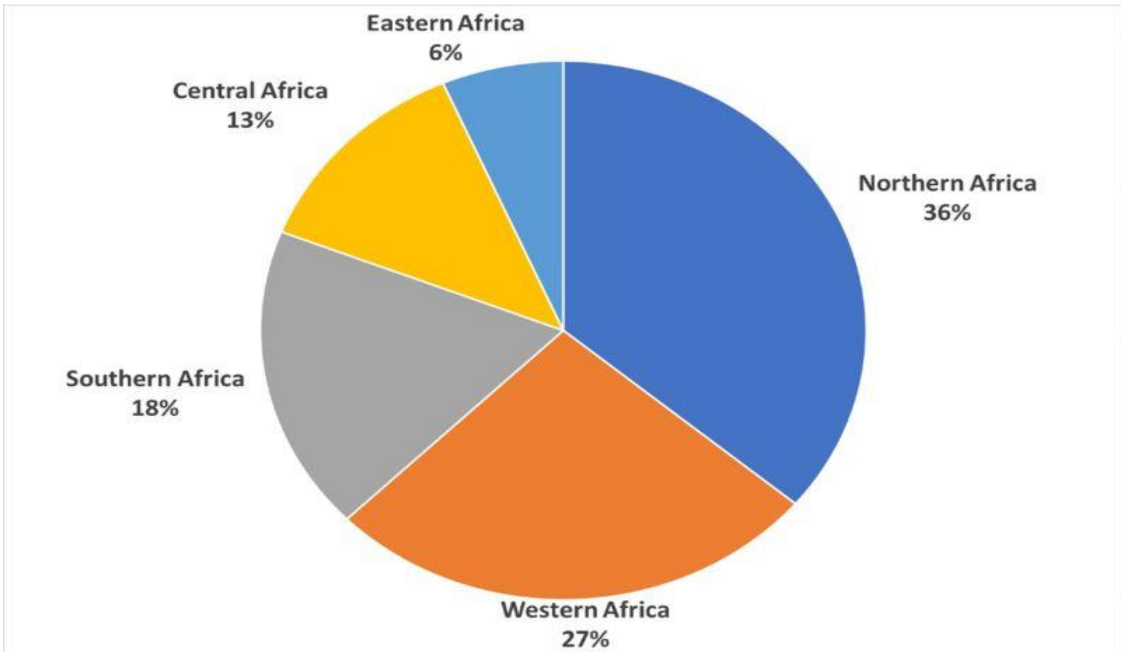
AFCFTA	African Continental Free Trade Area
ADF	Augmented Dickey Fuller
APMT	A. P. Moller Terminal
ARMA	Auto regressive moving average
AU	African Union
BDI	Baltic Dry Index
CTC	Container Terminal Concession
ECT	Error Correction Term
GDP	Gross Domestic Product
IMF	International Monetary Fund
ITF	International Transport Forum
KHR	Khmer riel
KPSS	Kwiatkowski-Phillips-Schmidt-Shin
ECOWAS	Economic Community of West African States
LIBOR	London Interbank Offered Rate
MLR	Multiple Linear Regression
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
PP	Phillips-Perron
TEUs	Twenty-foot equivalent unit
UNCTAD	United Nations Conference on Trade and Development
USD	United States dollar

1. Chapter One: - Introduction

1.1. Background of Study

The globalization of trade puts the maritime transport system at the center of intercontinental transport; with 80% by volume and 70% by value of the world´s, trade is carried by sea. In addition, container commodities account for 60% of the seaborne trade (UNCTAD, 2018b). Like in the rest of the world, 80% of Africa's international trade is done through shipping and ports. West and Central Africa account for 40% of all seaborne container traffic on the continent. When it comes to Sub-Saharan Africa, this figure jumps to 62 percent. Africa contributes 4% of worldwide-containerized trade, mainly constituted of imports of manufactured products. The creation of the African Continental Free Trade Agreement (AfCFTA) and a restructuring of the continent's trade network have the potential to boost containerized trade.

Figure 1: Sub-regional participation in Africa’s maritime trade, 2019.



Source: (UNCTAD, 2019)

In terms of maritime container transport, Africa's Atlantic facade straightened out from Tanger Med's port north to that of Cape Town in the south (figure 2). This geographic region is considered a trade unit. There are 26 ports engaged in international trade. The study analyzed the trend of container trade among six container terminals (Tanger, Dakar, Abidjan, Tema, Lome, Lagos) that are the most connected (UNCTAD, 2018) and capitalized the essential of container flows. Historically, the region's ports had little competition. Each port served just the hinterland of its respective country. Due to the development of multimodal transportation systems and land connections to landlocked nations, which account for one-third of Africa's population, the majority of today's ports share these hinterlands, compete, and collaborate to secure cargo volume. The types of port competition are categorically listed in five different forms (Goss, 1990). The one that applies here is the competition between ports in different countries.

Figure 2: Major ports in the Atlantic façade of Africa.

Source: (Alphaliner, 2020)

1.2. Problem Statement

The major trends in recent developments in the maritime container trade networks of western Africa reveal a variety of problems. The evolution of containers flow in ports does not align with the economic indicators and transportation factors that are significant to this trade globally. Indeed, although accounting for 12.8 % of the world population, Sub-Saharan Africa accounted for just 2.3% of global container volumes (ITF-OECD, 2014). In addition, it appears that the network configuration of the liner services should be optimized through collaboration and competition aspects between ports. An improvement of the network model will support the strategic orientations of the stakeholders to increase the volume of trade, lower the unit cost of transport, and enhance the port connectivity. However, the liner shipping carriers and the maritime services they provided are the major actors that reflect the trade characteristics in this region. The competitive behavior between ports must be included when conceptualizing the spatial evolution of maritime container transport networks.

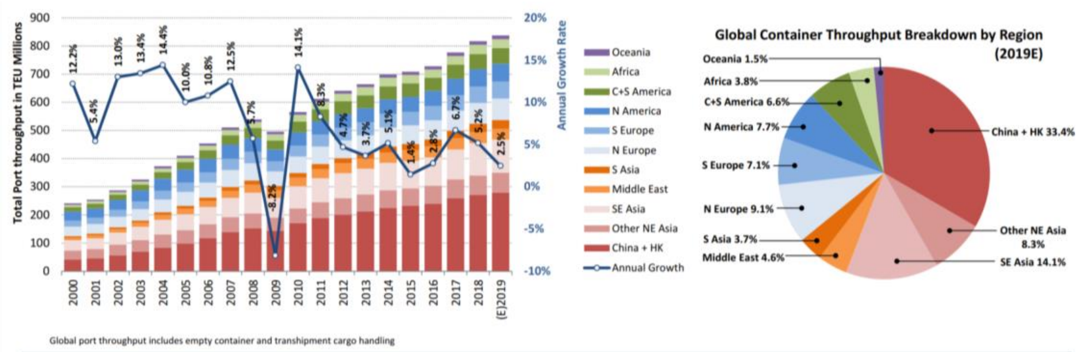
As countries achieve a sufficient growth rate, their ports compete for a larger part of the market and to profit from the economic boom. Africa's economy is heading in the direction of more interregional trade. Major container ports will be critical in this process. Due to the fact that the trade will be mostly handled by sea, ports that previously had exclusive access to their countries' domestic markets will share a common market as their hinterland and foreland markets overlap.

1.3. Value of the Research

The questions by actors for a lower unit operating cost and a better liner shipping connectivity does not adequately reflect the most recent transformations in maritime transport and the future trend of it in the African region (Carine, 2015). The study will look at the strategy that can make the container trade more profitable through optimization the strategic relationship between ports.

The research first looks at the quantitative analysis of the existing competition between major container ports on the west coast of Africa. It is noticed that, despite a significant increase in the capacity of container terminals through investment (World Bank, 2020), the container port flows are less compared to other parts of the world (see figure 3 for the global container throughput of 2019 before the outbreak of the COVID 19 pandemic).

Figure 3: Global Port Throughput



Source: (Alphaliner, 2020)

In a second part, the analysis focuses on the demonstrations that the future of trade in this part of Africa is likely to observe significant growth based on the economic dynamic, the new market reorganization, and the third step of the globalization process, which is mostly a regionalization of t world commerce. The intra-African commerce, which accounts for only 4% of the African trade, will grow faster and thus sustain the strategic co-opetition between ports.

1.4. Objective of the study

Following the Intensive development of international Maritime trade, Africa is seeking to develop its containerized trade volume, which is still tiny and devalued in accordance with its market potential. Ports as the nodal points of the transport system are supporting this effort to increase the continent's share in the global seaborne trade. To meet the objectives, greater integration and an optimized port network are the way forward. Thus, many investment decisions are made in which some are not successful. Optimizing the decision-making process is paramount to boost the container trade.

That should go through determining the type, characteristics, and intensity of the relationship between ports. Therefore, ports within the same region need to build strategic relationships. The market structure has changed from an exclusive monopoly to serve the domestic markets to fierce competition between adjacent ports when the hinterlands overlap. That authorities and decision-makers have to consider supporting less advanced ports, which positively influences their throughput development.

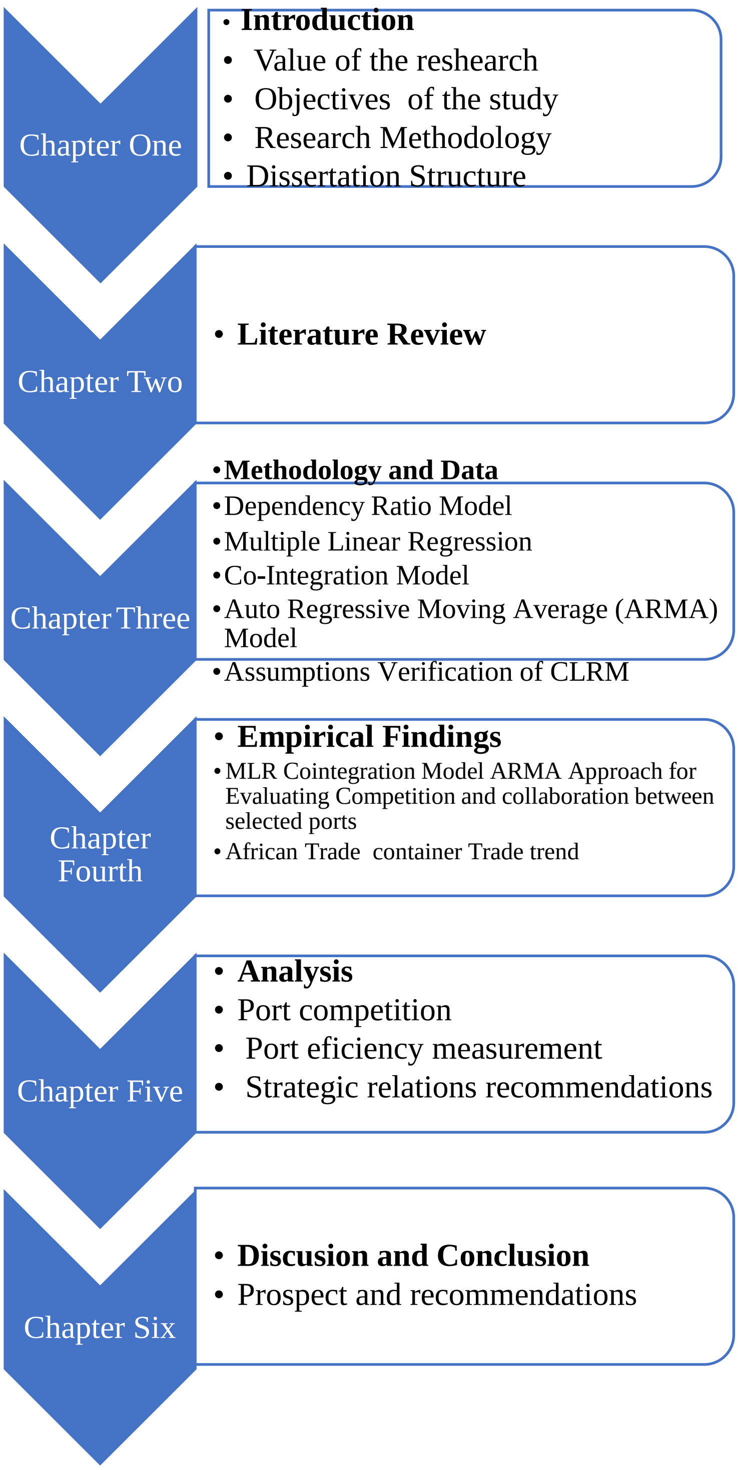
On the other hand, they should be willing to increase their market position under competition conditions to improve their service level, which is a crucial factor determining productivity. Most academic studies state that political and social-cultural decisions characterize the relationship between ports. Also, they did not develop a relationship between multiple ports. These qualitative approaches did not lead to organize the investment framework. This study uses an empirical methodology to quantify the throughput generated by six major ports in the west facade of Africa. Therefore, it constitutes a source of information for port authorities and governments to support decisions in their strategic relationship and investment projects.

1.5. Outline of the Study

Five main criteria are highlighted as having the most impact on port competitiveness from a consumer perspective. These factors collectively contribute to the development of container production by adding new volume and maintaining existing capacity. Cargo volume, port facilities, port location, service level, and port fees are the five competitive factors (Hales et al., 2016). Ports in the transshipment market leverage these elements to frame their strategy in terms of collaboration and competition with neighbors (Yeo & Song, 2006). Thus, measuring their interrelation enables us to determine the effectiveness and efficiency of the preceding factors considered by customers (lines) when port selection. Meanwhile, Africa's per capita GDP is increasing, which means that the potential for manufactured goods consumption is increasing as well. As a result, container trade demand is expected to increase. This global truth does not hold true when it comes to Africa for a variety of reasons, one of which being the revenue share and interdependence. The study examines the region's facts for container port collaboration and competitiveness. It employs an empirical study to measure how each of them produces containers in relation to the others. Thus, the insights can be used to develop and support strategic decisions to collaborate or compete in the domains of economies of scale, rationalization of port networks, technology transfers, overcoming trade and investment barriers, and risk mitigation.

1.6. Structure of the dissertation

Figure 4: Structure of the dissertation



1.7. Limitations and Challenges

As seen in the literature, six ports were identified as the most significant for container trade out of the 26 container terminals of the Atlantic facade of the continent. They represent 80% of the container flow. The container lines used to call these ports during their services. One year of data was collected about the selected port throughput and the shipping lines services to measure the port inter-dependency ratio. The study analyzes the container flow share and services between ports using AIS data of shipping lines that have the fix and constant services. Internal factors data from ports were unavailable owing to their scarcity. However, the author was successful in addressing the target objectives.

2. Chapter two: literature review

2.1. Introduction

Since the introduction of containers in the 1960s, this commodity has grown exponentially, from 85 million TEUs in 1990 to 651 million TEUs in 2013, an annual rate of 9,3% (Statista, 2021). That global trend is also perceived at the Atlantic coast of Africa. Therefore, the Seaborne trade plays the most crucial role in African international trade. Shipping and ports are also used to access the global market by landlocked countries, representing one-third of them. In value, Africa's share of the world merchandise trade is small. In 2018, it was about 2.5% of exports and 3% of imports. The percentage is relatively more significant in volume and 7% in export and 4.6% in imports. The northern and western African regions contribute 36% and 27% (UNCTAD, 2019).

2.2. Development of Global Maritime Transport

The importance of trade in the economies of major countries cannot be overstated. Early in the twentieth century, it was recognized that economic development and growth were dependent on foreign trade. Thus maritime transportation as a derived market are used to moving goods and adding value (Song et al., 2019).

Global maritime transport has gone through three distinct stages of growth. It began in the nineteenth century, following the industrial revolution and the development of the manufacturing industry. International trade was primarily pushed at this early period of growth by lowering transportation costs. The invention and introduction of steam engines changed global maritime transportation trends at the start of international trade that followed the industrial revolution 1.0. Countries that engaged in the early maritime trade exported mostly non-manufacturing goods. This era concluded in 1945. The subsequent stage began in the mid-twentieth century, characterized by technological advancements in maritime transport and shipping. Simultaneously, the need for trade was increasing, owing to nations' outsourcing of production. They made it possible for manufacturing and consumption to be separate across national borders. It is a period of rapid growth for marine transportation, fueled by general cargo trades. The second phase runs until the year 2000. This stage is defined by the proliferation of Global Value Chains (GVCs). It is the fragmentation of manufacturing systems. As a result, industrial processes were geographically scattered. Trade in intermediate and finished manufactured items grew exponentially, particularly in emerging economies. Since 2000, the third stage of global commerce has been defined by digitally-enabled trade. Once again, more significant cost savings in transportation and logistics, along with a considerable decrease in the costs involved with data or information transfer, are propelling this trend ahead. As a result, transaction expenses decreased, facilitating trade (Cariou, 2020).

However, global trade is still asymmetric; the technological revolution benefited only a few nations. Furthermore, the globalization process exacerbated the disparity between high-income and low-income countries. It is well known that the globalization of trade has resulted in economic inequality (Pascali, 2017). Commodity trading is becoming a haven for new finance, displacing equities and bonds (Angelopoulos et al., 2020). The second world war-induced rapid growth of global trade at a rate of 5.9 percent and 7.2 percent increase of manufactured goods. Containerization intensifies the process and improves the efficiency of the operations. That situation triggered a diminution of shipping costs. Econometrics shows a high correlation between the trade boom and the low cost of transportation (Hummels, 2007).

