Panama Canal expansion impact on Latin America and the Caribbean region

Doctoral Dissertation

PANAMA CANAL EXPANSION IMPACT ON LATIN AMERICA AND THE CARIBBEAN REGION

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LIST OF ABBREVIATIONS

BSTS	Bayesian Structural Time Series
CONTp	Control Ports
DID	Difference in Difference
DT	Dwell Time
DEA	Data Envelopment Analysis
DTrp	Treatment Ports
FDI	Foreign Direct Investment
GFCE	Government final consumption expenditure
HDI	Human Development Index
HLM	Hierarchical Linear Model
LAC	Latin America and the Caribbean
LP	Logistics Performance
LPI	Logistics Performance Index
LPCUST	Logistics Performance Customs
LPINFRA	Logistics Performance Infrastructure
LPQLS	Logistics Performance Quality Logistics Service
LPTT	Logistics Performance Tracking and Tracing
LPTL	Logistics Performance Timeliness
GDP	Gross Domestic Product
PLSCI	Port Liner Shipping Index
PCE	Panama Canal Expansion
PPI	Port Performance Indicators
POSTt	Post Treatment Period
OECD	Organisation for Economic Co-operation and Development
SFA	Stochastic Frontier Analysis
STS	Ship to Shore
SSM	State-space model
TE	Technical Efficiency
TRFR	Trade Freedom
UNCTAD	United Nations Conference on Trade and Development
UNECLAC	United Nations Economic Commission for Latin America and the Caribbean
IND	Industrial Index
QPI	Quality of Port Infrastructure

CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

1.1.1 Globalization

Globalization has impacted the evolution of the maritime trade, which has played a pivotal role in world trade and economic developments (UNCTAD, 2016). International shipping is the lifeblood of global trade, accounting for over eighty (80) percent of the world trade. Without shipping and logistics, international trade in bulk transport of raw materials and trade of affordable food and manufactured goods would not be possible. Therefore, shipping and logistics play an important role in world trade and global economic development. According to Kumar and Hoffman (2006), shipping transportation is considered one of the four cornerstones of globalization, communication, international standardization, and trade liberalization. Globalization has influenced maritime trade in logistics whereby most general cargo is transported in containers (UNCTAD, 2016). According to the UNCTAD (2019), the seaborne trade has gathered momentum by 4 percent, the fastest growth for five years. Seaborne trade reflects the world economic growth recovery and improvement in global merchandise trade. For example, in 2018, seaborne trade accounts for 11.08 billion tons, 1.88 billion tons more than in 2012. The Asia region was by far the largest trading region. In 2019, 4.16 billion tons of goods were loaded, and 6.1 billion tons were unloaded in Asian seaports (UNCTAD, 2020). The other continents recorded less than 50 percent of these amounts (UNCLAD, 2019). This momentum in trade has made containerization the main driver of the maritime trade, with increased demand for container transportation that transformed ship designs and ported infrastructural development (Rodrigue and Ashar, 2016; Gooley, 2018). Moreover, this growth in containerization has shown a strong correlation to economic growth, which has been the strategy for Latin America and the Caribbean countries to capitalize on the Panama Canal expansion (PCE).

1.1.2 Trade openness and economic growth

Trade openness is an important aspect of economic development (Naanwaab and Diarrassouba , 2013). The World Bank (2019) defines trade openness as the outward or inward orientation of a given country's economy. Outward orientation refers to economies that take significant advantage of the opportunities to trade with other countries, while inward orientation refers to economies that overlook taking or cannot take advantage of opportunities to trade with other countries (The World Bank, 2019; Çelebi, 2017). According to Çelebi, 2017 (2019), factors determining trade policy decisions' outward or inward orientation are trade barriers, import-export, infrastructure, technology, scale economies, and market competitiveness (Çelebi, 2017). Most economists believe that outward economies should experience increased economic growth while closed economies with restrictive tariffs and are not open to trade would experience no economic growth. Numerous studies have been performed concerning the theory of openness-to-growth correlation has been upheld (Çelebi, 2017; Ortiz-Ospina, 2018). The Open Market Index (OMI) also measures a country's degree of global trade openness is also measured by Open Market Index (OMI). According to the World Bank (2017), the OMI grades four major categories of economic issues: (1) Trade openness (including trade to GDP ratio and real growth of imports. (2) trade policy regime (including applied tariffs, tariff profile, border efficiency). (3) Openness to foreign direct investment (FDI) (including FDI inflow to GDP and ease of business establishment. (4) Infrastructure open for trade (including logistics performance, communications infrastructure, telephone lines, Internet).

1.1.3 Logistics impact on trade

Globalization has dramatically influenced the growth and advancement of the logistics and supply chain, changing how manufacturers operate, offering an opportunity to reach new customers in new markets (Mrak, 2000; Islam et al., 2019; Rodrigue and Notteboom, 2021; Ural Marchand, 2017). Therefore, Logistics performance affects trade. Furthermore, several studies revealed that logistics performance improves a country's ability to compete effectively within the global economy (Hausman et al., 2013; Ural Marchand, 2017).
Logistics play an essential role in a nation's growth and economic development (Rodrigue, 2020; Ural Marchand, 2017). It facilitates international trade and is a major financial contributor to several developed countries like Singapore and Germany (Sezer and Abasız, 2017). However, the logistics contribution may differ for competitiveness and national output (Cosco, 2017; Park, 2020; Celebi, 2017). Henceforth, its supporting role within an economy cannot be overlooked, especially its ability to improve trade.

Globalization has essentially broken through most trade barriers providing free trade that opens doors to improvement in international trade. However, the logistics and transportation sector plays an integral role in providing better economies of scale, lowering the cost of imported goods while creating job creations within that sector (Islam et al., 2019; Rodrigue and Notteboom, 2021; Ural Marchand, 2017). Several studies have revealed a positive and strong correlation between logistics and trade and, most essential long-term economic growth (Cosco, 2017; Park, 2020; Celebi, 2017; Islam et al., 2019; Rodrigue and Notteboom, 2021; Ural Marchand, 2017). Although Logistics plays an integral role in supporting commercial activities and economic growth, most studies revealed that most Latin American andCaribbean (LAC) countries lack the logistic infrastructure to support global trade dynamics. Thus, the main question still lingers, whether the PCE has influenced the logistics improvement within the region and what income classification has benefited from this initiative?

1.1.4 Maritime transportation, containerization influence trade, and economic growth

Maritime transport is the backbone of global trade and the global economy (IMO, 2019). The role of maritime transport is essential to a country's economic development. According to Stopford (2018), economists have fully supported the importance of sea transport to economic development. He alluded to the fact that as productivity increases and businesses produce more goods than they can sell locally, they need access to wider markets; therefore, maritime shipping enables a country access to a wider market than land base transport (IMO, 2019; ICS, 2020). Shipping helps ensure that the benefits of trade and commerce are more even spread (IMO, 2019), however according to the World Bank (2019), poorer and landlock countries face several disadvantages in trade than developed nations because they experience higher transportation costs, delays, and less trade (World Bank, 2020). Nevertheless, the creation of jobs and livelihoods of billions of people in the developing world and the standard of living in the industrialized and developed world depends on ships and shipping (Kumar and Hoffman, 2006; Martin, 2011; Meersman, 2009). International shipping represents over 80 percent of the world trade and by large the fuelled by the growth in global supply chain. This growth as enabled both developed and developing countries to reap benefits of the improvement of socio-economic factors such as Human Development Index (HDI) and rate of Unemployment which are keen issues that governmental bodies seek to address (Corbett et al., 2007; Meersman, 2009; Martinez et al., 2016; ICS, 2019). The strong correlation between seaborne trade and economic development is supported by several authors (Kumar and Hoffman, 2006; Martinez et al., 2016; Meersman, 2009). Whereby, the growth in container trade that is driven by economic growth clearly depicts strong correlation with each other (Islam et al., 2019; Rodrigue and Notteboom, 2021; UNCTAD, 2020). This relationship has increased trade routes and regional port development that influence infrastructural development toward improvement in intermodal connectivity in order to tap into economic benefits from containerization trade (Islam et al., 2019; Rodrigue and Notteboom, 2021; Ural Marchand, 2017). The growth in containerization has impacted trade routes which has influenced evolution of major water channel such as Panama and Suez Canal. These canals have expanded to accommodate mega ships and increase traffic through dual shipping lane. The seaborne trade is ever emerging and increasing size because of global demand (UNCTAD, 2020; Rodrigue and Notteboom, 2021).

The Panama Canal is one of the seven wonders of the modern world which has played a pivot role in maritime shipping and global economic development (Rodrigue and Notteboom, 2021; UNCTAD, 2020; IMO, 2019; ICS, 2020). Undoubtably, the strong correlation between seaborne trade and economic growth has allowed the recent expansion to shape the development of ports within the LAC region. The PCE has impacted port development in infrastructural expansion, draughting of harbour, and acquisition of STS gantry cranes for the accommodation of Meg-ships (Neo-Panamax). However, few studies investigate the causal effect of the PCE as an intervention within LAC region during pre and post PCE era. Impact evaluation methods are necessary for evaluating the overall impact of the PCE on regional container throughput, the evaluation of port efficiency during the pre and post PCE era, to investigate logistics performance in relation LAC's exports, and to determine the economic impact of PCE among these countries.

1.2 STATEMENT OF THE PROBLEM

The Panama Canal expansion (PCE) has influenced the development and improvement of many ports within the region, and the introduction of neo-Panamax and some post-Panamax vessels have increased cargo tonnage and transshipment activities throughout the region. This increase in tonnage and maritime traffic has influenced port development, expansion, and equipment upgrades within the regions with the strategic goal of economic growth (Sarriera et al., 2015). Furthermore, the rapid cargo dispatch in the LAC region in container shipments reveals an increasing trend that has led port terminals to specialized in container handling (Sarriera et al., 2015; Rodrigue and Notteboom, 2021). However, to what extent have the PCE impacted the logistics performance, port efficiency, container throughput of regional ports, including traditional transshipment ports, and economic (GDP)growth within the region. Interestingly, the US East Coast and Gulf ports seek to capitalize on the economic benefits of this expansion by investing in port development and logistics infrastructure to accommodate neo-Panamax ships. This investment will increase port competitiveness within the regions. However, that can be proven disadvantageous for some regional ports within the transshipment activities zone known as the "Caribbean Transhipment triangle" that may experience container volume losses to US ports. Several studies confirm a strong correlation between port productivity and economic growth whereby logistics performance relationship with export can determine trade competitiveness. Major ports have made several initiatives in building, upgrading port infrastructure, channel deepening, and logistics centres to accommodate the anticipated rise in container throughput from mega-ships; however, a reactive approach or lax in timely investment can affect port productivity in a competitive environment.

The Panama Canal expansion (PCE) was necessary for the canal to remain a competitive trade route; however, there are LAC ports benefiting from the expansion with the advent of Neo-Panamax vessels (Mega-ships), and are these investments proven to be feasible since PCE and are they reaping economic growth through seaborne trade? Some of these questions will be addressed within this research.

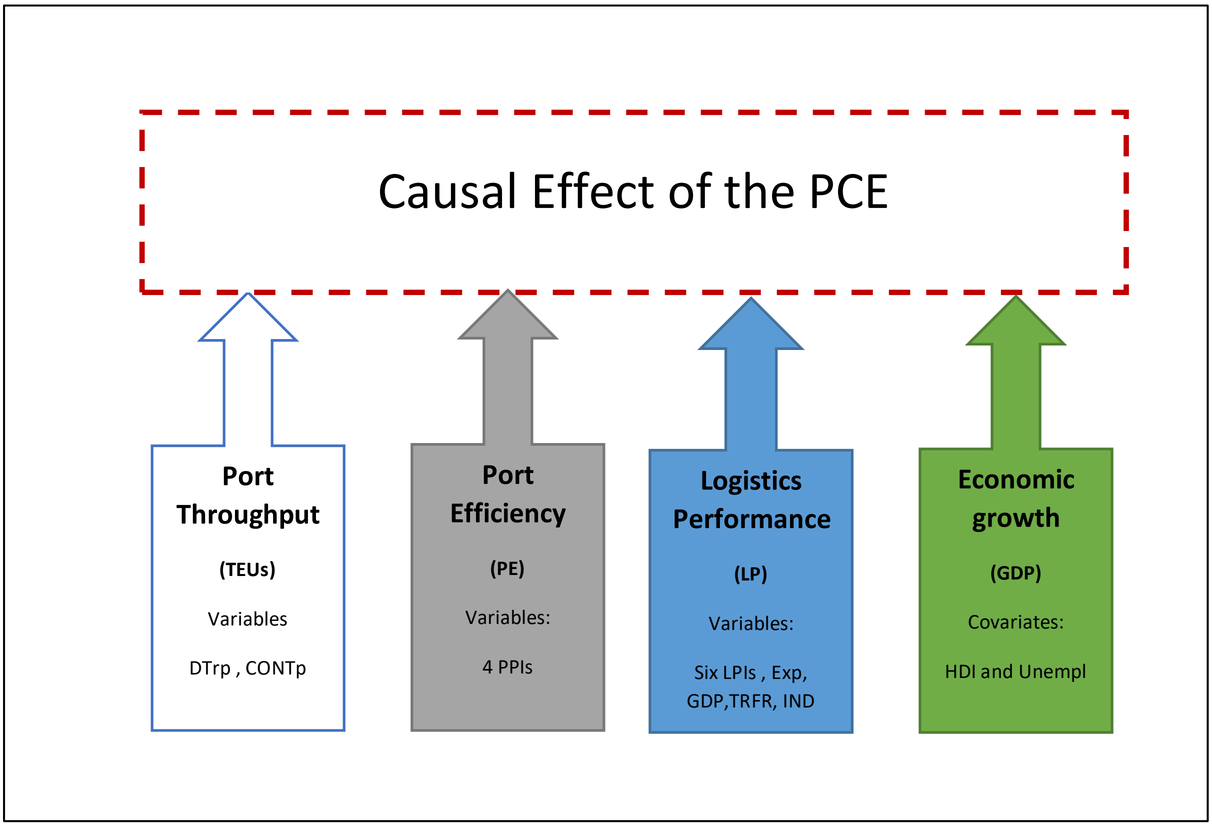
1.3 CONCEPTUAL FRAMEWORK FOR THE STUDY

Analyzing the impact of the PCE on the LAC region using the impact evaluation methods. First, it is necessary to determine the PCE impact among regional port throughput (TEUs) within the three sub-regions of Latin America and the Caribbean (LAC); Central America, the Caribbean, and South America (Rodrigue and Ashar, 2016; Bhadury, 2016; Park et al., 2020; Nicholson and Boxill, 2017). The PCE influences the container throughput, port competition, liner ship network, port development, and shipping routes (Reyes et al., 2019; Martinez et al., 2016; Van Hassel et al., 2018; Achurra-Gonzalez et al., 2016; Shibasaki et al.,2018). Therefore, evaluating the PCE's impact will determine the feasibility of regional policies and port infrastructural developments to facilitate this intervention or project (Hawkins et al., 2015, pp 26). Port throughput was commonly used to measure port performance (Shetty and Dwarakish, 2018; Talley, 2006).

Port performance measurement depends on port performance indicators (PPIs) that affect regional competitiveness and optimum throughput (Melalla, Vyshka, and Lumi, 2015; Shetty and Dwarakish, 2018; Talley, 2006). Therefore, analyzing port efficiency among regional ports during the pre and post PCE era is necessary for determining the overall improvements in port performance and keen PPIs that effectively measure port efficiency within the region performance (Tally, 2006; Shetty and Dwarakish, 2018; UNCTAD, 2016; Munim et al.,2018).

Logistics and exports are essential components that support economic growth (Rodrigue, 2020; OECD and WTO, 2013; Segal, 2021;). Therefore, logistics will foster more productivity in the export sector and link the domestic export market to the international economy (Gani, 2017). The World Bank Group developed the overall logistics performance (LPI), the perception of a country's logistics performance based on six (6) LPI components (Ekici et al., 2016; Yang and Chen, 2016; Ekici et al., 2016; Lakshmanan, 2001; Gillen and Waters, 1996; Vickerman et al., 1999). Therefore, studying the relationships between these components and exports per income classification is necessary to determine the PCE influence on logistics relationship to export within the LAC as per income classification (Pham et al., 2018; Gani, 2017; Seabra et al., 2016; Ronit, 2014).

Several factors can determine the socio-economic impact of the PCE on the region; however, the keen variables that are used to determine the research objectives are Gross Domestic Product (GDP), Human Development Index (HDI), and rate of Unemployment were used to determine the PCE's overall causal effect for countries within the subregion (Rodrigue and Notteboom, 2021; Jouili, 2016; Michail, 2020; Stopford, 2018). No other study shows the causal effect of the PCE on these variables.



Source: Own elaboration

Fig.1.1 Schematic diagram of the causal effect of the PCE

Fig.1.1 represents a schematic layout of the important variables and covariables used to analyze the PCE's impact on the research objectives.

1.4 PURPOSE OF THE STUDY

The study seeks to investigate the impact of Panama Canal expansion on LAC ports since the advent of neo-Panamax vessels. The following research questions will determine the PCE impact. First, this research seeks to analyse the impact of the PCE among 100 ports within the Caribbean, Central, and South America sub-regions. Secondly, the port performance will be assessed among nineteen (19) top regional ports within Latin America and the Caribbean to determine technical efficiency during the pre and post PCE era. Third, this research will investigate the relationship between exports and the six sub-indexes of logistics performance index (LPI) among Latin America and the Caribbean (LAC) countries. Finally, this paper seeks to analyse this expansion's economic impact since the introduction of neo-Panamax vessels.

1.5 RESEARCH QUESTIONS

1. What is the causal effect of the PCE on container throughput among LAC ports since the advent of mega-ships (Neo-Panamax)?
2. What effect has the PCE had on regional port performance, and how has this effect improved regional ports technical efficiency (TE)?

3. How has the relationship between logistics performance and export within the region been affected by the PCE, and how has this relationship impacted LAC countries as per income classification?
4. What is the causal effect has the PCE had on the LAC economy since the advent of neo-Panamax and port development?

1.6 METHODOLOGY

Analyzing the impact of Panama Canal expansion (PCE) on the Latin American and the Caribbean (LAC) region was obtained using secondary qualitative data from several data resources from the World Bank, UNCTAD, Lloyd List Intelligence, Marinetraffic, and regional port data for the period 2000 to 2019 from thirty-three (33) countries consisting of 118 ports. To achieve the four research objectives, the methodology of this research will apply four impact evaluation methods to assess the causal effect of the PCE on the port container throughput, port performance, logistics relationship to exports, and economic growth within the region. First, the Difference in Difference (DID) will determine the LAC's three (3) sub-regionals and transshipment causal effects of PCE on container throughput and port activities. This evaluation uses DID as an alternative method for assessing a policy and interventions causal effect in the maritime sector among 100 ports within the LAC region. Second, analyzing port performance within the LAC region will be ascertained by using the Scholastic Frontier (SF) to measure the technical efficiency (TE) among nineteen (19) top regional ports within LAC during the pre and post-PCE era. Third, to empirically determine the interrelations logistics to Latin America and the Caribbean (LAC) region exports using the Hierarchical Linear Model (HLM) and Pearson's correlation coefficient to determine logistics performance (LP) relationship with exports, data sample will be the source from thirty-three (33) countries within LAC region based on income classification. Finally, analysing the expansion's effect on the LAC economies (GDP), the Bayesian Structural time-series (BSTS) model will be applied among a sample of thirty-three (33) LAC countries.

1.7 SIGNIFICANCE OF THE STUDY

The Panama Canal expansion (PCE) has enabled the neo-Panamax and some post-Panamax vessels (mega-ships) to transit through the Latin American and the Caribbean (LAC) region. As a result, many studies predicted that the expansion could influence the growth within the maritime sector in port activities, logistics, and trade, which can ultimately improve the economic growth projections within the region. However, infrastructural improvement among the US East and Gulf coast ports could negatively impact container throughput, transshipment volumes, and sports activities due to increase competition for container volumes from mega-container vessels. Although, the PCE has influenced the infrastructural development of ports and logistics sectors through substantial investments from governmental policies and stakeholders, few academic studies address the causal effect of the PCE on port activity, port performance, logistics performance relationship to export, and economic growth during the pre and post-PCE era. Therefore, the significance of this study is to 6nalyse the impact of PCE within the LAC region by applying impact evaluation methods such as Difference in Difference (DID), Hierarchical Linear Model (HLM), and Bayesian Structural time-series (BSTS) that are typically non-traditional evaluation methods for assessing causal effects of endogenous and exogenous factors within the maritime sector. Findings from this research will highlight critical factors that need to be improved for the region to leverage its global competitiveness in seaborne trade.

1.8 ORGANIZATION OF THE STUDY

Chapter 1 gives the structure of this research depicted in table 1 as follows; Chapter 2 presents the literature of 4 topics; section 1. the impact of the Panama Canal Expansion (PCE) on Latin American and the Caribbean (LAC) ports. This section comprises an introduction, the Panama Canal's impact on the region, liner shipping, trading routes, and the advent of neo-Panamax vessels. Section 2. Assessment of port efficiency within LAC. This section comprises the introduction, port development's impact on economic growth, the relationship between dwell time (DT) and port productivity, and Port performance and port efficiency (PE). Section 3. The impact of LPI on LAC's exports. This section comprises an introduction, logistics impact on economic growth, trade, foreign direct investment (FDI), LPI and core components of LPI, and exports. Section 4; the economic impact of PCE in LAC. This section comprises an introduction, Seabourne relationship of economic growth, economies of scale, and causal inference.

Chapter 3 is the methodology segment comprising the statistical model used for four(4) topics. Section 1 Difference in Difference (DID); background of the regional port competition, the concept of DID, Parallel trend assumption (PTA), Model, Data sample, and list variables not used within the model. Section 2; Stochastic Frontier Analysis (SFA) comprises of model and data. Section 3; Hierarchical Linear Model (HLM); Model, sample data, and LAC's LPI sub-dimension trends. And section 4; Bayesian Structural Time Series (BSTS); sampling and data collection.

In Chapter 4, the empirical results, descriptive statistics, and analysis of the DID, SFA, HLM, and BSTS models. Chapter 5 discusses the results in the context of causal effects of PCE on regional port performance, port efficiency, logistics performance, and exports, and economic growth. Chapter 6 gives an overall summary, recommendation, and conclusion. Finally, chapter 7 outlines the limitations of the research and the opportunity for further research.

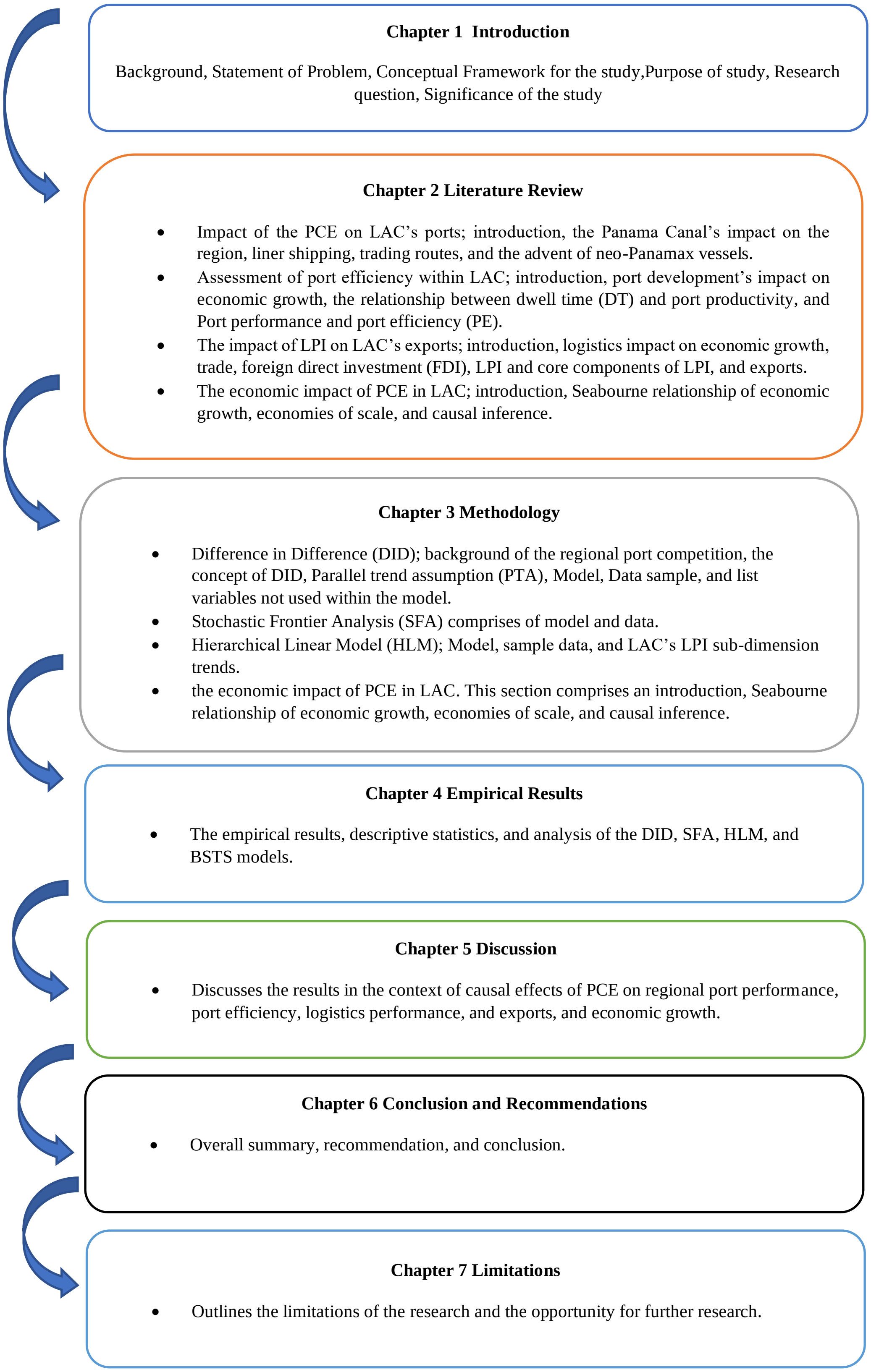


Fig. 1.2. Structure of Thesis

CHAPTER 2

LITERATURE REVIEW

IMPACT OF THE PANAMA CANAL EXPANSION ON LATIN AMERICA AND CARIBBEAN PORTS

2.1 INTRODUCTION

The Panama Canal (PC) is one of the two most strategic artificial waterways critical to global maritime trade, and the other is the Suez Canal. The Panama Canal (PC) is a narrow isthmus approximately 65 km between the Caribbean Sea and the Pacific Ocean. The canal was completed on August 15, 1914, becoming an essential route connecting vessels sailing from the West and East coasts of the United States and the LAC regions (Cho et al., 2019). Before the canal's existence, the Cape horn was the only trading route for ships connecting the East and West Coast of the Americas, and vessels sailing from Europe to the West coast had to sail around the Cape horn of South America (Gro, 2016). The Panama Canal (PC) is the shortest operative route connecting maritime trade between the Atlantic and Pacific oceans. It is also the shortest passage for gas cargoes from the Gulf of Mexico to Northern Asia (Rodrigue, 2015). For instance, for LNG carriers, the Gulf of Mexico's distance to Japan is approximately 17,064 km (9,214 nm) compared to 27,317 km (14750 nm) through the Suez Canal (Thomas, 2015). The Panama Canal (PC) is essential to global trade, wherein an estimate of over $270 billion worth of cargo crosses the canal each year; this serves over 140 maritime routes to over 80 countries (Panama Canal Authority, 2019). The expansion was completed on June 26, 2016, allowing Neo-Panamax and some Post-Panamax vessels to transit; thus, increasing port competition, trade, cargo tonnage, and shipping activities within the regions for the US East and Gulf Coasts (Rodrigue, 2020).

Mega-ships have increased the economy of scale in maritime transport, boosting regional ports' transshipment activities (ACS, 2017). For example, in the Caribbean, global hub port terminals such as Kingston; Jamaica, Freeport; Bahamas, Caucedo; Dominican Republic, and Juan; Puerto Rico (US territory) seek to capitalize on the anticipated increase in transshipment activities. However, investments in deepening harbors and expanding capacity handling may not be sustainable or profitable due to increased competition among regional ports (Gooley, 2018). The widening of the canal and the increase in container volume have provided promised growth for United States cargo and transportation among East and Gulf coast ports such as New York and New Jersey, Port of Houston, South Carolina Ports, Port of Miami, et cetera. However, to what extent has this expansion impacted container port throughput (TEUs) growth within the LAC region. It is essential to quantify the impact that PCE contributes to the LAC region to determine if ports benefit from this expansion (intervention). Major ports in the LAC region have made substantial investments towards improving port services and infrastructure. However, are these investments reaping success in container throughput growth (container handled at ports that include the port of origin, destination, and transshipment)? An impact evaluation of the PCE among LAC ports is vital for improving strategies to mitigate endogenous and exogenous factors that may contribute to unsatisfactory outcomes (Hawkins et al., 2015). These factors may include port development, international trade, economics, and policies that directly impact TEU growth (Notteboom et al., 2021).

This paper seeks to analyze the impact of the PCE among 100 ports within the Caribbean, Central, and South America sub-regions. One of the impact evaluation methods, Difference in Difference (DID), will determine the overall and sub-regional causal effects. This evaluation aims to use the DID as an alternative method for assessing a policy and interventions' causal effect in the maritime sector.

2.2 PANAMA CANAL IMPACT ON THE REGIONS

Undoubtedly, the expansion of the Panama Canal has impacted both North America and the LAC regions. It has allowed the transit of mega-ships such as Neo and Post Panamax vessels to increase container throughput (TEUs) and Cargo tonnage at ports within the region. PCE has increased competition among important transshipment ports in Panama, Brazil, Jamaica, Mexico, the Bahamas, and Dominican Republic (Rodrigue and Ashar, 2016). Most of these countries have made considerable investments in port expansion, dredging, and logistics centers to accommodate and attract mega-ships to their shores.

Using an impact evaluation method was necessary to assess the impact of the expansion within this region. Hawkins et al. (2015, pp 26) define impact as a longer-term result generated by policy decisions, often through intervention, project, or programs. The PCE project has influenced the Americas' subprojects, including the LAC region, in dredging and port infrastructural improvements (Link, 2015). Rodrigue and Ashar (2016), UNCTAD (2014), and Singh et al. (2015) stated that the advent of Mega-ships through the now expanded canal would influence greater transshipment yield and container traffic among transshipment ports. On the other hand, Marle (2016) alluded that the PCE has raised fears that the LAC container terminals were overcapacity due to port infrastructure and usage. Gooley (2018) also stated that the Port of Panama (ACP) indicated that some carriers shift from mega-ships due to high operating costs per container. He further stated that International Maritime Organization (IMO) mandated on January 1, 2020, that the use of low sulfur fuel could see more ships slow steaming to reduce fuel consumption by using the longer Suez route instead of shorter transits via Panama.

The expansion of the Panama Canal has impacted ports on the East and Gulf ports of the USA. According to Bhadury (2016) and Park et al. (2020), the PCE has increased cargo traffic flow from the West Coast to the East Coast, decreasing transportation costs and increasing transit time. This impact will enable more cargo traffic to transit the Panama Canal and increase transshipment activities within the Caribbean region. Nicholson and Boxill (2017) strongly believe that if most of the US East Coast ports become "ship ready" by improving port infrastructure such as longer quays, bigger cranes to accommodate 18 to 22 containers, more storage space for containers, deeper channel and berth, and higher bridges, then most Caribbean ports could see a reduction in transshipment activities. For example, ports such as Baltimore, Charleston, Miami, Philadelphia, and Virginia have official increases in container throughput (TEUs) due to ships transiting the expanded Panama Canal.

2.2.1 Panama Canal impact on liner shipping and trading routes

The World Shipping Council (WSC) (2019) defines Liner shipping as the service of transporting goods utilizing high-capacity, ocean-going ships that regular transit routes on fixed schedules. WSC (2019) further stated there were 400 liner services in operation providing weekly sailing from the port of call. Several authors studied the impact of the PCE on liner shipping concerning routes section, intermodal options, container vessel sizing, economic growth, and trading routes. The PCE had substantial impacts on the structure of liner services in terms of capacity deployment. Rodrigue (2020) stated that the first notable impact was the rapid transition from Panamax ships towards Neo-Panamax ships for Deep-sea services between major ports.

Pham et al. (2018) studied the PCE and its effects on East and West Liner Shipping route choice. An empirical study was conducted for ocean-borne trade between New York and Hong Kong. They examined route selection decisions for the PCE post-era by combining qualitative and quantitative studies. Using a two-stage methodological framework to assess both the Panama and Suez Canals and the US intermodal system alternative route competitiveness. The findings indicated that transportation was an essential element for route selection, followed by the duration of transportation, dependability, and route characteristics. The Panama Canal was the preferred route over the Suez and US intermodal options.

Fan and Gu (2019) studied the PCE impact on container shipping route networks. They used a dual-target route distribution model to evaluate the PCE. The results revealed that during the PCE post-era, 15000 TEU and 6500 TEU container vessels were mainly deployed through the expanded canal while 8500 TEU, 10500 TEU, and 12500 TEU used the Suez Canal.

Wang (2017) studied the impact of the Panama Canal on global shipping. The research was based on empirical studies using annual reports and publications from the Panama Canal Authority (ACP). Findings revealed that the expansion had generated more revenue since the Neo-Panamax vessel deployment, which has resulted in further economic growth for Panama.

Liu et al. (2016) analyzed the potential impacts of the PCE on the advancing competitive, collaborative relations and the allocation of market dominance among the supply chain (SC) players on US container markets. Cooperative Game theory was used to assess this impact. The results revealed that Mega-ships transiting the canal would increase East Coast markets by 32% while negatively impacting West Coast markets by 22%. Findings also revealed that the Ocean Carrier sub-coalition between West Coast SC companies would shift to the preferred sub-coalition between Ocean Carriers and East Coast SC companies after the PCE.

Carral et al. (2018) studied the impact of PCE on vessel size and seaborne transport. Statistical analysis was used to assess this effect on the type and size of ships transiting the canal. The findings revealed that growth in size and traffic for the container, LNG, and LPG vessels had significant growth since PCE.