2.3. Maritime Container Trade

The maritime container trade sector's importance is underscored by the fact that seaborne transport accounts for about 80% of global trade in terms of value. International maritime container trade is estimated to account for around 60% of all seaborne trade, with a value of approximately 14 trillion U.S. Dollars in 2019 (Steenken et al., 2004). Shipping lines, container terminals, freight forwarders, and shippers are the key maritime container trade stakeholders. The current decade has seen a significant increase in global container shipping, necessitating the need for efficiency. The maritime container trade is getting ready to run mega-vessels capable of transporting up to 20,000 TEU. Additionally, container ports are modernizing to optimize the processing of those ships' cargo. As a result, the terminals' goal is to deliver efficient and cost-effective services. They must make significant investments to fulfil the increasingly rigorous demands for faster service and greater quality (Stahlbock & Voß, 2008).

2.4. Liner Shipping

Liner shipping companies face three distinct levels of decision-making challenges. The strategic-level considerations encompass long-term decisions about the size and composition of the vessel fleet, alliance strategies, and network design. Decisions made at the tactical level address changing shipping demands. Thus, they determine the frequency of liner shipping services, vessel deployment, vessel sailing speeds, and vessel schedule designs. The operational level addresses cargo booking, cargo routing, and vessel rescheduling in response to interruptions such as port congestion, poor weather, and failing vessel engines.

Liners must consider the following factors while working with terminals: arrival and departure timings, waiting periods, potential vessel arrival delays, arrival time windows (TWs), and handling rates. Effective vessel schedules are essential for liner shipping companies and other major supply chain actors, such as container terminal operators, shippers, and alliance partners, when it comes to the container trade. Additionally, liner shipping companies use slow steaming to reduce overall fuel costs by lowering fuel consumption. However, it lengthens the duration of each voyage and the overall turnaround time of the vessel. The liner shipping company may need to deploy additional ships to maintain the service frequency. However, this results in an increase in the total running cost of the vessel.

Additionally, it may violate transit time frames for some types of goods and an increase in inventory costs. The overall vessel turnaround time can be reduced by proposing a handling rate with higher handling productivity at ports. However, a greater handling rate along with better handling productivity will increase the total cost of port handling. The liner shipping company must balance the competing interests to build cost-effective vessel schedules (Dulebenets et al., 2021).

2.5. Container trade growth factors

Among all the seaborne trade commodities, maritime container trade has the higher growth rate. Three major players are identified in this industry, the traders, the carriers composed of liner companies, and container terminals. The maritime containerized trade and the global economy are becoming increasingly inextricably linked.

Container trade is a result of economic growth. Economic and income growth lead to an increase in the amount of manufactured goods in circulation. Furthermore, the new global supply chain, which is defined by outsourcing and fragmentation of industrial processes, lengthens the distances covered by containerized freight. As a result, container transportation capacity is increased to satisfy the rapidly rising demand. The introduction of large vessel sizes enables economies of scale.

Additionally, automation of terminals has become a new trend to reduce resource utilization. Containerization is primarily accomplished through the capture of the break-bulk cargo market. This was especially the case for consumer goods, which were the first to be containerized. About 90% of break-bulk freight has been containerized to date; this process is complete. Thus, the containerization market's development potential is reliant on diversification and inventories.

Containerized flows are seldom balanced, requiring empty containers to be repositioned to sites with available export cargo. Thus, the more unbalanced the traffic, the greater the need for containerized capacity for repositioning. Additionally, this leaves open the potential of utilizing empty backhauls and the related discounted freight prices. Further, changes in manufacturing locations as a consequence of the recent trend toward regionalizing manufacturing systems may result in a reduced requirement to reposition containers (Rodrigue, 2020).

2.6. Competition collaboration

The maritime transport market is derived from international trade: the container trade market, one of Africa's most developed and widespread trades. Therefore the trade pattern between the 28 countries on the west coast of Africa, whose one-fourth among them are landlocked, is characterized by different market conditions such as competition and cooperation between container ports. As they are engaged in the same market, they should collaborate to compete as a win-win strategy rather than a win-lose one (Song & Panayides, 2008).

The container trade is a capital-intensive industry base on liner shipping and port operations. There is a limited differentiation of the sea transport services for containers. Therefore, the competition is mainly based on cost. The mainliners, which represented two-thirds of the market, are making alliances to benefit from the economy of scale. Their location and services mainly characterize ports. Therefore, they can benefit from cooperation and competition throughout the liner operations (Lee & Song, 2017).

Ports face versatile challenges at the center of logistics and supply chains (Lee & Song, 2017). The ports use competition to react to the highly volatile maritime transportation market. However, they also have to collaborate in some activities to achieve common goals. Thus, their cooperation in a win-win situation is regardless of their size. However, the port's capacity affects the type of strategic competition or cooperation they establish among them. Therefore, the difference in size also determines the nature of their strategic relation and engagement (Song et al., 2015).

The source of their contests is more about the hinterland (Notteboom, 2010). In Africa, as one-third of the countries are landlocked, ports that serve mainly domestic demands dispute those countries' markets (UNCTAD, 2019).

The term coopetition conceptualized by Brandenburger and Nalebuff reflects the relations between ports on the west coast of Africa. They, therefore, simultaneously compete and cooperate. Unfortunately, the literature is yet to discuss competitive strategies between African ports. No analytic study exists to examine the nature of the relation between African container ports. Region-based coopetition research of the container trade industry, using liners activities data and AIS data, will determine the aspects of the market. The collaboration between ports enables a reciprocal benefit: Location, inventory, and connectivity, as ports' main factors, are optimized through competitive strategies (Donselaar & Kolkman, 2010).

2.7. Container trade demand

Container demand is ordered by domestic, transit, and trans-shipment markets. The standard of living between rich and developing countries differs by more than a factor of 30. That determinant is related to the productivities of countries. It generates friction to trade (Waugh, 2010). The standard of living in Africa is growing at the rate that should generate more trade demand, especially in terms of manufactured goods. Thus, container trade demand is high in Africa when the supply is constantly at a low rate. The measurement of those factors through quantitative analysis of container trade demand can quantify the gap and anomalies through economic and transportation variables. Maritime container transport is driven by three main variables, throughput, transshipment, and origin-destination (OD) flow. Geography determines the characteristics of the variables. The port infrastructures affect throughput and transshipment. Besides, the area's physical characteristics determine the transshipment need and intensity. The origin and destination flow express the level of trade for the region (Russo & Musolino, 2013). The African countries on the Atlantic Ocean coast have all the three leading indicators that induce a positive potential of demand growth of container trade.

2.8. Research Gap and Contributions

The literature review was undertaken to compile all available information on maritime container transportation. The chosen articles were classified into the following categories: the trade trends and changes, the liner shipping characteristics, port competition and collaboration, container trade demand. The maritime containerized trade and the global economy are increasingly closely connected (Haralambides, 2019). Along with global population and GDP, the world economy will continue to impact container trade demand substantially. Globalization, which accelerated the expansion of international maritime trade around the turn of the century, has had a diminishing effect in recent years (Cariou, 2020).

Although optimized strategic relation between neighbouring ports is widely recognized as very important for maritime container trade development in a region, very few researches look at the port competition and cooperation especially. No analytic study is found for that subject. The majority of the reviewed papers primarily evaluate the share of the neighbouring ports in the transit of containers to serve the landlocked countries. Certain studies examine the selection of hub ports based on criteria related to the land mode of transportation.

The study s contribution resides in conducting an empirical examination of the volume of container flow and its various trends using data from an automatic identification system. It circumvents the challenges inherent in doing an analytical study on container production volumes due to a deficiency of internal data that port authorities in this region should hold. Numerous port investment projects are now underway in Africa. Certain types are more effective than others. For optimal investment, precise information on the port's market position should be considered. The research seeks to support decision-making in this respect by establishing the dependence pattern between ports. Thus, the reciprocal benefit a port receives from investing in developing the productivity of a nearby port with which it collaborates.

Finally, the paper will perform a comparative analysis of the present ports network situation and an optimized system through collaboration and competition between ports to support decision-making. As port system configuration is an enabler of good container trade flow, the prerequisites include planning and establishing effective port networks and improving the foundation for competition and collaboration.

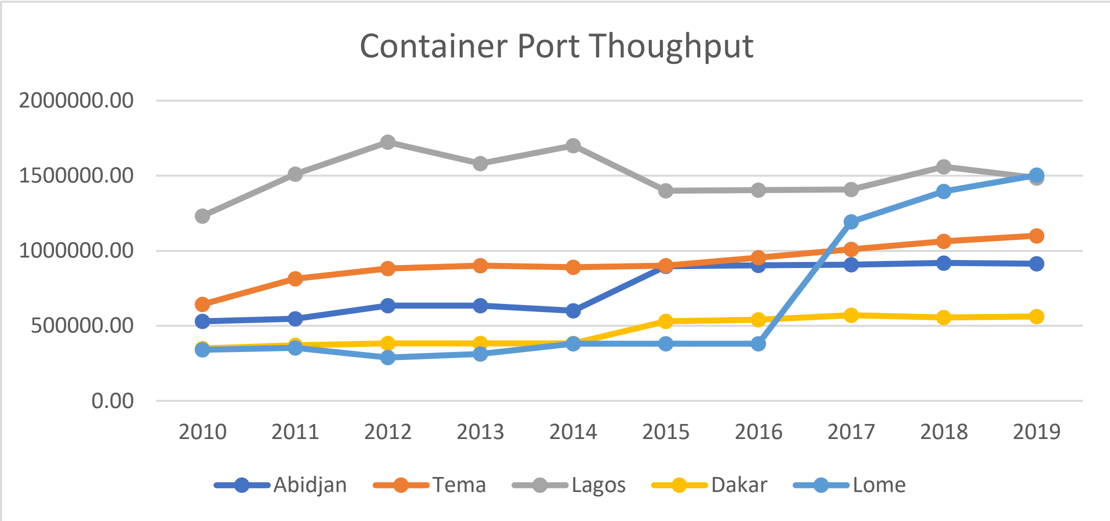
3. Chapter three: Methodology and Data

3.1. Methodology

Four components comprise the methodology used to address the research questions. The first is the dependence ratio model, which measures collaboration and competition in terms of throughput volumes. The second goal pursued through a Multiple Linear Regression model is to find the significant variables for each of the three specified port throughputs using t-tests. Then, a Co-integration test Model is used to determine the short- and long-run nature of the relationship of pair ports. Finally, an ARIMA model is performed to predict the nature of the relationship between adjacent ports, taking into account the maritime industry's seasonality. Understanding the strengths and limitations of selected Ports' relationships will support in planning for their strategic partnership choices.

Historically, African ports have mostly been oriented on their domestic markets, with very little transit traffic to inland countries. Globalization's expansion of international trade altered the paradigm, allowing liners to structure container exchanges among neighboring ports. This study focuses on determining the container throughputs and market shares of Tanger, Dakar, Abidjan, Tema, Lome, and Lagos, which compete and collaborate to serve domestic demand and transshipment traffic landlocked countries such as Mali, Niger, Burkina Faso, and Tchad. Cargo volume is one of the major factors that are significant for port competitiveness. Shipping liners, in that essence, are seeking to achieve a higher economy of scale. Hence, major ports are used for hub ports (Bae et al. 2013). On the west coast of Africa, the cargo volume of ports is usually dependent on the economic characteristics of their countries since ports are to play an inducing role in national economic development(Jung, 2011). The coopetition aspect is mostly for transshipment cargos, as ports do not share their gateway functions to support their countries' imports and exports of containers. Therefore, the transshipment activities of ports are sources of the risk of port and generate throughput volatility (Notteboom et al., 2019). Thus, port with higher transshipment volume is engaged in a competition to increase their volume or retain the existing one. As seen in (Figure 1), all five of West Africa's major ports have witnessed an increase in throughput. Despite the port of Lome's limited local demand, its container production has increased fourfold since 2016. This shows that the port of Lome attracts a high volume of transshipment and has established itself as the region's major port.

Figure5: Annual container throughput for five major ports in the west coast of Africa



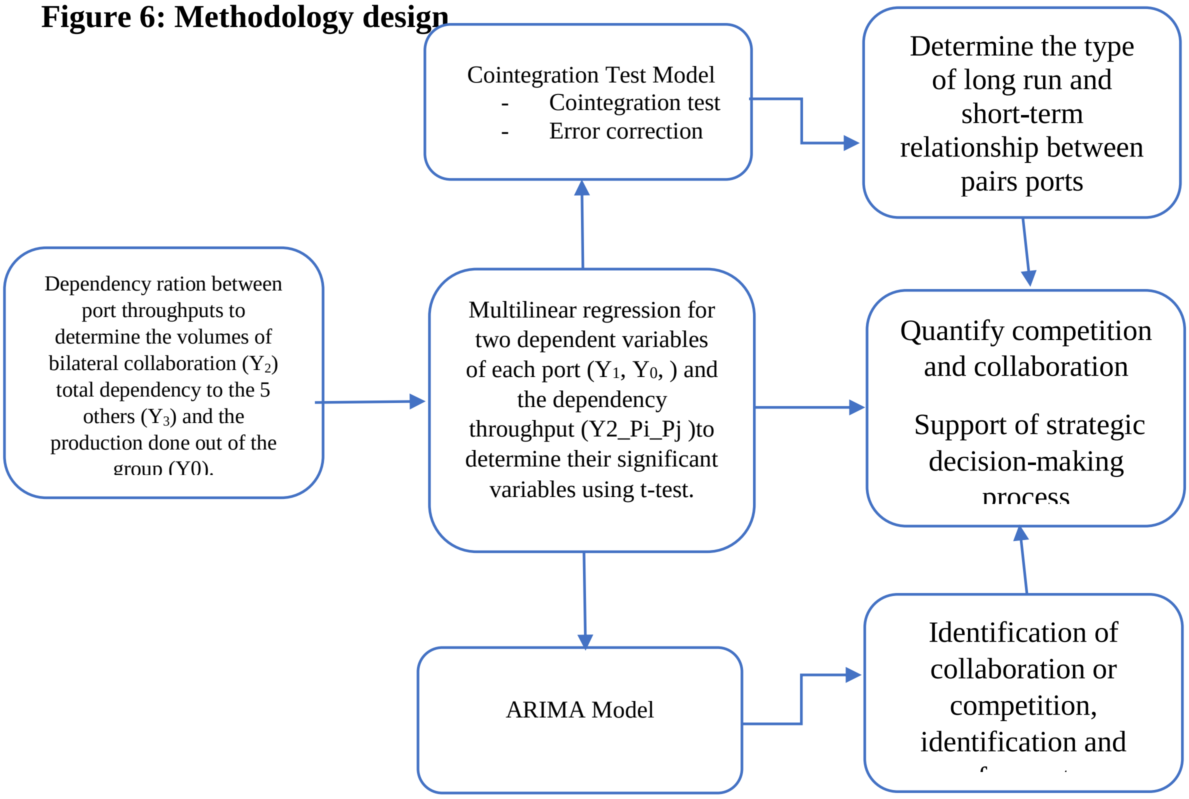
Source: made by the author using data from UNCTAD.

Africa has a small market share in the worldwide container trade, as was mentioned in the introduction. As a result, it is critical to assist decision-making in maximizing container traffic in the region and to establish the criteria for port selection by liners pursuing economies of scale in the region. Ports should compete due to market pressure. Meanwhile, crucial regional container ports have to collaborate to improve their ability to accommodate liner shipping services (Asgari et al., 2013). A general approach to assessing container trade developments in Africa is to undertake a quantitative analysis of how container ports generate throughput. To understand the game theory strategy for competition and cooperation between players, the term coopetition was developed (Brandenburger & Nalebuff, 1995). The marine industry's perspective, particularly for ports, is concerned with the strategic linkage and interdependence of regional ports. Several adjacent ports strategically cooperate along with the natural competition between them to thrive in an increasingly competitive market environment (Song, 2002).

In the context of West Africa, the patterns of liners' service in the region require collaboration between neighboring ports. Vessels use joint services to collect or discharge sufficient numbers of containers. Ports create and share value-added activities as part of their strategy.

The study will utilize an empirical method to ascertain the dependence relationship between the container throughputs of Africa's six largest container ports on the west coast. Thus, it determines the ratio of throughput they share and runs multiple linear regressions on total throughput, bilateral dependency ratio, and multilateral dependency of each of their throughput. To better support the decision-making process, predictions will be made about the dependency using the SARIMA (Seasonal Autoregressive Integrated Moving Average) model. It is to look at the future collaboration and competition trend.

Figure 6: Methodology design



3.1.1 Dependence Ratio

As a result, the following formula is used to calculate a port's dependence on its five adjacent ports:

$$R_i^{\sum(j)} = \frac{TEU_{\sum(j)}}{TEU_i} \quad \text{(Eq.1)}$$

Where denotes $\left(R_i^{\sum(j)}\right)$ the interdependency ratio of port i on the adjacent ports j that have common liner services. $TEU_{\sum(j)}$ indicates the container throughput in TEUs handled by port i coming from the other adjacent ports j using the same services and at the same time. Therefore the dependence ratio $\left(R_i^{\sum(j)}\right)$ indicates the percentage of the volume of cargo which a port i depends on the reference ports j compare to its total volume at the same time.

A higher $\left(R_i^{\sum(j)}\right)$ indicates a higher direct impact of the references ports j on port i's container throughput.

3.1.2 Multiple Linear Regression

The multiple linear regression or the multivariate model is used applying the ordinary least squares (OLS). It is to determine the relationship between several independent variables and a dependent variable. It is about a general-to-specific model-building strategy. The model assumes a linear link between the dependent variable Y and the explanatory variable X_i. A multivariate model will retrieve meaningful information from the data. The method of ordinary least squares is adequate for estimation. The multivariate model will convey relevant understanding from the data (Andrews, 1974).

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + \varepsilon \quad \text{(Eq.2)}$$

α is the intercept, also known as the constant. β_i is The slope for the variable X_i. It indicates the amount by which the value of Y increases when X_i is increased by one unit, and k is the number of observations.

ε denotes the error term or residual. It is the difference between the predicted and actual values.

$$\varepsilon = Y - \hat{Y} \qquad \text{(Eq.3)}$$

$\hat{Y}$ refers to the predicted value; Y refers to the observed or actual value.

At the beginning of the regression modeling analysis, we use descriptive statistics to explore, visualize and understand the data. This has two purposes. We look at the maximum, the minimum, the mean, skewness, and the standard deviation of the variables after plotting their time-series graphs. It provides preliminary information about the data, the variables' quality, and their relevance for the model by considering their standard deviations, among other things.

3.1.2.1 Unit Root test

The data sets must have stationary characteristics in order to be processed in a regression analysis. It is to avoid the long-run occurrence of common unit roots between sets. It eliminates spurious regressions in which non-stationary variables might lead to a high R^2 and significant t-distribution results (Phillips, 1986). Thus, if the regressors are stationary, they are processed at level or at the first or second differences, thereby conferring them stationary characteristics. Therefore, their Augmented Dickey-Fuller (ADF) and Philip Peron (PP) P-values should be less than the crucial value of 0.05 for this reason (Dickey & Fuller, 1981).

3.1.2.2 T-test

A correlation analysis is performed on the independent variables based on their stationary level prior to this test. It displays the proportion of correlation between them using Microsoft Excel. If the correlation between two independent variables is more than 80%, one of them is penalized based on economic or maritime considerations (Brooks, 2019).

A t-test is conducted using stationary time series of the independent variables. It is to determine those which significantly affect the dependent variable. The analysis of the probability value of each independent variable will judge the null hypothesis, which is the variable is equal to zero. If the variable's probability value (P-value) is greater than 5%, the null hypothesis is rejected. It is accepted when the P-value is more than 5%.

The first method identifies the significant variables to the different port throughputs categories.

3.2 Co-integration test Model

3.2.1 Co-integration test

The cointegration test is done firstly for the purpose of the MLR. It is to make a linear combination between the dependent and independent variables, which are stationary at the first difference. It optimizes the performance of the model by, for instance, increasing the adjusted R-square. Then a unit root test is conducted on the residuals to check their stationarity. Error correction terms (Ect) will be added to the model as new independent variables if significant (P-value less than 5%).

For the second utilization of this test, cointegration can be applied to determine the existence of a long-run relationship between various port pairs in West Africa. Here the cointegration examines the linear combination of two ports throughputs that are non-stationary at level. Cointegration requires that both time series of variables have the same order of integration I(1). The absence of cointegration between two pairs of variables indicates a lack of long-term equilibrium among them so that they can move away from each other randomly.

Once the long-run equilibrium behavior of a group is determined, we can use the vector autoregressive (VAR) to determine whether the ports are in collaboration or competition mode.

To estimate multiple cointegrating vectors we consider the Vector Autoregression (VAR) of order *q* (Engle & Granger, 1991, Johansen, 1991).

$$\Delta TEU_t = \varphi TEU_{t-1} + \sum_{t=1}^{q-1} \Psi_i \, \Delta TEU_{t-1} + \beta X_t + \varepsilon_t \qquad \text{(Eq.7)}$$

$$\Psi_i = -\sum_{j=i+1}^{q} A_j \qquad \text{(Eq.8)}$$

$$\varphi = \sum_{i=1}^{q} A_i - I \qquad \text{(Eq.9)}$$

where TEU_t is a k x 1 vector of $I(1)$ variables, Ψ_i and φ_i denote k x k matrices of unknown parameters to be estimated, β represents a k x h matrix, X_t represents a h x 1 vector of $I(0)$ variables, and ε_t refers to a vector of error terms.

The following Cointegrating Equation (CE) shows the linear combination of two cointegrated port throughputs.

$$TEU_A = \alpha + \theta TEU_B + \widehat{e}_t \qquad \text{(Eq.10)}$$

TEU_A is the container throughput handled by port A

TEU_B represents the container throughput handled by port B,

α is the constant term,

θ denotes the long-term inter-port relationship,

$\hat{e}_t$ represents the residual.

3.2.2 Error Correction Model

By integrating Autoregression, Moving Average, and error correction, deviations from the relationship among cointegrated variables may be adjusted without compromising the residuals' stationarity. The model is referred to as the Vector Error Correction (VECM). It is built from the CE in order to establish the short-run relationship between port throughputs (R. F. Engle & Granger, 1987). For port pair throughput analysis of ports A and B, the following two-equation system represents the VECM for port pair throughput analysis, where the two variables are cointegrated at the level one (I) processes.

$$\Delta TEU_{A,t} = \beta_1 + \beta_2 \bar{e}_{t-1} + \sum_{i=1} \theta_1 \Delta TEU_{A,t-1} + \sum_{i=1} \theta_2 \Delta TEU_{B,t-1} + \mu t \quad \text{(Eq.11)}$$

And

$$\Delta TEU_{B,t} = \beta_3 + \beta_4 \bar{e}_{t-1} + \sum_{i=1} \theta_3 \Delta TEU_{A,t-1} + \sum_{i=1} \theta_4 \Delta TEU_{B,t-1} + \omega_t \quad \text{(Eq.12)}$$

$TEU_{A,\,t}$ is the container throughput handled by port A

$TEU_{B,\,t}$ is the container throughput handled by port B

$$\Delta TEU_{A,t} = TEU_{A,t} - TEU_{A,t-1}$$

$$\Delta TEU_{B,t} = TEU_{B,t} - TEU_{B,t-1}$$

$$\bar{e}_{t-1} = -\alpha + TEU_{A,t-1} - \delta TEU_{B,t-1} \quad \text{(Eq.13)}$$

It represents the correction of the lack of equilibrium in the short-term timeframe. The correction coefficients β2 and β4 can entail positive or negative autocorrelation, meaning collaboration or competition relationship between the pair ports.

In this model, we began with an unconstrained VAR method using AIC and BIC tests to determine the proper lag and then examined the integration order of the variables using the DF and ADF tests. We do a cointegration test as the third step. It establishes the existence of a long-run relationship between the throughputs of two ports, allowing us to evaluate whether the relationship is competitive or cooperative. The short-run dynamic of the relationship was assessed using a VEMC model.

3.3 Seasonal Autoregressive Integrated Moving Average SARIMA (p,r,q) (l,m,n)

The Seasonal Autoregressive Integrated Moving Average (SARIMA) is a Multiplicative ARIMA Model. It is an application of the ARIMA approach that incorporates seasonality. It is capable of identifying complicated patterns in data and forecasting. SARIMA models can be used to evaluate and forecast seasonal univariate time series data, which are the characteristics of the maritime industry. The SARIMA model function is defined as (p,d,q) (l,m,n), with **p** denoting the number of autoregressive elements, **d** denotes non-seasonal differences, and **q** indicates lagged forecast errors. The number of periods is denoted by **l**, the number of seasonal autoregressive terms is indicated by **m**, and the number of seasonal moving averages is represented by **n**. SARIMA (p,d,q) (l,m,n) will be developed in three stages. They include identification, estimate, and forecasting.

$$\phi(L)\Phi(L)(1-L)^d(1-L^s)^m y_t = c + \theta(L)\Theta(L)\varepsilon_t. \quad \text{(Eq.14)}$$

$(1-L)^d$ is the non-seasonal differencing operator

$(1-L^s)^m$ is the seasonal differencing operator

$$\phi(L) = (1 - \phi_1 L - \ldots - \phi_p L^p) \quad \text{(Eq.15)}$$

it is the degree *p* Autoregression (AR) operator polynomial

$$\theta_q(L) = (1 + \theta_1 L + \ldots + \theta_q L^q) \quad \text{(Eq.16)}$$

it is the degree *q* Moving Average (MA) operator polynomial

$\Theta(L)$ is an invertible, degree *m* MA operator

The cointegration and Error Correction Model represents the third method used to quantify the competition and collaboration relationship between the selected ports after the interdependency ratio analysis and the Multiple Linear Regression model.

3.4 Assumptions Verifications

At the conclusion, a residual diagnostics test is performed to validate the assumptions. As the initial condition of linear regression, a Jacque Berra test for normality is used to determine if the mean of the residual is close to zero. To compensate for the lack of normal distributions, dummy variables are included. A HAC test is conducted to determine if the residuals' serial distribution has heteroscedastic and correlation. A white correction is performed in the presence of only an Autoregressive Conditional Heteroscedasticity (ARCH) effect. If a serial correlation exists in addition, a Newey-West correction is applied.

Ramsey-Reset test

The Ramsey-reset test for linearity is used to determine whether or not there is a linear connection between the Independent and Dependent variables. It is to ensure that a linear relationship exists between the independent and dependent variables at this stage so that the condition for running the Ordinary Least Square regression is still satisfied.

The Chow break Test

This test enabled us to determine the breakpoint of our variables' data series. The primary objective of the test is to ensure that important variables remain consistent following any shock. In other words, the chow break test is frequently used to determine if independent factors have varying effects on various subgroups of the population.

3.5 Data Analysis

The availability of information to quantify the competition and collaboration of those six ports is a significant obstacle. As a result, advanced data collecting and mining techniques were used in the research. The dependency ratio between container ports was established in two stages. Firstly, data was collected to compare the six ports' bilateral liner connectivity. Then, to ascertain the dynamic of container port competition and collaboration on Africa's Atlantic facade, data on container throughput for the ports of Tanger Med, Dakar, Abidjan, Tema, Lome, and Lagos was sourced from the Alphaliner database by AXSMarine. Alphaliner is based on container liner services in conjunction with the ships' automated identification systems (IAS) to give up-to-date itineraries and ports of calls. Therefore, data of the container liner services are used to assess the Container throughput trend for the period 2006-20122013 of 2021.

MLR Concept

The container throughput time series of the respective ports are used in the first stage to assess their dependencies. It is to determine the ports' total throughput (Y1_Pi) , the bilateral dependency (Y2_Pi_Pj), the total dependency (Y3_Pi_All), and their exclusive throughput (Y0_Pi) (table 1). The model uses quarterly base frequencies observations of the variables. In the second section of the study, multiple linear regression is conduct to support strategic decisions to choose the efficient type of relationship with the neighboring ports.

Table 1: Dependent Variables

Port	Total throughput	Bilateral dependency	Multilateral dependency	Exclusive throughput
Tanger	Y1_Ta	Y2_Ta_P*j*	Y3_Ta_All	Y0_Ta
Dakar	Y1_Dk	Y2_Dk_P*j*	Y3_Dk_All	Y0_Dk
Abidjan	Y1_Ab	Y2_Ab_P*j*	Y3_Ab_All	Y0_Ab
Tema	Y1_Te	Y2_Te_P*j*	Y3_Te_All	Y0_Te
Lome	Y1_Lo	Y2_Lo_P*j*	Y3_Lo_All	Y0_Lo
Lagos	Y1_La	Y2_La_P*j*	Y3_La_All	Y0_La

Note:

- Y1_Pi is the total throughput of port i. it is the total number of containers coming to port Pi from all directions. It is considered in a quarterly base from 2013 to 2021.
- Y2_Pi_Pj it is the throughput generate by port Pi coming from port Pj. It is consider as bilateral dependency. For each pair ports, we have two variables:

the flow from port I to port j (Y2_Pi_Pj) and the one from port j to port i (Y2_Pj _Pi).

- Y3_Pi_All is the throughput of port i generated from all of the five other ports. It is the shared of all the other five selected ports in the total throughput of port i.
- Y0_Pi is the throughput of port i "only". It is generated without collaboration with any of the other five ports.

The independent variables are in two groupes:

Financial and economic indicators:

- BRVMCI: is the index of west African 100 major multinational companies that operate in height countries.
- Nigeria_SE: Nigeria is the major economy in the region, this index reflects the production of the main companies in the country including maritime transportation.
- Libor_IR: London Interbank Offered Rate is a short-term lending rate in the international interbank market, which serves as a reference for major global banks lending to one another in the international interbank market.
- Ex_Rate_China: the exchange rate of China's currency (Yuan) and the US dollar.
- World_Steel_Prod: the world crude steel production index

Maritime transportation factors:

- Con_NBP_Index: Container New Building Price Index
- Con_SHP_Index: Container Second Hand Price Index
- Con_TCR_Index: Container Time Charter Rate Index
- CCFI_China_Wafr: The average China Containerized Freight Index fort West Africa

Seaborne trade indicators:

- World_Exp_Vo_Index: The world exportation volume index.
- Afr_Exp_Vo_Index: the index of the volume of African exportations.
- SSA_Exp_Vo_Index: The index of the Volume of Sub-Saharan African exportations.
- Wafr_Exp_Vo_Index: The index of the Volume of West African exportations.
- Wasia_NoAfr_Exp_Vo_Index: The exportation of west Asia to North Africa.
- AU_Exp_Vo_Index: The index of the Volume of West African exportations.
- EW_Exp_Vo_Index : The index of the Volume of Economic Comitee of West African States exportations.
- EW_Imp_Vo_Inde: The index of the Volume of Economic Committee of West African States importations.

Three regressions are run for each port to test its dependent variables (Y1, Y2, Y3), using the ports' internal and external factors such as economic indicators, traffic, and internal indicators.

Table 2: Data characteristics

Dependent Variables (Y_s)	Factors	Indicators	Independent Variables (X_i)
Throughput: Y1_*i*(Total) of port *i* Y0_*i*(Only) of port *i* Y3_i_All (Total dependency) Three dependent variables for each port is processed (Table 1)	External Factors	Financial and Macroeconomic	BRVMCI (X_{1})
			Nigeria_SE (X_2)
			Libor_IR (X_3)
			Ex_Rate_China (X_4)
			World_Steel_Prod (X_5)
		Seaborne Trade	World_Exp_Vo_Index (X_6)
			Afr_Exp_Vo_Index (X_7)
			SSA_Exp_Vo_Index (X_8)
			Wafr_Exp_Vo_Index (X_9)
			Wasia_NoAfr_Exp_Vo_Index
			AU_Exp_Vo_Index (X_{11})
			EW_Exp_Vo_Index (X_{12})
			EW_Imp_Vo_Inde (X_{13})
		Maritime transportation	Con_NBP_Index (X_{14})
			Con_SHP_Index (X_{15})
			Con_TCR_Index (X_{16})
			S&P 500 (X_{17})
			CCFI_China_Wafr (X_{18})
			Container time charter Index (X_{19})
			BRVM Index (X_{20})
			World Trade (X_{21})
			Con_OB_Index (X_{22})
	Internal Factors	Y2_*i*_*j*(Bilateral Dependency):throughput generated by port *i* from port *j*.	Y2_Ta_Pj: (X_{23} to X_{27})
			Y2_Dk_Pj: (X_{28} to X_{32})
			Y2_Ab_Pj: (X_{33} to X_{37})
			Y2_Te_Pj: (X_{38} to X_{42})
			Y2_Lo_Pj: (X_{43} to X_{47})
			Y2_La_Pj: (X_{48} to X_{52})

4. Chapter Fourth: Empirical Findings

The study's primary goal is to support the decision-making in terms of competition or collaboration between ports on the west coast of Africa. The six-ports are identified from north to south: Tanger Med, Dakar, Abidjan, Tema, Lome and Lagos. As the first approach, the study used the dependency ratio theory to determine the volume of throughput that each port gets only (Y0_i); it means the competitive part of its throughput. The part obtains from collaboration with another port (Y2_i_j).

In this case, we have five types of products representing the throughput of port i get from each of the other five separately. (Y3_All) is the throughput from all of the five taking together. We considered the total throughput of each port using the dependency ratio theory.

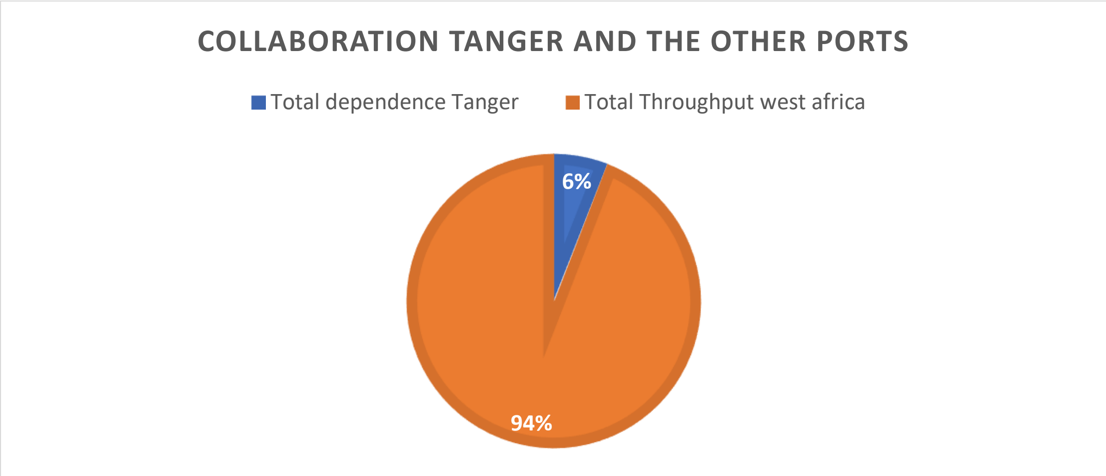
The multiple linear regression is used to identify the significant relationships between the category of throughput, 34 observations from 2013 to the second quarter of 2021. This is processed using some dependent variables as controlled variables, economic indicators, and maritime factors. This model shows how significant each port's throughput is to another using a t-test process.