Zupanovic et al. (2019) analyzed the impact of PCE on cost-saving in the shipping industry. The paper examined operational cost savings for three types of post-Panamax vessels; bulk, container, and tanker vessels on three different routes. The results revealed savings range from 33-76%, equivalent to saving from US$227,562 to US$ 1,042,324. Hence the PCE will result in a significant saving for specific categories of ships.

Shibasaki et al. (2018) studied the anticipated impact of PCE and Northern Sea routes on LNG imports of Asian countries from macroeconomic and diversification perspectives from exporting countries. The finding revealed that the divergence of exporting countries for LNG imports was not affected by the change in Japan's import pattern, and some degree of impact was observed for these countries' national economies.

Achurra-Gonzalez et al. (2016) studied the use of different liner shipping network scenarios such as natural disasters or infrastructure development impacts on container trade routes. They used a cost-based network model for Southeast Asia to Europe liner shipping trade. The results suggested that interconnectivity was susceptible to disruptions.

Van Hassel et al. (2018) analyzed the PCE influence on perspective shifts of cargo flow from US and European ports. They used model design to calculate the container transportation cost using the Panama Canal. Studies were conducted before and after the PCE for shipments from the US to Europe. The study concluded that the expansion had impacted port selection mainly for the United States and, to a lesser extent Europe.

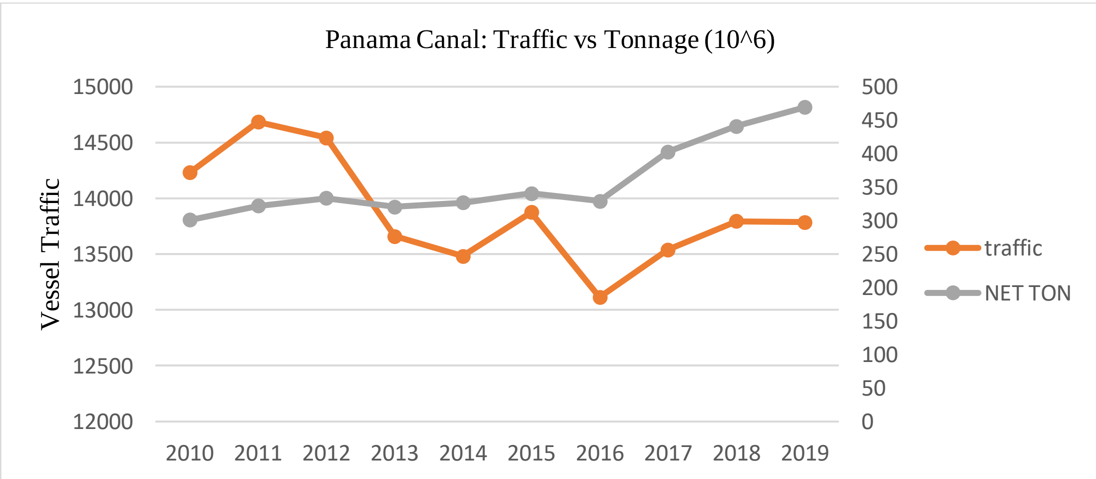
Martinez et al. (2016) studied the PCE effect on the shipping routes of Asian imports into the United States. They investigated factors affecting routing decisions by using a Coast Choice Model. The simulation results showed that the PCE would generate significant time saving on shipments from Asia and was projected to shift significant traffic flow from West to East Coast ports, establishing vital policy repercussions for port operators on both coasts.

Reyes et al. (2019) studied the impact of PCE on Caribbean Ports. They examined how ports can adapt to the opportunities available from the expansion. Adaptive Port Planning (APP) framework was used to assess long-term planning for Caribbean ports. The study revealed that in the short-term Caribbean ports will experience decreases in transshipment container volume due to direct service deploying Neo-Panamax vessels calling to East Coast and Gulf of Mexico new ports.

All authors agree that the PCE has impacted the liner shipping and trading routes, resulting in comparative cost savings for some vessel classification. Undoubtedly, this shift in liner shipping routes will affect both Caribbean and US west coast ports.

2.2.2 The advent of Mega-ships to LAC (economy of scale)

The Panama Canal is one of the main passages connecting the Pacific and Atlantic oceans, accounting for approximately 6 % of global trade (FreightWaves, 2020). According to Panama Canal Authority (2019), in 2018, United States, China, Japan, Mexico, and Colombia were the primary Canal users, with the United States account for 68.3 % of the total cargo transiting the canal. This expansion has opened the doors to Neo-Panamax and Post-Panamax vessels, impacting cargo throughput volumes for intraregional ports, US Gulf, and East coast ports.



Source: Panama Canal Authority (2019).

Fig. 2.0 Panama Canal Traffic and Traffic vs. Net Tonnage comparison for period 2010-2018.

Fig. 2.0 shows that after the expansion in 2016, there was a surge in cargo tonnage through the expanded canal, while no significant changes were observed for the number of transits (Rodrigue, 2020). Several authors supported the positive effects of mega-ships on international and regional ports.

Merk (2018) stated that doubling the maximum container ship size has reduced total vessel cost per transported container by roughly a third over the last decade. OECD (2015) supported his view, stating that containerization has contributed to decreased transportation costs. On the other hand, Lim (2011) studied the economies of scale in container shipping. The findings revealed that although huge container ships will produce economies of scale and significantly reduce the slot cost in container trade to which ship assigned, the industry may never make an adequate return because of over demand. Therefore, the benefits of economies of scale will diminish over time. Kapoor (2016) studied the economics of scale for mega container vessels. The report revealed four (4) significant findings; (1) that the economies of scale diminish for vessel sizes beyond 18000 TEUs; (2) that terminals will incur significant capital expenditure to handle larger vessels size and requires terminal yard to increase by third in order to avoid congestion; (3) terminal will have to increase productivity to comply with the increase in vessel size and (4) vessel upsizing risk the results of no significant cost benefit that will furthermore contribute to higher supply chain risk as volumes will be concentrated on fewer ships that will compile environmental issue of dredging deeper channels. Overview of the authors revealed that vessels were getting larger because of the theory of economy of scale. However, the effects of diminishing 'scale of economic' of mega-ships may not be necessarily beneficial for some regional ports.

2.2.3 Summary

The impact of the PCE on the US ports and LAC region has been studied by several authors such as Rodrigue and Ashar (2016), Singh et al. (2015), Bhadury (2016), and Park et al. (2020). They strongly agreed that PCE had impacted port infrastructure improvement within both regions. Pham et al. (2018), Rodrigue (2020), Fan and Gu (2019) studies agreed that PCE has influence liner shipping, trading routes, and cost savings for LAC and US ports on both east and west coasts. Several authors, such as Merk (2018), Lim (2011), Kapoor (2016), and Rodrigue (2020), strongly agreed that the advent of mega-ships had impacted container throughput and cargo tonnage. On the other hand, few authors address the causal effects of PCE on the LAC regional ports before and after the expansion to determine its overall impact. Several methodology applications such as port choice, route planning, adaptive port planning, and Cost-base analysis models were used to assess the effect of this expansion on global and US ports. However, limited authors use impact evaluation methods to determine the causal impact of the PCE as an intervention within the LAC. This research gap will be addressed using impact evaluation; Difference in Difference (DID), to assess the PCE implications for all three LAC sub-regions and transshipment ports.

ASSESSMENT OF PORT EFFICIENCY WITHIN LATIN AMERICA

2.3 INTRODUCTION

The evolution in supply chain and logistics models has caused container terminals to rethink their logistics processes. The concept of ports and their functions have evolved throughout the decades. In the 19th and 20th centuries, the port sector tended to be instruments of the state, and port access was deemed to control markets. As a result, there was a minimum competition between ports, and ports related costs were insignificant compared to ocean and inland transport costs, resulting in a lack of initiative to improve port efficiency (PE). Currently, ports are competing globally and reaping tremendous gains from ocean transportation and improvement in logistics. This drive has made the port sectors focus on improving PE, lower cargo throughput handling costs, and providing added value service to catering to other components of the global distribution network (Talley, 2017, Notteboom et al., 2021). Port activity and seaborne trade are often associated with positive socio-economic effects, such as GDP and employment growth (Nogue-Alguero, 2019; Notteboom et al., 2021; Munim et al., 2018; Rodrigue et al., 2020; Talley, 2006; Talley, 2017). In addition, ports are the drivers of urban and regional economic growth, which is a function of port productivity (Lonza and Marolda, 2016; Munim and Schramm, 2018; Tally, 2017; Shetty and Dwarakish, 2018).

Port Performance Indicators (PPIs) is simply defined as a measured aspect of a port's operation to maximize profitability and economic objectives (UNCTAD, 2016). Hence a cost-effective port must achieve optimum and technical efficient (TE) throughput to meet its goals (Shetty and Dwarakish, 2018; Talley, 2006). A port performance measurement depends on several PPIs that affect regional competitiveness and optimum throughput. These factors may vary depending on the port location and region; however, the essential PPIs are berthing capacity, storing capacity, loading/unloading equipment, floor size, and the number of gates lanes (Melalla, Vyshka, and Lumi, 2015). Nevertheless, the standard measurement of port performance is related to several factors such as vessel dwell time (DT), loading/unloading the cargo, quality storage, and inland transport (Shetty and Dwarakish, 2018). Traditionally, a port performance was assessed by actual throughput and optimum service levels, where the optimum throughput is the maximum (TE) throughput that the port can handle under certain conditions (Talley, 2006).

Several authors agreed that PPIs is necessary for rational decision and precise performance measurement. These PPIs reflect port activities that determine overall port performance (Tally, 2006; Shetty and Dwarakish, 2018; UNCTAD, 2016; Munim et al.,2018). Port activity can be evaluated using container traffic, voyage productivity, container dwell time, berth area, wharf entrance, departure gates, and port-channel (Depth of channel) (Talley, 2017; Suarez-aleman et al., 2015; Figueiredo de Oliveira and Cariou, 2015). On the other hand, port performance can be affected by both endogenous and exogenous factors. Endogenous factors involve the port affairs originating from the public and private sectors, such as administration and management inefficiencies. Exogenous factors refer to the shipping and logistics industries and trade economies directly impacting port activities (CEPAL, 2019).

The geographical location of ports can also influence port performance. The changing geography of seaports is impacted by technical constraints such as the port users, intermodal connectivity, and maritime shipping networks (Notteboom et al., 2021).

Asian Ports (Singapore, Tianjin, Yokohama, Busan, and Nhava Sheva) have the highest global port performance and rankings. While African ports have displayed mixed trends (Lagos, Durban, and TangerMed) (UNCTAD, 2020; WorldBank, 2019), most developing countries have shown significant advances in port performance and TE (Sarriera et al., 2015, UNCTAD, 2020). The Latin America and the Caribbean (LAC) regional ports demonstrated an increase in container throughput during 2000 at 17 million TEUs to 53.4 million TEUs in 2018, representing 6.6 percent of global throughput (UNCTAD, 2019). The top fifteen ports of LAC, shown in Table 1, have also demonstrated sustained positive container throughput growth (UNCTAD, 2020; WorldBank, 2020).

The Panama Canal (PC) has played a vital role in LAC's port infrastructural developments and transport logistics improvements. The Panama Canal expansion (PCE) has further improved PE among regional ports since the advent of Neo-Panamax ships (Sarriera et al., 2015; Suarez-aleman et al., 2015; Figueiredo de Oliveira and Cariou, 2015). Port infrastructural developments involve; deepening the water channel, acquiring neo-Panamax ship-to-shore (STS) cranes and post-Panamax cranes, and port expansion to construct berths and terminals. These developments have fuelled competition within the regions where US gulf and East coast ports compete for container traffic. This increasing competition depicts that LAC ports will have to display improving levels of TE to be competitive while maintaining optimum service to satisfy economic objectives to maximize profits (Sarriera et al., 2015; Rodrigue and Notteboom, 2021; Talley, 2017; Talley, 2006). However, it is also essential to determine which PPIs are most significant to port productivity within the LAC region and ascertain whether regional ports have experienced improvements in port performance and TE during the Post-PCE era. A port's productivity depends on the type of PPIs that need to be measured. The individual performance of each port is vividly measured by the output increase in container throughput (Pallis and Rodrique, 2021).

This research seeks to investigate the effect of Panama Canal expansion (PCE) on technical efficiency (TE) for LAC ports during the pre-and post-PCE era among 19 regional ports that account for over 85 percent of container throughput (TEUs) by using Stochastic Frontier Analysis (SFA). Our objectives focus on determining port performance indicators (PPIs) necessary to improve LAC regional ports productivity and efficiency. This study aims to contribute to the body of academic research regarding the Panama Canal expansion (PCE) impact on regional port efficiency (PE) by analyzing the technical efficiency (TE) during the pre and post-PCE era.

In this section, we summarize the existing studies in three research areas: (i) the impact of port development on economic growth, (ii) the relationship between dwell time (DT) and port productivity, and (iii) port performance indicator and port efficiency.

2.4 PORT DEVELOPMENT AND ECONOMIC GROWTH

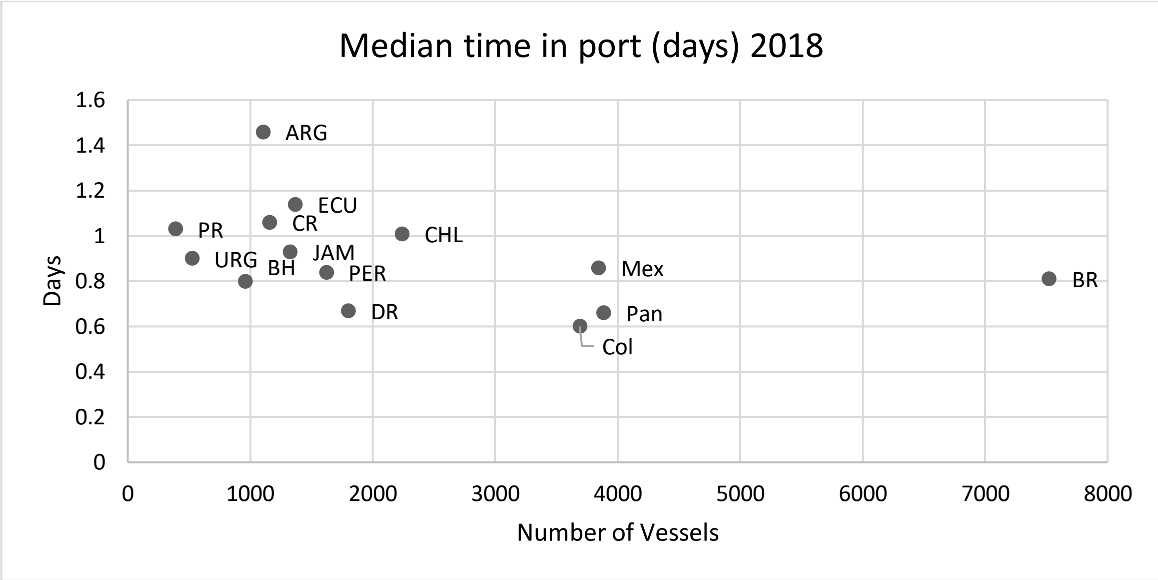
Ports are harbor areas where marine terminal facilities transfer cargo and passengers between ships and land transportation (Rodrigue and Notteboom, 2021). Talley (2017) referred to ports as the engine for economic development. Thus, port development is a keen driver towards economic growth in a rapidly changing competitive market. Munim and Schramm (2018) studied the impact of port infrastructure and logistics performance on economic growth. The structural equation model (SEM) provided empirical evidence of this objective among 91 countries from 2010 to 2014. The findings revealed that it is of utmost importance for developing countries to continuously improve port infrastructure and logistics to achieve higher yields in economic growth. Mudronja et al. (2020) analyze the effects of seaports on regional growth. Endogenous growth theory based on research and development (R&D) was used for a sample of 107 ports within the European Union (EU) from 2005 to 2015. The findings revealed that seaports significantly contributed to economic growth among ports within the EU region. The results also showed a close relationship between investment in transportation infrastructure and economic growth. On the other hand, not all port development and productivity contribute to local economic growth. Jung (2011) studied the economic contribution of ports to the local economies in Korea. Content analysis was conducted on port-city, and input-output linkage on ports was investigated. Empirical data of the port throughput and economic indicators were used to find the relationship between ports and the financial performance of major cities in Korea. The results revealed that readily available port services do not guarantee economic success for port cities. Therefore local economies were not benefiting from nearby ports. Consequently, not in all cases does infrastructural expansion contribute to productivity. For example, Herrera and Pang (2008) studied the efficiency of the infrastructure of container ports. They used non-parametric methods to estimate the efficiency of frontiers on 86 ports globally. The results revealed that most ports in developing countries could reduce inefficiency by increasing the scale of operation. However, 33 percent of these ports can also reduce inefficiency by contracting the scale of operation.

2.4.1 Dwell time and port productivity

Port dwell time (DT) is the amount of time a cargo or ship spends within a port (Rodrigue and Notteboom, 2021). It is also an indication of the efficiency levels of a seaport (Notteboom et al., 2021). DT impacts port productivity and efficiency; thus, reducing DT will improve port productivity. Port productivity is used frequently to measure and compare the performance of a firm's ratio of output over input, while PE analyses the ability of a port to obtain the maximum result under a given amount of input (Suarez-Aleman et al., 2015; Talley, 2017). Several authors studied the relationship between DT and port productivity. Shetty K and Dwarakish (2018) reviewed the relationship between performance parameters and the port's productivity. PPI's data was retrieved from the new Mangalore port from 1990 to 2015. Results revealed a strong negative correlation between idling time at berth, turnaround time of a vessel, and idle time at berth to the port's productivity. Aminatou et al. (2018) studied the impact of long cargo DT on port performance. A shipment level analysis was conducted using original and extensive data on container imports in the Port of Douala, Cameroon. They investigated why containers stay an average exceeding two weeks at berth. Their findings revealed that internal factors such as the logistics performance of consignees, port operations, and the efficiency of customs clearance operations and external factors such as customs procedures, shippers, and shipping lines were the main contributors to long DT. Hassan et al. (2017) analyze the DT of containers at container terminals in Indonesia. Root Cause Analysis and Problem Tree framework analyzed operational data and interviews. The results from the simulation revealed that container handling equipment had a significant impact on DT. Finding also revealed that most DT was contributed by a prolonged time of containers stay at the terminal yard.

Understanding and resolving the root cause of long DT at port terminals are essential for improving port productivity and efficiency. Furthermore, predicting the container dwell time is vital for enhancing port operations. According to PortStrategy (2020), the German container terminals will predict DT by implementing a new terminal operation system (TOS) based on machine-learning technology. This system will improve container stacking and optimize pick-up handling.

. 2.1 below shows the median time spend in port for container ships per LAC country. This DT indicates the overall port productivity of the country. For example, Panama and Colombia have the least time delay for increasing vessel traffic at 0.66 days for 3883 vessels and 0.6 days for 3689 vessels, respectively. On the other hand, Argentina has the highest median time in ports, showing 1.46 days for 1104 vessels. DT can also indicate the efficiency of a port's processes and infrastructure (Shetty and Dwarakish, 2018).



Source: World Bank (2020)

Fig. 2.1. Median Time (Days) and Number of vessels (No.) for leading container ports (country) within LAC.

2.4.2 Port performance Indicators and Port efficiency

2.4.2.1 Port performance Indicator

PPIs are used to measure various aspects of a port's operation. The weight of these indicators may vary based on location, throughput volumes, nature of cargoes, port infrastructure, equipment, and facilities (Mellalla et al., 2016; Talley, 2017). These indicators measure a port's performance by monitoring activities, checking their efficiency, and comparing the present with past performance (Shetty and Dwarakish, 2018; Notteboom et al., 2021). Port performances require a set of measures related to vessel dwell time, cargo throughput volumes, berth area, harbor depth, quality storage, and inland transport (Shetty and Dwarakish, 2018). However, not all measurements are related to a port's physical infrastructure.

Langen et al. (2007) studied the feasibility of using performance indicators from the airport and the business industries to the port sector. New indicators such as services variability and average time to deliver cargo could potentially measure port performance. Furthermore, they analyzed performance indicators in other economic and spatial entities such as airports, regional economies, and business parks. The results revealed that these new PPIs would be useful for the port industry.

2.4.2.2 Port efficiency

PE analyses the ability of a port to obtain the maximum output under a given number of inputs. Therefore, gains in efficiency represent an improvement in performance closer to optima (Suarez-Aleman et al.,2015). PE is a keen component of port performance (Notteboom et al., 2021). Several authors studied the effects of PE on transportation cost, trade, port competition, and socio-economic issues.

Serebrisky et al. (2013) explored the driver of PE in LAC. The Stochastics Frontier model developed a TE evaluation on container ports within LAC. Using data from 1999 to 2009 among 63 ports of container throughput, port terminal area, berth length, and the number of available cranes, thefinding revealed an overall improvement in the average TE of ports within the region, from 52 percent to 64 percent. Furthermore, the results showed a positive and strong correlation between TE and private port operation.

Perez et al. (2016) analyzed the development of major container terminals within LAC. The paper's main objective was to investigate factors that influenced container port inefficiency among inter-port and intra-port competition. Stochastic Production Frontier was used for this analysis for all LAC ports from 2000-2010. The results revealed that PE within the LAC has positively evolved despite the economic crisis, whereby container terminals located among Mercosur countries with three or four container terminals were more efficient than transshipment ports within the region. Interestingly, transshipment ports were least efficient than other types of ports.

Merk and Dang (2012) studied the global PE for container and bulk cargo. Data envelopment analysis (DEA) methodology was used to find the overall efficiency score of 63 of the largest international container ports. The findings revealed that ports with noticeable increases in TE showed significant improvement in PE. Also, promoting port policies to raise throughput levels was essential for improving production scale inefficiencies. However, they also found production scale inefficiency increases whenever a port throughput level is below or above optimum operating terminal capacity. This inefficiency was predominantly found for ports that handled crude oil and iron ore, suggesting that efficiency was affected by exogenous factors relating to traffic flow.

Blonigen and Wilson (2007) studied PE and Trade flow. The Gravity Trade Model was used to analyze US imports and associated imports cost, yielding estimates across ports, products, and time. The results revealed that PE significantly increases trade volumes.

Clark, Dollar, and Micco (2004) examined shipping costs to the United States using 300,000 observations per year on the shipments of products accumulated for various global ports. They found that PE was an essential element of shipping costs. Enhancing PE from the 25th to the 75th percentile reduced shipping costs by 12 percent. Overall, their research revealed that a port's (in) efficiency also increased handling and shipping costs.

Figueiredo de Oliveira and Cariou (2015) studied competition on container port (in) efficiencies. They investigated competition impacts on container PE scores at regional, local and global levels. Using truncated regression with Bootstrapping model for 200 container ports from the period 2007 to 2010. Results revealed that PE decreased with competition intensity varies with distance. For instance, regional range from 400-800 km, local range from less than 300 km, and global level more than 800 km were insignificant at all three levels. Estimates also show a tendency for ports that invested from 2007 to 2010 to experience a general decrease in efficiency scores, which the time lag between the investment could explain.

Tongzon and Heng (2005) examined port privatization, efficiency, and competitiveness. They also investigated the determinants of port competitiveness using principal component analysis and Linear regression model among international container terminals. The results of the study revealed that private sector participation in the port industry could improve port efficiency, therefore, increasing port competitiveness.

The efficiency of ports can be affected by endogeneity and exogenous factors. Several authors extensively studied the link between PE in relation to corruption and socio-economic issues. Suarez-Aleman et al. (2015) examine the drivers of productivity and the efficiency changes for ports among developing regions. Using data from the period 2000 to 2010. The results revealed that PE for developing regions improved, increasing from 51 percent to 61 percent in 2010. The analysis indicated public sector corruption that PE in developing countries could be improved if there were reduced ship liner connectivity improvements and increased multimodal connectivity among ports.

Several authors' studies revealed a positive link between port productivity and economic growth (Mudronja et al., 2020; Munim and Schramm, 2018; Talley, 2006). Furthermore, most research revealed that PE positively impacts trade volumes, freight transport, shipping cost, and DT (Shetty and Dwarakish, 2018; Aminatou et al., 2018; Hassan et al., 2017; PortStrategy, 2020). The authors also connect exogenous and endogeneity factors such as corruption and social-economic factors negative relationship to PE (Serebrisky et al.,2013; Perez et al., 2016; Merk and Dang, 2012). However, little research analyses the PCE influence on PE among the LAC region. The SFA model will address this research gap to determine the most significant PPIs towards PE and regional competitiveness.

2.4.3 Different Approaches to Technical Efficiency Frontiers

2.4.3.1 Data envelopment analysis (DEA) and Stochastic Frontier Analysis (SFA)

The assessment of multiport performance for TE of ports was conducted using the Frontier models. TE is usually calculated using two approaches, DEA and SFA, where both rely on the estimation efficiency frontier. The Frontier is most frequently used to determine the best performance of data sample information (Serebrisky et al., 2015) while the DEA is commonly used for multiport TE assessment. According to Talley (2017), DEA is a mathematical programming technique used to derive and estimate TE rating for a group of ports relative to each other. However, the main drawback to this approach is that it assumes sample measurement errors and random variation (Serebrisky et al., 2015).

SFA refers to a body of statistical techniques used to evaluate a port inefficiency by estimating performance and productivity. (Encyclopedia, 2021; Aigner et al., 1977). SFA relies on the parametric estimation of the production function with a stochastic component (Kuosmanen and Kortelainen, 2010). The error term of SFA is comprised of two random effects that depict statistical noise and other TE. Table 2.0 shows the main characteristic of DEA and SFA.

Table 2.0. Characteristics of DEA and SFA

DEA	SFA
Non-parametric approach	Parametric approach
Deterministic approach	Stochastic approach
Does not consider random noise	Consider random noise
Does not allow statistical hypotheses to be contrast	Allow statical hypotheses to be contrasted
Does not include an error term	Imposes assumptions on the distribution of the inefficiency term
Does not require specifying a functional form	Requires specifying a functional form
Sensitive to the number of variables measurement errors and outliers	Can confuse inefficiency with a poor specification of the model
Estimation method: mathematical programming	Estimation method: econometric

Source: Serebrisky et al. (2016)

Cullinane et al. (2006) use both DEA and SFA approaches to analyze the performance of the world's largest container ports and compare the findings. The results revealed a high level of TE for private-sector-owned and transshipment ports than gateway ports. Similarly, Notteboom, Coeck, and Broeck (2000) presented an approach for assessing the container terminal efficiency using the Bayesian Stochastic Frontier modeling. The model was tested using a sample of thirty-six (36) European container terminals and four (4) Asian container ports. The results revealed that feeder ports were less efficient than terminals located in hub ports. Finally, Yang et al. (2011) used SFA and other inefficiencies such as Delphi technique models to evaluate the efficiency of seaport operations. The study results highlightedareas of seaport operations that need to be resolved and showed which characteristic needed rectification.

The SFA model was applied and supported by several authors to calculate the TE of port performance; both the DEA and SFA were used in various articles to analyze the TE. The two approaches have different strengths and weaknesses. DEA is sensitive to measurement errors or noise within the data because of its deterministic approach. However, the SFA considers stochastic noise in data and allows statistical testing of hypotheses concerning production structure and degree of inefficiency as shown in Table 2.2. The SFA model will assess the port performance of nineteen (19) top-performing ports within LAC regions. The results will be necessary to determine the PCE impact on top regional ports and the TE since the expansion.

THE IMPACT OF LOGISTICS PERFORMANCE INDEX (LPI) ON THE LAC'S EXPORTS

2.5 INTRODUCTION

Logistics plays an essential role in a nation's growth and economic development (Rodrigue, 2020). They facilitate international trade, which is a financial contributor to several developed countries such as Singapore and Germany. However, the logistics contribution may differ for countries in competitiveness and national output. Henceforth, its supporting role within an economy cannot be overlooked, especially its ability to improve trade. The connection between transportation and logistics is the facilitation of international trade, which delivers several beneficial economic and social outcomes (OECD and WTO, 2013).

Globalization has breakthrough international barriers to free trade that boost growth in the 21st century (Islam et al., 2019). It has improved international trade by expanding markets for exporters to provide better economies of scale, lowering prices for imported goods and higher quality goods and services while providing job creation in the logistics and transportation sectors (Rodrigue and Notteboom, 2021; Ural Marchand, 2017). Therefore, nations that focus on improving transportation infrastructures and logistics systems can take advantage of business opportunities for growth and poverty reduction (Rodrigue, 2020). However, it is important to note that logistics services' quality and efficiency determine international trade development, in which this global trade integration can be negatively impacted by inadequate logistics infrastructure and operations (Devlin & Yee, 2005). According to Töngür et al. (2020) and Gani (2017), poor logistics infrastructure in developing countries increases the costs and time required for a trade, hindering the efficient movement of goods.

On the other hand, investing in logistics capabilities improves the integration between global trade and the supply chain, providing better national transport assets, increasing productivity, and competitive exports. (Rodrigue, 2012; Lakshmanan et al., 2001). Exports are one component of international trade that is vital to modern economies (Segal, 2021). Therefore, the role of logistics will foster more productivity in the export sector. Moreover, logistics service links sectoral logistics for the local or domestic export market to the international economy, making logistics a pivotal driver and platform to support and enhance economic growth (Gani, 2017).

Maritime transport is undeniably the primary mode of international transportation for goods worldwide. 70 % of global trade by value was carried by sea and handled by ports accounting for 80 % of global trade volume (UNCTAD, 2018). The role of container ports has become vital to both trade and logistics. Therefore, a port's productivity and efficiency widely depends on its infrastructure and logistical capabilities to support operations (Rodrigue, 2012, pp 300-350). The Panama Canal expansion (PCE) in 2016 has allowed both neo-Panamax and post-Panamax vessels to transit to the Latin America and the Caribbean (LAC) regions. These have stimulated international maritime trade for exports and imports driven by economies of scale (Mega ships) and maritime activities in transshipment and container among competing ports within the regions (Rodrigue, 2020).

The Latin America and the Caribbean (LAC) regions have made an effort to remove tariff and non-tariff barriers (Trade freedom) to stimulate economic growth. However, the crucial areas of logistics and transport infrastructures, which are components of logistics performance, have long been governments' agenda within the Latin America and the Caribbean (LAC) regions (Dolabella and Durán Lima, 2021). Globally, logistics plays an integral role in supporting commercial activities and economic growth; however, most Latin America and the Caribbean (LAC) countries lack the logistic infrastructure to support global trade dynamics. This flaw in logistics systems and infrastructure has proven to be a significant barrier to trade and economic development Gani, 2017).

Few articles analyze the importance of logistics performance influence on Latin America and the Caribbean (LAC) exports and its supporting role in changing trade policy to expedite growth and development in international trade. Instead, most articles cover the global perspective of logistics impact on trade, limiting academic recommendations tailored to the region.

The Latin America and the Caribbean (LAC) region comprises thirty-three (33) countries with diverse economies driven by trade and services in agricultural products, tourism, and natural resources. This diversification is uniquely impacted by maritime trade and logistics, fueled by the Panama Canal expansion (PCE). Therefore, this research will investigate the relationship between exports and the six sub-indexes of logistics performance index (LPI) among Latin America and the Caribbean (LAC) countries. It will also evaluate the Pre and Post- PCE era Logistics Performance Indicator (LPI) and its influence on the relationship between LPI components and Exports concerning income classification. The main aim is to recommend sensitive LPI and economic variables to policymakers to improve logistics performance and economic growth through exports. Therefore, this study will empirically examine the interrelations of logistics to Latin America and the Caribbean (LAC) region exports using the Hierarchical Linear Model (HLM) and Pearson's correlation coefficient to determine logistics performance (LP) relationship with exports.

2.6 LOGISTICS IMPACT ON ECONOMIC GROWTH, TRADE, AND FOREIGN DIRECT INVESTMENTS

Logistics plays an integral role in the facilitation of international trade (Gani, 2017). It is one of the tools that impact changes and improves economic indicators (Sezer and Abasız, 2017). For example, the logistics industry has provided significant macro and micro contributions to a nation's economy in providing jobs, creating national income, and attracting FDI (Hilda, 2020). Singapore is a central logistics hub, obtaining the first rank in logistics competence and timeliness of service in Asia (World Bank, 2020). The logistics sector is an essential pillar of Singapore's economy, in which the logistics sector contributed a value-added of 6.8 billion in 2018 and generated more than 86,300 jobs (Enterprise Singapore, 2020). Although logistics is vital to economic growth, the World Bank (2017) studies revealed that the logistics performance (LP) gap widens between high-, middle- and low-income countries. This generally because Logistics Performance Index (LPI) rankings depend on the country's level of income (Gani, 2017). comparably, Budkin (2018) believes that transportation and logistics obstacles were the reason for this widening gap for developing countries. The importance of logistics as a determinant to international trade was supported and studied by several authors.

Cosco (2017) reviewed quantifies the impact that logistics has on a country's exports and the extent to which inadequate logistics infrastructure affects trade barriers. Their findings revealed that improvement in logistics infrastructure, services, and customs processes lead to increased trade flows and facilitates exports from countries in a statistically significant fashion. Gani (2017) explored the effects of logistics performance on international trades using the LPI index. The results revealed that the logistic performance (LP) was practical and significant for import and export countries. The author believes that constant improvements in logistical infrastructure and services will positively impact international trade and policies.

Celebi (2017) studied the role of logistics performance in promoting trade. Using gravity model to determine logistics performance impact on income level. The findings revealed that logistics performance benefits exports for low and lower-income countries while logistics performance benefits imports for high and upper middle-income countries. Tongur, Turkcan, and Ekmen-Ozcelik (2018) examined the effects of logistic infrastructure on export variety. Using export data for Turkey's trade with 174 countries over the period 2007-2017,the results suggested that logistics infrastructure positively influences export values. Finally, Tang and Tang and Abosedra (2019) analyzed hypothesis validity that the export-led growth (ELD) was reliant on the logistics performance. The study was conducted among 23 Asian countries from 2010 to 2016. Their finding revealed that the validity of the export-led growth hypothesis was factual for all the examined countries.

Park (2019) investigated whether a comparative advantage was associated with logistics and transport infrastructure quality in industries for which logistics services were essential. Their findings revealed that a country's ability to provide high-quality transport infrastructure and logistics has a comparative advantage. Behar, Manners, and Nelson (2009) investigated trade logistics on trade cost for a country's exports. The indings revealed that although improvement in trade logistics has a positive effect on exports, its magnitude depended on the country's size. The results also showed that an average-size country would raise exports by about 46 percent after a one standard deviation improvement in logistics. Finally, Hausman, Lee, and Subramaniam (2013) studied the impact of logistics performance on global bilateral trade. The research was conducted among 80 countries using the Gravity model to assess the impact of logistics on trade. The result showed that logistics performance (LP) was statistically significant for bilateral trade volume among 80 countries.