We use the cointegration technique as per Engle-Granger, between two pairs of throughput determined from the dependency model, which are stationary in I(1) process. The cointegration model identified the type of relationship between the different categories of throughput. It is to know if they are engaged in competition or collaboration and the intensity of that relationship. This chapter will present the sequence of processing the data. Thus, it quantifies the intensity of their link and their nature.

4.1. Finding the type of throughput based on the DRM

The study applies the dependence ratio to the port of Tanger and the rest of Africa's western facade ports. The container traffic from North America, Europe, and South-East Asia via the East-West route through the Suez Canal is increasingly utilizing the port of Tanger as a hub to connect the ports on Africa's Atlantic façade. However, the proportion of container traffic flowing from Tanger to the other studied ports is insignificant at the moment. Tanger accounted for around 6% of the total throughput in Dakar, Abidjan, Tema Lome, and Lagos in 2020, according to data gathered from AXSMarine by the author (figure).

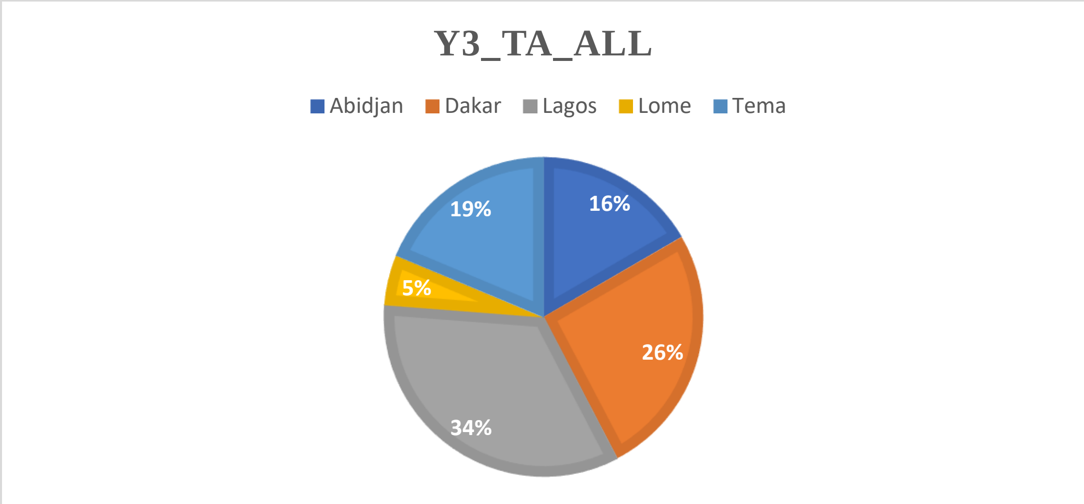
Figure 7: The Share of the five ports coming from Tanger



Source: Alphaliner year 2020

This volume of throughput is shared among the five major ports in West Africa. It is distributed to four ports, but most importantly, the port of Lagos generates 35% of the multilateral elaboration, and 60% of it is divided between Dakar, Abidjan, and Tema. This indicates that Tanger collaborates more with Lagos and Dakar. This finding will be tested in the second phase over a longer time period.

Figure 8: The Share of each port in their multilateral dependence



Source: Alphaliner year 2020

The same ratio is used in calculating between the other ports as bilateral collaboration throughput. They show the throughput generated by port I from its collaboration with j. The following table shows their volumes for the year 2020. This helps the author quantify the specific throughput used for the multiple linear regression for the considered period.

Table 3: Dependence ratio of throughput for year 2020

	Abidjan	**Dakar**	**Lagos**	**Lome**	**Tanger**	**Tema**	**Total Throughput**
Dependence to Abidjan		391,026	302,234	345,571	2,782	579,447	**2,403,897**
Dependence to Dakar	344,432		5,187	229,501	296,442	13,692	**1,919,531**
Dependence to Lagos	80,504	79,407		484,170	4,496	888,201	**2,584,248**
Dependence to Lome	387,095	45,747	371,836		41,761	796,828	**3,426,306**
Dependence to Tanger	144,846	224,334	295,222	44,333		162,992	**15,787,666**
Dependence to Tema	108,781	80,177	202,933	681,385	240,104		**3,548,638**
Total dependence	**1,065,658**	**820,691**	**1,177,412**	**1,784,960**	**585,585**	**2,441,160**	

Source: Author calculation from container throughput in 2020, Alphaliner

Note: This table shows:

- The inbound and outbound of container coming from port A (In the columns) the throughput generated in relation to adjacent port A (dependence ratio to port A) in the total throughput of port B.

Xi	Row	ADF P-Value	ADF Stat	PP P-Value	PP Stat	KPSS P-Value	KPSS Stat
X1	Y1_Ta_0	0.776	0.372	0.776	0.372	0.1	0.073
	Y1_Ta_1	0.001	-10.482	0.001	-10.482	0.1	0.064
X2	Y2_Ta_Dk_0	0.37	-0.743	0.37	-0.743	0.01	0.334
	Y2_Ta_Dk_1	0.001	-8.961	0.001	-8.961	0.1	0.062
X3	Y2_Ta_Ab_0	0.247	-1.081	0.247	-1.081	0.1	0.1
	Y2_Ta_Ab_1	0.001	-5.576	0.001	-5.576	0.1	0.046
X4	Y2_Ta_Te_0	0.251	-1.07	0.251	-1.07	0.025	0.177
	Y2_Ta_Te_1	0.001	-7.087	0.001	-7.087	0.1	0.025
X5	Y2_Ta_Lo_0	0.695	-3.606	0.695	-3.606	0.081	0.129
	Y2_Ta_Lo_1	0.001	-9.476	0.001	-9.476	0.1	0.022
X6	Y2_Ta_La_0	0.247	-1.08	0.247	-1.08	0.01	0.261
	Y2_Ta_La_1	0.001	-4.443	0.001	-4.443	0.1	0.032
X7	BRVMCI_0	0.08	-1.721	0.08	-1.721	0.01	0.282
	BRVMCI_1	0.005	-2.977	0.005	-2.977	0.01	0.257
X8	Nigeria_SE_0	0.765	0.34	0.765	0.34	0.023	0.182
	Nigeria_SE_1	0.005	-3.009	0.005	-3.009	0.066	0.137
X9	Con_NBP_Index_0	0.667	0.07	0.667	0.07	0.01	0.312
	Con_NBP_Index_1	0.002	-3.345	0.002	-3.345	0.1	0.097
X10	Con_SHP_Index_0	0.893	0.885	0.893	0.885	0.068	0.137
	Con_SHP_Index_1	0.004	-3.161	0.004	-3.161	0.1	0.097
X11	EW_Exp_Gro_Rate_0	0.147	-1.983	0.047	-1.983	0.01	0.349
	EW_Exp_Gro_Rate_1	0.001	-5.758	0.001	-5.758	0.1	0.071
X12	EW_Exp_Vo_Index_0	0.471	-0.467	0.471	-0.467	0.01	0.239
	EW_Exp_Vo_Index_1	0.001	-5.992	0.001	-5.992	0.1	0.114

4.2. Finding the significant variables of the Total Throughput of the ports based on the MLR

Twenty variables were chosen for the study; after completing correlation and stationary analyses, eight variables were eliminated to avoid spurious models. The T-Test eliminated non-significant independent variables comprised of port throughputs and economic indices. Multiple linear regressions were carried out for each port individually. Using the total throughput of the port (Y1_i) as a dependent variable, the first of these models is constructed. It measures the relevance of the throughputs created in partnership with others as well as the total output of the company in question. The second regression evaluates the significance of the various dependent port throughputs using the throughput obtained without interaction with the other ports (Y0_i). The goal is to examine the established link between the container output at Port I and the port's cooperation or competition with the other ports in the region.

4.2.1 Preliminary statistics

The descriptive statistics of all of the variables in the model are computed and shown in the report. Its purpose is to ensure that the collected data can statistically fit into a regression model before proceeding.

Unit Root Test

The study used the MATLAB program to create the multiple linear model, which was then tested. The total throughput of the port of Tanger was the first dependent variable to be evaluated in this study. Following the processing of the data and the verification of their principal statistic, a unit root test was performed to determine the stability of the variables in the dataset. According to the results of the Augmented Dickey-Fuller and Philip Perron tests, all of the variables, including the dependent variable, are stable at the first difference. Six of them reflect the ratio of port throughput to total throughput. The remaining variables are control variables that indicate economic indicators or factors affecting marine trade.

Table 4: Unit Root Test

Correlation between the independent variables

After examining the relationship between the independent variables, those with an 80% or higher correlation were eliminated. It mostly consists of certain economic indicators related to Africa, some trade variables, such as the continent's exportation and importation with the rest of the globe. Some financial indexes were also highly correlated among them. Thus, the snp500 or BRVMCI m Nigeria Stock Exchange were excluded from consideration. In terms of the port's throughput, the multilateral throughput and the throughput created through competition were significantly correlated (over 80%) with bilateral throughputs; as a result, the author decides to eliminate both.

Table 5: correlation test among independent variables

Row	Y3_Ta_All	Y2_Ta_Dk	Y2_Ta_Ab	Y2_Ta_Te	Y2_Ta_Lo	Y2_Ta_La	ExRateChi	BRVMCI	LiborIR	WorldStee	World_Exp	ConNBPIn	Wasia_No	ConSHPInd	ConTCRInd	NigeriaSE	CCFIChina	AU_Exp_G	EW_Exp_V	EW_Imp_V	Afr_Imp_V	SSA_Imp_V	WAfr_Imp	WorldTrade
Y3_Ta_All	1																							
Y2_Ta_Dk	0.7	1																						
Y2_Ta_Ab	0.43	0.02	1																					
Y2_Ta_Te	0.16	-0.14	-0.13	1																				
Y2_Ta_Lo	0.4	0.33	0.4	-0.49	1																			
Y2_Ta_La	0.7	0.44	-0.07	-0.02	0.18	1																		
ExRateChina	0.52	0.11	0.29	0.3	-0.13	0.5	1																	
BRVMCI	-0.51	-0.03	-0.16	-0.28	-0.09	-0.56	-0.67	1																
LiborIR	-0.1	-0.56	0.3	0.35	-0.07	-0.21	0.36	-0.43	1															
WorldSteelProd	0.36	-0.18	0.32	0.31	0.17	0.26	0.57	-0.86	0.63	1														
World_Exp_Vo_Index	-0.08	-0.37	0.2	0.44	-0.07	-0.33	0.34	-0.41	0.77	0.65	1													
ConNBPIndex	0.17	0.12	0.07	-0.18	0.37	0.12	-0.13	-0.46	0.2	0.41	0.06	1												
Wasia_NoAfr_Exp_Vo_Index	-0.27	-0.52	0.22	0.32	-0.1	-0.44	0.25	-0.28	0.87	0.5	0.87	0.11	1											
ConSHPIndex	0.11	-0.11	-0.05	0.23	0.17	0.04	-0.07	-0.5	0.5	0.55	0.49	0.59	0.42	1										
ConTCRIndex	0.14	-0.08	0	0.26	0.16	0.01	-0.04	-0.51	0.44	0.61	0.51	0.68	0.42	0.83	1									
NigeriaSE	-0.44	-0.55	-0.18	0.26	-0.04	-0.45	-0.51	0.09	0.4	0.12	0.38	0.06	0.38	0.57	0.49	1								
CCFIChinaWAfrica	0.08	-0.02	-0.05	-0.22	0.33	0.25	0.26	-0.59	0.4	0.53	0.25	0.64	0.29	0.45	0.56	-0.01	1							
AU_Exp_Gro_Rate	-0.62	-0.61	-0.03	0.04	-0.12	-0.62	-0.34	0.29	0.34	-0.08	0.42	-0.22	0.52	0.13	0.15	0.65	0.01	1						
EW_Exp_Vo_Index	0.04	-0.24	0.17	-0.03	0.1	0.12	0.27	-0.67	0.58	0.61	0.47	0.56	0.5	0.57	0.64	0.23	0.76	0.28	1					
EW_Imp_Vo_Index	0.52	0.44	0.15	-0.12	0.24	0.48	0.4	-0.63	-0.05	0.5	0.08	0.58	-0.06	0.25	0.32	-0.45	0.45	-0.5	0.35	1				
Afr_Imp_Vo_Index	0.07	-0.03	0.06	0.32	-0.12	-0.07	0.22	0.24	-0.04	-0.09	0.17	-0.73	-0.05	-0.4	-0.37	0	-0.49	0.06	-0.51	-0.49	1			
SSA_Imp_Vo_Index	-0.04	-0.09	0.08	0.2	-0.17	-0.16	0.18	0.32	-0.05	-0.15	0.17	-0.76	-0.03	-0.44	-0.46	-0.02	-0.57	0.08	-0.53	-0.49	0.94	1		
WAfr_Imp_Vo_Index	-0.13	-0.09	0	0.08	-0.08	-0.21	-0.24	0.49	-0.27	-0.26	-0.03	-0.6	-0.26	-0.4	-0.38	0.11	-0.64	0.08	-0.62	-0.51	0.77	0.83	1	
WorldTrade	-0.2	-0.5	0.13	0.38	-0.13	-0.31	0.3	-0.43	0.85	0.66	0.93	0.12	0.9	0.5	0.54	0.46	0.36	0.5	0.6	0	0.04	0.06	-0.13	1

	Estimate	SE	tStat	pValue
(Intercept)	0.027	0.055	0.489	0.631
Y2_Ta_Dk	0.204	0.057	3.593	0.001
Y2_Ta_Ab	1.085	0.228	4.759	0.001
Y2_Ta_Te	0.579	0.189	3.066	0.007
Y2_Ta_Lo	0.220	0.077	2.860	0.011
Con_NBP_Index	-3.410	1.522	-2.240	0.040
Con_SHP_Index	1.804	0.491	3.677	0.002
EW_Exp_Gro_Rate	-0.208	0.074	-2.810	0.013

Number of observations: 24, Error degrees of freedom: 16
Root Mean Squared Error: 0.261
R-squared: 0.902, Adjusted R-Squared: 0.86
F-statistic vs. constant model: 21.2, p-value = 5.79e-07

4.2.2 T-test

Table 6: First T-test, Y1_Ta = [Linear formula with 12 terms in 11 predictors]

	Estimate	SE	tStat	pValue
(Intercept)	0.063	0.067	0.944	0.364
Y2_Ta_Dk	0.162	0.071	2.288	0.041
Y2_Ta_Ab	1.124	0.254	4.427	0.001
Y2_Ta_Te	0.721	0.278	2.590	0.024
Y2_Ta_Lo	0.243	0.123	1.980	0.071
Y2_Ta_La	0.054	0.228	0.235	0.819
BRVMCI	1.440	1.109	1.299	0.219
Nigeria_SE	-0.581	0.865	-0.671	0.515
Con_NBP_Index	-3.810	1.79	-2.129	0.055
Con_SHP_Index	2.085	0.725	2.875	0.014
EW_Exp_Gro_Rate	-0.237	0.108	-2.200	0.049
EW_Exp_Vo_Index	0.585	1.338	0.437	0.670

Number of observations: 24, Error degrees of freedom: 12
Root Mean Squared Error: 0.277
R-squared: 0.918, Adjusted R-Squared: 0.842
F-statistic vs. constant model: 12.2, p-value = 7.03e-05

Table 7: Final T-test, Y1_Ta = 1 + Y2_Ta_Dk + Y2_Ta_Ab + Y2_Ta_Te + Y2_Ta_Lo + Con_NBP_Index + Con_SHP_Index + EW_Exp_Gro_Rate

Specifically, the t-test looks at the independent variables whose coefficients are different from zero in the linear equation, indicating that the probability values are less than 5%. The author presents the first and last t-tests to identify independent factors that are statistically significant for the port throughput of Tanger. It appears that some control variables and certain port throughputs have their coefficients equal to zero, based on the results of the test shown in table 7, which was performed using multiple restriction variables (probability value more than 5%). This indicates that they are not statistically significant in relation to the dependent variable (Y_1).

Y1_Ta is the total throughput of Tanger Med; this throughput was associated with the dependency throughputs and some control variables. Its examination across the four models indicates that its association with the other throughputs is not linear. The Ramsey Reset test at the end of the multiple linear model confirms that the P-value of the Y^2 is significant. The results are presented in appendix A. An ARCH or GARCH model is adequate to study the regression between the total throughput of Tanger when associated with the other adjacent ports. These non-linear models are not in the scope of this study.