Hellstrom et al. (2017) examined the importance of logistics towards improving trade investments and its invaluable contributions towards FDI and global trade. Panel data analysis was used to measure each variable's substantial impact on trade and investment among twenty (20) Asian countries for 2006-2014. The findings revealed that the relationship between logistics and trade was statistically significant, whereby transport infrastructure such as ports and road quality was also an essential factor affecting trade. Their study's results revealed that that one of the main restrictions for trade among low-income countries was the effect of tariffs and non-tariff measures, despite their accessibility to preferential programs. They indicated that improving logistics performance (LP) to facilitate trade would positively impact developing countriestrade, specifically exports.

2.6.2 Logistics performance index and core components of (LPI)

The World Bank Group developed the overall logistics performance (LPI), the perception of a country's logistics performance which is based on six (6) LPI components; the efficiency of customs clearance processes, the quality of the trade and transportation infrastructure, the ease of competitive pricing international shipments, the quality of logistics services, the ease of tracking and tracing consignments, and the frequency of shipment to a consignee within the proposed time (World Bank, 2019). Furthermore, according to Rezaei et al. (2018), globalization has increased demand for international freight transportation and global logistics; therefore, the LPI was created to measure a country's logistics performance (LP). In addition, several studies have been conducted on the importance of economic gains associated with logistics performance.

According to the World Bank (2019), the Customs (LP-CUST) component of LPI determines the effectiveness and efficiency of customs procedures related to speed, simplicity, and predictability. Several studies see Customs as an essential component of logistics and transport efficiency (Ekici et al., 2016; Yang and Chen, 2016). Infrastructure is necessary for faster economic growth through trade. Numerous studies connect logistics, transport infrastructure to economic and trade volume (Ekici et al., 2016; Lakshmanan, 2001; Gillen and Waters, 1996; Vickerman et al., 1999).

Transportation infrastructure (LP-INFRA) is an essential component to trade (Bensassi et al. (2015), Ekici et al., Gillen and Waters, 1996). Ho and Chang (2015) studied the factors contributing to invention and service capabilities and logistics services (LP-QLS) impact on corporate performance. Their results revealed that innovation and service capabilities positively affect corporate performance, and they also observed that innovation capabilities enhance logistics services.

Timeliness refers to the reliability of shipments delivered at the right time and place (Rezaei et al., 2018). Nordas, Pinali, and Grosso (2006) studies revealed that timeliness positively affects logistics performance (LP-TL). In addition, Hummels and Schaur (2013) established that a 1 % reduction in processing time export containers would result in a 0.4% improvement in bilateral trade.

Tracking and tracking systems (LP-TT) are essential in satisfying customer demands (Shamsuzzoha and Helo, 2011). The data for the LPI for 2018 results show Germany's best overall LPI score of 4.20. In 2018, Germany had the best infrastructure in the world. It was characterized by having one of the world's best port infrastructures, with around 60 main and auxiliary ports and a very competitive logistics operators market. Table 2.1 below shows the LPI for the top 10 high-income economies, and Table 2.2 below shows the lowest LPI were all low-income countries.

Table 2.1. Top 10 High-Income Countries: LPI 2018

Country	Ranking 2018	General LPI	Customs	Infrastructure	International Shipments	Tracking & Tracing	Timeliness
Germany	1	4.2	4.09	4.37	3.86	4.24	4.39
Sweden	2	4.05	4.05	4.24	3.92	3.88	4.28
Belgium	3	4.04	3.66	3.98	3.99	4.05	4.41
Austria	4	4.03	3.21	4.18	3.88	4.09	4.25
Japan	5	4.02	3.99	4.25	3.59	4.05	4.25
Netherland	6	4.02	3.92	4.21	3.68	4.02	4.25
Singapore	7	4	3.89	4.06	3.58	4.08	4.32
Denmark	8	3.99	3.92	3.96	3.53	4.18	4.41
United Kingdom	9	3.97	3.77	4.03	3.67	4.11	4.33
Finland	10	3.97	3.82	4	3.56	4.32	4.28

Source: World Bank (2020)

Table 2.2. The 10 Lowest LPI of Low-income Countries: LPI 2018

Country	Ranking 2018	General LPI	Customs	Infrastructure	International Shipments	Tracking & Tracing	Timeliness
Central African Rep	154	2.15	2.24	1.93	2.3	2.1	2.33
Zimbabwe	155	2.12	2	2.06	2.16	2.26	2.39
Haiti	156	2.11	2.03	2.01	2.19	2.05	2.44
Libya	157	2.11	1.95	1.99	2.05	1.64	2.77
Eritea	158	2.09	2.13	1.86	2.09	2.17	2.08
Sierra Leone	159	2.08	1.82	1.82	2.18	2.27	2.34
Niger	160	2.07	1.77	2	2	2.22	2.33
Burundi	161	2.05	1.69	1.95	2.21	2.01	2.17
Angola	162	2.05	1.37	1.86	2.2	2	2.59
Afghanistan	195	1.73	1.81	2.1	1.7	2.8	2.38

Source: World Bank (2020)

Several studies were conducted on logistics performance and its core components influence on economic growth and trade. Martin et al. (2017) studied the impact of logistics performance among developed and developing nations. They used Data Envelopment Analysis (DEA) on benchmark countries. The findings revealed that the LPI scores were highly ranked for high-income earning countries than developing countries. The findings also revealed that that LP depends mainly on the geographical income area. Whereby high-income countries were the best performers that were mainly within the EU.

Barakat et al.(2018) investigated the relationship between the logistics performance index and its components and exports, focusing on the Middle East and African countries. The regression model was used to analyze the relationship between the Logistics performance index and component on exports. The results revealed the logistics performance improves these countries' exports. All components of the logistics performance index (LPI) except logistics quality, competence, tracking, and tracing positively impacted exports. Cemberci et al.(2015) studied the impact of the Global Competitiveness Index (GCI) on dimensions of the Logistics Performance Index (LPI). Hierarchical regression analysis to analyze this effect using data from the World Bank. The findings revealed that the main three variables among GDP, GCI, and LPI relationships were highly significant to each other.

2.6.3 Panama Canal expansion impact on logistics, economic, and trade routes

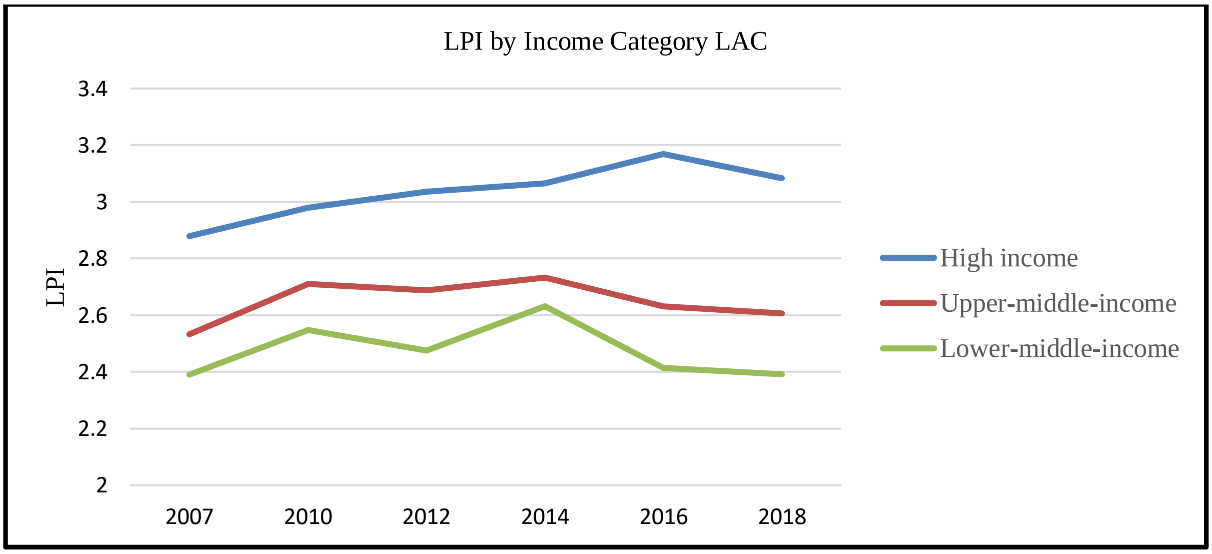
The Panama Canal expansion (PCE) has radicalized the supply chain related to the West Coast vs. East Coast, whereby shipping routes have shifted from the West Coast ports and intermodal connectivity to the East coast (Pham et al., 2018). This shift has been propelled by the advent of neo-Panamax vessels transiting to PCE towards East Coast and Gulf Coast ports (Link, 2015). Furthermore, this shift influences the relocation of serval logistics companies from the West Coast to the east coast, improving value-added services to East and Gulf coast ports, thereby enhancing intermodal connectivity through logistics infrastructure (Pham et al., 2018; Reyes et al., 2019; Van Hassel et al.,2020).

Liu et al. (2016) also evaluated the potential impacts of the PCE on the evolving competitive cooperative relationships among the supply chain players in the United States container import market and the distribution of market power among them. The study results showed that the enlargement of the ship size passing through the Panama Canal would increase the East Coast players' market by 32% while negatively affecting the West Coast players by 22%. Wang (2017) studied the impact of PCE on global shipping. He analyzed the impact of the PCE on cargo throughput, liner shipping, and competition for the canal route. His paper was based on an empirical study by collecting the relevant data from annual reports of the Panama Canal Authority and publications related to the same field. The findings revealed that the expansion generated more revenue for the Panama government by allowing mega-vessels to transit and deploy new Panamax vessels, thereby expediting further economic development of the country. Mega ships have increased economies of scale in maritime transport, boosting transshipment activities among regional ports (ACS, 2017). Merk (2018) stated that doubling the maximum container ship size over the last decade has reduced total vessel cost per transported container by roughly one-third.

The PCE has increased competition among major transshipment ports within LAC (Rodrigue and Ashar, 2016). Most of these countries have made huge investments in port expansion, dredging, and the development of logistics centers to accommodate and attract mega-ships to their shores. However, inadequate logistics systems and infrastructure could render these investments unfruitful if these countries fail to improve endogeneous logistics performance. Trade liberalization (Trade freedom) has triggered the improvement of trade within the region. Nevertheless, it is not sufficient for improving trade growth (Seabra et al., 2016). According to Seabra et al. (2016), the slow process of customs clearance in goods has fueled institutional breakdown and corruption while increasing the transaction cost has been a serious barrier to trade within the LAC.

2.6.4 Latin America and the Caribbean Logistics Performance (LP) and Income category

LAC region is becoming a major maritime route because of the PCE. This region has increased in Cargo tonnage and vessel traffic since the Panama Canal expansion in 2016. Container throughput (TEU) in the LAC port systems increased from 15.9 million TEUs in 2000 to 53 million TEUs in 2019 (World Bank, 2020). LAC comprises 33 countries, as shown in Tables 2.3 and 2.4. These countries are a mixture of three (3) income classifications; High-income, middle-income, and low-income. Fig. 2.2 shows the LPI scores and income classification within the regions.



Source: Own Elaboration.

Fig. 2.2. Average overall Logistics Performance Index (LPI) by income category (LAC).

Fig. 2.2. below illustrates the income classification gap among the High-income, Upper-middle, and Lower middle-income countries in LAC, revealing that upper-income countries have a higher LPI than Upper- Middle and Lower- middle- income in the LAC.

Table 2.3. LPI 2018 of Latin America and the Caribbean countries

Country	Ranking 2018	General LPI	Infrastructure	Logistics Quality and Competence	Customs	Tracking & Tracing	International Shipments	Timeliness
Chile	34	3.317	3.209	3.125	3.274	3.203	3.272	3.797
Panama	38	3.276	3.130	3.333	2.866	3.4	3.314	3.596
Mexico	51	3.051	2.847	3.02	2.769	3.004	3.102	3.529

Brazil	56	2.986	2.926	3.091	2.406	3.111	2.881	3.51
Colombia	58	2.942	2.667	2.867	2.612	3.084	3.194	3.171
Argentina	61	2.886	2.774	2.777	2.417	3.047	2.924	3.369
Ecuador	62	2.881	2.721	2.751	2.801	3.071	2.751	3.189
Costa Rica	73	2.05	2.791	2.494	2.705	2.628	2.777	3.155
Paraguay	74	2.782	2.547	2.722	2.64	2.613	2.693	3.445
Peru	83	2.693	2.228	2.421	2.529	2.554	2.843	3.445
Uruguay	85	2.685	2.433	2.708	2.514	2.78	2.735	2.906
Dominican Republic	87	2.662	2.357	2.442	2.405	2.975	2.77	2.981
Honduras	93	2.603	2.473	2.722	2.238	2.677	2.662	2.833
El Salvador	101	2.575	2.249	2.723	2.238	2.677	2.662	2.834
Bahamas, The	112	2.525	2.408	2.268	2.684	2.518	2.501	2.751
Jamaica	113	2.518	2.324	2.536	2.415	2.481	2.534	2.793
Trinidad and Tobago	124	2.416	2.382	2.536	2.423	2.267	2.586	2.532
Guatemala	125	2.415	2.196	2.249	2.157	2.416	2.332	3.111
Bolivia	131	2.358	2.152	2.211	2.318	2.132	2.535	2.742
Guyana	132	2.358	2.089	2.224	2.554	2.437	2.168	2.647
Venezuela, RB	142	2.229	2.097	2.207	1.787	2.294	2.379	2.581
Cuba	146	2.197	2.041	2.202	2.029	2.148	2.27	2.462
Haiti	153	2.112	1.944	2.186	2.031	2.054	2.005	2.439

Source: World Bank (2020)

Table 2.4. LAC's Income Classification and LPI 2018

Country	Ranking 2018	GDP per Capita	In-come Classification	General LPI
Chile	34	15001	High-income	3.317145
Panama	38	15166	High-income	3.275982
Mexico	51	9224	Upper-middle	3.051375
Brazil	56	9881	Upper-middle	2.98579
Colombia	58	6429	Upper-middle	2.9416
Argentina	61	14508	Upper-middle	2.886984
Ecuador	62	6214	Upper-middle	2.881649
Costa Rica	73	11573	High-income	2.791664
Paraguay	74	5776	Upper-middle	2.782299
Peru	83	6723	Upper-middle	2.693249
Uruguay	85	16341	High-income	2.685087
Dominican Republic	87	7213	Upper-middle	2.661765
Honduras	93	2437	Lower-middle	2.603918
El Salvador	101	3883	Lower-middle	2.575521
The Bahamas,	112	31856	High-income	2.525412
Jamaica	113	5061	Upper-middle	2.518664
Trinidad and Tobago	124	15952	High-income	2.415642
Guatemala	125	4471	Upper-middle	2.414617
Bolivia	131	3351	Lower-middle	2.358376
Guyana	132	4671	High-income	2.358312
Venezuela, RB	142	10000	Upper-middle	2.229216
Cuba	146	8541	Upper-middle	2.197159
Haiti	153	766	Lower-middle	2.112341

Source: World Bank, 2018

2.6.5 Exports

Export is a very important contributor to economic growth. Several researchers would agree that there is a significant and close relation between economic growth and exports. Although some may contemplate whether export promotes economic growth or contrarywise, the undeniable fact is that both influence each other. Ronit (2014) studied the relationship between the growth of exports and the growth of India's gross domestic product. Using Granger Causality to test relationship using data from 1969 to 2012. The finding revealed that Export has a stronger influence on the change in GDP, confirming that India's economy backs the growth-led export theory.

On the contrary, Arteaga et al. (2020) studied the impact on China and economic growth for Latin America and the Caribbean (LAC). Using panel data technique from the periods 1990 to 2017. The findings revealed that exports to China had different effects on the worldwide exports on LAC growth whereby, South American countries were positively impacted; however, Central America and the Caribbean countries were negatively impacted when China entered the WTO.

The impact of Foreign Direct Investment (FDI) investment on Exports is also debatable for several authors. Kutan and Vuksic (2007) study Foreign Direct Investment (FDI) and Export performance. Using Empirical evidence on data from 1996 to 2007. The findings revealed that FDI has positively impacted exports from the EU. However, Sun and Li (2018) studied exports, FDI, and welfare gains from trade liberalization. Their result revealed that FDI had no effects on exports. Findings also revealed that trade liberation had positively impacted exports.

Trade freedom (TRFR) allows bilateral trade among countries to improve exports and imports. Several author studies show that trade liberation or trade freedom have a positive impact on exports. For example, Naanwaab and Diarrassouba (2013) studied the influences of economic freedom on bilateral trade in intra-African. Using Cross-country analysis among 33 African countries. Their findings revealed that trade agreements have a positive impact on bilateral trade among African countries. On the contrary, Tran (2019) reveals that Trade freedom (TRFR) hinders trade and economic growth among ASEAN countries.

Several authors have supported the link between Export and logistics and other economic variables such as GDP, IND, TRFR, and FDI; however, the effect and relation to export may differ based on policymakers, income classification, the size of a country, and geographical location (Behar, Manner and Nelson, 2009; Liu et al. (2016); Seabra et al., (2016); Hausman, Lee, and Subramaniam (2013).

Few studies analyze the relationship between exports and Logistics performance and the influence of the pre and post PCE era on LPI relationship with exports in LAC. This research gap will be analyzed among 33 Latin American and the Caribbean countries (LAC) using the Hierarchical Linear Model (HLM) to determine which component of Logistics performance influences export volume among Latin American countries.

THE ECONOMIC IMPACT OF PCE IN LAC REGION

2.7 INTRODUCTION

The Panama Canal (PC) has revolutionized international trade, bridging the Asian, North, and Latin American markets. The opening of the PC has significantly impacted the US and Latin American economies through regional and global trading (Carral et al., 2014). Port development within the region has played an integral role in economic development by being the gateway to all trade (Casella et al., 2019). The expansion of the Panama Canal has marked an era of revolution for Neo-Panamax vessels transiting the region, therefore, presenting opportunities for increased transshipment, trade freedom, and economy of scale that will seemingly benefit and improve the LAC region's socio-economic status (Rodrigue and Ashar, 2016; Singh et al., 2015, Bhadury, 2016; Park et al., 2020).

The traditional benefit of using the PC was to reduce voyage time between Asia and the US East Coast compared to using the route via the Suez Canal or around the Cape of Good Hope (Cho et al., 2019; Gro, 2016). Take, for instance, from Hong Kong and South China and any other point further north; the Panama route would be shorter than Suez Canal. However, in recent years Suez route grew in popularity because of the shift in some production from China to lower-income countries such as Vietnam and Bangladesh and is the shorter route for the middle east, India Subcontinent, and Southeast Asia (UNCTAD, 2020).

The Panama Canal expansion (PCE) has impacted liner shipping, trading lanes, and port development within both LAC and US coast ports (Pham et al.,2018; Fan and Gu, 2019; Wang, 2017; Liu et al., 2016; Carral et al., 2018; Shibasaki et al.,2018). However, not all trading routes use the PC For example, the Suez Canal (SC) remains the fastest and most direct maritime route between Asia and Europe. According to Suez Canal Authority (2021), approximately 12 percent of global trade transit the SC, representing 30 percent of international container traffic. Furthermore, in 2019, 1 billion tonnes of cargo transit the waterway, representing four times the tonnage transiting the PCE during that period (UNCTAD, 2021).

The link between Port development and trade has always been the channel to economic growth and poverty reduction (Munim and Schramm, 2018). Economic growth is the most powerful tool for improving the human development index, unemployment, and poverty reduction (OECD,2009).

The strong correlation between seaborne trade and economic growth has been the main influence of US East and Gulf coast and LAC ports developments since the PCE. The LAC region has experienced the lowest annual GDP growth at 3 percent for the past 15 years in comparison to other developing regions, such as China, South Asia, and Sub-Saharan Africa, growing at the rate of 5 percent more during that period (Cadena et al., 2017). Therefore, the PCE may serve as an economic intervention since maritime transport is the backbone of international trade and global economic growth (UNCTAD, 2018).

The PCE was created to prevent bottlenecks and effectively compete with the SC for maritime traffic. It also seeks to stimulate maritime activity through the advent of mega-ships that will increase maritime activities through trade (exports) and transshipment. The LAC region has experienced container throughput growth, likewise US East and Gulf coast ports (ACS, 2017; Bradbury, 2016; Gooley, 2018; Park et al., 2020). These vessels economies of scale attracted interest among LAC countries, seeking to follow Port countries economic model such as Singapore and the Netherland (de Langen et al., 2020). Several ports within the Caribbean "transshipment triangle," such as Colon, Freeport, Kingston, Mariel, San Juan, and Port of Spain, have made several logistics and port infrastructural improvements to accommodate Neo-Panamax and some post-Panamax vessels (Bradury, 2016; Gooley, 2018; Park et al., 2020). Port infrastructural development and improvements were initiated with the sole aim of reaping the economic benefits of maritime transport from the PCE (ACS, 2017; UNCTAD, 2018). According to Shan et al. (2014), a 1 % increase in port cargo can increase GDP per capita growth by 7.6%, and port throughput positively impacts neighbouring economies. Similarly, analysing the impact of the PCE on the economic growth within the LAC region since the advent of neo-Panamax vessels is essential for determining the PCE causal effect.

Although several authors have covered the study of the PCE impact on international trade routes and supply chain, few articles study the impact of the PCE effect on the LAC's economy using the Bayesian structural time series (BSTS) model. The BSTS model is frequently used to determine the causal effect of a project or an intervention. Although the Bayesian models analyse several research objectives within the maritime sector, very few use this methodology to determine the causal effects of an intervention within the maritime industry. This model can measure the economic impact of the Panama Canal expansion (PCE). The BSTS is a statistical technique that can also measure the causal effect by forecasting, nowcasting, and inferring causal impact (Scott et al., 2015; Feroze, 2020; Scott and Varian, 2012; Brodersen et al., 2015). Therefore, this paper seeks to analyse this expansion's economic impact among 21 LAC countries using HDI and unemployment rate covariates in the Bayesian Structural time-series

In this section, we summarize the existing studies in two research areas: (i) Seaborne relationship to Economic growth, (ii) Economies of scale, and (iii) Causal inference using Bayesian structural time series (BSTS).

2.8.1 Seaborne relationship to Economic growth

The PCE has increased cargo tonnage and vessel traffic throughout the LAC region, stimulating marine growth in container throughput (TEUs) and transshipment activities (Rodrigue, 2020). The advent of the neo-Panamax vessels through the expanded canal's third lock has influenced regional governments to politically evaluate the feasibility of economic growth through seaport activities (Nicholson & Boxill, 2017). Therefore, motivating requests for public funds and foreign direct investment (FDI) to develop existing infrastructure or construct a new seaport to facilitate mega-ships (neo-Panamax, and post-Panamax). Several authors support the strong correlation between seaborne trade and economic growth. Ports are the gateway of trade and economic development within the supply chain that economically benefits a nation direct and indirectly (Rodrigue and Notteboom, 2021).

Jouili (2016) studied the role of seaports in the process of economic growth. Their research aimed to measure public investments of seaports on the economic progress from 1987 to 2014. The results showed that investments in seaports generated positive contributions to Tunisian economic growth. Michail (2020) studied the relationship between seaborne transport demand and the global economic environment, using annual data from crude oil, petroleum products, and dry cargo transports. These variables were examined by the vector error correction model (VECM). The findings revealed that the global economic environment affected all three variables. Zhang and Zhang (2005) investigated the relationship between China's local container throughput, FDIs, and the industry's gross product value. Empirical research was conducted on the Pearl River Delta Region. Their findings revealed that regional economic growth and FDIs depended on local container transport development. Shan, Yu, and Lee (2014) performed an empirical review on the effect of the seaport economy on major ports in China. The econometric analysis was used to measure the impact on significant seaports in China from 2001 to 2010. The study revealed that port cargo throughput has a positive effect on the host city's economic growth. Lane and Pretes (2020) explored the five factors in maritime dependency correlation to economic prosperity. The finding reveals that there is a significant relationship between maritime dependency and economic prosperity. Osadume and Blessing (2020) used the Granger causality and Bound test approach to examine the relationship between maritime trade and economic development. Their study concluded that maritime trade causes economic development.

On the contrary, not all port development contributes to economic growth. Jung (2012) examined the link between ports and the economic performance of Korea's major cities. Empirical data was used to find the relationship between port throughput and economic indicators. The findings revealed that local port services could not guarantee cities economic success based on their location; therefore, local economies experience limited benefits from nearby ports because of the advancement of logistics technology and economic structural change. Munim and Schramm (2018) studied the impact of port infrastructure and logistics performance on economic growth. The finding revealed that although these variables were vital for developing countries economic growth. However, this association between these variables weakens as the developing countries become more prosperous. Grossmann (2008) claims that economic growth has shifted to newer economic sectors; therefore, understanding the extent of ports impact on the nation's economy is essential as several factors contribute to economic development.

The relationship between economic growth and seaborne trade is highly correlated, as agreed by several authors. Undeniably, the development of infrastructure to support global trade can payoff in economic growth as in the case of Singapore, Holland, and China, but these benefits diminish for local economies for developed nations (Gross, 2008; Munim and Schramm, 2018).

2.8.2 Economies of scale

Globalization has fuelled the demand for mega-ships that have changed the dynamics of global trade. This effect has caused the PC to be expanded to accommodate neo-Panamax and some post-Panamax vessels. The PCE influences port development within the LAC region to accommodate these ships for potential economic benefits by increasing transshipment and value-added services (Lim, 2011; Rodrigue and Notteboom, 2021). The PCE in 2016 has allowed an increasing number of larger ships like the neo-Panamax crossing the canal implies a more significant number of containers going through the canal. The increased neo-Panamax transiting the PCE will impact regional ports, including the Gulf and East coast ports (Gooley, 2018; Rodriguez, 2020). Several authors support the benefits of these mega-ships.

Merk (2018) stated that doubling the maximum container ship size has reduced total vessel cost per shipped container by roughly 35% over the last decade. Containerization has undoubtedly contributed to a decrease in transportation costs (OECD, 2015). The increased vessel size has benefited the liners by reducing shipping costs (Helmy and Shrabia, 2016). On the other hand, although the economy of scale may benefit liner shipping, as the ship's size increases, the diseconomies are more apparent within a port infrastructure and operations (Rodrigue, 2020). Lim (2011) and Kapoor (2016) study the impact of mega-ship on ports and economies of scale. Their studies revealed the diseconomies increases for vessels over 18000 TEUs. Ports within the LAC region have made substantial investments in port development to acquire STS gantry for Neo-Panamax vessels, deepening channel, and hinterland expansion.

The regional countries implemented investment towards port development and logistics infrastructure to gain economic benefits from the PCE. Although container shipping has benefited from economies of scale in maritime shipping, an overview of the authors revealed. However, as ships increase in the TEUs, the benefits of lower cost per TEUs increase, thus, there is a powerful trend towards increasing shipssize, but this may lead to "diseconomies of scales" of mega-ships that may not necessarily benefit some regional ports (Rodrigue, 2020).

The PCE is an intervention that seeks to increase maritime activities within the US and Latin American regions. The project's sole purpose is to allow the PCE to accommodate Mega ships (Neo-Panamax and Post-Panamax vessels) to reduce the bottleneck effect and remain a competitive route to the SC. Several authors' studies agreed that PCE has to increase maritime traffic within the region, especially for container shipping which is the main focus of this research (Lim, 2011; Rodrigue and Notteboom, 2021; Gross, 2008; Munim and Schramm, 2018). The strong correlation between seaborne trade and economic growth has influenced regional governments initiatives to promote port development (Nicholson & Boxill, 2017; Rodrigue, 2020; Jouili, 2016; Zhang and Zhang, 2005; Shan, Yu, and Lee,2014). Several authors agreed that economy of scale had impacted port development, port infrastructure and operation, freight rate, and maritime traffic. The authors used several methodologies to study the economic impact of the seaborne industry using econometric models, the Structural equation model (S.E.M.), and the Bayesian model. However, few authors studied the Causal Inference on the PCE impact on LAC's economy since the advent of container mega-ships. This research gap will be focused on container shipping (TEUs volume) within the region and its impact on economic growth and trade since the PCE using the Bayesian Structural Time Series (BSTS).

Maritime transport is the backbone of global trade and the global economy (IMO, 2019). Therefore, the role of maritime transport is essential to a country's socio-economic development. According to Stopford (2018), the importance of sea transport to economic development is fully supported by several economists.

2.9 CAUSAL INFERENCE

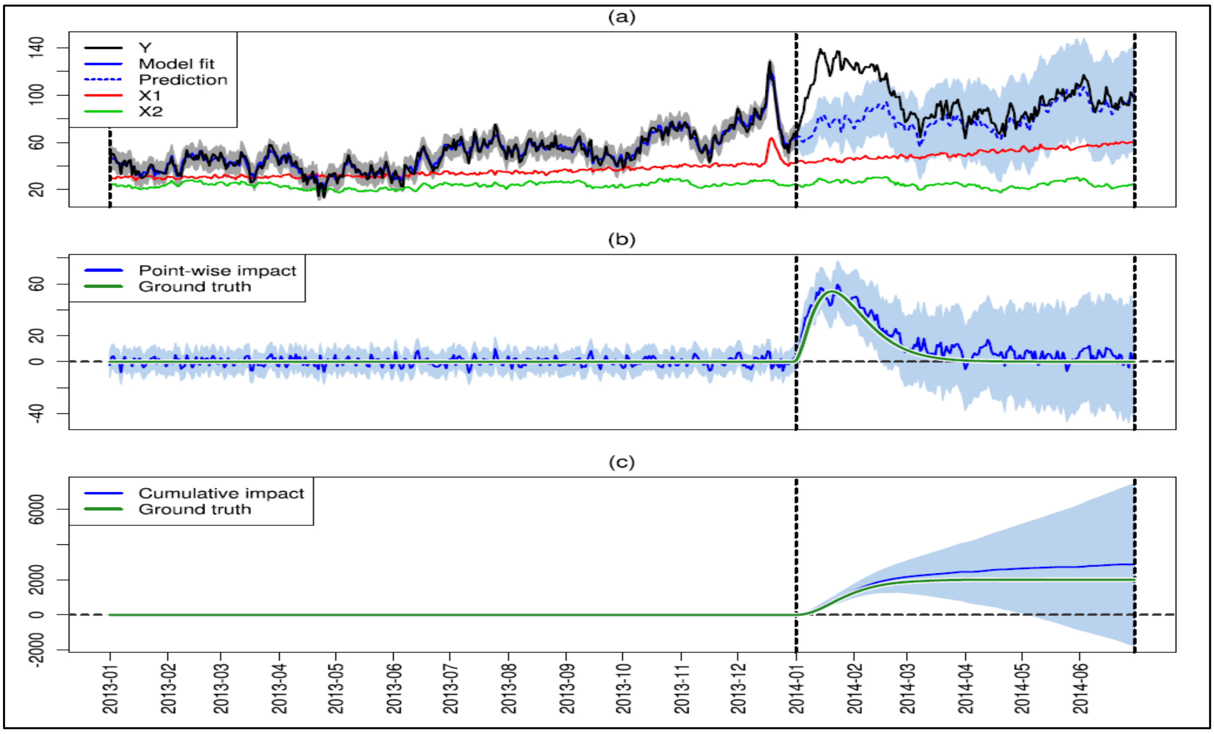
Causal Inference determines the effect of an event or intervention based on the desired outcome (Cox, 2020). It can determine if an event or intervention caused the changes to a metric. Analysing an intervention is important to decide how a series trend would be without the intervention (Hawkins et al., 2015). Using the Bayesian structural time series (BSTS) models, the causal Inference predicts and compares the counterfactual with the factual observations (Pinilla et al., 2018; Feroze, 2020; Mokilane et al., 2018; Scott and Varian 2012; Jun 2019).

2.9.1 Bayesian Structural Time-Series Models (BSTS)

BSTS model is a statistical technique used for machine learning (feature selection), time series forecasting, nowcasting, inferring causal impact, and many other applications. It is designed to work with time-series data. This model is a promising component in the field of analytical marketing and econometric. For example, this model assesses how different marketing campaigns change web search volumes, product sales, and brand popularity. Although, it is an alternative to causal effect models such as the difference in difference (DID) and interrupted time series (ITS) designs.

In contrast, to the DID model, BSTS uses state-space models (SSM) that refers to a class of probabilistic dependence between latent state variable and the observed measurement (Gamerman, 2013). SSM makes it possible to (i) infer the temporal evolution of attributable

impact, (ii) incorporate empirical priors on the parameters in a fully Bayesian treatment, and (iii) flexibly accommodate multiple sources of variation, including the time-varying influence of contemporaneous covariates (Chen, 2013).
The BSTS model consists of three main components: (i) Kalman filter, Spike and slab method, and Bayesian model averaging. The Kalman filter is the technique for the time series decomposition. Researchers can add different state variables such as trend, seasonality, and regression. Spike and slab method, where the most important regression predictors are selected, which is done using the Bayesian variable selection techniques (Scott and Varian, 2013). Moreover, Bayesian model averaging; combines the results and the prediction calculation.
The state-space time series model has three primary components of state; 1. Linear regression on the contemporaneous predictors. 2. The ability to choose from large set potential controls by placing a spike-and-slab prior on the set of regression coefficients. 3. Allowing the model to average over the set of controls (George and McCulloch, 1995). These components allow computation of the posterior distribution of the counterfactual time series given the value of the target series (Brodersen et al., 2015). The structural interpretation is given using a marketing example below.



Source: Brodersen et al., (2013)

Fig. 2.3 Inferring causal impact of marketing strategic intervention for period 2013 to 2014.

Inferring causal impact through counterfactual predictions whereby (a) Y is the simulated trajectory of the treated market from January 2014 as shown in Fig. 2.3 above. The other markets (X1 and X2) were not subjected to the intervention and allowed the construction of a synthetic control (Scott et al., 2013; Brodersen et al., 2015). The prediction line (blue) displayed what would have happened to Y if the intervention had not taken place (posterior predictive expectation of the counterfactual with pointwise 95% posterior probability intervals). (b) the difference between the observed data and counterfactual predictions is the inferred causal impact of the intervention. (c) visualizing posterior inferences is utilizing a cumulative impact plot. It shows, for each day, the summed effect up to that day. Here, the 95% credible interval of the cumulative impact crosses the zero-line about five months after the intervention, at which point we would no longer declare a significant overall effect.