The author decided to conduct a regression between the multilateral dependence throughput of Tanger and each bilateral throughput with the other five ports. It is to ascertain which of the ports are significant for Tanger Med's involvement in West Africa. This approach is in line with the research objectives to support strategic decision-making.

Two of the most significant variables in determining the total throughput of the Tanger port are the throughput generated by the port of Tanger coming from Dakar (T2_Ta_Dk) and the throughput generated in collaboration with the port of Abidjan (T2_Ta_Ab). The third significant variable in determining the total throughput of Tanger port is the index of the volume of exportation of the economic West African state Community. Throughout the t-test process, the adjusted R square (R^2), which is the testing coefficient of determination, is slightly increasing from 84.2%. Thus, the model has been assigned a confidence level of 86% as per the results of the last T-test.

4.3 Co-Integration Model

For the cointegration model, the significant variables from the T-test were paired with the total throughput of Tanger. The purpose of this study is to establish whether or not there is a linear combination (Eq2) between pairs of variables, which implies the presence of a long-run relationship between them and the nature of that relationship. The condition for this is that all of the variables must be integrated at the same level. This is a requirement that our model meets. After running the unit root test, all of the variables are stationary at the I(1) process. As a result, three pairs were created. The new regression is used for each pair of variables, with the stationarity of the residuals being taken into consideration. An error correction term will be introduced if the residual is stationary at level zero I(0). If the residual is not stationary, the variable will be deleted. As a result, the ECOWAS export volume index was deleted from our model, and an error correction term based on the throughput of Tanger in conjunction with the port of Dakar was included. As the following table demonstrates, all of the factors are statistically significant. Furthermore, the model's adjusted R2 is increased from 73% to 87 %. Tanger's bilateral throughputs in its relationship with Dakar and its throughput originating in Abidjan are significant and have a positive impact on the total throughput of the Tanger port, as seen in the table below.

Table 8: Co-Integration results, Y1_Ta = [Linear formula with 9 terms in 8 predictors]

	Estimate	SE	tStat	pValue
(Intercept)	0.065	0.029	2.198	0.044
Y2_Ta_Dk	0.127	0.034	3.798	0.002
Y2_Ta_Ab	0.793	0.134	5.896	2.9368e-05
Y2_Ta_Te	0.319	0.105	3.028	0.008
Y2_Ta_Lo	0.140	0.042	3.552	0.003
Con_SHP_Index	1.119	0.258	4.343	0.001
EW_Exp_Gro_Rate	-0.130	0.040	-3.250	0.005
ect_Y2_Ta_Dk	-0.273	0.078	-3.483	0.003
ect_Y2_Ta_Ab	-0.254	0.082	-3.095	0.007

Number of observations: 24, Error degrees of freedom: 15
Root Mean Squared Error: 0.138
R-squared: 0.975, Adjusted R-Squared: 0.961
F-statistic vs. constant model: 72.1, p-value = 1.41e-10

4.4. ARIMA model

Throughout the tests, by adding moving average and autoregressive variables to the model, the introduction of only one AR is retained that maintains the significance of the actual variables. In the process, the error correction term was removed as it becomes insignificant. After comparing the Akaike's Information Criteria (AIC) and Bayesian Information Criteria (BIC) of the cointegration model, the ARMA model, and the Heteroscedasticity and Autocorrelation-test, the author decides to keep the ARMA results as its the AIC and BIC after are the lowest. Thus, the model`s adjusted R2 is 77%. The container time charter rate index becomes insignificant to the model; hence it is removed from the results.

Table 9: ARIMA Y1_Ta = [Linear formula with 10 terms in 9 predictors]

	Estimate	SE	tStat	pValue
(Intercept)	0.054	0.014	3.832	0.002
Y2_Ta_Dk	0.106	0.023	4.599	0.000
Y2_Ta_Ab	0.700	0.092	7.593	3.9431e-06
Y2_Ta_Te	0.250	0.051	4.888	0.000
Y2_Ta_Lo	0.122	0.022	5.493	0.000
Con_SHP_Index	0.572	0.170	3.360	0.005
EW_Exp_Gro_Rate	-0.116	0.029	-4.016	0.002
ect_Y2_Ta_Dk	-0.173	0.048	-3.648	0.003
ect_Y2_Ta_Ab	-0.104	0.045	-2.298	0.039
MA	-1.110	0.221	-5.007	0.000

Number of observations: 23, Error degrees of freedom: 13
Root Mean Squared Error: 0.0605
R-squared: 0.865, Adjusted R-Squared: 0.771
F-statistic vs. constant model: 9.22, p-value = 0.000245

4.5. Assumptions Verifications

Residual diagnostics test

During this stage, the model was tested to see whether it still satisfied all of the requirements of multiple linear regression. Because of this, a test for heteroscedasticity and autocorrelation were performed. There is an ARCH effect, but there is no serial correlation, according to the results. It was necessary to apply a White Correction. It eliminates the ECOWAS' exportations, importations volume, and the error correction terms of the bilateral throughput of Tanger and Dakar. In addition, the adjusted R^2 has dropped to 69 percent in the test. The mean of the residual almost equal to zero (-1.4179e-17).

Figure 9: The residual histogram

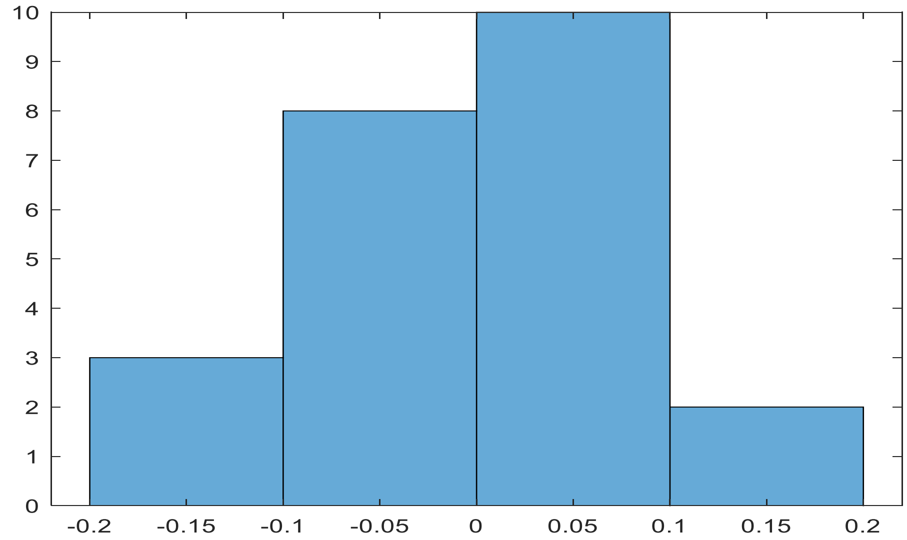
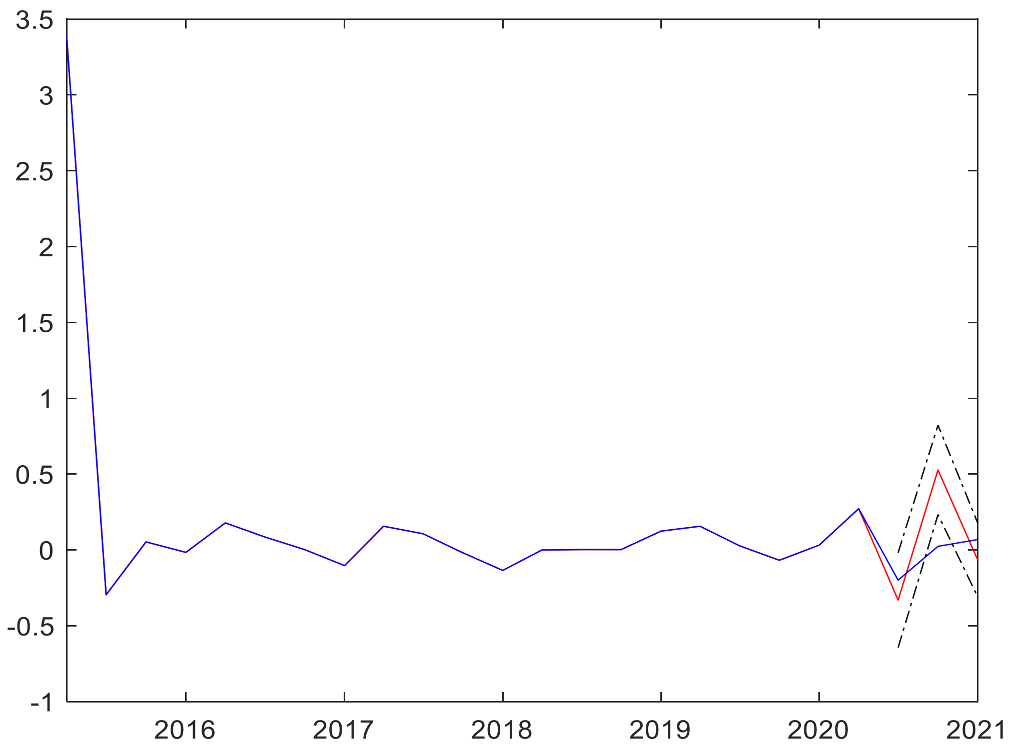


Figure 10: Forecasting - out of sample test ot Tanger total throughput



Stability Diagnostics test

The stability test confirms that the fitted Y2 is not significant since its p-value (0,16) is greater than 0,05. As a result, the model is linear.

Table 10: Residual test results, 1 + y_fit_p2

	Estimate	SE	tStat	pValue
(Intercept)	0.013	0.023	0.577	0.570
y_fit_p2	-1.607	1.581	-1.017	0.321

Number of observations: 23, Error degrees of freedom: 21
Root Mean Squared Error: 0.0889
R-squared: 0.0469, Adjusted R-Squared: 0.00152
F-statistic vs. constant model: 1.03, p-value = 0.321

Total throughput of Dakar

After running the models for the total throughput of the port of Dakar, it was discovered that the only throughput generated by the port's multilateral dependence on the other ports and its competitive throughput were significant. When they are paired and evaluated using the cointegration model, they indicate that they are in a positive relationship. One moving average variable (AR) was included in the model. In the end, the testing of the assumptions indicates that the model had an ARCH effect but no serial correlation. A White correction was applied. The test for normality incorporated a dummy variable and penalized the moving average. The model is shown to be linear since the Y fit Square P-value is greater than 0.05. The adjusted R-square of the model is relatively high, at 0.996. The results of the normality test have a lower AIC than the results of the t-test. Therefore, they are seen as determining the characteristics of the dependent variable.

Table 11: Dakar total throughput results

	Estimate	SE	tStat	pValue
(Intercept)	0.002	0.005	0.310	0.760
Y3_Dk_All	0.230	0.012	19.652	6.423e-18
Y0_Dk	1.633	0.019	86.731	1.393e-35
dummy5	0.106	0.025	4.183	0.001

Number of observations: 32, Error degrees of freedom: 28
Root Mean Squared Error: 0.0244
R-squared: 0.997, Adjusted R-Squared: 0.996
F-statistic vs. constant model: 2.84e+03, p-value = 7.17e-35

Total throughput of Abidjan

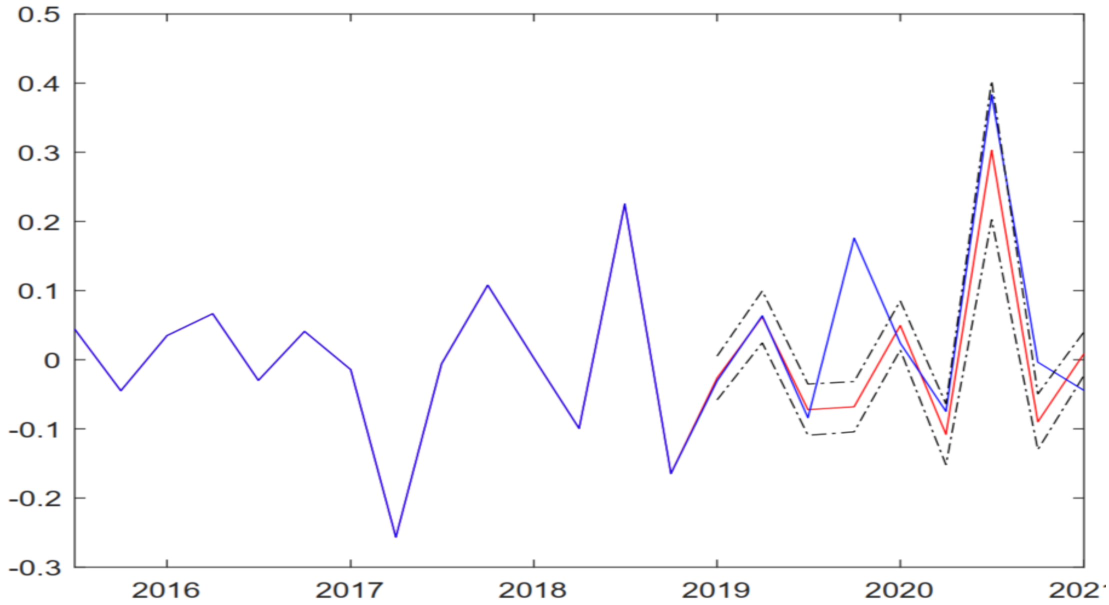
The bilateral throughputs of Abidjan from Dakar and Tema contribute significantly to the total throughput of Abidjan port. A long-term positive relationship exists between the three ports too. According to the cointegration model, a one percent increase in Abidjan's total throughput leads to a 0.31 % increase in its throughput in collaboration with Tema and a 0.23 percent increase in its bilateral throughput with Dakar. Our model's AIC of -76.0307 is linear and displays a high degree of confidence, with a present forecast that fits the confidence interval. The modified R-squared is equivalent to 88 %. There is a strong correlation between its multilateral throughput (more than 80 %) and its bilateral throughput with Tema. As a result, it was removed from the model following the correlation test. Abidjan's competition throughput (Y_0) was also removed from the model to avoid creating a spurious model.

Table 12: Abidjan total throughput results

	Estimate	SE	tStat	pValue
(Intercept)	0.013	0.009	1.437	0.166
Y2_Ab_Dk	0.226	0.038	6.017	6.980e-06
Y2_Ab_Te	0.311	0.031	10.220	2.192e-09

Number of observations: 23, Error degrees of freedom: 20
Root Mean Squared Error: 0.0436
R-squared: 0.898, Adjusted R-Squared: 0.887

Figure 11: Forecasting - out of sample test ot Abidjan total throughput



Total throughput of Tema

Table 13: Dakar total throughput results

	Estimate	SE	tStat	pValue
(Intercept)	0.064	0.047	1.349	0.188
Y2_Te_Dk	0.236	0.074	3.203	0.003
Y2_Te_La	0.59	0.083	7.180	6.650e-08

Number of observations: 32, Error degrees of freedom: 29
Root Mean Squared Error: 0.263
R-squared: 0.725, Adjusted R-Squared: 0.706
F-statistic vs. constant model: 38.2, p-value = 7.53e-09

Tema has two significant bilateral throughputs that contribute to its total throughput. It is the throughputs of Dakar and Lagos. There is a high correlation (more than 80 %) between its multilateral and bilateral throughput with Lagos. The AIC is low (8.1799), and the Adjusted R-Squared is equal to 0.706, indicating the model's acceptable accuracy. The port of Tema works mostly in cooperation with the port of Lagos. An increase of 1% in Tema's total throughput leads to a rise of 0.6 percent in the port's bilateral throughput with Lagos and 0.2% in the port's bilateral throughput with Dakar.

Total throughput of Lome

Table 14: Lome total throughput results

	Estimate	SE	tStat	pValue
(Intercept)	-0.084	0.058	-1.457	0.158
Y2_Lo_La	-0.768	0.300	-2.558	0.017
Y3_Lo_All	1.828	0.113	16.178	2.070e-14
CCFIChinaWAfrica	-0.664	0.298	-2.229	0.036

Number of observations: 27, Error degrees of freedom: 24
Root Mean Squared Error: 0.554
R-squared: 0.577, Adjusted R-Squared: 0.541
F-statistic vs. constant model: 16.3, p-value = 3.33e-05

After evaluating the throughput of Lome, by using the other dependency throughputs as regressors, the author noticed that the throughput coming from Lagos and the multilateral throughput are statistically significant at a level of confidence of 54 percent. Furthermore, the coefficient of significance for the throughput that Lome exchanges with Lagos is negative. That means Lome is losing in its cooperation with Lagos. The cointegration model generates an error correction term. Hence, these two ports are in a negative pattern in the long run. The ARMA model additionally generates one moving average. Its second significant variable is its multilateral throughput. It implies that there is a positive long-term relationship between the total throughput of Lome and its multilateral interdependence with the other five ports; Lome benefits from its collaboration with the other nearby ports in the region. The ARCH effect and serial correlation are absent from the model used for this test. Following this correction, a Ramsey Reset test was performed. The results of the reset indicate that the model is linear. As a result, the model complies with the Classical Assumptions of Ordinary Least Squares analysis (OLS).

Total throughput of Lagos

Table 15: Lagos total throughput results

	Estimate	SE	tStat	pValue
(Intercept)	-1.903	0.183	-10.41	1.4153e-10
Y2_La_Ta	0.014	0.020	0.728	0.047
Y0_La	0.741	0.071	10.4	1.403e-10
ect_Y2_La_Ta	-0.173	0.016	-10.71	7.897e-11
AR	-0.813	0.114	-7.148	1.716e-07
MA	3.198	0.410	7.8	3.6518e-08

Number of observations: 31, Error degrees of freedom: 25
Root Mean Squared Error: 0.00498
R-squared: 0.917, Adjusted R-Squared: 0.9
F-statistic vs. constant model: 55, p-value = 1.09e-12
AIC=-235.4121

The bilateral dependence throughput is significant with Tanger is significant for Lagos as well as its exclusive throughput. The Adjusted R-Squared is equal to 0.9. The model is linear as its P-Value $Yfit^2$ = 0.21, and there is no ARCH effect and no serial correlation. The co-integration model shows a solid long-term partnership with Tanger.

Table 16: Lagos Ramsey reset test results

	Estimate	SE	tStat	pValue
(Intercept)	-0.002	0.003	-0.772	0.447
y_fit_p2	28.147	21.966	1.2814	0.210

Number of observations: 31, Error degrees of freedom: 29
Root Mean Squared Error: 0.0128
R-squared: 0.0536, Adjusted R-Squared: 0.0209
F-statistic vs. constant model: 1.64, p-value = 0.21

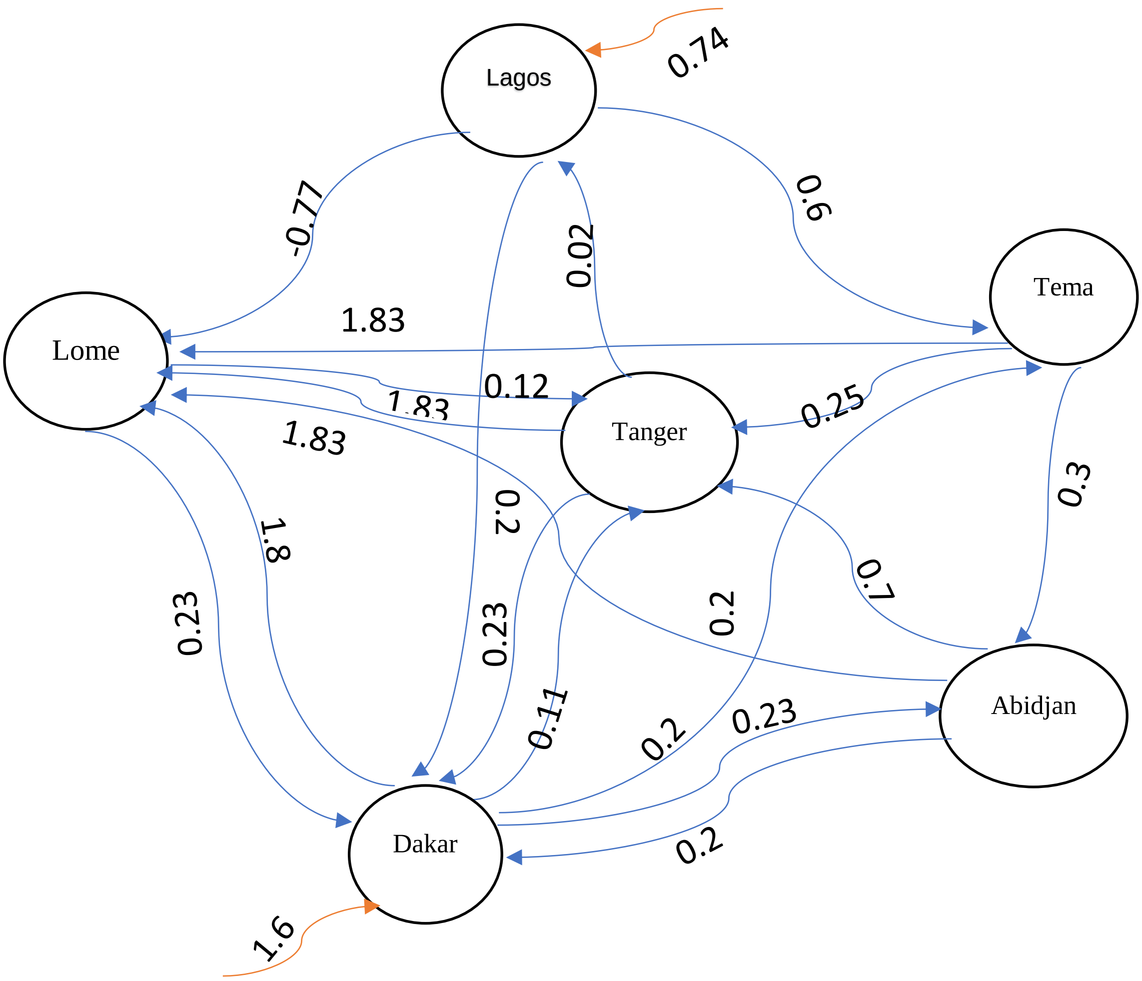
5. Chapter Five: Analysis and Discussion

Analysis

Table 17: Ports competition and collaboration patterns

Port	The origin of Throughput	Observations
Tanger	Dakar: 0.13	Long-term collaboration with Dakar and Abidjan.
	Abidjan: 0.79	
	Tema: 0.31	
	Lome: 0.12	
	Lagos: NIL	
Dakar Exclusive throughput: 1.63	Tanger: 0.23	
	Abidjan: 0.23	
	Tema: 0.23	
	Lome: 0.23	
	Lagos: 0.23	
Abidjan	Tanger: NIL	
	Dakar:0.23	
	Tema: 0.31	
	Lome: NIL	
	Lagos: NIL	
Tema	Tanger:	
	Dakar:0.24	
	Abidjan:	
	Lome:	
	Lagos:0.60	
Lome	Tanger:1.83	
	Dakar:1.83	
	Abidjan:1.83	
	Tema: 1.83	
	Lagos: -0.77	
Lagos Exclusive throughput: 0.74	Tanger: 0.02	long-term collaboration with Tanger
	Dakar: NIL	
	Abidjan: NIL	
	Tema: NIL	
	Lome: NIL	

Figure 10: coefficients (Eq.10), relating the nature and intensity of the relationship between port throughputs



Source: computed by the author from the coefficients of the models employed.

Note: Table 16 and figure 10 are constructed mostly using the results of co-integration models. This is because they frequently offer the least amount of information (AIC, BIC).

The paper studies the relationship between six major ports in the Atlantic facade of Africa. The results are presented starting from north to south. The container throughputs generated by the port of Tanger coming from Dakar, Abidjan, Tema, and Lome have been found significant for the total container throughput of Tanger. the model (Eq.2) postulates that an increase in 1% of the inbound volume of containers from Abidjan (Y2_Ta _Ab), Dakar (Y2_Ta_Dk), Lome (Y2_Ta_Lo), and Tema (Y2_Ta_Te) leads to an increase of Tanger's total throughput by respectively 0.20%, 1.09%, 0.58%, and 0.22%. (table 7). Both the cointegration and the ARMA model indicate that (Eq.10 and Eq.11), Abidjan and Dakar have the most substantial long-term bilateral cooperation with Tanger.

The port of Tanger has the highest volume of container throughput in the region, which is on average five times greater than the volume of container handle in each of the other ports. It is a transshipment port servicing the biggest hinterland in the region, going from Africa to the Mediterranean area.

It has the potential to play the role of a regional hub connecting West Africa to Europe. The study finds that an investment in developing the throughput of Dakar and Abidjan is profitable for Tanger.

Dakar benefits mainly from multilateral and exclusive throughput. The volume of containers coming from all five different ports is significant to the total throughput of Dakar. Meanwhile, it is servicing the ports of Tanger, Abidjan, Tema and Lome. Dakar has the most diversified network with height services tight to its adjacent ports. However, its main volume of containers comes from out of this group of ports. Due to its location, it is halfway between Tanger and the group of the five ports studied. The port of Dakar has the lowest volume within the group. Its theoretical container throughput capacity is 600 000 TEUs (UNCTADSTAT, 2021). Investment to increase its production volume will benefit its collaboration with Tanger, Lome, and Abidjan ports.

The results indicate that Abidjan receives a substantial volume of containers from Dakar and Tema and has strong collaboration with Tanger for outbound containers. Furthermore, increasing 1% of Abidjan throughput coming from Dakar leads to a growth of 0.23 % of its total throughput. Also, a 1% increase in cooperation with Tema for the inward volume of containers can boost Abidjan's total throughput by 0.31 %.

Furthermore, the three ports compete to service the landlocked countries in the region: Mali, Niger, Tchad, and Burkina Faso. The study's results do not ascertain that aspect.

The analysis reveals a negative correlation between the port of Lome's total throughput and the volume of containers it receives from Lagos. Meaning that Lome is losing in its cooperation with Lagos. We see from the cointegration model that these two ports will be in a negative relationship for the long run. Thus, Lome should invest in developing tools to face rivalry with Lagos. The second significant variable for Lome is its multilateral cooperation. It implies a positive long-term relationship between the total throughput of Lome and the volume it receives from the other five ports. In fact, Lome is a transit port, serving landlocked countries but mostly Nigeria, where its hinterland overlaps with Lagos, thus engaging their competition.

Lagos's exclusive throughput is the main aspect of its production, followed by its collaboration with Tanger. An increase of 1% of the volume of containers generated from its bilateral cooperation with Tanger will cause only an increase of 0.02% of its total throughput. Thus, the port primarily exports TEU to other ports and does not collect enough from them. Lagos is the entry point of containers in the region. It also has the biggest hinterland among the ports in West Africa, mainly representing the territory of Nigeria and Tchad. It generates a significant amount of cargo due to its high self-sufficiency ratio.

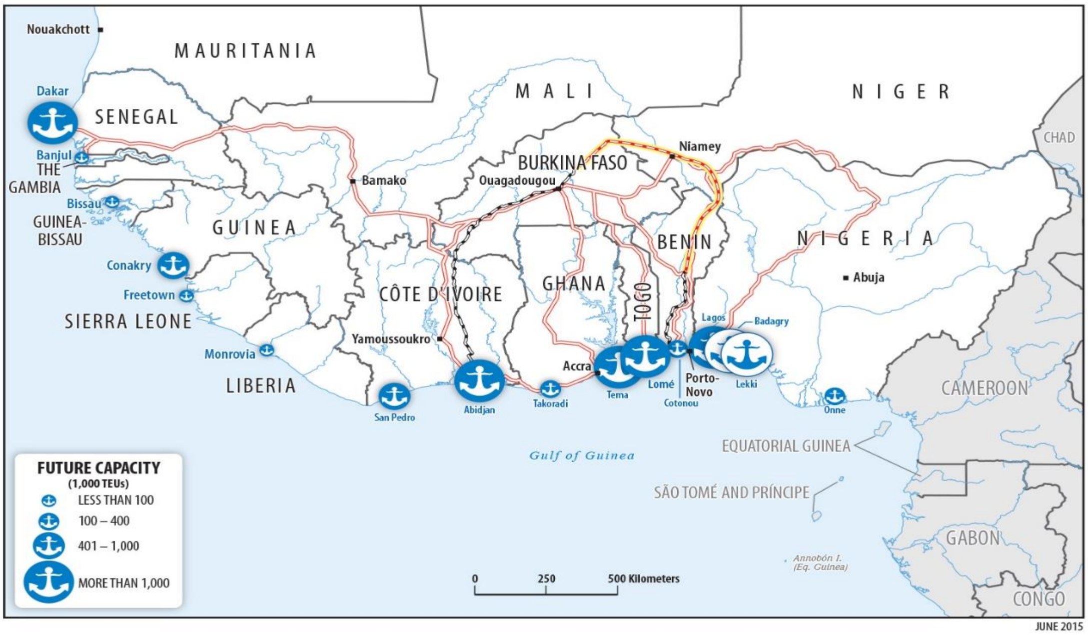
Table 18: Ports concession agreements

Port	Country	Participation	Date	Duration
Abidjan	Cote d'Ivoire	Bolloré Group, APMT	2013	25
Tanger Med	Morocco	Bolloré Group, APMT	2005	25
Tema	Ghana	Bolloré Group, APMT, GPHA	2004	20
Lagos	Nigeria	APMT	2005	25
Dakar	Senegal	DP World	2007	25
Lome	Togo	MSC/Bolloré Group	2010	35

Source:(World Bank, 2013)

The container terminal concessioners play an essential role in the port sector in the region. As shown by table 17, CTCs often operate in different ports through joint ventures. They influence the port selection by liners, thus the connectivity of ports. However, Dakar's container terminal concessioner (CTC) is DP World, while the other ports are jointly concessions by Bollore Africa Logistics and APMT. It has the most diverse partner network since Tanger, Abidjan, and Tema all profit from the increased throughput created by their collaboration with Dakar, indicating that Dakar interacts with all ports equally. Due to its strategic location in the region, it interacts with neighboring ports, despite its concessionaire not being present in those countries.

Figure 11: West African container terminal network



Source: World Bank 2013

According to the results, the Container terminal Concessioners do not influence the nature and degree of connection between ports. They are the national entities in the region, focusing largely on domestic demand. Lome and Lagos compete while sharing A.P. Moller Terminal (APMT) as a CTC; their hinterlands' overlap and fuels their competition. As a transit port, Lome serves the Nigerian markets, which Lagos principally supplies.

6. Chapter Six: Conclusion

The research covers a period of nine years, from 2013 to 2021. The total throughputs of each port examined in the paper. It investigated the container trade in Africa by examining port competition and cooperation. The research has focused on six specific ports in the region, namely Tanger Med (Morroco), Dakar (Senegal), Abidjan (Ivory Coast), Tema (Ghana), Lome (Togo), and Lagos (Nigeria). These ports handle the largest number of containers in the region. The study aims to understand, by quantifying it, the situation of competition and cooperation among them in order to inform the strategic decisions about the future of the network. The appendixes contain the findings of the port's exclusive throughputs. As discussed previously, the relationships in this group of ports are different in nature and intensity. Their variation over time is also captured. Firstly, the research has examined the dependency between ports in terms of cargo flow volume. The port network in Africa is not as well structured as those in other regions of the world. The growth of container flow in the Atlantic facade of Africa can be supported by developing strategic relationships between adjacent ports. Secondly, the four-stage modeling process was implemented in MATLAB software.

The dependency ratio model considers the flow of containers arriving at one port from another in the study's group of ports. It represents the two ports' bilateral collaboration. This volume of throughput is then utilized as an independent variable in the multiple linear models to assess its significance in proportion to the ports' total throughput.

In the analysis of the empirical results, we include the hinterland aspect and the Container Terminal concessions. As in the recent past, the ports were state-owned, and currently they are privately held by foreign investors such as world shipping lines companies and Container Terminal operators.

Two transshipment ports are identified in the group assessed in the literature and confirmed by the results of the study. They are Tanger and Lome. Tanger is engaged in cooperation and benefit from its bilateral relationship with Dakar and Abidjan and when Lome competes with Lagos will serve the same hinterland which is primarily comprised of Nigerian territory.

Due to globalization, container liners now wield greater market power and have greater port selection options. Ports' hinterland and foreland are expandingas a result. Ports are increasingly subjected to intense competition. Feeder ports and hub ports will arise and disappear over time. They should create strategic partnerships in this context to improve their competitiveness in the regional or international market (Song, 2003). To support such choices, a comprehensive understanding of management is necessary. This study provides critical information regarding the type and intensity of existing interactions between ports along Africa's Atlantic façade. It may be useful in determining how future cooperation or competition between adjacent ports should be structured. The most important criteria used in the study is container traffic volumes; hence, the study can also support the decision making to determine whether ports need more investment to expand their capacity.

As a port authority considers increasing its throughputs, it may consider supporting its most connected port development. Therefore, the port authority of Tanger should consider assisting the development of the ports of Dakar and Abidjan when Tema would like to increase its relationship with Dakar and Lagos. The port of Dakar should continue to diversify its port partners in the region. The port of Lome will be willing to invest in more competition mostly with Lagos. Dakar has the transit time advantage being half the distance between Tanger and the group of the fourth ports. It is a highly diversified network of cooperation that should be enhanced to serve as an original close hub. Tema has the highest increase of throughput, followed by Lome in recent years. This Ghanaian port has an intense cooperation with Lagos will contribute to increasing the volume of its cargo due to the high potential domestic demand in Nigeria.

Various methods exist to assist decision-makers in port competition or collaboration. However, the study's approach of measuring the port-established relationship through the dependency on throughput between adjacent ports compensates for the absence of inadequacy of data. These variables are not disclosed for the study ports. However, this limitation was overcome, and the research objectives were achieved.

The author's recommendations for future research are to look at the port investment's efficiency in relation to the potential demand and the hinterlands characteristics. Another accommodation is to investigate the establishment of the new African free trade Zone and its impact on container demand. It will increase the trade within the region, carried mainly by shipment. Furthermore, the West African maritime transport industry is characterized by a high freight rate; a study to support the decision to optimize its maritime Network will assist in resolving this issue.

References

Alphaliner. (2020). *Alphaliner Montly Monitor*. https://www.alphaliner.com/resources/Alphaliner_Monthly_Monitor_Jan_2020.pdf

Andrews, D. F. (1974). A robust method for multiple linear regression. *Technometrics*, *16*(4), 523–531.