Several authors in the maritime transport academic research support the application of the Bayesian models such as Bayesian probabilistic forecasting, Bayesian vector autoregressive, and Bayesian Network model applications. Although few maritime publishing uses the BSTS model, this statistical technique is quite popular in time series forecasting, nowcasting, and inferring causal impact (Brodersen et al., 2015; Scott and Varian, 2014). In addition, several authors used the BSTS model for assessing causal effects in marketing, economics, sales, and policies.

Garcia and Vengas-Martinez (2018) use the BSTS approach to forecasting Mexico's Consumer index. The time series model in the state-space model was used to predict the value of Mexico's consumer index. Kohns and Bhattacharjee (2020) studied the Developments on the BSTS Model: Trending Growth. They investigated the added benefits of internet search data in the form of google trends for nowcasting real US GDP growth. The results revealed that the application of BSTS was effective for nowcasting GDP growth. Finally, Scott and Varian (2012) use the Bayesian Variable selection for forecasting Economic Times. Three Bayesian techniques were used: Kalman filtering, Spike and slab regression, and Bayesian averaging. This approach was illustrated using search engine query data as predictors for consumer sentiment and gun sales.

On the other, one possible drawback to this model is its mathematical complexity and underpinning of difficulties of computer programming that can be an obstacle for researchers without a solid mathematical background (Scott and Varian, 2012; Kohn and Bhattacharjee, 2020). However, the R programming language has a package for calculating BSTS models. The BSTS model is extensively used to determine a policy and intervention (Garcia and Vengas-martinez, 2018; Kohn and Bhattacharjee, 2020; Scott and Varian, 2012). Therefore, this model's application is unique for determining both the economic and trade impact of PCE on the LAC region. In addition, the BSTS model is used in several applications for assessing the causal effect of an intervention, policy, and programs in various academic research (Pinilla et al., 2018; Feroze, 2020; Mokilane et al., 2018; Scott et al.; 2013).

CHAPTER 3

METHODOLOGY

DIFFERENCE IN DIFFERENCE (DID)

3.1 COMPETITION AMONG PORTS ON THE US EAST COAST FOR CARGO

The PCE has influenced the development of ports within the US, especially on the East Coast, regarding traffic patterns, infrastructural upgrades, and intermodal connectivity (Kendrick, 2020). In addition, the anticipated improvement in the shipping industry among the East Coast and the Gulf of Mexico has increased container throughput growth (TEUs). This growth was because more container ships from Asia will directly access East Coast markets (Morley and Ashe, 2019).

Table 3.0 shows the container throughput for five (5) major ports on the East and Gulf coasts. In 2019, TEUs growth percentage, the port of New York and New Jersey (4%), Port of Houston (11%), Port of Miami (3%), Port of Charleston (5%), and the Port of Savannah (6%). These improvements in East Coast and Gulf of Mexico ports attract more container traffic at the expense of ports within the Caribbean and some parts of the Americas (Morley and Ashe, 2019).

Table 3.0. Top 5 US East and Gulf of Mexico Ports, TEU annual Percentage Growth (%)

Year	Port of NY/NJ	Port of Houston	Port of Miami	Port of Charleston	Port of Savannah
2010	16%	1%	5%	16%	25%
2011	4%	3%	7%	1%	4%
2012	0%	3%	0%	10%	1%
2013	-1%	1%	-1%	6%	2%
2014	6%	0%	-3%	12%	10%
2915	-10%	9%	15%	10%	12%
2016	-2%	2%	2%	1%	-2%
2017	7%	13%	0%	9%	11%
2018	7%	10%	6%	6%	8%
2019	4%	11%	11%	5%	6%

Source: Own Elaboration

The top five (5) major ports within the region have experienced small increases in TEUs except for the port of Balboa. The improvement of US East and Gulf ports has increased competition among East Coast for cargo, impacting transshipment volumes within the LAC region.

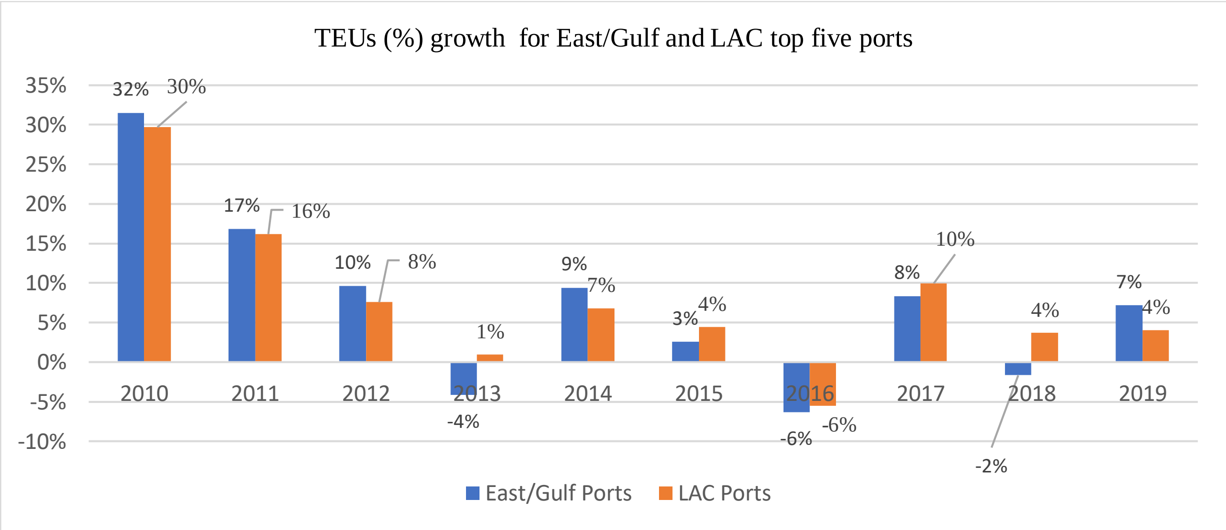
Table 3.1 shows the top five ports within the LAC region regarding the annual percentage growth in TEUs from 2010 to 2019. Among five other transshipment hubs, these ports represent approximately 84.1% of cargo's total regional movement (CEPAL, 2020). The TEU growth (%) for Port of Colon (1%), Port of Santos (2%), Manzanillo (0%), Cartagena (2%) and Balboa (15%).

Table 3.1. Top 5 LAC ports percentage growth (%) in container throughput.

Year	Colon, Panama	Santos, Brazil	Manzanillo, Mexico	Cartagena, Colombia	Balboa, Panama
2010	27%	20%	36%	28%	37%
2011	20%	10%	17%	17%	17%
2012	4%	-1%	13%	19%	2%
2013	-5%	17%	6%	-10%	-4%
2014	-2%	3%	11%	13%	9%
2015	9%	2%	8%	8%	-5%
2016	-9%	-7%	1%	-4%	-9%
2017	19%	5%	10%	15%	0%
2018	11%	7%	9%	7%	-16%
2019	1%	2%	0%	2%	15%

Source: Own Elaboration.

The comparison of container throughput (TEU) growth shown in Fig. 3.0, the percentage of US East and Gulf ports vs. top five (5) LAC ports, shows that in 2019, the top five (5) East coast ports recorded more percentage growth than LAC ports.



Source: Own Elaboration

Fig.3.0. The top five regional ports for both East/Gulf and LAC TEUs growth (%).

3.2 THE DIFFERENCE IN DIFFERENCE (DID)

An impact evaluation provides evidence about the impacts that have been produced or the impacts that are expected to be produced (Hawkins et al., 2015). The choice of methods and designs for evaluating policies, projects, and programs, can be difficult to be evaluated and may come with unique challenges (Hawkins et al., 2015). White and Sabarural (2014) stated that a quasi-experimental approach is an empirical intervention study used to estimate an intervention's causal impact or test causal hypotheses. The most frequently used quasi-experiment approach is Differences in Differences (DID), based on a combination of before - after and treatment - control group comparisons (Frediksson and Oliveira, 2019; World Bank, 2021). Several authors used the Difference in Difference (DID) approach to assess government policies and programs' impact and their effectiveness.

Card and Krueger (1994) studied the impact of the increase in the minimum wage on employment for fast-food restaurants in New Jersey, the US, and Eastern Pennsylvania before and after the increase. The findings revealed that by using DID. There was no indication that an increase in the minimum wage reduced employment. Finally, Qiu and He (2017) researched the impact of the Green Traffic Policy on air quality in China. They concluded that the pilot program was effective in reducing the annual concentration of pollutants.

However, although the DID method is popular among various research fields, it is not without limitations. Bertrand et al. (2003) mention that the great appeal for DID estimation comes from its simplicity and potential to circumvent many of the endogeneity problems that arise when comparing heterogeneous groups. Wing, Simon, and Bello-Gomez (2018) supported Bertrand's (2003) view, they stated that the Difference in Difference (DID) design was not an ideal alternative for randomized experiments, but it often signifies as a viable way to learn about causal relationships. They further concluded that multiple quasi-experimental techniques might be an essential support for the Difference in Difference (DID) approach.

3.2.1 Parallel Trend Assumption (PTA)

All the assumptions of the Ordinary Least Square Model apply equally to Difference in Difference (DID). Many assumptions, such as Parallel Trend Assumption (PTA), exchangeability, and Stable Unit Treatment Value Assumption (SUTVA), must hold to ensure the models' internal validity (Columbia Public Health, 2019; McKenzie, 2021). Two of the most popular assumptions are Parallel Trend Assumption (PTA) and Stable Unit Treatment Value Assumption (SUTVA).

According to Lechner (2011), SUTVA indicates that there should be no spill-over influences between the treatment and control groups, as the treatment effect would then not be identified. The Parallel Trend Assumption (PTA) is the most critical of the above assumptions to ensure the DID Model's internal validity and may be difficult to execute because it requires that the difference between the treatment and control groups be constant over time (Lechner, 2011). Furthermore, the assumption is fundamentally untestable because the treatment group is only observed as treated (Fredriksson and Oliveira, 2019). "One can lend support to the assumption, however, using several periods of pre-reform data, showing that the treatment and control groups exhibit a similar pattern in pre-reform periods" (Fredriksson and Oliveira, 2019, p.523).

These studies focused on using the DID approach for assessing treatment effects on policies and programs in the sector of education, finance, and the public sector economic, healthcare, sales, and marketing. This research will focus on using the DID model for the Maritime Industry to assess the PCE impact on TEUs growth among ports in Latin America and the Caribbean regions (LAC).

3.3 MODEL

Albouy (2015) evaluated an intervention, program, or treatment on an effect Y over an individual's population. Two groups were indexed by treatment status T = 0, 1 where 0 denotes individuals who were not offered treatment, classified as the control group, and 1 indicates the group that received treatment, classified as the treatment group (Heckman et al., 1997). Two time periods were assumed on the observed individual, t = 0, 1 where 0 indicates a time before the treatment; pre-treatment and 1indicates a time after the treatment; post-treatment (Athey and Imben, 2006). All observations were indexed by $i = 1 \ldots N$ whereby, the individuals will have two observations each, pre-treatment and post-treatment denoted as follows: for average sample outcome for the treatment group, Y_0^{-T} and Y_1^{-T} and the average outcome for the control group, Y_0^{-c} and Y_1^{-c}

The outcome of Y_i was modeled by Albouy (2004) and Abadie (2005) in the following equation.

$$Y_i = \alpha + \beta T_i + \gamma t_i + \delta(T_i \, . t_i) + \varepsilon_i$$

Where α = constant term

β = treatment group-specific effect (accounting for average permanent differences between treatment and control)

γ = time trend common to control and treatment groups

3.3.1 Simple Pre versus Post Estimator

According to Albouy (2015), "a simple Pre versus Post Estimator Consider first an estimator based on comparing the average difference in the outcome Y_i before and after the treatment for the treatment group."

$$\hat{\delta}_1 = \hat{Y}_1^T - \hat{Y}_0^T$$

The expectation of the estimator is as follows.

$$E[\tilde{\delta}_1] = E[\hat{Y}_1^T] - E[\hat{Y}_0^T]$$

$$= [\alpha + \beta + \gamma + \delta] - [\alpha + \beta]$$

$$= \gamma + \delta$$

According to Albouy (2015), the estimator will be biased $\gamma \neq 0$, which is the constant average differences in outcomes Y_i post-treatment, between the treatment.

3.3.2 Simple Treatment versus Control Estimator

Now, considering the estimator that will be established on evaluating the median outcome Y_i, post-treatment, between the treatment and control groups,

$$\hat{\delta}_1 = \hat{Y}_1^T - \hat{Y}_1^C$$

The expectation of the estimator is as follows.

$$E[\tilde{\delta}_1] = E[\hat{Y}_1^T] - E[\hat{Y}_1^C]$$

$$= [\alpha + \beta + \gamma + \delta] - [\alpha + \gamma]$$

$$= \beta + \delta$$

According to Albouy (2015), the estimator is biased so long as $\beta \neq 0$, which is the constant average differences in outcomes Y_i , post-treatment, between the treatment.

3.3.3 The Difference in Difference (DID) Estimator

DID estimator is defined as the difference in the treatment group's average outcome before subtracting the control group's average outcome before and after treatment (Albouy, 2015; Abadie, 2005).

$$\hat{\delta}_{DD} = \hat{Y}_1^T - \hat{Y}_0^T - (\hat{Y}_1^C - \hat{Y}_1^C)$$

According to Albouy (2015), the expectation of this estimator will become unbiased.

$$\hat{\delta}_{DD} = E[\hat{Y}_1^T] - E[\hat{Y}_0^T] - (E[\hat{Y}_1^C] - E[\hat{Y}_1^C])$$

$$= \alpha + \beta + \gamma + \delta - (\alpha + \beta) - (\alpha + \gamma - \gamma)$$

$$= (\gamma + \delta) - \gamma)$$

$$= \hat{\delta}_{DD}$$

3.3.4 The Difference in Difference (DID) model for LAC ports.

The following equation below shows the DID model formulation for LAC's TEUs outcome.

TEUs = α + β TreatmentPort + γ PostTreatment + δ (TreatmentPort · Posttreatment) + ε_i *(Outcome)*

TEUs: the average container throughput for Latin America and Caribbean ports from the period 2010 to 2019.

Treatment Port (DTr_p): Treatment dummy variable T when T = 1 represents container port throughput above 1 million TEUs. Treatment port (DTr_p) includes transhipments that are both global and intra-regional ports. Treatment port (DTr_p) invest in port development in hinterland expansion, dredging, and ship to shore (STS) gantry cranes (Neo Panamax compatibility) before the Panama Canal expansion in July 26, 2016. T = 0, represents container port throughput below 1 million TEUs. Control Ports (CONTp) include regular ports (non-transshipment ports) that cannot accommodate Neo-Panamax and Post-Panamax container vessels. Post-Treatment ($Post_t$) is the time variable dummy that reflects periods; 'Before' intervention T = 0 and 'After' intervention T = 1.

Table 3.2 further explains the descriptive classification of ports within the LAC region that will be used to measure the impact of the Panama Canal expansion. The sample size of 100 ports was selected from 118 LAC ports from thirty-one (31) countries. These ports were selected based on throughput volume (TEUs) that were greater than 20000 TEUs. Therefore, ports with less throughput volume were removed from the observation. Ports excluded from the sample were mostly Eastern Caribbean and some Central America.

Table 3.2. Classification of Treatment and Control Groups (100 Ports) within LAC.

Groups	Code	Description
Treatment Ports (DTrp)	1	Treatment ports include transshipment ports and ports with annual throughputs of over a million TEUs. 500,000 ≤ TEUs ≤5,000,000.
Control Ports (CONTp)	0	Control ports include regular ports (non-transshipment ports) within the regions with annual TEUs below 1 million. 20,000 ≤ TEUs ≤ 500,000.

Time	Code	Description

Post-Treatment Period ($Post_t$)	1	The period after the PCE from 2016 to 2019. Condition: $2016 \leq After \leq 2019$
	0	Period before the PCE from 2010 to 2016 Condition: $2010 \leq Before \leq 2016$*

* the completion date for the expansion was July 26, 2016. Source: Own Elaboration

3.4 Data Analysis Software

STATA and R packages were used to analyze the impact of the PCE on the top 100 ports within the LAC region using the DID method.

3.4.1 Sampling and Data Collection

The data sample comprises 100 ports within the LAC region divided into three (3) sub-regions, South America, Central America, and the Caribbean. The container throughput (TEUs) data from these regional ports were retrieved from the CEPAL and the World Bank. Port profiles and characteristics data were retrieved from the following websites: Logistics Capacity Assessment, Marine Traffic, Ports.com, and regional port websites. The LAC regional ports within the research are listed in sub-regional categories, South America, Central America, and the Caribbean, as shown in Table 3.3.

Table 3.3. LAC Ports and Rankings 2020

Rank	Port (County, Region)	Rank	Port	Rank	Port
1	Colon, Panama, CA	36	Lirquen, Chile, SA	71	Imbituba, Brazil, SA
2	Santos, Brazil, SA	37	Salvador, Brazil, SA	72	Georgetown, Guyana, SA
3	Manzanillo, Mexico, CA	38	Mariel, Cuba, C	73	Purto Chipas, Mexico, CA
4	Cartegena, Colombia, SA	39	Caldera, Chile, SA	74	Mazataland, Mexico, CA
5	Balboa, Panama, CA	40	Paita, Peru, SA	75	Natal, Brazil, SA
6	Callao, Peru,	41	Iquique, Chile	76	Puerto Plata, DR. C
7	Guayaquill, Ecuador, SA	42	Port of Spain, TT, C	77	Rosano, Argentina, SA
8	San Antonio, Chile, SA	43	Fort de France,Martinque, C	78	Tuxpan, Mexico, CA
9	Kingston, Jamaica, C.	44	Itaguai, Brazil	79	Castries, St Lucia, C
10	San Juan, Puerto Rico, C.	45	Acujutla, El Salvador, CA	80	Georgetown, Cayman, C
11	Buenos Aires, Argentina	46	Vitoria, Brazil, SA	81	San Lorenzo, Honduras, CA
12	Freeport, Bahamas	47	Arica, Chile, SA	82	Austral, Chile, SA
13	Lazaro C. Mexico, CA	48	Jarry/Point-a-Pier, Guate. CA	83	Llo, Peru, SA
14	Caucedo, Dominican R., C	49	Point Lisas, T&T, C	84	Bahia Blanca, Argentina, SA
15	Tapai, Brazil	50	Corinto, Nicargo, CA	85	San Antonio Est ARG, SA
16	Limon Moin, Costa Rico, CA	51	Nassau, Bahamas, C	86	Guaymas, Mexico, CA
17	Veracrus, Mexico, CA	52	Puerto Bolivar, Ecuador, SA	87	Belize City, Belize
18	Bueraventura, Colombia, SA	53	Progreso, Mexico, CA	88	San Andres, Colombia, SA
19	Valpraiso, Mexico, CA	54	Barranquilla, Colombia, SA	89	Esmeraldas, Ecuador, SA
20	Altamira, Mexico, CA	55	Zarate, Argentina, SA	90	Deseado, Argentina, SA
21	Parangua, Brazil,SA	56	Vila do Conde, Brazil, SA	91	Madryn, Argentina, SA
22	Rio Grande, Brazil, SA	57	Santa Marta, Colombia, SA	92	CPCP, St Vincent, C
23	Montevideo, Uruguay	58	Puerto Castilla, Hondura, CA	93	Coatzacoalcos, Mexico, CA

24	San Francisco, Brazil	59	Nieuwe Haven, Surinam, SA	94	Matarani, Peru, SA
25	Puerto Cortes, Honduras, CA	60	Philipsburg, St. Maarten, C	95	Matarani-TISUR, Peru, SA
26	Coronel, Chile	61	Coronel, Chile, SA	96	Big Creek, Belize, CA
27	Santos Tomas, Guatemala, CA	62	La Guaira, Venezuela, SA	97	Manzanillo, DR, C.
28	Haina, Dominica R. C.	63	Antofagasta, Chile, SA	98	Porto Velbo, Brazil, SA
29	Peurto Quetzai, Guatemala, CA	64	Willemstad, Curacao, C	99	General San Martin, Peru, SA
30	Swape Brazil, SA	65	Almirante, Panama, CA	100	Pisco, Peru
31	Puerto, Baitrios, Guatemala, CA	66	Turbo, Colombia		
32	Pecem, Brazil	67	Oranjestad, Aruba		
33	Rio de Janerio, Brazil, SA	68	Santos Domingo,		
34	Talcahuano, Chile, SA	69	Puerto Chiapas, Venezuela, SA		
35	Ensenada, Mexico, CA	70	Degrad des Cannes, FG, SA		

100 LAC ports listed, SA-South America, CA- Central America and C- Caribbean regions Source: Own elaboration; Referred to CEPAL (2020)

Table 3.3 shows the sample data of 100 ports within the LAC region, giving these conclusive research results of the PCE's impact on regional and sub-regional ports. Table 3.4 shows the profile and characteristics of the top 25 ports within the region detailing the infrastructure of each port; Area, Mobile Crane, S.T.S. gantry, Depth, and the number of berths that can be used as variables that influence container throughput volume (output) for each port (Sarriera et al., 2015; Logistics Capacity Assessments, 2021; Marine Traffic, 2021; World Port Source, 2021).

Table 3.4 Characteristics of 25 LAC Ports.

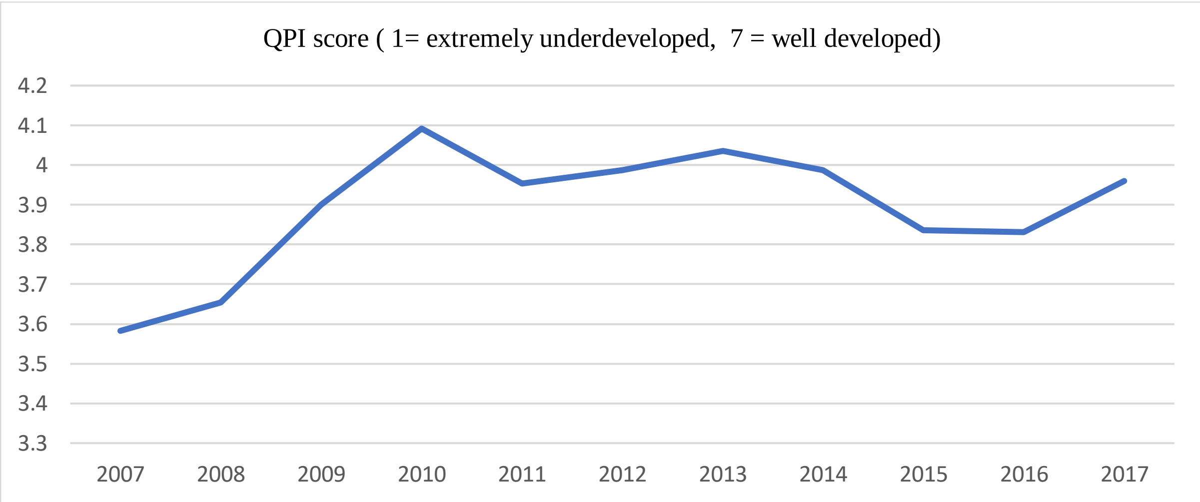
Rank	Port	Growth (%) 2010-2019	Ave TEUs (2010-2019)	Area (m^2)	Mobile Crane with Capacity> 4t (Units)	STS Gantry Cranes (Units)	Depth(m)	Berth
1	Colon, Panama, CA	56%	3577481	384000	33	8	16.5	4
2	Santos, Brazil, SA	44%	3404192	597000	46	13	16	6.5
3	Manzanillo, Mexico, CA	103%	2383731	437000	8	9	16.5	13
4	Cartegena, Colombia, SA	86%	2309143	225000	2	28	21	8
5	Balboa, Panama, CA	5%	3064109	300000	8	17	16.5	13
6	Callao, Peru,	72%	1948871	441080	6	3	16	4
7	Guayaquill, Ecuador, SA	73%	1651670	228273	3	6	10.5	4
8	San Antonio, Chile, SA	96%	1228410	495000	6	13	15	9
9	Kingston, Jamaica, C.	-13%	1710747	1037671	3	19	15.5	11
10	San Juan, Puerto Rico, C.	-1%	1361987	287273	0	6	17	46
11	Buenos Aires, Argentina	-14%	1598995	2200000	10	13	10.7	5
12	Freeport, Bahamas	24%	1226886	320125	0	13	16	3
13	Lazaro C. Mexico, CA	41%	1099694	1850000	3	2	14	11
14	Caucedo, Dominican R., C	-34%	1048944	800000	2	6	15.2	15
15	Itapai, Brazil	212%	579320	180000	3	2	14	11
16	Limon Moin, Costa Rico, CA	-56%	1090248	677276	0	6	10.2	6
17	Veracrus, Mexico, CA	33%	924736	402909	1	5	14	3
18	Bueraventura, Colombia, SA	0%	927158	68500	3	8	15	14
19	Valpraiso, Mexico, CA	-25%	937775	280710	5	3	14	3

20	Altamira, Mexico, CA	80%	664444	396570	1	4	12	3
21	Parangua, Brazil,SA	-11%	735064	4129000	10	6	12.5	24
22	Rio Grande, Brazil, SA	-16%	691709	536023	8	3	16.5	2
23	Montevideo, Uruguay	-4%	807434	12000	7	8	14	11
24	San Francisco, Brazil	493%	315620	247947	17	6	16	13
25	Puerto Cortes, Honduras, CA	-79%	603491	75000	5	1	12.5	3

Source: Own Elaboration

3.4.2 Quality of Port Infrastructure in the LAC region

Quality of Port Infrastructure (QPI) evaluates business executives view of a country's port facilities (World Economic Forum, 2018). Improving port infrastructure quality contributes to higher logistics performance, seaborne trade, and higher economic growth (Munim and Schramm, 2018). Quality of port infrastructure, WEF (1 = extremely underdeveloped to 7 = well developed and efficient by international standards).



Source: World Economic Forum, 2018.

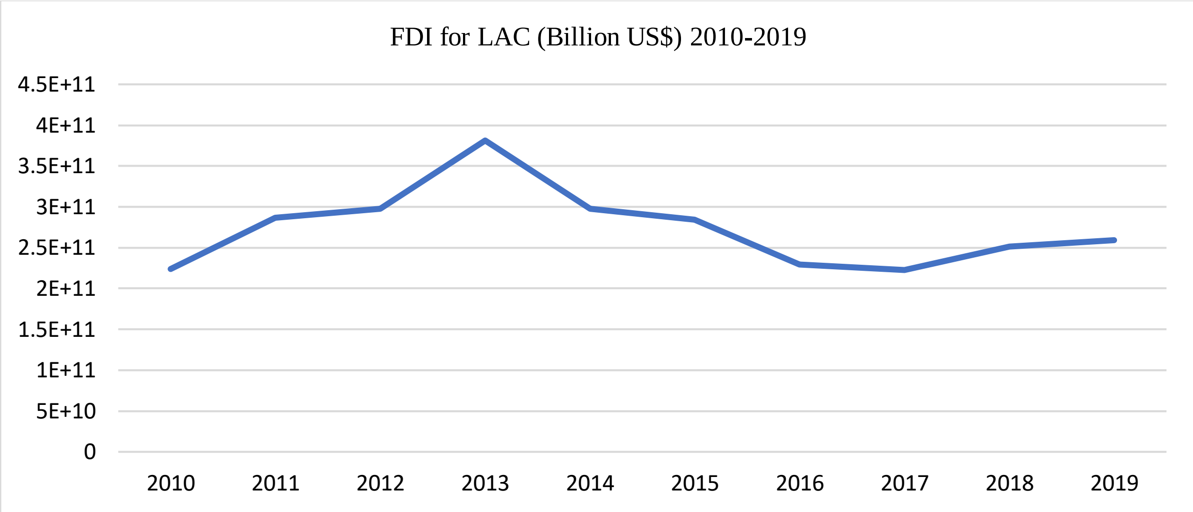
Fig. 3.1. Quality of Port Infrastructure (QPI) scores for LAC. The QPI score for the LAC region from 2007 to 2018.

As shown in Fig. 3.1, the Quality of Port infrastructure in the LAC region has improved from 3.6 in 2007 to 3.96 in 2017. The highest score was recorded at 4.1 in 2010, then gradually declined through 2011 to 2015, then rebounded in 2016 to 3.96, which was the year that PCE was completed.

3.4.3 Foreign Direct Investment (FDI)

FDI is a key component in international economic amalgamation (OECD, 2020). It is also a major investment funding source; therefore, developing countries offer incentives to encourage FDI (United Nations, 2005). FDI has a positive effect on trade because companies expand their production operations for larger capital and borrow from international markets, thus benefiting from economies of scale, leading to an increase in trade for the host country (OECD, 2020). FDI investment within the LAC region has increased since the inception of the expansion. For example, Panama's FDI growth has increased since the canal expansion (Lloyd, 2017). Fig.

3.2 shows the FDI (US$) investment in LAC for the period 2010 to 2019 that 2013 was the highest recorded FDI, 3.812 Billion declined to 2.589 Billion in 2019. During the period 2017 to 2019, there was a gradual increase from 2.226 Billion (US$) to 2.589 Billion (US$), representing a 16 percent FDI growth in the region.

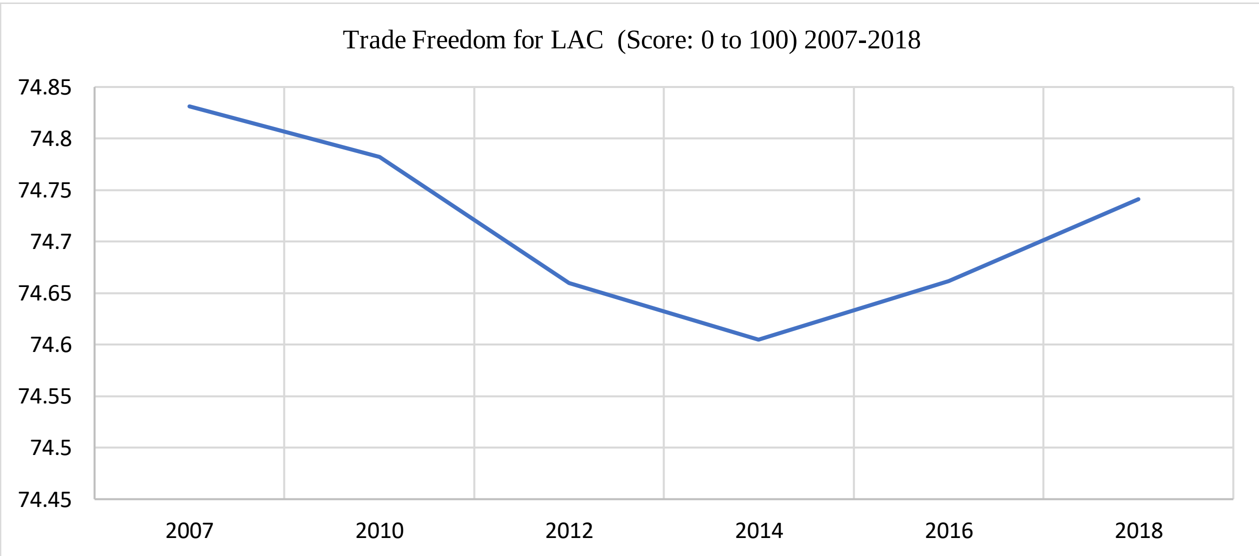


Source: World Bank 2021.

Fig. 3.2. FDI (Billion US$) trend in the LAC region.

3.4.4 Trade Freedom (TRFR)

TRFR is a composite measure of the absence of tariff and non-tariff barriers that affect the trade of goods and services. Trade freedom (TRFR) is based on trade-weight, average, and Non-tariff barriers (Index of Economic Freedom, 2020). The growth in trade freedom was declined from 74.8 in 2007 to 74.6 in 2014, then rebounded to 74.7 in 2018, as shown in Fig.3.3. It is showing that there were improvements in Trade Freedom (TRFR) within the region.

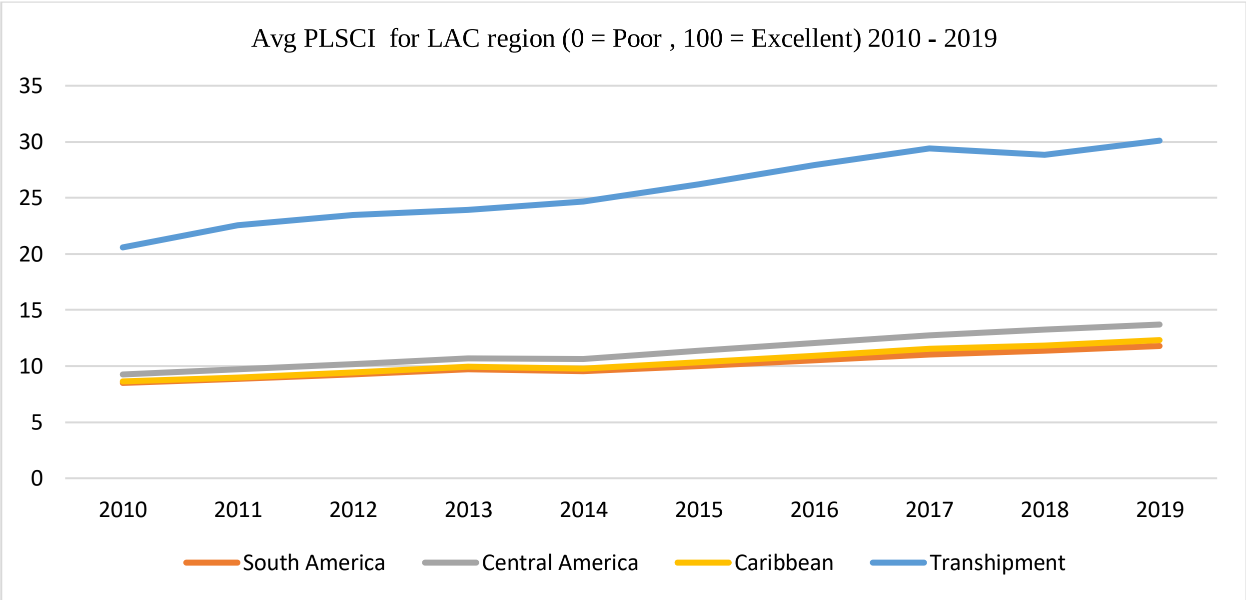


Source: World Bank, 2021.

Fig. 3.3. LAC region Trade Freedom (TRFR) from 2007 to 2018.