Angelopoulos, J., Sahoo, S., & Visvikis, I. D. (2020). Commodity and transportation economic market interactions revisited: New evidence from a dynamic factor model. *Transportation Research Part E: Logistics and Transportation Review*, *133*, 101836. https://doi.org/https://doi.org/10.1016/j.tre.2019.101836

Asgari, N., Farahani, R. Z., & Goh, M. (2013). Network design approach for hub ports-shipping companies competition and cooperation. *Transportation Research Part A: Policy and Practice*, *48*, 1–18. https://doi.org/https://doi.org/10.1016/j.tra.2012.10.020

Bank, W. (2021). *International Domestic LPI*. WORLD BANK. https://lpi.worldbank.org/domestic/performance/2018/C/SEN#chartarea

Brandenburger, A. M., & Nalebuff, B. J. (1995). *The right game: Use game theory to shape strategy* (Vol. 76). Harvard Business Review Chicago.

Brooks, C. (2019). *Introductory econometrics for finance* (4th ed.).

Carine, A. C. F. (2015). Analyzing the Operational Efficiency of Container Ports in Sub-Saharan Africa. *Open Journal of Social Sciences*, *3*(10), 10.

Cariou, P. (2020). *Changing Demand for Maritime Trade*. https://www.itf-oecd.org/sites/default/files/docs/changing-demand-maritime-trade_0.pdf

Dickey, D. A., & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica: Journal of the Econometric Society*, 1057–1072.

Donselaar, P. W.-V., & Kolkman, J. (2010). Societal costs and benefits of cooperation between port authorities. *Maritime Policy & Management*, *37*(3), 271–284.

Dulebenets, M. A., Pasha, J., Abioye, O. F., & Kavoosi, M. (2021). Vessel scheduling in liner shipping: a critical literature review and future research needs. *Flexible Services and Manufacturing Journal*, *33*(1), 43–106.

Engle, R. F., & Granger, C. W. J. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: Journal of the Econometric Society*, 251–276.

Engle, R., & Granger, C. (1991). *Long-run economic relationships: Readings in cointegration*. Oxford University Press.

Goss, R. O. (1990). Economic policies and seaports: The economic functions of seaports. *Maritime Policy & Management*, *17*(3), 207–219.

Hales, D., Lee Lam, J. S., & Chang, Y.-T. (2016). The balanced theory of port competitiveness. *Transportation Journal*, *55*(2), 168–189.

Haralambides, H. E. (2019). Gigantism in container shipping, ports and global logistics: a time-lapse into the future. *Maritime Economics & Logistics*, *21*(1), 1–60. https://doi.org/10.1057/s41278-018-00116-0

Hummels, D. (2007). Transportation Costs and International Trade in the Second Era of Globalization. *Journal of Economic Perspectives*, *21*(3), 131–154. https://doi.org/10.1257/jep.21.3.131

ITF-OECD. (2014). *The Competitiveness of Ports in Emerging Markets*. https://www.internationaltransportforum.org/Pub/pdf/14Durban.pdf

Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica: Journal of the Econometric Society*, 1551–1580.

Jung, B. (2011). Economic Contribution of Ports to the Local Economies in Korea. *The Asian Journal of Shipping and Logistics*, *27*(1), 1–30. https://doi.org/https://doi.org/10.1016/S2092-5212(11)80001-5

Lee, C.-Y., & Song, D.-P. (2017). Ocean container transport in global supply chains: Overview and research opportunities. *Transportation Research Part B: Methodological*, *95*, 442–474. https://doi.org/https://doi.org/10.1016/j.trb.2016.05.001

Notteboom, T. E. (2010). Concentration and the formation of multi-port gateway regions in the European container port system: an update. *Journal of Transport Geography*, *18*(4), 567–583.

Notteboom, T. E., Parola, F., & Satta, G. (2019). The relationship between transhipment incidence and throughput volatility in North European and Mediterranean container ports. *Journal of Transport Geography*, *74*, 371–381. https://doi.org/https://doi.org/10.1016/j.jtrangeo.2019.01.002

Pascali, L. (2017). The Wind of Change: Maritime Technology, Trade, and Economic Development. *American Economic Review*, *107*(9), 2821–2854. https://doi.org/10.1257/aer.20140832

Phillips, P. C. B. (1986). Understanding spurious regressions in econometrics. *Journal of Econometrics*, *33*(3), 311–340.

Rodrigue, J.-P. (2020). *The Geography of Transport Systems*. *FIFHT EDIT*, 456. https://transportgeography.org/

Russo, F., & Musolino, G. (2013). Estimating demand variables of maritime container transport: An aggregate procedure for the Mediterranean area.

Research in Transportation Economics, *42*(1), 38–49. https://doi.org/https://doi.org/10.1016/j.retrec.2012.11.008

Song, D.-W. (2002). Regional container port competition and co-operation: the case of Hong Kong and South China. *Journal of Transport Geography*, *10*(2), 99–110.

Song, D.-W. (2003). Port co-opetition in concept and practice. *Maritime Policy & Management*, *30*(1), 29–44.

Song, D.-W., Cheon, S., & Pire, C. (2015). Does size matter for port coopetition strategy? Concept, motivation and implication. *International Journal of Logistics Research and Applications*, *18*(3), 207–227.

Song, D.-W., & Panayides, P. M. (2008). Global supply chain and port/terminal: integration and competitiveness. *Maritime Policy & Management*, *35*(1), 73–87. https://doi.org/10.1080/03088830701848953

Song, D.-W., Seo, Y.-J., & Kwak, D.-W. (2019). Learning from Hanjin Shipping's failure: A holistic interpretation on its causes and reasons. *Transport Policy*, *82*, 77–87. https://doi.org/https://doi.org/10.1016/j.tranpol.2018.12.015

Stahlbock, R., & Voß, S. (2008). Operations research at container terminals: a literature update. *OR Spectrum*, *30*(1), 1–52.

Statista. (2021). *Container shipping - statistics & facts*. https://www.statista.com/topics/1367/container-shipping/

Steenken, D., Voß, S., & Stahlbock, R. (2004). Container terminal operation and operations research-a classification and literature review. *OR Spectrum*, *26*(1), 3–49.

UNCTAD. (2018). *Prosperity for all*. UNCTAD Communications and Information Unit. https://unctad.org/press-material/maritime-trade-and-africa

UNCTAD. (2019). *Economic Development in Africa Report*. https://unctad.org/webflyer/economic-development-africa-report-2019

UNCTADSTAT. (2021). *Liner Shipping connectivity index*. Retrived from UNCTADSTAT. https://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=92

Waugh, M. E. (2010). International Trade and Income Differences. *American Economic Review*, *100*(5), 2093–2124. https://doi.org/10.1257/aer.100.5.2093

World Bank. (2020). *The World Bank in Africa: overview*. www.worldbank.org/en/region/afr/overview

Yeo, G.-T., & Song, D.-W. (2006). An application of the hierarchical fuzzy process to container port competition: policy and strategic implications. *Transportation*, *33*(4), 409–422.

Appendix A

The Analysis of the throughput generated by Tanger Med in competition (Y0_Ta) with the other five selected ports.

1.1. T-test results

Y1_Ta = 1 + Y2_Ta_Dk + Y2_Ta_Ab + EW_Exp_Vo_Index

	Estimate	**SE**	**t-Stat**	**pValue**
(Intercept)	0.076	0.075	1.008	0.325
Y2_Ta_Dk	0.308	0.075	4.104	0.001
Y2_Ta_Ab	1.232	0.298	4.140	0.001
EW_Exp_Vo_Index	-3.024	1.033	-2.929	0.008

Number of observations: 24, Error degrees of freedom: 20
Root Mean Squared Error: 0.363
R-squared: 0.765, Adjusted R-Squared: 0.73
F-statistic vs. constant model: 21.7, p-value = 1.7e-06

1.2. Co-Integration Model

Y1_Ta = 1 + Y2_Ta_Dk + Y2_Ta_Ab + ect_Y2_Ta_Dk

	Estimate	SE	tStat	pValue
(Intercept)	0.1122	0.053	2.154	0.044
Y2_Ta_Dk	0.220	0.053	4.143	0.001
Y2_Ta_Ab	0.685	0.233	2.941	0.008
ect_Y2_Ta_Dk	-0.609	0.097	-6.268	4.045e-06

Number of observations: 24, Error degrees of freedom: 20
Root Mean Squared Error: 0.252
R-squared: 0.887, Adjusted R-Squared: 0.87
F-statistic vs. constant model: 52.1, p-value = 1.23e-09

1.3. ARIMA model

	Estimate	SE	tStat	pValue
(Intercept)	0.112	0.052	2.154	0.044
Y2_Ta_Dk	0.219	0.053	4.143	0.001
Y2_Ta_Ab	0.685	0.233	2.941	0.010
ect_Y2_Ta_D	-0.609	0.098	-6.268	4.045e-06

Number of observations: 24, Error degrees of freedom: 20
Root Mean Squared Error: 0.252
R-squared: 0.887, Adjusted R-Squared: 0.87

Assumptions Verifications

	Estimate	SE	tStat	pValue
(Intercept)	0.112	0.052	2.154	0.044
Y2_Ta_Dk	0.219	0.053	4.143	0.000
Y2_Ta_Ab	0.685	0.233	2.941	0.008
ect_Y2_Ta_Dk	-0.609	0.097	-6.268	4.045e-06

Number of observations: 24, Error degrees of freedom: 20
Root Mean Squared Error: 0.252
R-squared: 0.887, Adjusted R-Squared: 0.87

pValue_RESET = 0.0066, thus the model is not linear: It cannot be used in the findings of this study

Appendix B

The Analysis of the throughput generated by Dakar Y0_Dk in competition with the other five selected ports.

1.4. T-test results

	Estimate	SE	tStat	pValue
(Intercept)	0.005	0.006	0.872	0.391
Y3_Dk_All	0.228	0.015	15.582	1.253e-15
Y0_Dk	1.648	0.023	71.379	3.833e-34

Number of observations: 32, Error degrees of freedom: 29
Root Mean Squared Error: 0.0305
R-squared: 0.995, Adjusted R-Squared: 0.994
F-statistic vs. constant model: 2.71e+03, p-value = 1.08e-33

1.5. Co-integration Model

Estimated Coefficients:

	Estimate	SE	tStat	pValue
(Intercept)	0.005	0.006	0.872	0.391
Y3_Dk_All	0.228	0.015	15.582	1.253e-15
Y0_Dk	1.648	0.023	71.379	3.833e-34

Number of observations: 32, Error degrees of freedom: 29
Root Mean Squared Error: 0.0305
R-squared: 0.995, Adjusted R-Squared: 0.994
F-statistic vs. constant model: 2.71e+03, p-value = 1.08e-33

1.6. ARMA Model

	Estimate	SE	tStat	pValue
(Intercept)	0.004	0.005	0.847	0.405
Y3_Dk_All	0.238	0.014	17.285	3.972e-16
Y0_Dk	1.646	0.021	79.354	1.56e-33
MA	-0.563	0.194	-2.901	0.007

Number of observations: 31, Error degrees of freedom: 27
Root Mean Squared Error: 0.0274
R-squared: 0.996, Adjusted R-Squared: 0.996
F-statistic vs. constant model: 2.24e+03, p-value = 1.8e-32

1.7. Assumptions Verifications

	Estimate	SE	tStat	pValue
(Intercept)	-0.001	0.006	-0.043	0.966
y_fit_p2	0.002	0.010	0.14612	0.885

Number of observations: 31, Error degrees of freedom: 29
Root Mean Squared Error: 0.0302
R-squared: 0.000736, Adjusted R-Squared: -0.0337
F-statistic vs. constant model: 0.0214, p-value = 0.885

Appendix C

The Analysis of the Total throughput generated by Abidjan using bilateral throughput with the other five selected ports.

1.8. T-test results

	Estimate	SE	tStat	pValue
(Intercept)	0.013	0.009	1.437	0.166
Y2_Ab_Dk	0.226	0.038	6.017	6.980e-06
Y2_Ab_Te	0.311	0.031	10.220	2.192e-09

Number of observations: 23, Error degrees of freedom: 20
Root Mean Squared Error: 0.0436
R-squared: 0.898, Adjusted R-Squared: 0.887
F-statistic vs. constant model: 87.6, p-value = 1.27e-10

1.9. Co-integration Model

	Estimate	SE	tStat	pValue
(Intercept)	0.013	0.010	1.437	0.166
Y2_Ab_Dk	0.226	0.038	6.017	6.980e-06
Y2_Ab_Te	0.311	0.031	10.22	2.192e-09

Number of observations: 23, Error degrees of freedom: 20
Root Mean Squared Error: 0.0436
R-squared: 0.898, Adjusted R-Squared: 0.887
F-statistic vs. constant model: 87.6, p-value = 1.27e-10

1.10. ARMA Model

	Estimate	SE	tStat	pValue
(Intercept)	0.013	0.009	1.437	0.166
Y2_Ab_D	0.226	0.038	6.017	6.980e-06
Y2_Ab_Te	0.311	0.031	10.220	2.192e-09

Number of observations: 23, Error degrees of freedom: 20
Root Mean Squared Error: 0.0436
R-squared: 0.898, Adjusted R-Squared: 0.887
F-statistic vs. constant model: 87.6, p-value = 1.27e-10
AIC= -76.0307

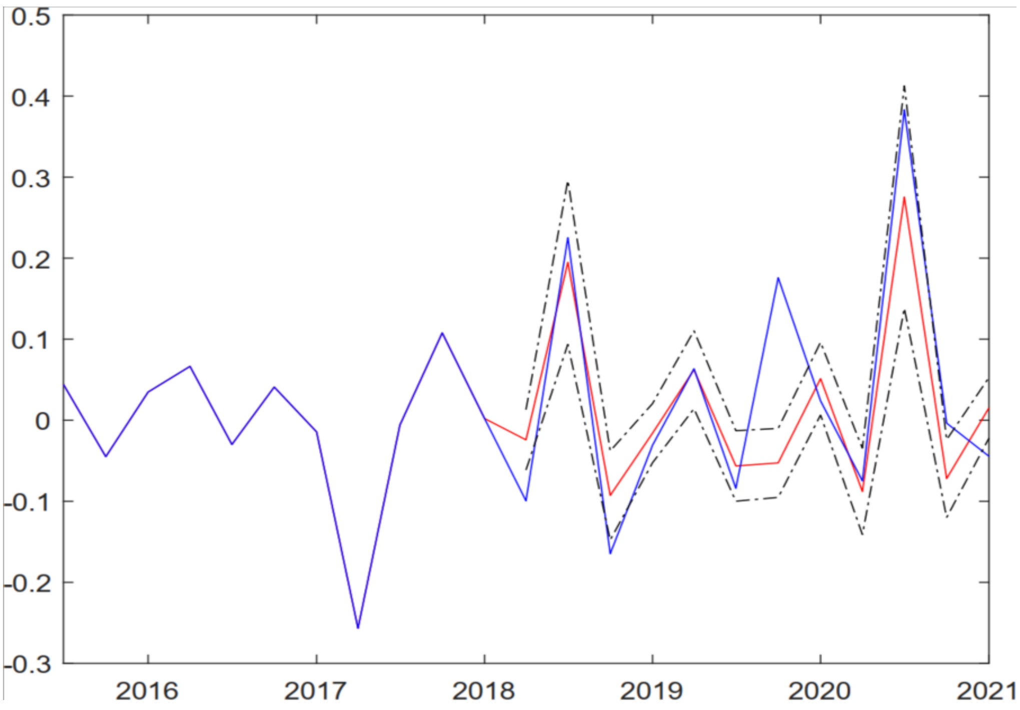
1.11. Assumptions Verifications

'with ARCH effect but no serial correlation'

	Estimate	SE	tStat	pValue
	________	__________	_______	___________
(Intercept)	0.013	0.009	1.437	0.166
Y2_Ab_Dk	0.226	0.038	6.017	6.9797e-06
Y2_Ab_Te	0.311	0.031	10.22	2.192e-09

Number of observations: 23, Error degrees of freedom: 20
Root Mean Squared Error: 0.0436
R-squared: 0.898, Adjusted R-Squared: 0.887
F-statistic vs. constant model: 87.6, p-value = 1.27e-10

Forecast



"MSE"	"0.0071469"
"MAE"	"0.060543"
"RMSE"	"0.084539"
"Bias Proportion"	"0.028814"
"Variance Proportion"	"0.25685"
"Covariance Proportion"	"0.80263"

Appendix D

The Analysis of the total throughput generated by Lagos in competition (Y0_La) with the other five selected ports.