3.4.5 Port liner shipping connectivity index (PLSCI) in LAC and Transhipment ports.

PLSCI assesses how well a country links to the global shipping networks (UNCTAD, 2021). The LSCI is measured by five components of the maritime transport sector: number of ships, container-carrying capacity, maximum vessel size, number of services, and companies that deploy container ships in a country's ports (World Economic Forum, 2018). Port infrastructure and PLSCI impacts freight rates in the LAC region (Wilmsmeier & Monios., 2006). The port liner connectivity is an important factor determining trade activity in the maritime industry for regional ports within LAC and US East and Gulf coast. The PCE has largely impacted LSCI. The growth of the LSCI is shown in Fig. 3.4 that reveals the average Liner shipping Connective Index (LSCI) for ports within the LAC region.



Source: UNCTAD (2020).

Fig. 3.4 Port Liner Shipping Connectivity Index (PLCI). Index (Maximum Q1 2006 = 100).

The average Port Liner Shipping Index (PLSCI) for the three (3) regions showed consistent growth in South America, Central America, and the Caribbean. As shown in Fig. 3.4, for South America (SA), the PLSCI score increases from 8.50 to 12.40, Central America (CA) score increases from 8.63 to 13.82, and the Caribbean score from 8.63 to 12.41. In 2019, the top three transshipment ports within the region located in Central America; Colon; Panama (33.2), Balboa; Panama (35.2), and Manzanillo; Mexico (37.8). Regional transshipment within the LAC such as Colon; Panama; Balboa; Panama; Cartagena; Colombia, Santos; South America, Kingston; Jamaica, Freeport; Bahamas, Buenaventura; Colombia, Caucedo; Dominican Republic, San Juan; Puerto Rico and San Antonio; Chile; PLCI scores were way above the average regional PLSCI scores.

3.5 LAC PROFILE

The LAC region is a diverse economy that is mainly export-driven. This region comprises thirty-three (33) countries that are divided into three (3) sub-regions; South America, Central America, and the Caribbean. Fig. 3.5 shows the main sub-regions of Central America, the Caribbean, the east coast of South America (ECSA), Mexico (both coasts), the north coast of South America (NCSA), and the west coast of South America (WCSA).

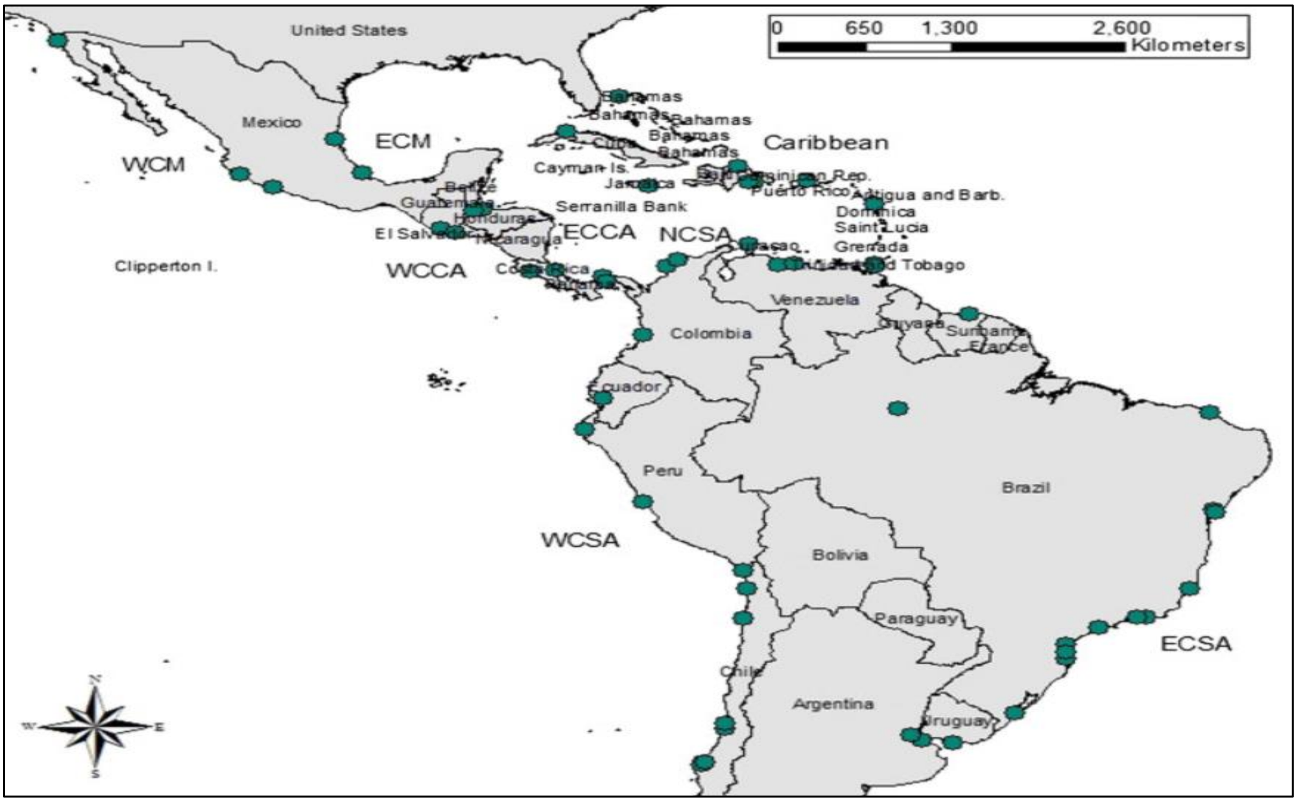
3.5.1 LAC Port System

The rapid increase in global container trade in the past two decades has significantly influenced the LAC region's port geography (Wilmsmeier & Monios, 2016). The LAC system can be classified by territory and coastline into Central America (split by East and West coast), South America (split by East, West, and North Coast), and the Caribbean. The geographic location of the LAC region, as shown in Table 3.5 and Fig. 3.5 consists of 575 terminals on the eastern coast of South America, representing 38% of the regional total. In comparison, 390 terminals were located on the western coast of South America, representing 25.7% of the regional total (Wilmsmeier & Monios, 2016). In addition, the Caribbean has 345 terminals, representing 22.5% of the regional total (22.8%), and Central America has 205 terminals, representing 13.8% (CEPAL, 2020). Table 3.5 shows the number of terminals in the region: South America (East coast and West coast) has 49 container terminals, the Caribbean has 27 container terminal ports, and Central America has 13 container terminals.

Table 3.5 Number of Terminals by Location and Specialisation

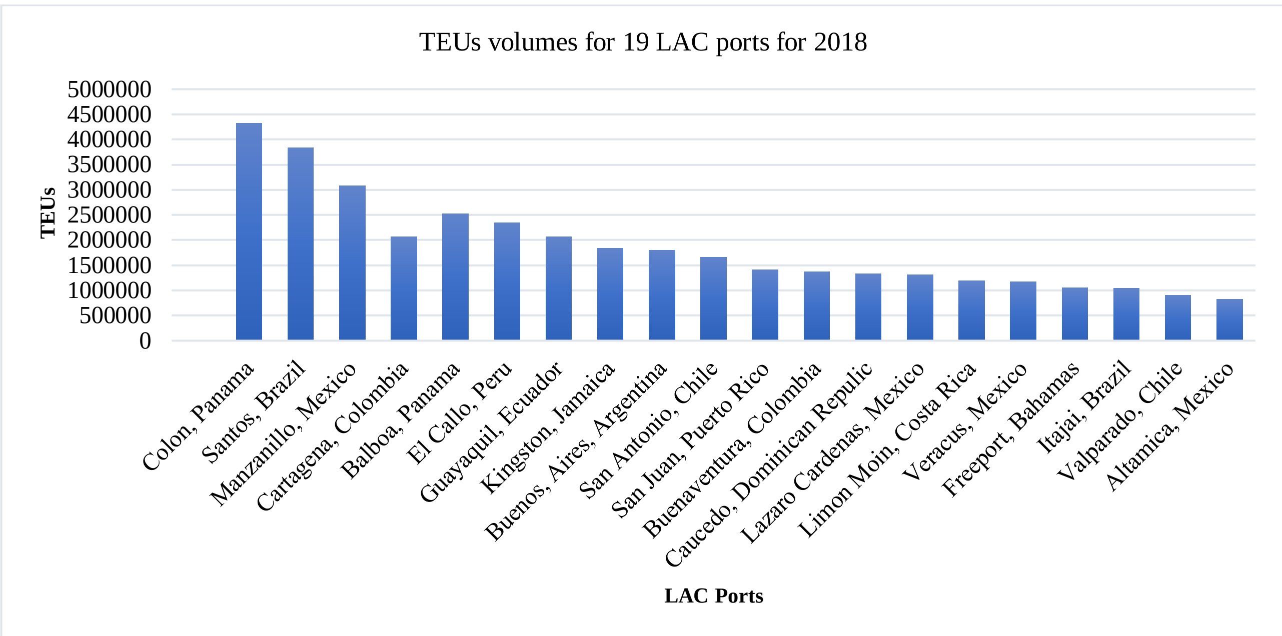
Coast	Container	Passenger	Liquid	Dry Bulk	Dry and Liquid Bulk	Multipurpose	Roll-on/off
East Coast of South America	37	16	138	16	16	185	19
West Coast of South America	12	14	135	86	4	138	1
The Caribbean	27	53	81	46	1	137	0
Central America	13	25	57	50	5	53	2
Total	89	108	411	198	26	513	22

Source: CEPAL (2020)



Source: Wilmsmeier & Monios, 2016.

Fig. 3.5 Map shows Latin America's and the Caribbean port system (TEU).



Source: World Bank (2020)

Fig. 3.6 Container throughput for 2018 for the Nineteen (19) LAC ports

The quality of port infrastructure (QPI) measured business executives' perception of their country's port facilities where WEF (1 = extremely underdeveloped to 7 = well developed and efficiency by international standards) as shown in Table 3.6. Panama tops the region's ranking at 5.7, proving that SFA results were justifiable overall port performance. Brazil had the lowest overall rank at 3.2; however, Brazil comprises 175 ports; therefore, only top-performing ports were considered because each port will have different TE performance and QPI.

Table 3.6 . Quality of Port Infrastructure among the 19 top Port countries in Latin America and the Caribbean.

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Argentina	3.8	3.7	3.6	3.7	3.7	3.8	3.8	3.7	3.7	3.9
The Bahamas,	Na	Na	Na	Na	Na	Na	Na	Na	Na	Na
Brazil	2.9	2.7	2.6	2.7	2.7	2.7	2.7	3.1	3.1	3.2
Colombia	3.5	3.4	3.2	3.5	3.7	3.6	3.6	3.8	4	4.1
Costa Rica	2.7	2.3	2.4	2.9	3	3.1	3.1	3.4	3.5	3.9
Dominican Republic	4.4	4.4	4.7	4.6	4.6	4.5	4.5	4.8	4.6	4.9
Ecuador	3.7	3.8	3.9	4.2	4.2	4.8	4.8	4.6	4.4	4.5
Jamaica	5.3	5.3	5.1	5.1	4.9	4.7	4.7	4.9	4.5	4.5
Mexico	3.7	4	4.3	4.4	4.3	4.3	4.3	4.3	4.3	4.3
Panama	6	6.4	6.4	6.4	6.3	6.3	6.3	6.2	5.7	5.7
Peru	3.3	3.5	3.5	3.7	3.7	3.6	3.6	3.7	3.6	3.8
Puerto Rico	5.4	5.3	5.2	5.3	5.4	5.4	5.4	5.4	5.4	5.4
Paraguay	3.4	3.4	3.6	3.4	3.2	3.1	3.1	3.3	3.4	3.5
Uruguay	5.2	5.1	4.9	4.7	4.7	4.7	4.7	4.9	4.8	4.8
Chile	5.4	5.2	5.2	5.2	5.2	5	4.9	4.9	4.6	4.9

Source: World bank (2020).

Table 3.7 shows the port infrastructure and the average annual throughput of each port. The data period spans eight years, from 2010 to 2018. Displaying keen port infrastructural indicators such as berth length, port area, number of mobile and quay cranes, ship-to-ship (STS) gantry cranes, number of berths, draft, transshipment, and the annual container throughput in TEUs.

Table 3.7 Key port infrastructural indicators for the 19 LAC ports.

Country /ports	Ave Annual Throughput (TEU) 2010-2018	Ave. Berth Length (m)	Ave. Area (m^2)	Ave. Mobile Crane with Capacity>1 4t(No.)	Ave. STS Gantry Cranes (No.)	Ave.Depth (m)	Ave. Container (No.)	Ave. Berth (No.)
Colon, Panama	3483631	1258	384000	33	8	16.5	1258	4
Santos, Brazil	3264961	1980	597000	46	13	16	1980	65
Manzanillo, Mexico	2311089	380	437000	8	9	16.5	1240	13
Cartagena, Colombia	2150673	270	225000	2	28	21	225000	8
Balboa, Panama	3082469	442	300000	8	17	16.5	5	7
El Callo, Peru	1908291	183	441080	6	3	16	24300	4
Guayaquil, Ecuador	1619845	1320	228273	3	6	10.5	228273	4
Kingston, Jamaica	1717676	138	1037671	3	19	15.5	2400	11
Buenos, Aires, Argentina	1608412	500	220000	10	13	10.7	220000	5
San Antonio, Chile	1174939	537	495000	6	13	15	495000	9
San Juan, Puerto Rico	1325861	610	287273	0	9	17	287273	46
Buenaventura, Colombia	901142	440	68500	3	8	15	68500	14
Caucedo, Dominican Repulic	1089203	922	800000	2	6	15.2	800000	15
Limon Moin, Costa Rica	1075357	210	677276	0	6	10.2	4930	6

Veracruz, Mexico	900680	507	402909	1	5	14	402909	11
Freeport, Bahamas	1204841	1294	320125	0	13	16	57000	3
Itajai, Brazil	1010553	1035	180000	3	2	14	180000	4
Valparado, Chile	942106	740	280710	5	3	14	280710	3
Altamica, Mexico	635007	973	396570	1	4	12	600	12

Source: Own elaboration.

Table 3.8 shows that all ports recorded significant growth except for regional ports in Central America and the Caribbean that Balboa Panama (-9%), Kingston; Jamaica (-3%), San Juan; Puerto Rico (-8%), and Freeport; Bahamas (-7%) for the 2010 to 2018 period.

Table 3.8. LA America and the Caribbean top 19 Ports (TEU)

Port Activity	Region	Throughput (TEUs) 2018	Compound Annual Growth Rate, 2010-2018 (%)	Growth Rate 2010-2018 (%)
Colon, Panama	Central America	4324478	5.8%	57%
Santos, Brazil	South America	3836487	4.4%	41%
Manzanillo, Mexico	Central America	3078505	9.3%	104%
Cartagena, Colombia	South America	2064281	3.4%	31%
Balboa, Panama	Central America	2520587	-1.1%	-9%
El Callo, Peru	South America	2340657	7.2%	74%
Guayaquil, Ecuador	South America	2064281	9.0%	99%
Kingston, Jamaica	Caribbean	1833053	-0.4%	-3%
Buenos Aires, Argentina	South America	1797955	0.5%	4%
San Antonio, Chile	South America	1660832	8.4%	91%
San Juan, Puerto Rico	Caribbean	1405348	-1.0%	-8%
Buenaventura, Colombia	Caribbean	1369139	9.5%	107%
Caucedo, Dominican Republic (DR)	Caribbean	1331907	3.6%	33%
Limon Moin, Costa Rica	Central America	1187760	4.1%	38%
Veracruz, Mexico	Central America	1176253	7.4%	78%
Freeport, Bahamas	Caribbean	1050140	-0.9%	-7%
Itajai, Brazil	South America	1045813	3.2%	29%
Valparado, Chile	South America	903296	0.3%	3%
Altamica, Mexico	Central America	820092	6.7%	68%

Source: Own elaboration

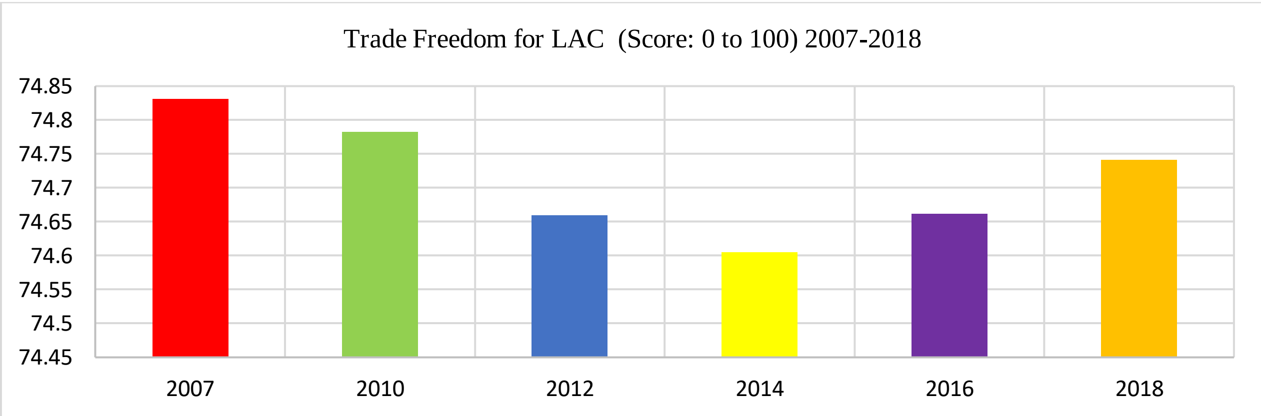
3.5.2 Influential factors that affect port efficiency (PE) within the LAC

The maritime industry is dynamic and responsive to global economic changes; therefore, several factors have influenced port development and efficiency during the pre and post PCE era. Factors include trade policy, port liner shipping connectivity, and the world seaborne trade growth.

3.5.2.1 Trade policy influence on trade

Trade plays an integral role in ending global poverty because it has a positive and statistically significant impact on economic growth (WorldBank, 2020). Open trade and investment with the rest of the world are essential to sustainable economic growth, mainly determined by the type of trade policies in place (IMF, 2001). Trade Policy allows bilateral trade among countries to improve exports and imports. Although several studies support that port efficiency (PE) positively impacts trade (Tongzon,1995; Shetty and Dwarakish, 2018). However, a port's ability to handle export and import volumes efficiently indicates a level of port performance. Naanwaab and Diarrassouba (2013) studied the influences of economic freedom on bilateral trade in intra-African. Their findings revealed that trade agreements (trade policy) positively impact bilateral trade among African countries. Further results indicated that port inefficiencies in Africa had hindered trade growth. On the contrary, not all trade policies are beneficial. According to Tran (2019), Trade freedom (TRFR) inhibits trade and economic development among some ASEAN countries.

Trade Freedom (TRFR) Index for Latin America and the Caribbean (LAC), as shown in Fig. 3.7, declined from 74.8 in 2007 to 74.6 in 2014, then rebounded to 74.7 in 2018. Overall, showing improvements in Trade Freedom (TRFR) within the region.



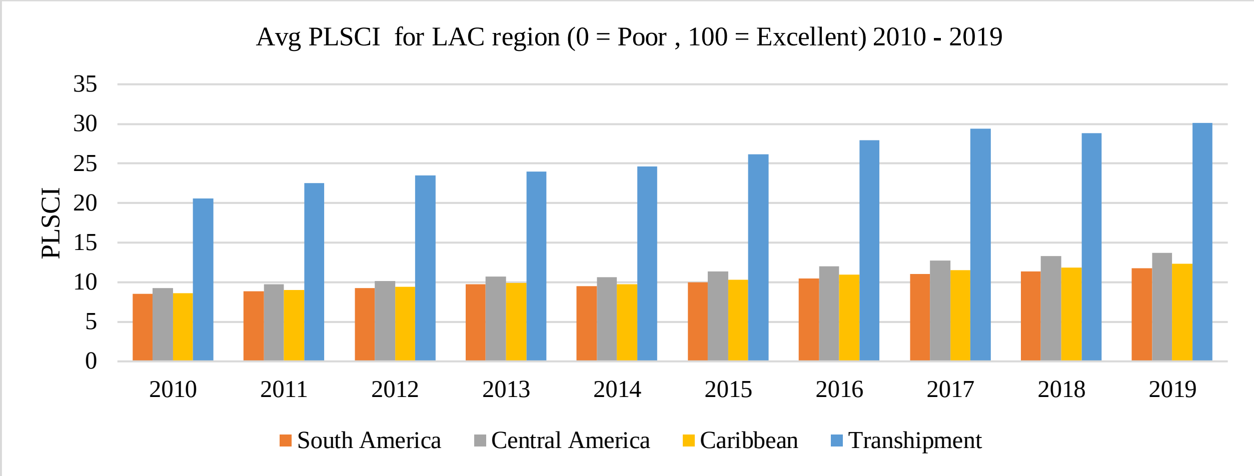
Source: World Bank, 2021.

Fig. 3.7 LAC region Trade Freedom (TRFR) from 2007 to 2018.

3.5.2.2 Port liner shipping connectivity index (PLSCI) in LAC

The Port liner shipping connectivity index (PLSCI) assesses how well a country links to the global shipping networks (UNCTAD, 2021). The LSCI is measured by five (5) components of the maritime transport sector: number of ships, container-carrying capacity, maximum vessel size, number of services, and companies that deploy container ships in a country's ports (World Economic Forum, 2018). Port infrastructure and PLSCI strongly affect freight rates in the LAC region (Wilmsmeier & Monios, 2016). The port liner connectivity is an essential factor influencing trade activity in the maritime industry for regional ports within LAC and US East and Gulf coast. Therefore, PLCSI also indicates the level of efficiency of a port.

In recent times within the LAC region, the global recession has influenced significant consolidation of shipping lines, whereby shipping lines were forced to reduce cost and optimize ship deployment and services to their customers. Overall, this has led to a higher concentration of container handling among regional ports (Caribbean Development Bank (CDB), 2017). For example, G6 Alliance was established during that period consisting of Hapag-Lloyd, NYK Line, OOCL, Hyundai Merchant Marine, APL, and Mitsui O.S.K. Lines. The merger between Maersk and MSC, forming the 2M alliance. And several other international and regional unions not listed have influenced port efficiency (PE) within the region (Rodrigue and Notteboom, 2021; CDB, 2017; UNCTAD, 2021).



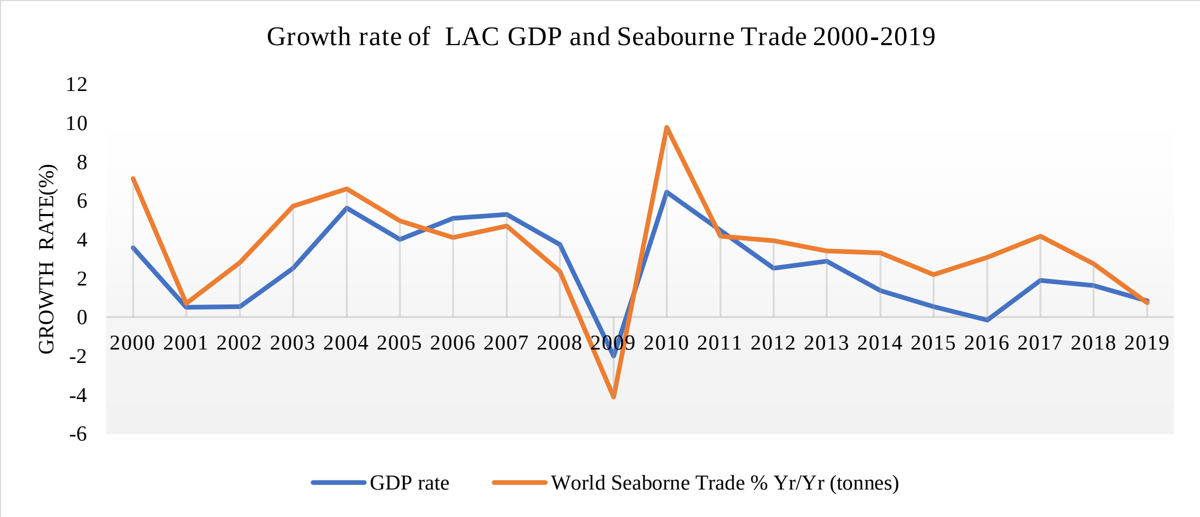
Source: UNCTAD (2020).

Fig. 3.8 Port Liner Shipping Connectivity Index (PLCI). Index (Maximum Q1 2006 = 100

The average Port Liner Shipping Index (PLSCI) for the three (3) regions showed consistent growth in South America, Central America, and the Caribbean. As shown in Fig. 3.8, for South America (SA), the PLSCI score increases from 8.50 (2010) to 12.40 (2019), Central America (CA) score increases from 8.63 (2010) to 13.82 (2019), and the Caribbean score from 8.63(2010) to 12.41(2019). Also, for transshipment ports, the PLSCI is significantly higher than the overall regional port. The PLSCI for transshipment ports increases from 20.6 (2010) to 30.1 (2019).

3.5.2.3 World seaborne trade influence on economic growth and port development

Port is the gateway of trade therefore, as trade increases so will economic growth. According to UNCTAD (2021), around 80 percent of volume trade in goods is carried by sea, by which the percentage is higher for developing countries. Several authors link port development, trade, and maritime transport to economic growth (Munim and Schramm, 2018; Tally, 2017; Töngür et al, 2020; Gani, 2017). Therefore investments towards port development in tandem with logistics infrastructure will improve PE and positively influence economic growth (Munim and Schramm, 2018). Poor port and logistics infrastructures among developing countries increase the costs and time required for trade (Töngür et al, 2020; Gani, 2017). For example, small Caribbean states have high transportation costs because of the inadequate port infrastructure that has hindered the efficient movement of goods (Munim and Schramm, 2018). Trade has a direct impact on GDP growth, therefore, as PE improves through infrastructural development as a result trade volume will be enhanced. Fig. 3.9 shows that the growth of the LAC's GDP with Seabourne trade % (Tonnage) is highly correlated.



Source: World Bank (2020)

Fig 3.9. LAC's GDP growth (%) and Global Seaboune trade (%).

3.6 MODEL

The characteristic of ports within the LAC region varies in infrastructure and added value services. The accommodation of Neo-Panamax port is the main agender for port development through the upgrade and acquisition of neo-Panamax compatible equipment such as cranes, hinterland expansion, and deepening of water channels. The PCE has fueled the port project among the region's major ports that seek to capitalize on container throughput and added value service, logistics hubs, and ship repairs. Table 2.5 shows the characteristics and profiles of the 19 top regional ports that account for 85 percent of regional container throughput.

SFA is a method used to calculate a port or firm's TE. It is known as comprised error, model for production function $y_i = g(x_i, \beta) + \varepsilon_i \ (i = 1, 2, 3, \ldots, N)$, (Battese and Coelli, 1992). Where y_i is the output for statement *i*, x_i is a vector of input for statement *i*, β is the vector of parameters, ε_i is error term for statement *i*, postulates that the error term ε_i is made up of two independent components, $y_i = g(x_i, \beta) + \varepsilon_i \ (i = 1, 2, 3, \ldots, N)$, $\varepsilon_i = v_i - u_i$ where v_i is a two-side error term representing statistical noise in any relationship; $u_i > 0$ is one-side error term representing technical inefficiency. The exponential form of the proposed model giving production function in equation (1) as,

$$y_{it} = \exp(x_{it} \beta + v_{it} - u_{it}) \quad (1)$$

Where, y_{it} is the production at the t^{th} observation ($t = 1, 2, \ldots, T$) for the i^{th} *firm* ($i = 1, 2, \ldots, N$); x_{it} is the logarithm of input variable v_{it} is random error assumed to be variance, $N(0, \sigma_v^2)$, and independently distributed of a non-negative random variable, u_{it}. The truncated normal distribution using Wald or generalized likelihood- ratio test (Battese and Coelli, 1995) is specified in this research to justify the selection of distribution form for technical inefficiency effects.

Regression of effects of inefficiency on the variables that explain inefficiency is given by Equation (2) as,

$$u_{it} = z_{it} \delta + W_{it} \quad (2)$$

Z_{it} is a vector of explanatory variable; δ is a vector of unknown scalar parameters; W_{it} is the truncation of normal distribution, $N(0,\ \sigma_v^2)$ truncation is such that point of truncation is $-z_{it}\ \delta$. The likelihood function is expressed in terms of variance parameter $\sigma_s^2 = \sigma_v^2 + \sigma_v^2$ *and* $\gamma = \sigma / \sigma_s^2$, inefficiency can therefore be defined in terms of the ratio between observed output and potential output is given input x_{it} *as,*

$$TE_{it} = y_{it} / exp\ (x_{it}\,\beta + v_{it}) = exp(-z_{it}\delta - w_{it}) \quad (3)$$

3.6.1 Scholastics Frontier Analysis (SFA) for LAC

In assessing the PE of 19 LAC ports using an SFA methodology is the production function specification (Cobb-Douglas form) as shown in equation (4) below. Time invariant TE is specified as follows.:

$$ln\,(Y_{it}) = \beta_0 + \beta_1\, ln(A_{it}) + \beta_2\, ln(B_{it}) + \beta_3\, ln(C_{it}) + \beta_4\, ln\,(Q_{it}) + v_{it} - u_{it} \quad (4)$$

These variables are defined as follows:

$$\forall\ I = 1...N \text{ and } t = 1...T$$

Where Y_{it} is the container throughput in TEUs handled by port *i* in period *t;* A_{it} is the total area (in square meters) of the container terminals in port *i* in period *t*; B_{it} is the total length (meters) of the berths used for container handling in port *i* in period *t;* C_{it} is the number of container cranes (Mobile Crane+ STS gantry cranes) owned by port *i* in period t, and the *number of berths* (Q_{it}) is the number of berths in port *i* in period *t.*

3.6.2 Sampling and Data Collection

The data was gathered from nineteen (19) top container ports in the LAC regions; nine (9) ports in South America, six (6) ports in Central America, and four (4) ports in the Caribbean, as shown in Table 3.5 The database was primarily populated with information published by CEPAL (2019), World port Source (WPS), and World bank (2020). Economic Commission for Latin America and the Caribbean (ECLAC) database gives the Port activity report of container throughput for 31 countries and 118 port and port zones. The World Port source (WPS) gives the profile on each regional port, and the World bank gives the data on container throughput and ports infrastructural rankings as shown in Fig. 3.6 and Table 3.6

HIERARCHICAL LINEAR MODEL (HLM)

3.7 MODEL

Hierarchical regression examines and tests both theoretically based hypotheses and assumptions (Petrocelli, 2003; Cohen, 2001). According to Petrocelli (2001), a hierarchical regression is a special type of multiple regression. Additional variables are added to the equation in subsequent "block or model" to determine how the added predictor variables change the model to predict the model-dependent variable (To and Mandracchia, 2019). this equation will be represented by six (6) blocks or models of the HLM in which the first block

(model1) will be a regression of economic variables; GDP, TRFR, IND, FDI. The second block (model 2) will be the second equation that includes the original predictors' variables (model 1) from the first equation with the added predictor variable, LPI components; LPCUST, LPINFRA, LPQLS, LPTT, and LPTL (Tabachnick & Fidell, 2013). Each LPI component will be in be sequential equation; LPCUST (Model 2), LPINFRA (Model 3), LPQLS (Model 4), LPTT (Model 5), and LPTL (Model 6).
Alternatively, the following Hierarchical Linear models were proposed to evaluate the relationship of each of the subdimensions that make up the logistic performance index:

Model 1: $LogEX_{LAC} = \beta_0 + \beta_1 \, logGDP_{LAC} + log\, \beta_2 TRFR_{LAC} + log\, \beta_3 FDI_{LAC} + \beta_4 \, logIND_{LAC} + \mu_{LAC}$

Model 2: $LogEX_{LAC} = \beta_0 + \beta_1 \, logGDP_{LAC} + log\, \beta_2 TRFR_{LAC} + log\, \beta_3 FDI_{LAC} + \beta_4 \, logIND_{LAC} + \beta_5 \, LPCUST_{LAC} + \mu_{LAC} (2)$

Model 3: $LogEX_{LAC} = \beta_0 + \beta_1 \, logGDP_{LAC} + log\, \beta_2 TRFR_{LAC} + log\, \beta_3 FDI_{LAC} + \beta_4 \, logIND_{LAC} + \beta_5 \, LPCUST_{LAC} + \beta_6 \, LPINFRA_{LAC} + \mu_{LAC} (3)$

Model 4: $LogEX_{LAC} = \beta_0 + \beta_1 \, logGDP_{LAC} + log\, \beta_2 TRFR_{LAC} + log\, \beta_3 FDI_{LAC} + \beta_4 \, logIND_{LAC} + \beta_5 \, LPCUST_{LAC} + \beta_6 \, LPINFRA_{LAC} + \beta_7 \, LPQLS_{LAC} + \mu_{LAC} (4)$

Model 5: $LogEX_{LAC} = \beta_0 + \beta_1 \, logGDP_{LAC} + log\, \beta_2 TRFR_{LAC} + log\, \beta_3 FDI_{LAC} + \beta_4 \, logIND_{LAC} + \beta_5 \, LPCUST_{LAC} + \beta_6 \, LPINFRA_{LAC} + \beta_7 \, LPQLS_{LAC} + \beta_8 \, LPTT_{LAC} + \mu_{LAC}$

Model 6: $LogEX_{LAC} = \beta_0 + \beta_1 \, logGDP_{LAC} + log\, \beta_2 TRFR_{LAC} + log\, \beta_3 FDI_{LAC} + \beta_4 \, logIND_{LAC} + \beta_5 \, LPCUST_{LAC} + \beta_6 \, LPINFRA_{LAC} + \beta_7 \, LPQLS_{LAC} + \beta_8 \, LPTT_{LAC} + \beta_9 \, LPTL_{LAC} + \mu_{LAC}$

Where:

EX = Is part of international trade along with imports. The exports of goods and services are the primary income of a country. (World Bank, 2020).

GDP = The market value or total monetary value of finished goods and services that the country produces within its border during a specific period (World Bank, 2020).

IND = The variable industrial measures the percentage of the industrial sector's added value over the economy's total. A positive relationship between the volume exported and the degree of industrialization of an economy (Rezaei et al., 2018).

OLPI = Logistics consists of different variables as shown in the context of LPI indicators. Therefore, evaluate the impact of different logistics dimensions (Beysenbaeu & Dus, 2020).

TRFR = Is based on the inputs of trade-weight of the average tariff and non-tariff barriers that affect trade for both goods and services. (Index of Economic Freedom (IEF), 2020).

FDI = Is the primary source of funding for investment, which positively impacts trade because it expands a country's production operations to generate more capital and easier accessibility of borrowing from international markets (OECD, 2020).

3.7.1 Sampling and Data Collection

Logistics performance data were sourced from the World Development Indicators (The World Bank, 2019). The overall Logistics Performance Index (OLPI) measured a scale of 1 (low) and 5 (high). LPI measures the weight of countries covered within this research in six sub-dimension of logistics performance. These sub-dimensions are as follows the ability to track and trace consignments (LP- TT); competence and quality of logistics services (LP-QLS); efficiency of the customs clearance process (LP-CUST); the frequency of shipment to the consignee within the expected time (LP-TL); and quality of trade and transport-related Infrastructure (LP-INFRA). These indicators were measured on a scale of 1 (low) to 5 (high). The Thirty-three (33) sample countries from the LAC are as follows: Argentina, Bahamas, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica Republic, Ecuador, Honduras, Haiti, Jamaica, Mexico, Guatemala, Uruguay, Panama, Peru, Paraguay, El Salvador, and Nicaragua. The following countries were excluded from the research due to limited and missing data on logistics performance; Cuba, Nicaragua, Belize, Antigua &Bermuda, Dominica, Puerto Rico (United States Territory), St. Lucia, Suriname, Barbados, Guyana, St. Vincent & Grenadines, Grenada, Trinidad &Tobago, St. Kitts & Nevis, and Venezuela.

3.7.2 Trends of LAC's LPI Sub-Dimensions

According to the World Bank collection of development indicators, Fig. 3.10 shows the LPI overall score for LAC countries listed in this research. Fig. 3.11 shows that the LAC countries' overall LPI decreased from 2007 to 2014 but rebounded from 2015 to 2016, then decreased in 2018. Fig. 3.12 shows that Customs declined from 2.498 to 2.485 from 2007 to 2014 and then rapidly grew from 2014 to 2016 with scores of 2.485 to 2.652 respectively, then declined in 2018 at 2.646.

Period 2014 to 2016 shows that PCE may have impacted these improvements. However, overall, the acute decline in the efficiency of customs shows that the LAC region customs procedures are not fully streamed line to speed up handling goods through the inefficiency of transport auxiliaries (Freight forwarder, transport operators, customs brokers). Logistics Infrastructure, which includes transportation operation road network, handling company, freight forwarder services, and air cargo terminal, Fig. 3.13 shows a drop from 2.53 in 2007 to 2.51 in 2018. Infrastructure showed improvement from 2.514 in 2014 to 2.523 in 2016, revealing an overall decline in logistics infrastructure's operational quality. Components of LPI such as infrastructure, quality of Logistics, and timelines, as shown in Fig. 3.14, 3.15, respectively, all displayed similar trends as explained for customs. However, LPI: Tracking and Tracing; and International shipment consistently declined throughout 2007 to 2018. The LPI components' graphs will explain the regression results for analyzing the impact of logistics performance on LAC Exports.

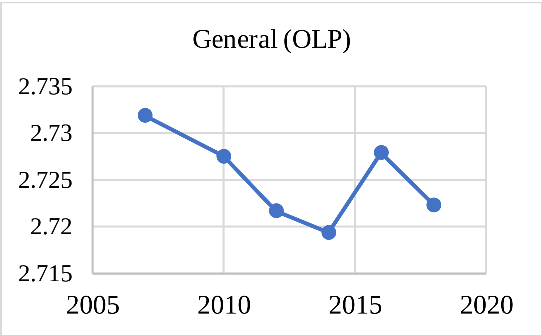


Fig. 3.10. OLPI: Overall Score. (1= Low to 5 = High)
Low to 5 = High).

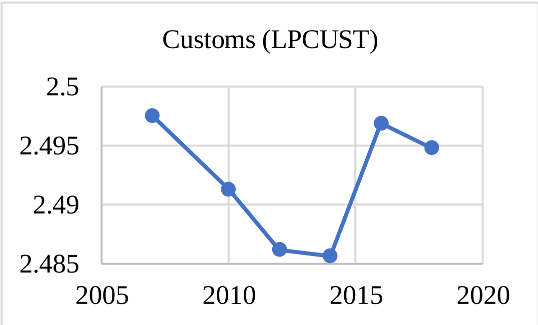


Fig. 3.11. LAC average LP-CUST low (1=

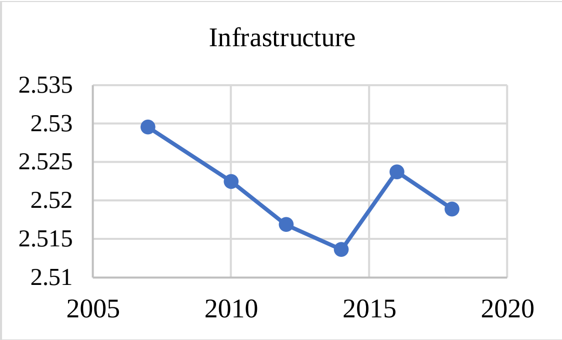
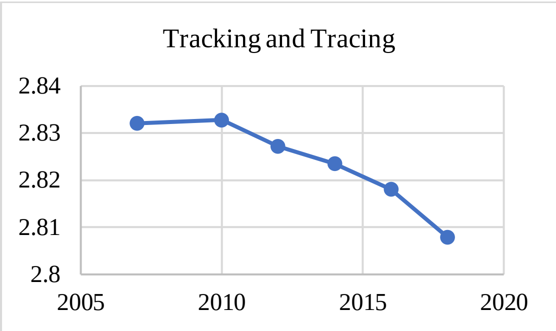


Fig. 3.12 LAC Average LP-INFRA (1 = Low to 5 = High). Fig. 3.13 LAC average LP-QLS (1= low to 5
= High).



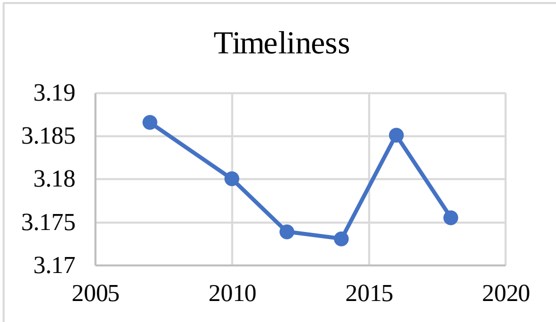
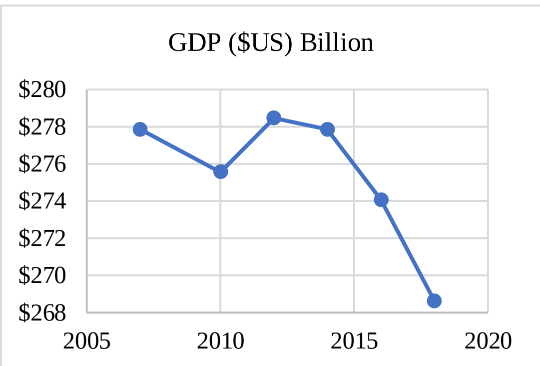


Fig. 3.14 LAC average LP-TT (1= low to 5 = High). Fig. 3.15 LAC average LP-TL (1= low to 5 =
High).

3.7.3 Economic Variables for LAC region

Economic variables used within the research seek to analyze each variable effects on export volumes in the LAC region. In addition, other variables use within the model are importantly impactful to exports. These variables are Log Gross Domestic Product (GDP), Industry Index (IND), Foreign Direct Investment (FDI), and Trade Freedom (TRFR).



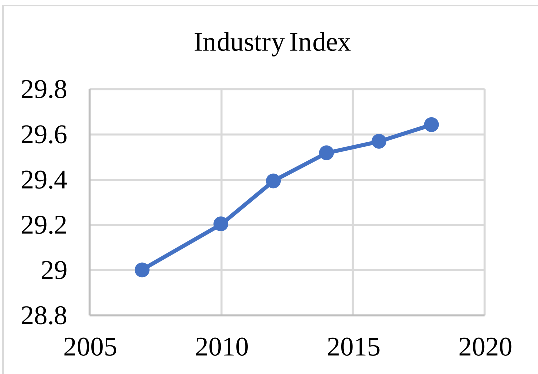


Fig. 3.16 LAC average GDP ($ US Billion). Fig. 3.17 LAC avg Indus.Index (0 = low to High =100)

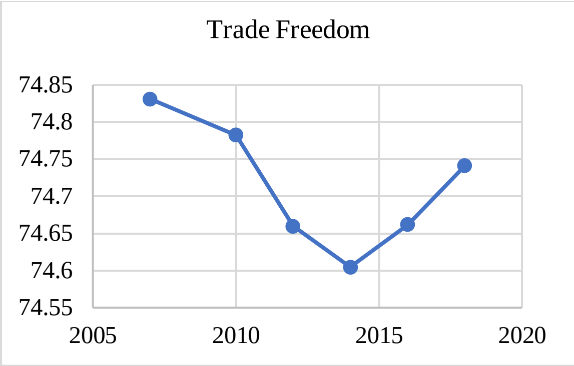


Fig. 3.18 LAC average TRFR (0 = Low to 100 = High)

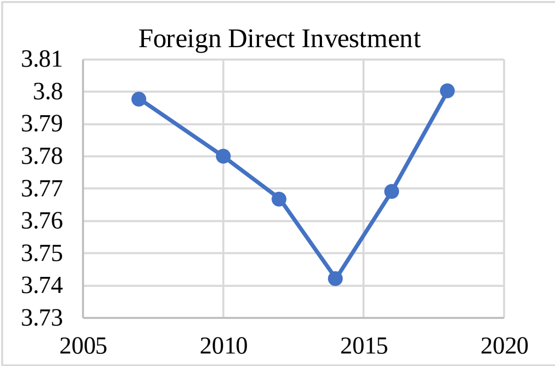


Fig. 3.19**.** LAC average FDI (0 = Low to 15 = High)

Fig. 3.16 shows that the Gross Domestic Product (GDP) for Latin America and the Caribbean from 2007 to 2018 shows a 3 percent decline in GDP. However, the Industry Index has shown improvement from 27 to 27.9 within the region, as shown in Fig. 3.17 As Fig. 3.18 in the LAC, trade freedom declined from 2007 to 2014; however, from 2014 to 2018, improvement was 74.6 to 74.74. As shown in Fig. 3.19, the Foreign Direct Investment drastic improvement from 3.74 to 3.8 from 2014 to 2018.

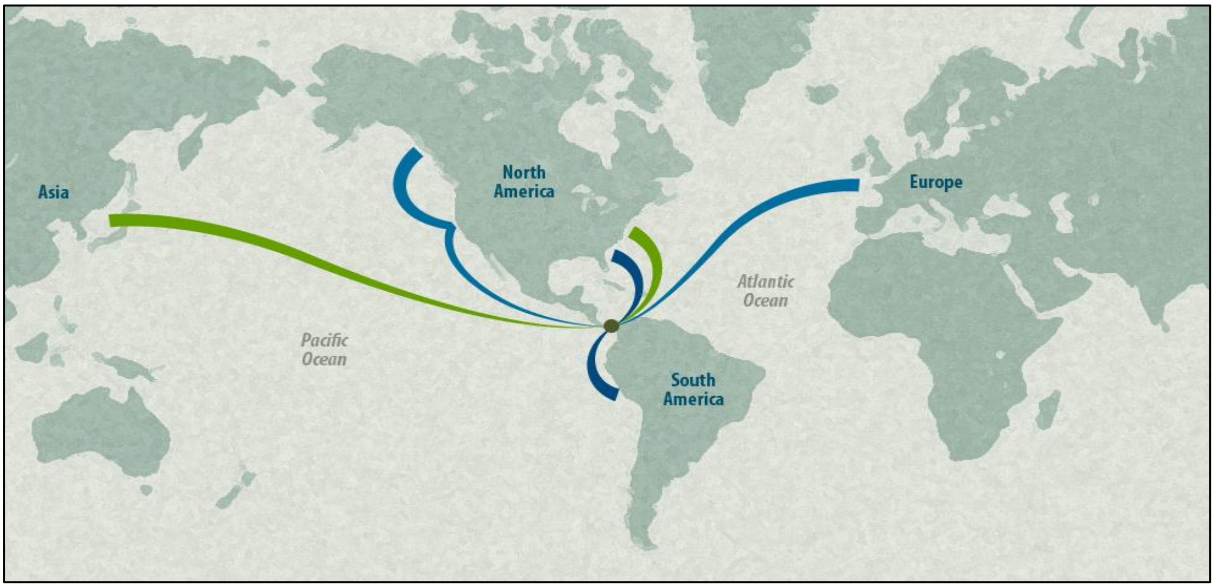
BAYESIAN STRUCTURAL TIME SERIES (BSTS) MODEL

3.8 PANAMA CANAL MAIN ROUTES

The geographical position of Panama in the narrowest point of the Central American isthmus strategically connects the countries of the world, especially those with commercial activities in the Atlantic and Pacific oceans. Moreover, as shown in Fig. 3.20, the accessibility provided by the Panama Canal competitively binds all global markets, mainly Asia, Europe, North and South America (Panama Canal Authority, 2021).

The main trade routes with traffic in the Panama Canal are:

- East Coast of the USA and Asia (Far East)
- East Coast of USA and West Coast of South America
- Europe and West Coast of South America
- East Coast of USA and West Coast of Central America
- Coast to Coast of South America



Source: Georgia Tech Panama Logistics Innovation and Research Center

Fig. 3.20 Panama Canal trade routes 2021

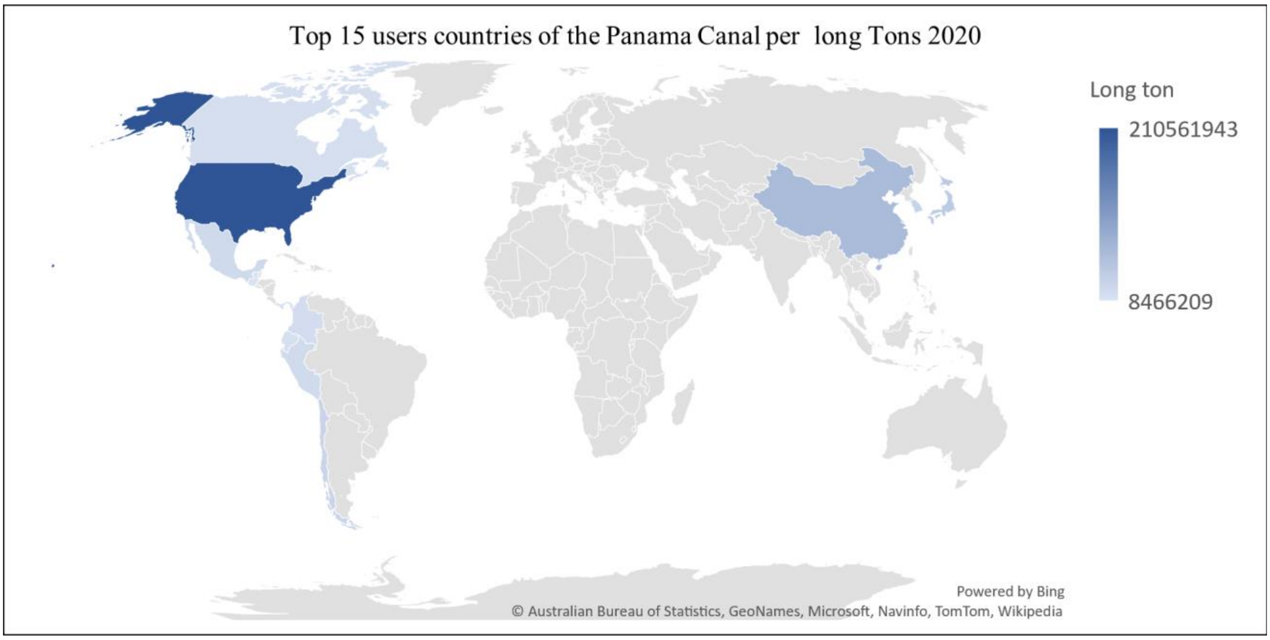
3.8.2. Top 15 Countries by Origin and Destination of Cargo

According to Panama Canal Authority (2021), the United States, China, Japan, Mexico, and Colombia were the canal's top users, with the United States accounting for 72.5.8% of the total cargo transiting the canal, followed by China, Japan, Chile, Korean Republic, and Mexico were 22.6 %, 14.7%, 10.1%, 9.7 %, and 7.3% respectively as shown in Table 3.9. The map of the top 15 countries by origin and destination per total tonnage (long ton) is shown in Fig. 3.21.

Table 3.9 Top 15 Countries by Origin and Destination of Cargo (Long tons)

Rank	Country	Origin	Destination	Intercoastal	Total	Total Excluding	Percentage of Total
1	United States	150144001	60417942	2137363	210561943	208424580	72.5%
2	China	19532327	44001705	-	63534031	63534031	22.1%
3	Japan	6756939	35389075	-	42146014	42146014	14.7%
4	Korea, Republic	9531942	19617272	-	29149215	29149215	10.1%
5	Chile	10912761	16931683	-	27844443	27844443	9.7%
6	Mexico	8712086	12806666	397676	21518751	21121076	7.3%
7	Peru	7159576	11979505	-	19139082	19139082	6.7%
8	Colombia	9770082	6889216	414943	16659299	16244356	5.7%
9	Canada	12441447	2365987	114	14807434	14807320	5.2%
10	Ecuador	6042168	6995061	-	13037230	13037230	4.5%
11	Panama	1811931	10468382	83052	12280565	12197513	4.2%
12	Guatemala	1525827	6940382	-	8466209	8466209	2.9%
13	Taiwan, Province of C	2339026	4113062	-	6452088	6452008	2.2%
14	Netherlands	1787179	3252427	-	5039606	5039606	1.8%
15	Spain	2387433	2213386	-	4600818	4600818	1.6%

Source: Panama Canal Authority Fiscal Year 2020

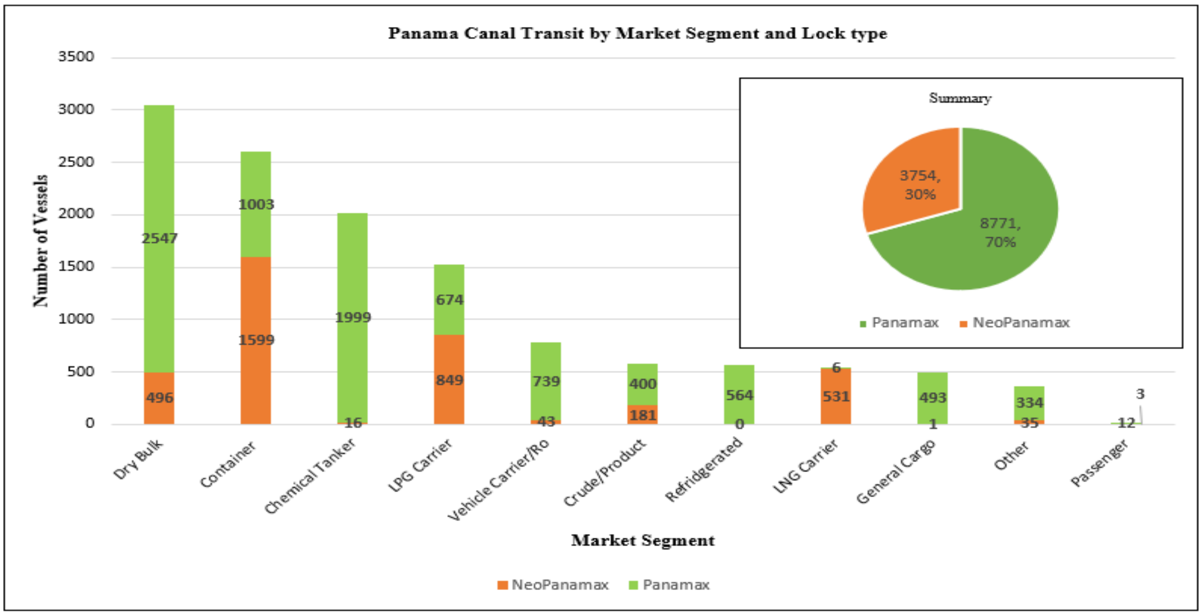


Source: Panama Canal Authorities., (2021)

Fig 3.21 Top 15 users of the Panama Canal per long tonnage 2021

3.8.3 LAC profile

The LAC region comprises 33 countries divided into South America, Central America, and the Caribbean. The PCE (Intervention) was projected to improve maritime activities within the region, stimulating economic activity through port activities such as transshipment, container throughput, and maritime activities. As a result, the PCE has increased marine traffic and cargo tonnage, enabling neo-Panamax and post-Panamax vessels to transit the third lock. Fig. 3.22 shows the number of vessels that transit the Panama Canal.

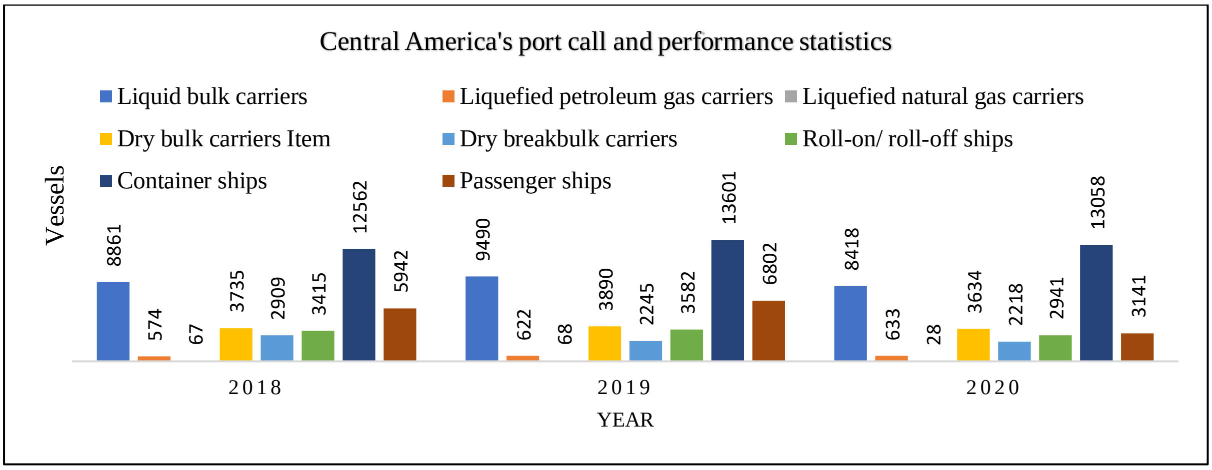


Source: UNCTAD (2021)

Fig.3.22. Panama Canal transit by market segment and lock type 2021

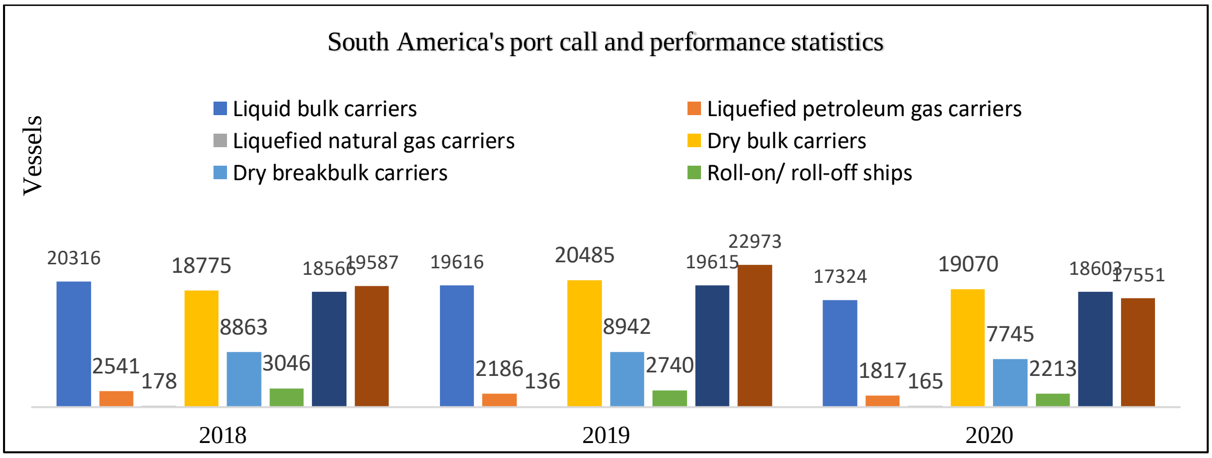
Main LAC sub-regions, i.e., Central America, Caribbean, the east coast of South America (ECSA), Mexico (both coasts), the north coast of South America (NCSA), and the west coast of South America (WCSA). Fig. 3.20, Fig. 3.21, and Fig. 3.22 show the overall port performance for each sub-region of Central America, South America, and the Caribbean.

For Central America, as shown in Fig. 3.22, from 2018 to 2020, container ships from 12562 in 2018 to 13058 in 2020 dominated port call and performance statistics than other ship categories. Liquid bulk had the second-highest port call and performance statistics. For South America, as shown in Fig. 3.23, three (3) ships dominated the port call and performance; Liquid Bulk Carrier, Dry Bulk Carrier, and Container ships were the most dominant ship category from 2018 to 2020. For the Caribbean region, as shown in Fig. 3.24, from 2018 to 2019, passenger ships were dominant for port calls; however, in 2020, passenger ships were negatively impacted by the COVID-19 pandemic. The other ship segment, such as the container ships, liquid bulk carriers, and dry breakbulk carriers, was dominant among Caribbean ports. Container ships traffic increased from 6192 vessels in 2018 to 7606 vessels in 2020 (UNCTAD, 2021, Barleta and Sanchez, 2020).



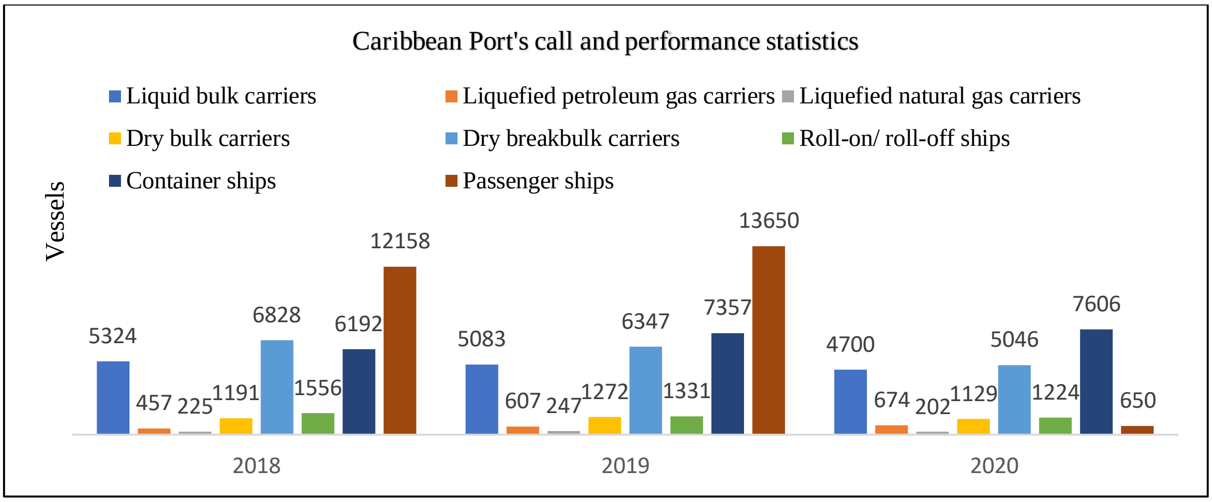
Source: UNCTAD (2021)

Fig. 3.22. Port call and performance statistics for Central America from 2018 to 2020



Source: UNCTAD (2021)

Fig. 3.23. Port call and performance statistics for South America from 2018 to 2020



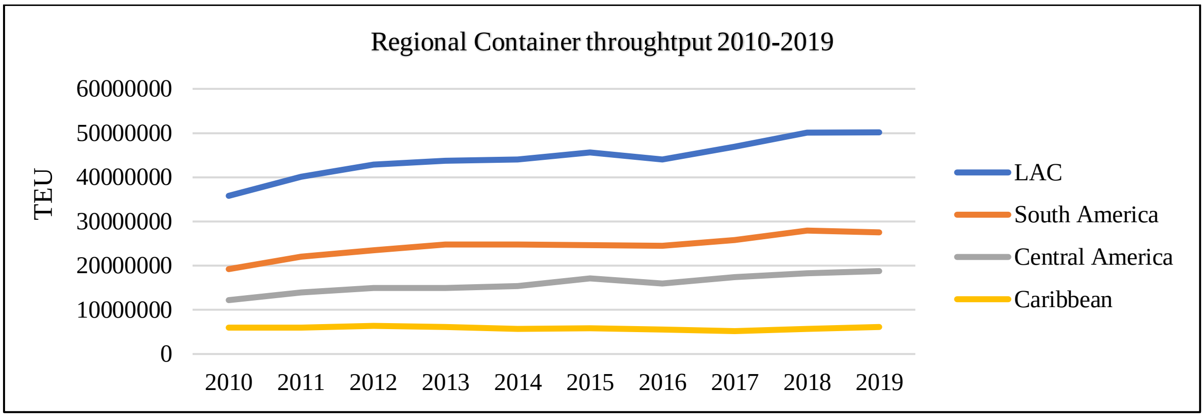
Source: UNCTAD (2021)

Fig. 3.24. Port call and performance statistics for Caribbean from 2018 to 2020

3.8.4 LAC Container throughput growth by region

Container throughput (TEU) in the LAC port system grew from 15.9 million TEUs in 2000 to 53 million TEUs in 2019 (World Bank, 2020). Throughput in 2019 represented 6.7 % of all global port movements. From 2000 to 2019, the percentage share of global port movement ranges from 7.1 % in 2000 to 6.7 percent in 2019. Although, there is progressive increase in TEUs from 2000 to 2019. However, the throughput increased by only 0.04% in 2019, representing 6.5%, slightly decreasing from 7.1% in 2018 of total global container throughput (Barleta and Sanchez, 2020). This analysis was taken from a sample of 126 ports and port areas in 36 countries.

The three (3) subregions, South America, Central America, and the Caribbean, Fig. 3.25, reveal that the container throughput (TEUs) for South America (SA) experienced an increase of 12% from 2016 to 2019, 24.5 to 27.5 million TEUs. Central America (CA) had an 18 % increase in 2016 to 2019 from 15.9 to 18.8 million TEUs. Moreover, the Caribbean had a 10 % increase in TEUs from 2016 to 2019 from 5.52 to 6.05 million TEUs.



Source: Own Elaboration

Fig 3.25. Container throughput (TEUs) for LAC, South America, Central America, and the Caribbean.

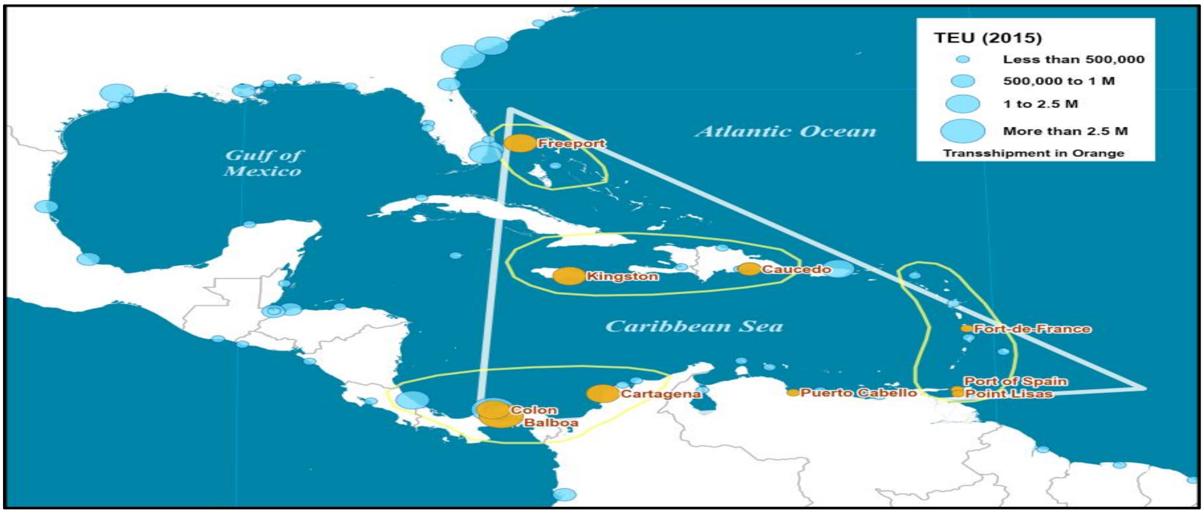
In 2019, ten Latin America and the Caribbean countries accounted for 81% of all cargo shipped in the region. As shown in Table 3.10, These countries are (highest to lowest in TEUs volumes); Brazil, Mexico, Panama, Colombia, Chile, Peru, Argentina, Ecuador, the Dominican Republic (DR), and Jamaica (UNCTAD, 2019).

Table 3.10 LA America and the Caribbean top 20 Ports (TEU)

Rank	Country	Throughput
1	Brazil	10396182
2	Panama	7347000
3	Mexico	7100644
4	Chile	4496578
5	Colombia	4402574
6	Peru	2678258
7	Ecuador	2127042
8	Dominican Republic	1894225
9	Argentina	1771628
10	Jamaica	1647609

Source: Barleta and Sanchez (2020)

Panama is the anchor point of the Caribbean transshipment triangle; a configuration of hub ports described as a triangle within the Caribbean basin. According to Rodrigue et al. (2019), the Caribbean basin is prone to transshipment activities that include ports that form corners of the triangle. Freeport, Colon, and Port of Spain. These ports have several strategic and proximity benefits. Take, an instance, the freeport (Bahamas) benefits from the strategic position near US East. However, the development of US East coast ports development could negatively impact TEU volumes. Port of Spain (Trinidad and Tobago) service has a transshipment port for the Lesser Antilles of the Caribbean (Rodrigue, 2020; McCalla et al., 2005). The geographical region of countries within the Transshipment triangle was expected to benefit economically from the container throughput volumes (Notteboom et al., 2021; Rodrigue and Ashar, 2016; Marle, 2016).
Fig. 3.26 shows that the Caribbean transshipment triangle, container port traffic, and transshipment traffic.