1.12. T-test results

	Estimate	SE	tStat	pValue
(Intercept)	-0.018	0.009	-2.081	0.047
Y2_La_Ab	0.065	0.030	2.142	0.041
Y3_La_All	-0.241	0.032	-7.489	4.689e-08
Y1_La	1.269	0.043	29.836	3.300e-22
EW_Exp_Vo_Index	0.237	0.095	2.499	0.019

Number of observations: 32, Error degrees of freedom: 27
Root Mean Squared Error: 0.0466
R-squared: 0.971, Adjusted R-Squared: 0.967
F-statistic vs. constant model: 225, p-value = 2.56e-20

1.13. Co-integration Model

	Estimate	SE	tStat	pValue
(Intercept)	-0.018	0.009	-2.081	0.047
Y2_La_Ab	0.065	0.030	2.1421	0.042
Y3_La_All	-0.241	0.032	-7.4885	4.689e-08
Y1_La	1.269	0.043	29.836	3.301e-22
EW_Exp_Vo_Inde	0.237	0.095	2.499	0.019

Number of observations: 32, Error degrees of freedom: 27
Root Mean Squared Error: 0.0466
R-squared: 0.971, Adjusted R-Squared: 0.967
F-statistic vs. constant model: 225, p-value = 2.56e-20

1.14. ARMA Model

	Estimate	SE	tStat	pValue
(Intercept)	-0.018	0.009	-2.081	0.047
Y2_La_Ab	0.065	0.030	2.142	0.041
Y3_La_All	-0.241	0.032	-7.489	4.689e-08
Y1_La	1.269	0.043	29.836	3.300e-22
EW_Exp_Vo_Index	0.237	0.095	2.499	0.019

Number of observations: 32, Error degrees of freedom: 27
Root Mean Squared Error: 0.0466
R-squared: 0.971, Adjusted R-Squared: 0.967
F-statistic vs. constant model: 225, p-value = 2.56e-20

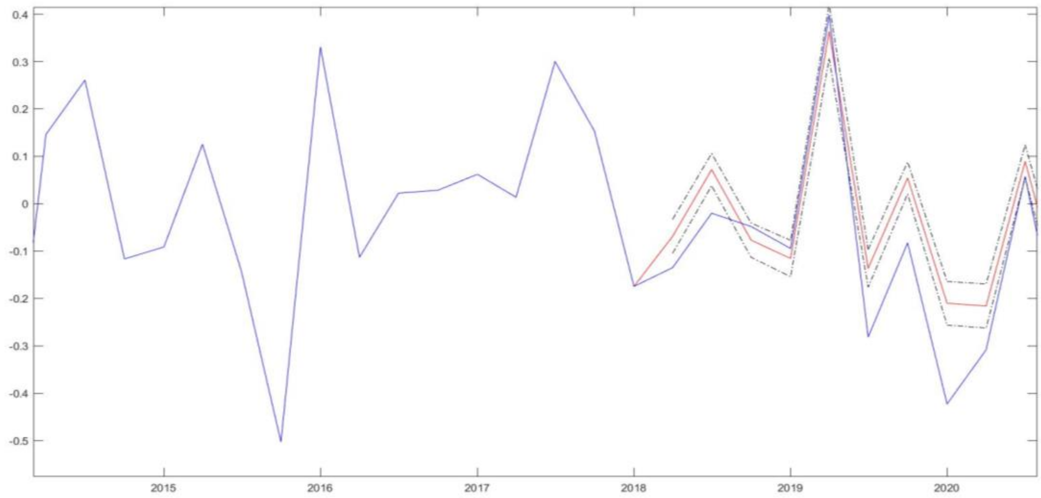
hac_result = 'with ARCH effect but no serial coorelation'

1.15. Assumptions Verifications

	Estimate	SE	tStat	pValue
(Intercept)	-0.002	0.017	-0.093	0.927
y_fit_p2	0.027	0.172	0.158	0.875

Number of observations: 32, Error degrees of freedom: 30
Root Mean Squared Error: 0.0776
R-squared: 0.000833, Adjusted R-Squared: -0.0325
F-statistic vs. constant model: 0.025**, p-value = 0.875 > 0.05**
The model is linear.

Forecasting - out of sample test



Appendix E

The Analysis of the total throughput generated by Lome in competition (Y0_Lo) with the other five selected ports.

1.16. T-test results

	Estimate	SE	tStat	pValue
(Intercept)	0.027	0.136	0.200	0.843
Y2_Lo_Dk	0.274	0.098	2.797	0.010
Y3_Lo_All	1.622	0.113	16.178	2.070e-14

Number of observations: 28, Error degrees of freedom: 24
Root Mean Squared Error: 0.299
R-squared: 0.922, Adjusted R-Squared: 0.912
F-statistic vs. constant model: 94.1, p-value = 2.07e-13

1.17. Co-integration Model

	Estimate	SE	tStat	pValue
(Intercept)	0.047	0.109	0.432	0.670
Y2_Lo_Dk	0.219	0.080	2.760	0.011
Y3_Lo_All	1.822	0.113	16.178	2.070e-14
ect_Y3_Lo_A	-1.2767	0.323	-3.956	0.001

Number of observations: 28, Error degrees of freedom: 24
Root Mean Squared Error: 0.299
R-squared: 0.922, Adjusted R-Squared: 0.912
F-statistic vs. constant model: 94.1, p-value = 2.07e-13
AIC=15.5113

1.18. ARMA Model

	Estimate	SE	tStat	pValue
(Intercept)	-0.084	0.058	-1.457	0.158
Y2_Lo_Dk	0.219	0.080	2.760	0.011
Y3_Lo_All	1.822	0.113	16.178	2.070e-14
ect_Y3_Lo_All	-1.277	0.323	-3.956	0.001

Number of observations: 28, Error degrees of freedom: 24
Root Mean Squared Error: 0.299
R-squared: 0.922, Adjusted R-Squared: 0.912
F-statistic vs. constant model: 94.1, p-value = 2.07e-13
AIC=15.5113

1.19. Assumptions Verifications

regression_results_7

	Estimate	SE	tStat	pValue
(Intercept)	-0.119	0.071	-1.685	0.104
Y3_Lo_All	1.686	0.129	13.080	6.066e-13

Number of observations: 28, Error degrees of freedom: 26
Root Mean Squared Error: 0.373
R-squared: 0.868, Adjusted R-Squared: 0.863
F-statistic vs. constant model: 171, p-value = 6.07e-13
AIC= 26.1082

hac_result = 'with ARCH effect but no serial coorelation'

	Estimate	SE	tStat	pValue
(Intercept)	0.017	0.073	0.238	0.814
y_fit_p2	-0.021	0.025	-0.818	0.421

Number of observations: 28, Error degrees of freedom: 26
Root Mean Squared Error: 0.368
R-squared: 0.0251, Adjusted R-Squared: -0.0124
F-statistic vs. constant model: 0.669, p-value = 0.421>0.05
The model is linear

Note: The AIC of the cointegration model results the lowest, thus these results are considered for the exclusive throughputs of Lome. They state that Lome is engaged in competition with Lagos. They contest market share in their overlap hinterlands.

Appendix F

The Analysis of the total throughput (Y1_Ta) and the multilateral throughput (Y3_Ta_All) of Tanger using the total throughputs of the other five selected ports.

1.20. T-test results of the multilateral throughput (Y1_Ta)

Y1_Ta ~ 1 + Y1_Lo

	Estimate	SE	tStat	pValue
(Intercept)	-0.002	0.033	-0.045	0.965
Y1_Lo	1.230	0.059	20.706	6.447e-16

Number of observations: 24, Error degrees of freedom: 22
Root Mean Squared Error: 0.158
R-squared: 0.951, Adjusted R-Squared: 0.949
F-statistic vs. constant model: 429, p-value = 6.45e-16

1.21. T-test results of the multilateral throughput (Y3_Ta_All)

Y3_Ta_All ~ 1 + Y1_Lo

	Estimate	SE	tStat	pValue
(Intercept)	-0.010	0.057	-0.173	0.864
Y1_Lo	1.285	0.102	12.575	1.611e-11

Number of observations: 24, Error degrees of freedom: 22
Root Mean Squared Error: 0.271
R-squared: 0.878, Adjusted R-Squared: 0.872
F-statistic vs. constant model: 158, p-value = 1.61e-11

1.22. Co-integration Model (Y1_Ta)

Y1_Ta ~ 1 + Y1_Lo+ ect_Y1_Lo

	Estimate	SE	tStat	pValue
(Intercept)	-0.008	0.026	-0.289	0.775
Y1_Lo	1.234	0.047	26.477	1.289e-17
ect_Y1_Lo	-0.793	0.206	-3.841	0.001

Number of observations: 24, Error degrees of freedom: 21
Root Mean Squared Error: 0.124
R-squared: 0.971, Adjusted R-Squared: 0.969
F-statistic vs. constant model: 356, p-value = 6.35e-17

1.23. Co-integration Model (Y3_Ta_All)

Y3_Ta_All ~ 1 + Y1_Lo + ect_Y1_Lo

	Estimate	SE	tStat	pValue
(Intercept)	-0.017	0.050	-0.334	0.742
Y1_Lo	1.276	0.090	14.218	3.007e-12
ect_Y1_L	-0.463	0.169	-2.748	0.012

Number of observations: 24, Error degrees of freedom: 21
Root Mean Squared Error: 0.238
R-squared: 0.91, Adjusted R-Squared: 0.902
F-statistic vs. constant model: 106, p-value = 1.03e-11

1.24. Assumptions Verifications (Y1_Ta)

	Estimate	SE	tStat	pValue
(Intercept)	-0.008	0.030	-0.260	0.798
y_fit_p2	4.010	7.962	0.504	0.620

Number of observations: 23, Error degrees of freedom: 21
Root Mean Squared Error: 0.122
R-squared: 0.0119, Adjusted R-Squared: -0.0351
F-statistic vs. constant model: 0.254, p-value = 0.62

The P-value Y^2 is greater than 0.05, meaning that the model is linear.

The Heteroscedasticity and autocorrelation test results show that the model has an ARCH effect but no serial correlation. A white correction is applied.

1.25. Assumptions Verifications (Y3_Ta_All)

	Estimate	SE	tStat	pValue
(Intercept)	-0.006	0.056	-0.114	0.911
y_fit_p2	0.013	0.023	0.536	0.597

Number of observations: 24, Error degrees of freedom: 22
Root Mean Squared Error: 0.269
R-squared: 0.0129, Adjusted R-Squared: -0.032
F-statistic vs. constant model: 0.287, p-value = 0.597

The P-value Y^2 is greater than 0.05, meaning that the model is linear.

The Heteroscedasticity and autocorrelation test results show that the model has an ARCH effect but no serial correlation. A white correction is applied.

Note: This appendix shows the results of the total throughput and the multi-lateral throughput of the port of Tanger. The independent variables are the total throughput of the other five ports. The analysis shows that the total throughput of the port of Lome is significant and has a long-term positive relationship with Tanger. Thus among the group, Lome is the port that benefits the most Tanger. The port authority of Tanger can make a strategic decision to cooperate and develop with Lome s production.

Appendix G

The Analysis of the multilateral throughput (Y3_La_All) of Lagos using the total throughputs of the other five selected ports.

1.26. T-test results of the multilateral throughput (Y3_La_All)

1.27.

Y3_La_All ~ 1 + Y1_Ab + BRVMCI

Estimated Coefficients:

	Estimate	SE	tStat	pValue
(Intercept)	-0.035	0.046	-0.751	0.462
Y1_Ab	0.265	0.065	4.079	0.001
BRVMCI	-1.574	0.713	-2.208	0.039

Number of observations: 24, Error degrees of freedom: 21
Root Mean Squared Error: 0.196
R-squared: 0.462, Adjusted R-Squared: 0.41
F-statistic vs. constant model: 9, p-value = 0.0015

1.28. Co-integration Model (Y3_La_All)

Y3_La_All ~ 1 + Y1_Ab + ect_BRVMCI

Estimated Coefficients:

	Estimate	SE	tStat	pValue
(Intercept)	0.014	0.039	0.367	0.718
Y1_Ab	0.191	0.061	3.130	0.005
ect_BRVMC	-0.398	0.145	-2.743	0.012

Number of observations: 24, Error degrees of freedom: 21
Root Mean Squared Error: 0.186
R-squared: 0.512, Adjusted R-Squared: 0.465
F-statistic vs. constant model: 11, p-value = 0.00054

1.29. Assumptions Verifications (Y3_La_All)

	Estimate	SE	tStat	pValue
(Intercept)	0.010	0.081	0.117	0.908
y_fit_p2	-4.617	31.840	-0.145	0.886

Number of observations: 24, Error degrees of freedom: 22
Root Mean Squared Error: 0.234
R-squared: 0.000955, Adjusted R-Squared: -0.0445
F-statistic vs. constant model: 0.021, p-value = 0.886

The P-value Y^2 is greater than 0.05, meaning that the model is linear.

The Heteroscedasticity and autocorrelation test results show that the model has an ARCH effect but no serial correlation. A white correction is applied.

<u>**Note:**</u> The port of Lagos has the second-largest throughput within the group. It also has the most considerable Hinterland. We present the regression result of its multilateral throughputs, using the other ports' total throughputs as independent variables. It appears that most of its collaboration within the group is done with Abidjan, meaning that the volume of containers coming from that port to Lagos is more significant than the flow from the other ports.

Appendix H

The Analysis of the total throughput (Y1_Lo) and the multilateral throughput (Y3_Lo_All) of Lome using the total throughputs of the other five selected ports.

1.30. T-test results of the multilateral throughput (Y1_Lo)

Y1_Lo ~ 1 + Y1_Ab

	Estimate	SE	tStat	pValue
(Intercept)	0.014	0.036	0.407	0.688
Y1_Ab	0.812	0.054	14.938	5.341e-13

Number of observations: 24, Error degrees of freedom: 22
Root Mean Squared Error: 0.169
R-squared: 0.91, Adjusted R-Squared: 0.906

1.31. T-test results of the multilateral throughput (Y3_Lo_All)

Y3_Lo_All ~ 1 + Y1_Ab + BRVMCI + Nigeria_SE + Con_NBP_Index + EW_Exp_Gro_Rate

	Estimate	SE	tStat	pValue
(Intercept)	6.568	3.005	2.186	0.042
Y1_Ab	0.736	0.065	11.244	1.427e-09
BRVMCI	-1.406	0.635	-2.216	0.040
Nigeria_SE	-0.636	0.292	-2.18	0.043
Con_NBP_Index	3.172	1.29	2.459	0.024
EW_Exp_Gro_Rate	0.178	0.055	3.257	0.004

Number of observations: 24, Error degrees of freedom: 18
Root Mean Squared Error: 0.149
R-squared: 0.9, Adjusted R-Squared: 0.872
F-statistic vs. constant model: 32.4, p-value = 2.12e-08

1.32. Co-integration Model (Y1_Lo)

Y1_Lo ~ 1 + Y1_Ab + ect_Y1_Ab

	Estimate	SE	tStat	pValue
(Intercept)	0.017	0.033	0.508	0.617
Y1_Ab	0.804	0.050	15.94	3.314e-13
ect_Y1_Ab	-0.303	0.140	-2.155	0.043

Number of observations: 24, Error degrees of freedom: 21
Root Mean Squared Error: 0.157
R-squared: 0.927, Adjusted R-Squared: 0.92
F-statistic vs. constant model: 132, p-value = 1.25e-12

1.33. Co-integration Model (Y3_Ta_All)

Linear regression model:
Y3_Lo_All ~ 1 + Y1_Ab + BRVMCI + Nigeria_SE + Con_NBP_Index + EW_Exp_Gro_Rate

	Estimate	SE	tStat	pValue
(Intercept)	6.568	3.005	2.186	0.042
Y1_Ab	0.736	0.065	11.244	1.427e-09
BRVMCI	-1.406	0.635	-2.216	0.040
Nigeria_SE	-0.636	0.292	-2.18	0.043
Con_NBP_Index	3.172	1.290	2.459	0.024
EW_Exp_Gro_Rate	0.178	0.055	3.257	0.004

Number of observations: 24, Error degrees of freedom: 18
Root Mean Squared Error: 0.149
R-squared: 0.9, Adjusted R-Squared: 0.872
F-statistic vs. constant model: 32.4, p-value = 2.12e-08

1.34. Assumptions Verifications (Y1_Lo)

Heteroscedasticity and autocorrelation test: hac_result = 'with ARCH effect but no serial coorelation'

resid ~ 1 + y_fit_p2

	Estimate	SE	tStat	pValue
(Intercept)	-0.005	0.035	-0.147	0.885
y_fit_p2	0.018	0.026	0.690	0.497

Number of observations: 24, Error degrees of freedom: 22
Root Mean Squared Error: 0.168
R-squared: 0.0212, Adjusted R-Squared: -0.0233
F-statistic vs. constant model: 0.477, p-value = 0.497

The P-value Y^2 is greater than 0.05, meaning that the model is linear.
The Heteroscedasticity and autocorrelation test results show that the model has an ARCH effect but no serial correlation. A white correction is applied.

1.35. Assumptions Verifications (Y3_Ta_All)

Resid ~ 1 + y_fit_p2

	Estimate	SE	tStat	pValue
(Intercept)	-0.002	0.033	-0.0512	0.960
y_fit_p2	0.011	0.045	0.237	0.815

Number of observations: 24, Error degrees of freedom: 22
Root Mean Squared Error: 0.159
R-squared: 0.00255, Adjusted R-Squared: -0.0428
F-statistic vs. constant model: 0.0562, p-value = 0.815

The P-value Y^2 is greater than 0.05, meaning that the model is linear.
The Heteroscedasticity and autocorrelation test results show that the model has an ARCH effect but no serial correlation. A white correction is applied.

Note: Lome is the port that has the highest increase of throughput in the region from 2016 (UNCTAD, 2019). The heavy investment in developing its container terminals capacity causes this good productivity. The study shows that the total throughput of Abidjan significantly affects its total and multilateral throughputs. Thus, Lome is receiving more volume from Abidjan than from the other destinations in the group of ports. Meanwhile, the port of Abidjan sees its production positively influence by Lome. A strategic decision to collaborate will be profitable to both ports.