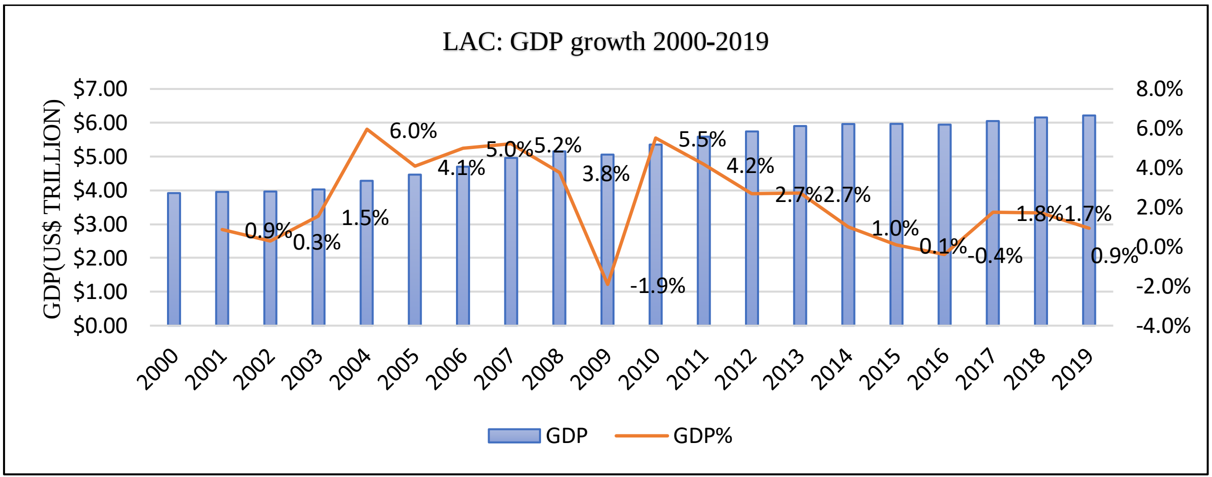


Source: Notteboom et al (2021)

Fig 3.26 Container Port traffic and Transhipment traffic

3.8.5 Latin America and the Caribbean (LAC) economic growth

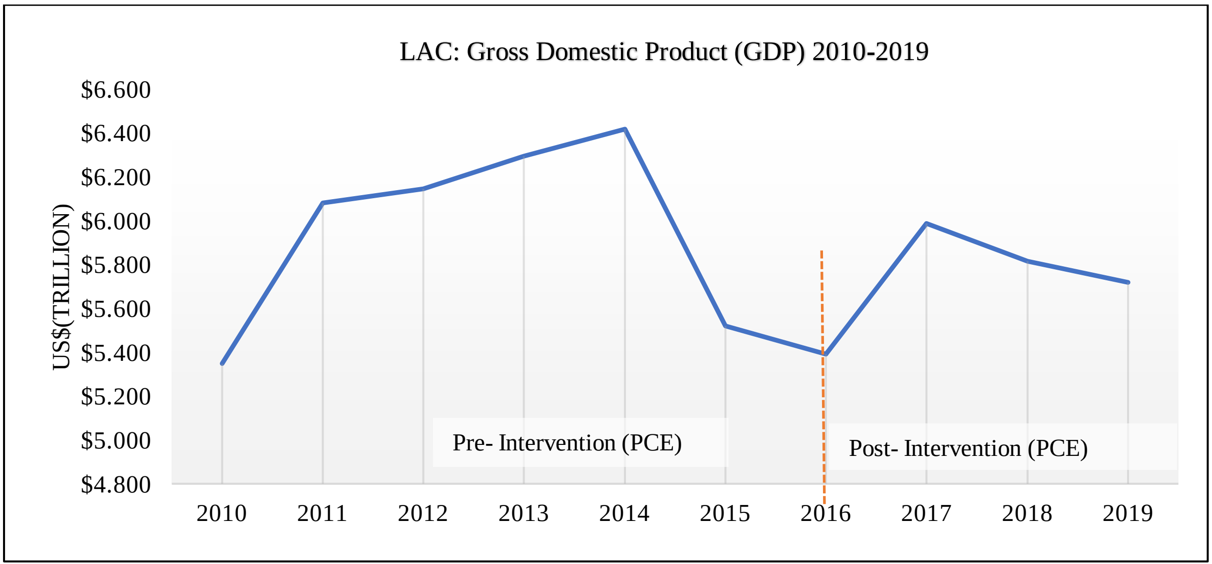
The Latin America region is an export-based economy consisting of North America (Mexico), Central America, South America, and the Caribbean. The Latin American region comprises 33 countries with a diverse economy. According to IMF (2020), the economic activity (GDP) for Latin America and the Caribbean (LAC) had a sluggish growth of 0.9% (2019) from the previous 2.3 % (2018), which was less than expected; however, the scope of this research will not look at socio-economic and structural vulnerabilities that may challenge economic growth. Fig. 3.27., shows the GDP growth of the LAC region from the period 2000 to 2019. The completion of the PCE on July 26, 2016, showed an increase of -0.4% in 2017 to 1.8% in 2018.



Source: World Bank (2020)

Fig. 3.27 LAC's GDP growth (%).

Fig. 3.28 shows the GDP growth for the LAC region for the pre-Intervention and post-intervention. The GDP growth in 2014 at US$ 6.4 trillion then sharply declined to US$ 5.4 Trillion in 2016, then increased to US$ 6.0 Trillion in 2017, then gradually decreased to US$ 5.7 Trillion in 2019.



Source: World Bank 2020

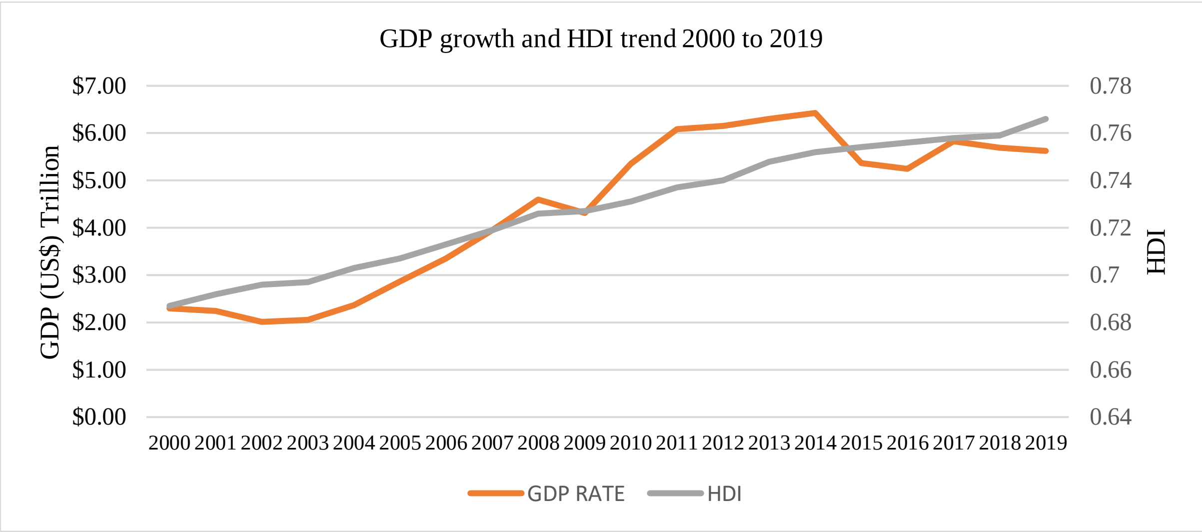
Fig. 3.28 Latin America and the Caribbean GDP (US$) 2010 to 2019

3.8.6 Human Development Index (HDI) relationship to economic growth

The Human Development Index (HDI) is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable, and having a decent standard of living (Gulcemal, 2020). In addition, HDI offers composite indices of human development issues, inequality, gender disparity, and poverty. Several studies confirm the strong relationship between economic growth and HDI.

Gulcemal (2020); studies seeks to test the effect of human and physical capital on GDP for 16 developing countries. Random and Fixed effects estimation techniques were employed to analyze and assess the significant relationship between economic growth and human development index (HDI) for the period 1990 to 2018 among 16 developing countries. The findings revealed that human development supports economic growth. It can be noticed that inflation is significant and negatively affects economic growth and development for our sample and period. In addition, it can be recorded that Labour (LAB) is significant and is positively related to economic growth. Government capital (GC) is positively related to growth (GDP) and significant. The key findings and results of the study suggested the existence of a positive and significant impact of human development on economic growth and development in developing countries.

On the contrary, economic growth does not necessarily reflect an improvement in HDI. Khodabakhski (2011) studied the relationship between GDP and HDI in India. The study evaluated the relationship and mutual effects among three human resource development indicators; long life, health, and education were independent variables in India's research model for 1980 to 2010. The findings revealed that even though the GDP per capita for India has shown progressive, however, HDI was very low in which the index shows a decreasing trend, as shown in Fig. 3.29.



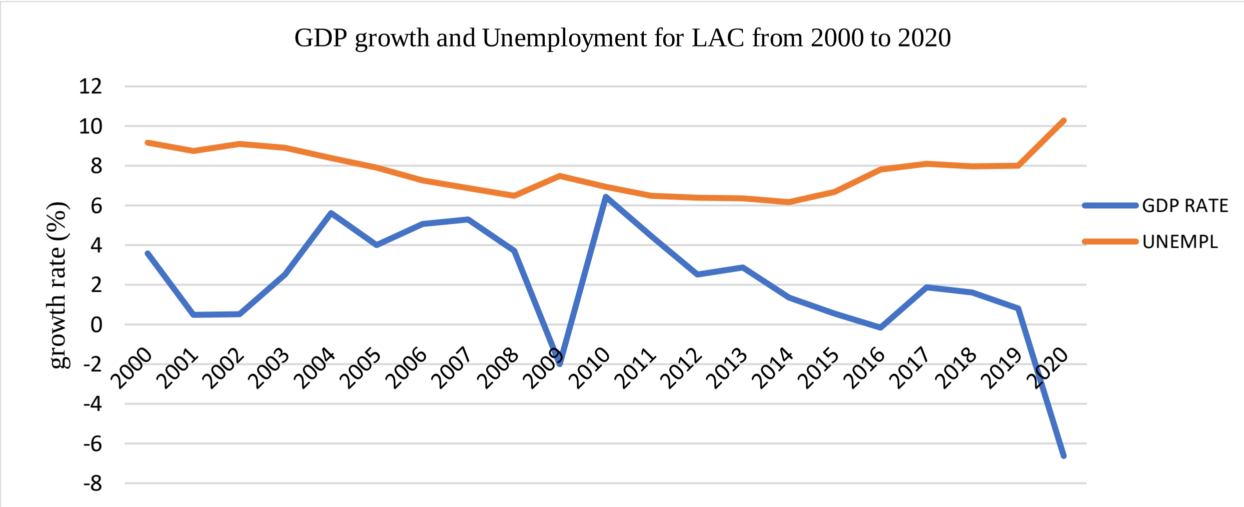
Source: CEPAL, (2021)

Fig 3.29. The GDP growth rate (%) and HDI for LAC from 2000 to 2020

3.8.7 Unemployment and the economic growth

Unemployment deters economic growth. Although it may impact economic growth, many factors affect GDP and unemployment. According to Okun's law, this relationship, history reveals that a 1 percent decrease in GDP has been associated with a slightly less than 2 percent point increase in unemployment (Sanchez and Liborio; 2012).

Several authors widely accept that the growth in the GDP of an economy increases employment and reduces unemployment in economics (Kreishan, 2010). Therefore, PCE has influenced the development of port and logistics infrastructure to support maritime traffic and transshipment activities. These investments seek to stimulate economic growth through logistics and port activities, with the long-term aim of reducing unemployment through maritime activities. Fig. 3.30 shows the GDP growth rate and unemployment. In 2020 LAC region had the lowest GDP rate of -6.6 % and unemployment of 10.28%, resulting from the Covid -19 pandemic.

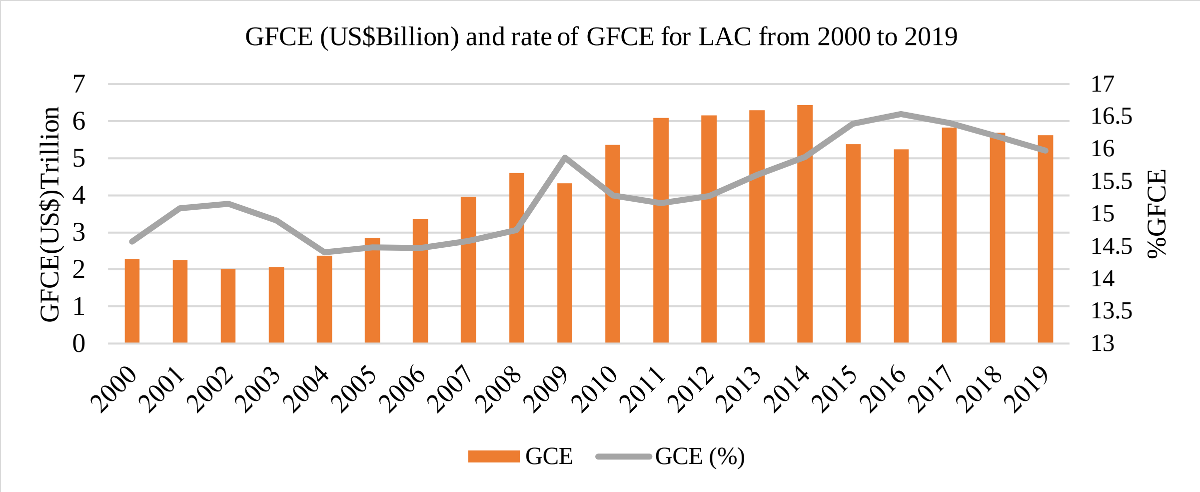


Source: CEPAL, (2021)

Fig. 3.30. The GDP growth rate (%) and unemployment (%) for LAC from 2000 to 2020

3.8.8 Government final consumption expenditure (GFCE)

Government final consumption expenditure (GFCE) - Government spending or expenditure includes all government consumption, investment, and transfer payments. In national income accounting, the acquisition by governments of goods and services for current use to directly satisfy the individual or collective needs of the community is classed as government final consumption expenditure (%GDP). It is also a percentage of GDP (World Bank, 2020; OECD, 2021). Figure 3.31; shows that from the period of 2000 to 2019. The rate of GFCE grew from 14.6 % of GDP in 2000 to 15.97% of GDP in 2019. During the pre-PCE and post-PCE era, the GFCE grew in 2011 from 15.16% of GDP to 16.54% of GDP; however, this rate steadily declined to 15.97% of GDP in 2019.



Source: World Bank, (2021)

Fig. 3.31 The GFCE (US$B) and GFCE (%) for LAC from 2000 to 2019

3.9 MODEL

3.9.1 BSTS package

BSTS package found in R was used to run the Bayesian structural time series (BSTS) model. This package uses Spike and slab prior for the regression component of the model and Kalman filter for the time series component (Chen, 2013). The Panama Canal's causal impacts, expansion on the LAC economy, and exports have been examined using the intervention evaluation under this model, which is the focus of this research.

3.9.2 Structural time series models

Two equations define a structural time series model. First, the observation equation relates the observed data y_t to a vector of latent variables α_t known as the "state."

$$y_t = Z_t^T \alpha_t + \epsilon_t \; (Observation\ equation)$$

Where α_t is vector of latent variables and Z_t is a vector of model parameters. The error term ϵ_t follows a Gaussian distribution with $\mu = 0$ and $\sigma^2 = H_t$. In addition, α_t is representing as the following

The *transition equation* describes how the latent state evolves through time.

$$\alpha_{t+1} = T_t \alpha_t + R_t \eta_t \; (Transition\ or\ state\ equation)$$

The error terms ϵ_t and η_t are Gaussian and independent of everything else. Where η_t has a Gaussian distribution with $\mu = 0$ and $\sigma^2 = Q_t$. This equation shows the update of unobserved latent variable α_t over time. T_t, and R_t are the transition matrix and structural parameter, respectively. The arrays Z_t, T_t, R_t are structural parameters. They may contain parameters in the statistical sense, but often they simply contain strategically placed 0's and 1's indicating which bits of α_t are relevant for a particular computation. Using this model, we can build time series models for short- and long-term forecasting. The term $R_t \eta_t$ allows us to incorporate state components of less than full ranks. The δ_t component is the expected increase in μ between times t and t + 1, so it can be thought of as the slope at time t .

The simplest useful model is the "local level model," in which the vector α_t is just a scalar μ_t. The BSTS is also based on general structural time series model in Equations (1) and (2) describe the state space of observed data. This provides the modeler with considerable flexibility choose components for modelling trend, seasonality, and regression. Also, we select Gaussian distribution as the prior of our BSTS model because we use the occurred frequency values from 0 to infinite [0, ∞). The following represents the basic structure of BSTS.

1) $y_t = \mu_t + \tau_t + \beta^T x_t + \varepsilon_t , \quad \varepsilon_t \sim N(0, \sigma_t^2)$

μ_t: Trend, τ_t: Seasonal, $\beta^T x_t$: regression

2) $\mu_t = \mu_{t-1} + \delta_{t-1} + u_t , \quad u_t \sim N(0, \sigma_u^2)$

3) $\tau_t = -\sum_{s=1}^{s-1} \tau_{t-s} + w_t , \quad w_t \sim N(0, \sigma_w^2)$

- y_t *is the time series that is modeling (GDP.)*
- x_t *is covariates (HDI and Unemployment)*
- μ_t *is the trend term captures the tendency of time series to move in a particular direction over time.*
- τ_t *is the seasonal terms capture association with periodic events (annual, calendar seasons).*
- $\beta^T x_t$ *is the regressors that are other time series that are predictive of the time series of interest.*

Where y_t is the GDP for each Latin American and the Caribbean (LAC) country within the three (3)sub-regions (South America, Central America, and the Caribbean) at a time (year) t, $\varepsilon_t \sim N(0, \sigma_t^2)$, $w_t \sim N(0, \sigma_w^2)$ and $V_t \sim N(0, \sigma_V^2)$ or iid standard errors (Takyi and Bentum-Ennin; 2020). The μ_t is the value of the trend at time t. w_t is the predictable increase in μ between times t and t + 1 and δ be referred to as the slope at time t (Scott et al.; 2015). And τ_t is referred to as the cyclical element, with *S* being the number of seasons. The BSTS equation estimates the Causal effect of the post-PCE occurrence difference between the observed time series of the variables GDP and two covariates HDI and Unemployment. Then the model will simulate a time series during the pre-PCE era. Thus, the causal effect of the model will at first estimate the pre-PCE period. Secondly, the model will predict the values of y_t (GDP.) then forecast for the post-PCE era. Finally, the difference between the forecasted values and the actual values data of y_t (GDP.) during the post-PCE period is interpreted as the causal impact of the economic impact of the PCE.

3.9.3 Sampling and Data Collection

Gross domestic product (GDP), Human Development Index (HDI), and rate of unemployment will be the primary data for the Bayesian Structural Time Series (BSTS) for 20 countries within Latin America and the Caribbean region. Although there are 33 Latin American and Caribbean countries, some of these countries' data were limited. Therefore, they had to be omitted from the model. Countries excluded from the model are Puerto Rico (US), Bolivia, French Guinea, Guyana, Paraguay, Suriname, Venezuela, and small Caribbean states. Please see table 3.5 for countries that are included within the model.

To achieve the objective of this paper is to determine the economic impact of the PCE. For the BSTS model, GDP will be the primary variables y_t, while covariates HDI (X_1) and rate of UNEMPL (X_2). These data were sourced from the World Bank (2020) from 2000 to 2019.

GDP = Gross domestic product (GDP) is the total monetary or market value of all the finished goods and services produced within a country's borders in a specific period. (World Bank, 2020).

GNI = Gross National Income (GNI) is the total money earned by people and businesses. It is used to measure and track a nation's wealth from year to year (World Bank, 2020).

The Human Development Index (HDI) is a statistic composite index of life expectancy, education, and per capita income indicators, used to rank countries into four tiers of human development (World Bank, 2020).

Table 3.11 L.A.C. Gross Domestic Product (GDP) and covariates Human Development Index (HDI) and unemployment (%)

LAC	Region	GDP ($ US.) Billion (Y)	HDI (X_1)	UNEMPL (%) (X_2)
Argentina	South America	$445	0.845	9.84
Bahamas	Caribbean	$13.6	0.814	10.11
Brazil	South America	$1840	0.765	11.93
Belize	Central America	$1.88	0.716	6.46
Chile	South America	$282	0.851	7.29
Cuba	Caribbean	$100	0.783	1.67
Colombia	South America	$324	0.767	9.96
Costa Rica	Central America	$61.8	0.81	11.49
Dominican Republic	Caribbean	$88.9	0.756	6.36
Ecuador	South America	$107	0.759	3.81
Honduras	Central America	$25.1	0.634	5.57
Guatemala	Central America	$76.7	0.663	2.36
Haiti	Caribbean	$14.3	0.51	13.48
Jamaica	Caribbean	$16.5	0.734	7.72
Mexico	Central America	$1270	0.779	3.48
Panama	Central America	$66.8	0.815	10.82
Peru	South America	$227	0.777	3.03
El Salvador	Central America	$27	0.673	3.96
Trinidad &Tobago	Caribbean	$24.3	0.796	3.46
Uruguay	South America	$75.9	0.817	9.34
Paraguay	South America	$116	0.728	6.60

Source: Own elaboration

CHAPTER 4

DIFFERENCE IN DIFFERENCE (DID)

4.0 RESULTS

The results on the impact of the Panama Canal expansion (PCE) on LAC regional ports were conducted using the traditional Difference in Difference (DID) equation – i.e., exactly the specification described.

$$TEUs = \alpha + \beta \text{ TreatmentPort} + \gamma \text{ PostTreatment} + \delta \text{ (TreatmentPort} \cdot \text{Posttreatment)} + \varepsilon_i$$

Where intercept (α), TreatmentPort(β), PostTreatment (γ), and Diff-in-Diff (δ) were all statistically significant at 1 %, 5%, and 10 % levels as shown in Table 4.0. The regression results for transshipment, Caribbean, Central America, and South America ports, r values were 0.41, 0.87, 0.83, and 0.31. Table 4.1, statistical description of three (3) sub-regional and transshipment hubs of 100 ports from the period 2010 to 2019; the coefficient β for the treatment (DTrp) and Control (CONTp) ports, were all statistical significance at 1 % level.

For transshipment hub ports, the estimated coefficient δ = 0.077 (statistically significant at the 10 % level) and indicates that the average container port throughput (TEU) of the DTrp increased by 20 % (170000 TEUs) more than that of non-transshipment ports within the LAC region since the PCE. For the Caribbean region, the estimated coefficient δ = 0.026 (statistically significant at the 5% level) and indicates that the average container throughput (TEU) for Treatment Ports (DTrp) decreased by 8% (140000 TEUs) less than control ports (CONTp). For the Central American region, the estimated coefficient δ = 0.087 (statistically significant at the 10 % level) and an average container throughput (TEU) increase of 12 % (280000 TEUs) than control ports (CONTp) since the PCE. For ports in the South American region, δ = 0.095 (statistically significant at the 10% level) and indicates 34.4 % (260000 TEUs) than control ports (CONTp) since the PCE.

Table 4.0 Statistical Descriptive.

Variables	Obs	Mean	Std Dev	Min	Max
Transshipment Ports	870	527308.2	765959.2	2	4379477
	Obs			Obs	
	Before				After
Control (CONTp)	390				260
Treated (DTrp)	132				88
Central America Ports	220	716259.2	1003011	2	4379477
	Before				After
Control (CONTp)	390				260
Treated (DTrp)	132				88
Caribbean Ports	210	359611.8	502276.6	6214	1891770
	Before				After
Control (CONTp)	102				65
Treated (DTrp)	24				19
South America Ports	280	758567.4	792303	59583	3904566
	Before				After
Control (CONTp)	78				52
Treated (DTrp)	90				60

Source: Own Elaboration

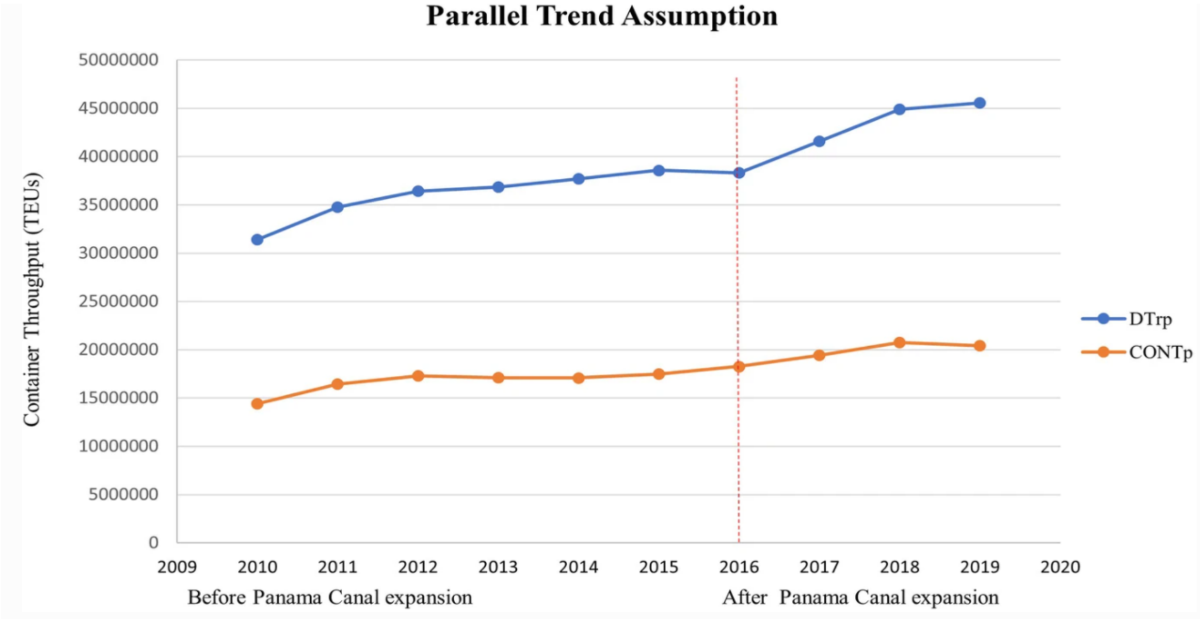
Table 4.1 Differences in Differences (DID) Regressions (2010 to 2019)

Variable	Transshipment		Caribbean C		Central America (CA)		South America (SA)	
	Before	After	Before	After	Before	After	Before	After
Control	23000	270000	130000	120000	320000	410000	270000	260000
Treated	1300000	1500000	1300000	1200000	2900000	3200000	1100000	130000
Diff (T-C)	1000000	1200000	1200000	1100000	2500000	2800000	820000	1100000
S.Err.	60000	73000	41000	48000	100000	130000	99000	120000
t	17.59	16.64	29.41	22.6	24.4	22.15	9.07	8.1
p-value	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Diff-in Diff (DID)	170000		-140000		280000		260000	
t	1.77		2.25		1.72		1.81	
p-value	0.077*		0.026**		0.087*		0.095*	
S.Err.	94000		63000		160000		260000	
R	0.41		0.87		0.83		0.35	

Note: the DID regression models for the dependent variable Y (TEUs) is average container port throughput for the four (4) variables transshipment, Caribbean, Central, and South America. The Post-treatment period (After PCE) is equal to 1, 2016, 2017, 2018, 2019. Pre-Treatment period (Before PCE) is equal to 0 in 2010, 2011, 2012, 2013, 2014, 2015. The treated port and Controlled port results were used to determine the Diff (T-C) for each "Before and After" period for transshipment and the three (3) regional ports. The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels. Source: Own Elaboration.

4.0.1 Parallel Trend Assumption test

The Parallel Trend Assumption (PTA) was used to test the model's validity to ensure no biased estimation of causal effects (Fredriksson and Oliveria, 2019). A validity check compares changes to the treatment and comparison group's changes before and after the program (Columbia Public Health, 2019; McKenzie, 2021). Table 3.2 was used to classify the LAC ports into treatment (DTrp) and control (CONTp) groups from 2010 to 2019. Pre-treatment period "Before" and "After" the PCE. Figure 4.0 shows that in 2016, there were increases in container port throughput (TEUs) from 2017 to 2019 for the total summation of Treatment Ports (DTr_p), while for the Control Ports ($CONT_p$) constant trend was seen during those periods. Therefore, the parallel trend assumption holds for the Treated Ports (DTrp) and Control Ports ($CONT_p$) because the Container throughput moves in tandem with each other until 2016, rapid growth container throughput (TEUs) was observed from that period to 2019 for the treated ports (DTrp).



Note: For 2010–2015, classified as the era "before" and "after" PCE. The DTrp showed that after the completion, TEU volumes increased. Source: Own Elaboration.

Fig. 4.0. This visual inspection satisfies the Parallel Trend Assumption (PTA).

STOCHASTIC FRONTIER ANALYSIS (SFA)

4.1 RESULTS

The results for TE were derived from the SF model for the period 2010 to 2018; as shown in Table 4.2, the TE of ports in LAC ranged from 43.3 to 100 percent. Port of Colon (Panama), Balboa (Panama), El Callo (Peru), Guayaquil (Ecuador) and San Juan (Puerto Rico) were 100 %. South American ports consisted of Santos (72%), Cartagena (87.5%), El Callo (100%), Guayaquil (100%), Buenos Aires, (54.5%), San Antonio (43.3%) Itajai (84.1%) and Valparaiso (58.5%). For Central America, the TE results were Port of Colon (100%), Balboa (100%), Manzanillo (85.4%), Limon Moin (74.2%), and Altamira (55.1%). For Caribbean Ports, TE were Kingston (60%), San Juan (100%), and Caucedo (66.7%).
Table 4.3 shows Stochastic Frontier analysis results for the 19 LAC ports for Output variables: Berth length (B_{it}), Area of port *(*A_{it}*), Cranes (*C_{it}*)*, and Number of Berths *(*Q_{it}*)* were all statistically significant at 1 percent with the following coefficient, -0.0622, 0.0621, 0.2719, and 0.0148, respectively with log-likelihood was 3.8095.

Table 4.2: Technical efficiency results for the 19 LAC ports. Period 2010-2018.

RANK	PORT/COUNTRY	TECHNICAL EFFICIENCY (%)
1	Colon, Panama	*100*
2	Santos, Brazil	*72*
3	Manzanillo, Mexico	*85.4*
4	Cartagena, Colombia	*87.5*
5	Balboa, Panama	*100*
6	El Callo, Peru	*100*
7	Guayaquil, Ecuador	*100*
8	Kingston, Jamaica	*60*
9	Buenos, Aires, Argentina	*54.5*
10	San Antonio, Chile	*43.3*
11	San Juan, Puerto Rico	*100*
12	Buenaventura, Colombia	*50.8*
13	Caucedo, Dominican Republic	*66.6*
14	Limon Moin, Costa Rica	*74.2*
15	Veracruz, Mexico	*70.6*
16	Freeport, Bahamas	*98.5*
17	Itajai, Brazil	*84.1*
18	Valparado, Chile	*58.5*
19	Altamica, Mexico	*55.1*

Source: Own elaboration

Table 4.3: Estimation of stochastic production frontier.

Variable	Parameter	Coefficient	Standard Error
Constant	β_0	13.17*	5.77E-06
B_{it} (Berth length)	β_1	-0.0622*	0.0000188
A_{it} (Area of Port)	β_2	0.0621*	3.24E-06
C_{it} (Cranes)	β_3	0.2719*	3.29E-06
Q_{it} (Number of Berths)	β_4	0.0148*	2.62E-04

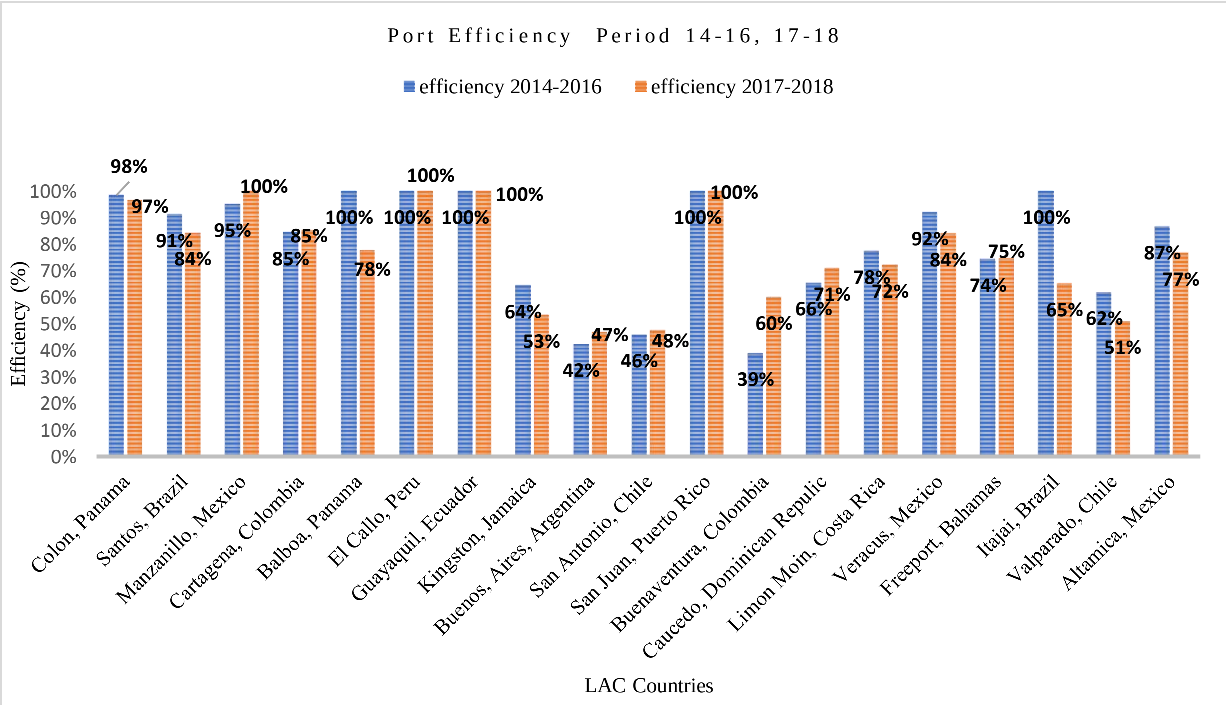
* Significant at 1 %   ** Significant at 5%

Source: Own elaboration.

The SFA model also revealed that the most TE container terminals are Colon, Balboa, El Callo, Guayaquil, and San Juan; these ports have a TE of 100 percent. The port of San Antonio recorded the lowest TE at 43.3 percent. The TE results for transhipment ports within the region, Colon (100%), Santos (72%), Balboa (100%), Cartagena (87.5%), Freeport (98.5%), Caucedo (66.6%) and Kingston (60%).

4.1.1 Pre and Post PCE Era

Fig.4.1 showed that during the pre and post- PCE era, 2014 to 2016 (Before) and 2017 to 2018 (After). The result shows El Callo, Guayaquil, and San Juan maintained 100% TE. Ports that have improved TE percentages were Manzanillo (95 to 100), San Antonio (46 to 48), Buenos Aires (42 to 47), Buenaventura (39 to 60), Caucedo (66 to 71) and Freeport (74 to 75). Declined TE; Colon (98 to 97), Santos (91 to 41), Balboa (100 to 78), Kingston (64 to 53), Itajai (100 to 65), Valparado (62 to 51) and Altamira (87 to77).



Source: Own elaboration.

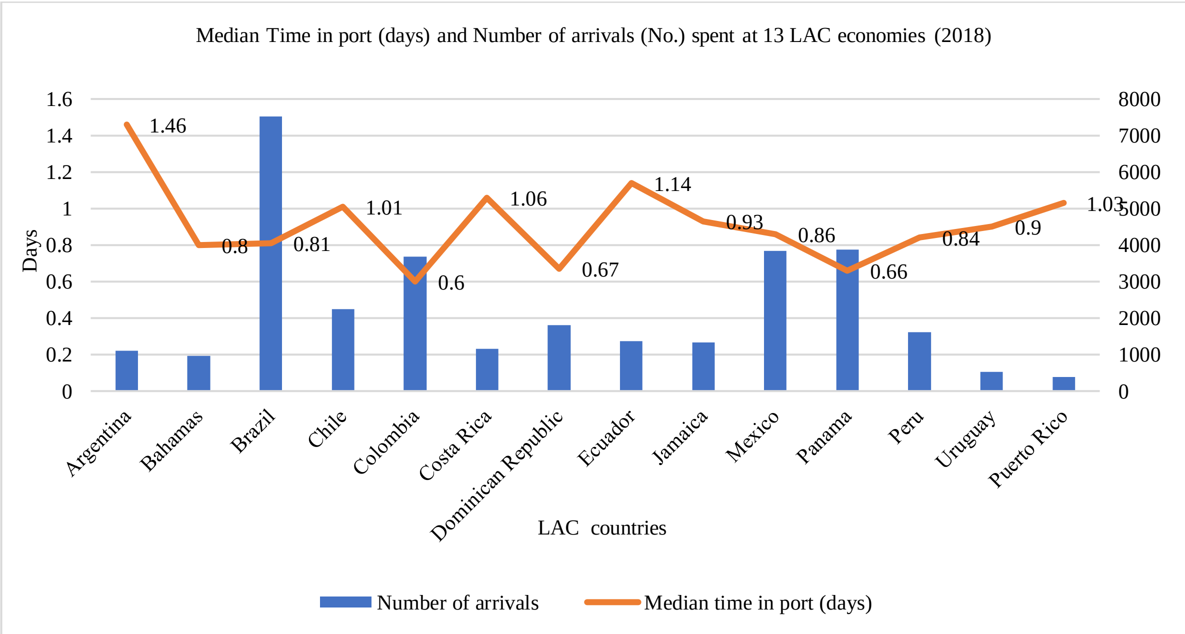
Fig 4.1. Technical efficiency (Period 2014-2016, 2017-2018).

The regional assessment shown in Table 4.4 reveals that the average TE for South American ports has increased from 72 to 75 percent for the pre- and post-expansion era. Conversely, Central American ports and Caribbean ports experience a reduction in TE. For example, central America had a percentage drop from 92 to 85 while, Caribbean ports experience a 1 percent reduction in TE percentage.

Table 4.4: Mean Technical Efficiency per Region, Pre and Post expansion era.

Region	Mean Technical Efficiency (TE) (2010-2018)	Pre	Post
South America	72%	72%	75%
Central America	92%	92%	85%
Caribbean	70%	76%	75%

Source: Own elaboration.



Source: UNCTAD 2020

Fig.4.2. Median Time at port and vessel arrivals for 13 LAC countries

Fig. 4.2 shows the median Time spent and the number of vessel arrivals. Colombia, Panama, and Dominican Republic (DR) recorded the lowest Time for ships at the port; 0.6, 0.66, and 0.67, respectively. Conversely, Argentina, Ecuador, and Costa Rica have recorded the highest time delay at 1.46, 1.14, 1.06, respectively. For transshipment port countries, Colombia's median Time was lowest at 0.6, followed by Panama at 0.66.

HIERARCHICAL LINEAR MODEL (HLM)

4.2 RESULT

4.2.1 Analysis and Findings

Table 4.5 shows the correlation among the variables using Pearson's correlation from Stata and R software. The Logistics variables show a strong correlation between each other; therefore, Hierarchica l Linear Model (HLM) was appropriate for regressing each variable based on individual block/model. The correlation results for the Export reveal all LPI components were statistically significant, displaying a positive relationship to export except for LP-Cust, which was a statistically significant but negative relationship to Export. The Pearson Correlation results show that for Export (Exp), a positive correlation was observed for economic variables such as Gross Domestic Product (GDP), Freedom of Trade (TRFR), Industrial Index (IND), and Foreign Direct Investment (FDI). For the Overall Logistics, there is a positive correlation between Gross Domestic Product (GDP), Freedom of Trade (TRFR), Industrial Index (IND), and Foreign Direct Investment (FDI).

For table 4.6, in the year 2010, the hierarchical multiple regression revealed that model 4, Infrastructure (LP-Infra) and Quality of Logistics Services (QLS), contributes significantly to the HLM regression model, F (1,12) = 3.646 and R^2 difference (ΔR^2) between Model 4 and Model 3 accounts for 1.9% of variations in Exports. For the year 2012, all LPI components were insignificant for the six models. However, for model 1, economic variables such as Gross Domestic Product (GDP), Trade Freedom (TRFR), and Foreign Direct Investment (FDI) were statistically significant with coefficients 3.404, 30.79, and -1.886, respectively. For the year 2014, the HLM results show that Quality of Logistics Service (QLS), Trace and Trace (TT), and Timeline (TL) were all statistically significant at 0.01, F(1,10) = 5.672 and R^2 difference (ΔR^2) models 6 and 5 accounts for 5.2% variations in Exports at a p-value of 0.036. For the year 2016, model 2, Customs (LP-CUST) was statistically significant, F(1,14) = 5.176 and R^2 difference (ΔR^2) between Model 2 and Model 1 account for 10.1% of variations in Exports. Finally, for the year 2018, the LP-CUST was statistically significant, F(1,14) = 4.640, and R^2 difference (ΔR^2) models 2 and 1 accounts for 7.0% variations in Exports.

Table 4.7 shows the relationship between LPI components on Export for income classification; High income, Upper Middle, and Low-income countries. The HLM results revealed that for High-income countries, LP-CUST was significant at 0.095, F(5,19) = 49.199, and R^2 difference (ΔR^2) between Model 2 and Model 1 account for 1.2% of variations in Exports. However, in upper-middle-income and Lower-income countries in LAC, all components of the LPI were insignificant. However, economic variable, for Upper middle income, IND was significant at 0.05 % level, and for the lower-income, foreign Direct Investment (FDI) was significant at 0.05% with a coefficient of 0.2535.

Table 4.8 reveals the Pre and Post PCE Era regarding the relationship between export and logistics performance. The HLM revealed that for the Pre-PCE Era through the years 2010, 2012, and 2014, LP-CUST was statistically significant at 0.043, F(5,54) = 54.444, and R^2 difference (ΔR^2) between Model 2 and Model 1 account for 1.3% of variations in Exports. Trade Freedom also had a significant relationship with exports among LAC countries. The post PCE era from HLM revealed that customs was statistically significant at 0.01 level, F(5,34) = 20.506, and R^2 difference (ΔR^2) between Model 2 and Model 1 account for 8.3 % of variations in Exports. For the overall logistics performance for the LAC during the Pre and Post-Era. The results revealed that the overall logistics performance relationship to exports was insignificant during the pre-Pce era. However, Trade Freedom (TRFR) during that period was most significant to export. The Post Pce era for the overall logistics performance was statistically significant at 0.004, F(5,34) = 19.477, and R^2 difference (ΔR^2) between Model 2 and Model 1 account for 7.3% of variations in Exports.

Table 4.5. Correlation within variables

LOG	Exp	OLPI	LPCUST	LPINFRA	LPQLS	LPTT	LPTL	GDP	TRFR	FDI	IND
Exp	1										
OLPI	0.1542	1									
LPCUST	-0.0081	0.8211***	1								
LPINFRA	0.1234	0.9332***	0.7773***	1							
LPQLS	0.1648*	0.9237***	0.7486***	0.8934***	1						
LPTT	0.1713*	0.8937***	0.6452***	0.8047***	0.7926***	1					
LPTL	0.1685*	0.8237***	0.5315***	0.7018***	0.6651***	0.7615***	1				
GDP	0.5050***	0.5618*	0.2788	0.6002***	0.5552***	0.5618***	0.4957***	1			
TRFR	0.7161***	0.0486	0.0637	-0.0367	0.0401	-0.247	0.0806	0.1057	1		
FDI	0.4305***	0.6292*	0.4080	0.6679***	0.6133***	0.6188***	0.4953***	0.8914**	0.1444	1	
IND	0.6812***	0.1530***	0.1180	0.1123	0.1649	0.0805	0.1757*	0.3083***	0.5850*	0.1788*	1

Source: Own elaboration

Table 4.6. Hierarchical linear model (HLM) Exports for LAC (2010, 2012, 2014, 2016, 2018)

Year	Model	R^2	F(df)	P	R^2 change	F(df) change	p
2010	*1*	*0.901*	*34.229(4,15)*	*0.000*			
	2	*0.906*	*26.870(5,14)*	*0.000*	*0.004*	*0.648(1,14)*	*0.433*
	3	*0.919*	*24.665(6,13)*	*0.000*	*0.014*	*2.193(1,13)*	*0.161*
	4	*0.938*	*25.966(7,12)*	*0.000*	*0.019*	*3.646(1,12)*	*0.079**
	5	*0.939*	*21.124(8,11)*	*0.000*	*0.001*	*0.147(1,11)*	*0.708*
	6	*0.940*	*17.418(9,10)*	*0.000*	*0.001*	*0.192(1,10)*	*0.670*
	*GDP (3.418) *** TRFR (32.42) *** Infra (-7.212) ** QLS (3.051) **				*N = 20*		
2012	*1*	*0.906*	*36.319(4,15)*	*0.000*			
	2	*0.908*	*27.518(5,14)*	*0.000*	*0.001*	*0.187(1,14)*	*0.672*
	3	*0.912*	*22.524(6,13)*	*0.000*	*0.005*	*0.682(1,13)*	*0.423*
	4	*0.914*	*18.212(7,12)*	*0.000*	*0.002*	*0.240(1,12)*	*0.632*
	5	*0.914*	*14.645(8,11)*	*0.000*	*0.000*	*0.026(1,11)*	*0.875*
	6	*0.916*	*12.102(9,10)*	*0.000*	*0.002*	*0.206(1,10)*	*0.659*
	*GDP (3.404) *** TRFR (30.79) *** FDI (-1.886) **					*N = 20*	
2014	*1*	*0.757*	*11.674(4,15)*	*0.000*			
	2	*0.772*	*9.494(5,14)*	*0.000*	*0.015*	*0.945(1,14)*	*0.346*
	3	*0.773*	*7.382(6,13)*	*0.001*	*0.001*	*0.048(1,13)*	*0.829*
	4	*0.786*	*6.297(7,12)*	*0.003*	*0.013*	*0.725(1,12)*	*0.410*
	5	*0.857*	*8.210(8,11)*	*0.001*	*0.071*	*5.409(1,11)*	*0.038***
	6	*0.908*	*11.028*	*0.000*	*0.052*	*5.672(1,10)*	*0.036***
	*TRFR (27.79) *** QLS (-6.960) ** LPTT (6.872) ** LPTL (-3.653) ***					*N = 20*	
2016	*1*	*0.627*	*6.298(4,15)*	*0.004*			
	2	*0.728*	*7.476(5,14)*	*0.001*	*0.101*	*5.176(1,14)*	*0.038***
	3	*0.735*	*6.006(6,13)*	*0.003*	*0.007*	*0.360(1,13)*	*0.558*
	4	*0.775*	*5.893(7,12)*	*0.004*	*0.040*	*2.118(1,12)*	*0.169*
	5	*0.781*	*4.899(8,11)*	*0.009*	*0.006*	*0.311(1,11)*	*0.588*
	6	*0.783*	*4.014*	*0.021*	*0.002*	*0.109(1,10)*	*0.748*
	*IND (11.669) ** LPCUST (-2.206) ***				*N = 20*		
	1	*0.718*	*9.564(4,15)*	*0.000*			

Year	Model	R^2	F(df)	P	R^2 change	F(df) change	p
2018	2	0.788	10.436(5,14)	0.000	0.070	4.640(1,14)	0.048**
	3	0.820	9.895(6,13)	0.000	0.032	2.310(1,13)	0.151
	4	0.835	8.705(7,12)	0.001	0.015	1.102(1,12)	0.313
	5	0.837	7.056(8,11)	0.002	0.001	0.098(1,10)	0.760
	6	0.845	6.060(9,10)	0.005	0.008	0.526(1,10)	0.484
	*TRFR (14.91) ** IND (10.41) ** LPCUST (-2.56) ***					*N = 20*	

Note: *** p <0.01, ** p <0.05, * p <0.1. Model 1 uses the general OLPI index (overall); model 2 uses the LPI Customs index; model 3 uses the LPI Infrastructure; model 4 uses the LPI Quality of Logistics Services index; Model 5 uses the LPI Tracking& Tracing index; Model 6 uses the LPI Timeliness. Source: own elaboration.

Table 4.7. Hierarchical linear model (HLM) Exports per Income classification

Year	*Model*	R^2	*F(df)*	*P*	R^2 *change*	*F(df) change*	*p*
High-Income LAC	1	0.917	55.030(4,20)	0.000			
	2	0.928	49.199(5,19)	0.000	0.012	3.072(1,19)	0.095*
	3	0.932	40.939(6,18)	0.000	0.003	0.902(1,18)	0.354
	4	0.933	33.948(7,17)	0.000	0.002	0.386(1,17)	0.542
	5	0.938	30.169(8,16)	0.000	0.005	1.181(1,16)	0.292
	6	0.942	27.137(9,15)	0.000	0.004	1.117(1,15)	0.306
	*TRFR (25.07) *** FDI (2.811) ** IND (11.982) ** LPCUST (-2.074) **					*N =25*	
Upper-middle -Income LAC	1	0.967	351.577(4,45)	0.000			
	2	0.969	272.099(5,44)	0.000	0.001	2.089(1,44)	0.155
	3	0.970	232.702(6,43)	0.000	0.001	2.088(1,43)	0.156
	4	0.970	194.904(7,42)	0.000	0.000	0.018(1,42)	0.895
	5	0.970	166.568(8,41)	0.000	0.000	0.021(1,41)	0.886
	6	0.972	153.486(9,40)	0.000	0.002	2.428(1,40)	0.127
	*GDP (0.8732) *** IND (0.482) ***					*N = 50*	
Lower-middle -Income LAC	1	0.928	64,064(4,20)	0.000			
	2	0.931	50.918(5,19)	0.000	0.003	0.807(1,19)	0.380
	3	0.931	40.672(6,18)	0.000	0.001	0.197(1,18)	0.662
	4	0.939	37.226(7,17)	0.000	0.007	2.068(1,17)	0.168
	5	0.939	30.720(8,16)	0.000	0.000	5.409(1,16)	0.862
	6	0.939	25.601(9,15)	0.000	0.000	5.672(1,15)	0.989
	*GDP (0.9885) *** FDI (0.2535) ****					*N =25*	

Note: *** p <0.01, ** p <0.05, * p <0.1. Model 1 uses the general OLPI index (overall); model 2 uses the LPI Customs index; model 3 uses the LPI Infrastructure; model 4 uses the LPI Quality of Logistics Services index; Model 5 uses the LPI Tracking& Tracing index; Model 6 uses the LPI Timeliness. Source: own elaboration.

Table 4.8. Hierarchical Linear Model (HLM) for Exports during the Pre and Post Era

Year	Model	R^2	F(df)	P	R^2 change	F(df) change	p
Pre-PCE Era (2010,2012,2014)	1	0.821	63.216(4,55)	0.000			
	2	0.834	54.444(5,54)	0.000	0.013	4.278(1,54)	0.043**
	3	0.835	44.659(6,53)	0.000	0.000	0.128(1,53)	0.722
	4	0.835	37.567(7,52)	0.000	0.000	0.011(1,52)	0.916
	5	0.842	34.066(8,51)	0.000	0.007	2.413(1,51)	0.126
	6	0.849	31.310(9,50)	0.000	0.007	2.303(1,50)	0.135

	*GDP (1.644) *** TRFR (25.335) *** LPCust (-1.112) ***					*N = 60*	
Post-PCE Era (2016,2018)	*1*	*0.668*	*17.625(4,35)*	*0.000*			
	2	*0.751*	*20.506(5,34)*	*0.000*	*0.083*	*11.295(1,34)*	*0.002****
	3	*0.751*	*16.614(6,33)*	*0.000*	*0.000*	*0.043(1,33)*	*0.838*
	4	*0.751*	*13.819(7,32)*	*0.000*	*0.000*	*0.016(1,32)*	*0.900*
	5	*0.754*	*11.890(8,31)*	*0.000*	*0.003*	*0.350(1,31)*	*0.558*
	6	*0.768*	*11.034(9,30)*	*0.000*	*0.014*	*1.783(1,30)*	*0.192*
	*TRFR (15.481) *** IND (11.172) *** LPCust (-2.261) ****					*N = 40*	
Pre-PCE Era (OLPI)	*1*	*0.821*	*63.219(4,55)*	*0.000*			
	2	*0.826*	*51.148(5,54)*	*0.000*	*0.004*	*1.333(1,54)*	*0.253*
	*GDP (2.019) *** TRFR (25.91) ****					*N = 60*	
Post-PCE Era (OLPI)	*1*	*0.668*	*17.625(4,35)*	*0.000*			
	2	*0.741*	*19.477(5,34)*	*0.000*	*0.073*	*9.588(1,34)*	*0.004*
	*GDP (1.306) *** TRFR (15.733) ** IND (10.870) *** OLPI (-2.312) ****					*N = 40*	

Note: *** p <0.01, ** p <0.05, * p <0.1. Model 1 uses the general OLPI index (overall); model 2 uses the LPI Customs index; model 3 uses the LPI Infrastructure; model 4 uses the LPI Quality of Logistics Services index; Model 5 uses the LPI Tracking& Tracing index; Model 6 uses the LPI Timeliness. Source: own elaboration.

BAYESIAN STRUCTURAL TIME SERIES (BSTS)

4.3 RESULTS

In this section, we will discuss the results of both the Bayesian posterior estimates and the Bayesian posterior distribution graphs for the causal effect of the PCE on the Gross Domestic Product (GDP) for each of the 21 countries within the LAC region.

The absolute effects from posterior estimates for each country within the three (3) sub-regions will be discussed in this section.

4.3.1 Central America

As shown in Table 4.9, in Panama during the post-PCE-era, the economic performance (GDP) had an average of approximately US$ 64.72 Billion. However, if the expansion had not taken place, then the expected average (predicted) would be US$56.10 Billion with a 95% confidence interval of this counterfactual prediction of [US$41.15Billion, US$71.32Billion]. This effect was US$8.61 Billion with a 95% interval [-6.40B, 24.57B]. Thus, in relative terms, GDP performance increased by approximately 15% percent with a 95% interval [-11%, 42%]. However, this positive effect observed during the PCE Neo-Panamax was statistically insignificant.

Table 4.9. Results of posterior estimates (Inference) of the PCE on Central America Economic (GDP)

Central America	Average Actual	Prediction (s.d)	Absolute effect (s.d.)	Relative effect (s.d.)	Posterior tail-area probability
Panama	6.5e+10	5.6e+10 (7.6e+09) [4.1e+10, 7.1e+10]	8.6e+09 (7.6e+09) [-6.4e+09, 2.4e+10]	15% (14%) [-11%, 42%]	0.122
El Salvador	2.6e+10	2.2e+10 (8.5e+08) [2.0e+10, 2.4e+10]	4.1e+09 (8.5e+08) [2.3e+09, 5.7e+09]	18% (4%) [11%, 27%]	0.001**
Mexico	1.2e+12	1.2e+12 (6.6e+10) [1.1e+12, 1.3e+12]	2.5e+10 (6.6e+10) [-9.9e+10, 1.5e+11]	2.1% (5.6%) [-8.3%, 13%]	0.356
Honduras	2.4e+10	2.2e+10 (1.1e+09) [2.0e+10, 2.4e+10]	2.4e+09 (1.1e+09) [2.1e+08, 4.6e+09]	11% (5.2%) [0.95%, 21%	0.018**
Guatemala	7.4e+10	6.6e+10 (4.2e+09) [5.8e+10, 7.4e+10]	7.4e+09 (4.2e+09) [-5.7e+08, 1.6e+10]	11% (6.4%) [-0.86%, 24%]	0.035**
Costa Rica	6.0e+10	5.6e+10 (3.4e+09) [4.9e+10, 6.3e+10]	4.1e+09 (3.4e+09) [-2.4e+09, 1.1e+10]	7.4% (6%) [-4.3%, 20%]	0.112
Belize	1.9e+09	1.7e+09 (8.6e+07) [1.5e+09, 1.9e+09]	1.6e+08 (8.6e+07) [-3078306, .4e+08]	9.6% (5%) [-0.18%, 20%]	0.029**

Note: The values in the brackets show 95 % confidence interval, while those in the parentheses are standard deviations. ** represent 5% significance level and p stands for Posterior tail-area probability.

Conversely, in El Salvador, as shown in Table 4.9, during the post-PCE-era, the economic performance had an average of approximately US$ 26.04 Billion. The predicted value is US$22 Billion with a 95% interval [20.1B, 24.3B]. In relative terms, GDP performance increased approximately 18% percent with a 95% interval of this percentage is [11%, 27%]. This positive causal effect was statistically significant at a 5% level, and a posterior tail-area probability value of 0.001 indicates a 0.1% chance that the PCE would have a negative effect on the GPD performance in El Salvador.

For the post-PCE-era, Mexico's GDP average of approximately US$ 1216.67 Billion. The predicted value is US$1200 Billion with a 95% interval [1.1e+12, 1.3e+12]. In relative terms, GDP performance increased approximately 2.1% at a 95% conference interval [11%, 27%]. However, the positive causal effect was statistically insignificant.

For Honduras, during the post-PCE-era, both the economic performance average of approximately US$ 24.09 Billion. In relative terms, GDP performance increased approximately by 11% with a 95% interval [0.95%, 21%]. The probability of obtaining this effect by chance is very small (Bayesian one-sided tail-area probability p = 0.018). This causal effect can be considered statistically significant.

For Guatemala, as shown in Table 3, the average GDP was US$74 Billion. The predicted value was US$66.01 Billion with 95% confidence interval [5.8e+10, 7.4e+10]. In relative terms, the economic performance was 11% with a 95% confidence interval [-0.86%, 24%]. The causal effect was statistically significant with a posterior tail-area probability of 0.035 or 3.5%.

Costa Rica, during the post-PCE-era, the economic an average of approximately US$ 60.28 Billion. Although, causal effects were positive with a relative effect of 7.4 % with a 95%

confidence interval [-4.3%, 20%]. However, this effect is not statistically significant and so cannot be meaningfully interpreted.

Belize during the post-PCE-era, GDP average approximately US$1.8 Billion. The relative effect for GDP was 9.6% [-0.18%, 20%]. With the posterior tail-area probability of 0.029 or 2.9%, the causal effect was also statistically significant at a 5% level.

4.3.2 South America

As shown in Table 4.10, Only Brazil positively affected economic performance during the post-PCE-era for South American countries. In relative terms, GDP increased 27% was statistically significant at the 5% level with a posterior tail-area probability of 0.024, indicating a 2.4% chance that the PCE would negatively affect the economic performance. However, causal effects were positive but statistically insignificant in Argentina, Chile, Colombia, Ecuador, Peru, Paraguay, and Uruguay.

Table 4.10. Results of posterior estimates (Inference) of the PCE on South America Economic (GDP.)

	Average				
South America	Actual	Prediction (s.d)	Absolute effect (s.d.)	Relative effect (s.d.)	Posterior tail-area probability
Argentina	5.4e+11	5.6e+11 (4.2e+10) [4.9e+11, 6.5e+11]	-2.9e+10 (4.2e+10) [-1.1e+11, 5.1e+10]	-5.1% (7.4%) [-20%, 9%]	0.252
Brazil	1.9e+12	1.5e+12 (1.9e+11) [1.2e+12, 1.9e+12]	4.1e+11 (1.9e+11) [3.9e+10, 7.7e+11]	27% (13%) [2.6%, 51%]	0.024**
Chile	2.9e+11	2.7e+11 (1.3e+10) [2.4e+11, 2.9e+11]	1.9e+10 (1.3e+10) [-8.0e+09, 4.3e+10]	6.9% (5%) [-3%, 16%]	0.089
Colombia	3.2e+11	3.2e+11 (2.8e+10) [2.7e+11, 3.7e+11]	5.5e+09 (2.8e+10) [-4.8e+10, 5.7e+10]	1.7% (8.7%) [-15%, 18%]	0.425
Ecuador	1.1e+11	9.8e+10 (5.6e+09) [8.7e+10, 1.1e+11]	8.6e+09 (5.6e+09) [-2.3e+09, 1.9e+10]	8.8% (5.7%) [-2.3%, 20%]	0.066
Peru	2.2e+11	2.1e+11 (1.6e+10) [1.1e+10, 1.3e+10]	3.8e+08 (6.1e+08) [-7.7e+08, 1.6e+09]	3.2% (5.2%) [-6.6%, 13%]	0.271
Paraguay	1.2e+10	1.2e+10 (5.9e+08) [1.1e+10, 1.3e+10]	3.8e+08 (5.9e+08) [-7.3e+08, 1.5e+09]	3.2% (5.1%) [-6.3%, 13%]	0.252
Uruguay	6.1e+12	6.1e+12 (3.0e+11) [5.5e+12, 6.7e+12]	4.1e+10 (3.0e+11) [-5.5e+11, 6.1e+11]	0.68% (4.9%) [-9%, 10%]	0.441

Note: The values in the brackets show 95 % confidence interval, while those in the parentheses are standard deviations. ** represent 5% significance level and p stands for Posterior tail-area

Argentina during the post-PCE-era, the economic performance had an average of approximately US$ 535.67 Billion. This effect was US$-29.60 Billion with a 95% interval of [-1.1e+11, 5.1e+10]. In relative terms, GDP performance decreased by approximately 5.1% percent. The 95% interval of this percentage was [-20%, 9%]. Although the intervention appears to have caused a positive effect, this effect is not statistically significant when considering the entire post-intervention period. Also, the posterior tail-area probability value of 0.252 indicates a 25.2% chance that the PCE would positively affect the GPD performance in Argentina.

Brazil, during the post-PCE-era, the economic performance had an average of approximately US$ 1930.00 Billion. This effect is US$410 Billion with a 95% interval of [3.9e+10, 7.7e+11]. In relative terms, GDP performance increased approximately 27% percent. The 95% interval of this percentage is [2.6%, 51%] which was statistically significant. Also, the posterior tail-area probability value of 0.024 indicates a 2.4% chance that the PCE would have a negative effect on the GPD performance in Brazil.

For Chile, the economic performance had an average of approximately US$ 285.67 Billion. This effect is US$19.1 Billion with a 95% interval of [-8.0e+09, 4.3e+10]. In relative terms, GDP performance increased approximately 6.9% [-3%, 16%]; however, this effect is not statistically significant when considering the entire post-intervention period.

Colombia during the post-PCE-era, the economic performance had an average of approximately US$ 323.33 Billion. This effect is US$ 5.49 Billion with a 95% interval of [-47.97B, 57.13B]. In relative terms, GDP performance increased approximately 2% percent. The 95% interval of this percentage is [-15%, +18%]. although the intervention appears to have caused a positive effect. However, this effect is not statistically significant when considering the entire post-intervention period.

During the post-PCE-era, Ecuador's economic performance had an average of approximately US$ 110.33 Billion. This effect is US$ 8.60 Billion with a 95% interval of [-2.3e+09, 1.9e+10]. In relative terms, GDP performance increased approximately 8.8% percent with a 95% interval of this percentage is [-2.3%, 20%]. However, the intervention appears to have caused a positive effect. However, this effect is not statistically significant when considering the entire post-intervention period. Also, the posterior tail-area probability value of 0.066 indicates a 6.6% chance that the PCE would have a negative effect on the GPD performance in Ecuador.

Peru during the post-PCE-era, the economic performance had an average of approximately US$ 220.00 Billion. This effect is US$ 380 Million with a 95% interval of [-7.7e+08, 1.6e+09]. In relative terms, GDP performance increased approximately 3.2% with a 95% interval of this percentage is [-6.6%, 13%]. This effect is not statistically significant when considering the entire post-intervention period. Also, the posterior tail-area probability value of 0.271 indicates a 27.1% chance that the PCE would have a on the GPD performance in Peru.

The economic performance for Paraguay had an average of approximately US$ 12.07 Billion. This effect is US$ 380.3 Million with a 95% interval of [-7.3e+08, 1.5e+09]. In relative terms, GDP performance increased approximately 3.2% percent. The 95% interval of this percentage is [-6.3%, 13%]. However, this effect is not statistically significant when considering the entire post-intervention period.

Uruguay during the post-PCE-era, the economic performance had an average of approximatel y US$ 6141.40 Billion. This effect is US$ 41 Billion with a 95% interval of [-5.5e+11, 6.1e+ 11]. In relative terms, GDP performance increased approximately 0.64% percent. The 95% in terval of this percentage is [-9%, 10%]. However, this effect is not statistically significant wh en considering the entire post-intervention period

4.3.3 the Caribbean

Table 4.11 showed that all Caribbean countries within the BSTS model; Cuba, Dominican Republic (DR), Jamaica, and The Bahamas, show positive statistical significance for both GDP and export except for Haiti and Trinidad & Tobago (TT), which revealed negative effect with only TT being valued was statistical significance. The positive effect on GDP observed during the PCE and advent of Neo-Panamax is statistically significant at a 5% level of significance for Cuba, Dominican Republic, Jamaica, and the Bahamas, showing positive effects 38%, 10%, 9.8%, and 9.2% respectively.

Table 4.11. Results of posterior estimates (Inference) of the PCE on Caribbean Economic (GDP).

	Average				
Caribbean	Actual	Prediction (s.d)	Absolute effect (s.d.)	Relative effect (s.d.)	p-value
Cuba	9.90E+10	7.1e+10 (5.5e+09)	2.7e+10 (5.5e+09)	38% (7.7%)	0.001**
		[6.1e+10, 8.2e+10	[1.7e+10, 3.8e+10]	[23%, 53%]	
Dominican Republic	8.5e+10	7.7e+10 (4.5e+09)	7.7e+09 (4.5e+09)	10% (5.9%)	0.050**
		[6.9e+10, 8.7e+10]	[-2e+09, 1.6e+10]	[-2.6%, 21%]	
Haiti	1.5e+10	1.6e+10 (6.9e+08)	-1.1e+09 (6.9e+08)	-6.6% (4.3%)	0.052
		[1.5e+10, 1.7e+10]	[-2.5e+09, 2.3e+08]	[-15%, 1.4%]	
Jamaica	1.6e+10	1.4e+10 (2.7e+08)	1.4e+09 (2.7e+08)	9.8% (1.9%)	0.001**
		[1.4e+10, 1.5e+10]	[8.8e+08, 1.9e+09]	[6.1%, 13%]	
Trinidad &Tobago	2.4e+10	2.6e+10 (1.4e+09)	-2.7e+09 (1.4e+09)	-10% (5.5%)	0.031**
		[2.3e+10, 2.9e+10]	[-5.4e+09, 6.0e+07]	[-20%, 0.23%]	
Bahamas	1.3e+10	1.2e+10 (2.9e+08)	1.1e+09 (2.9e+08)	5.7% (2.7%)	0.025**
		[1.1e+10, 1.2e+10]	[5.6e+08, 1.7e+09]	[0%, 11%]	

Note: The values in the brackets show 95 % confidence interval, while those in the parentheses are standard deviations. ** represent 5% significance level and p stands for Posterior tail-area probability.

Cuba, during the post-PCE-era, the economic performance had an average of approximately US$ 98.95 Billion. This effect is US$27.22 Billion with a 95% interval of [-1.05B, 18.41B]. Thus, in relative terms, GDP performance increased approximately 38% percent with 95% interval of [23%, 53%]. This positive effect observed during the PCE is statistically significant at a 5% level of significance. Also, the posterior tail-area probability value of 0.001 indicates a 0.1% chance that the PCE would have a negative effect on the GPD performance in Cuba.

The Dominican Republic, during the post-PCE-era, the economic performance had an average of approximately US$ 84.83 Billion. This effect is US$7.76 Billion with a 95% interval of [-2e+09, 1.6e+10]. In relative terms, GDP performance increased approximately 10% percent. The 95% interval of this percentage is [-2.6%, 21%]. The intervention appeared to have caused a positive effect and was statistically significant at a 5% level with a posterior tail-area probability value of 0.050.

Haiti, during the post-PCE-era, the economic performance had an average of approximately US$ 14.60 Billion. This causal effect was negative US$1.1 Billion with a 95% interval of [-2.5e+09, 2.3e+08]. In relative terms, GDP performance decreased by approximately 6.6% percent with a 95% interval of this percentage is [-15%, 1.4%]. However, the intervention appears to have caused a negative effect. However, this effect is not statistically significant when considering the entire post-intervention period.

Jamaica, during the post-PCE-era, the economic performance had an average of approximately US$ 16.24 Billion. This effect is US$1.42 Billion with a 95% interval of [8.8e+08, 1.9e+09]. In relative terms, GDP performance increased approximately 9.8% percent. The 95% interval of this percentage is [6.1%, 13%]. This positive effect observed during the PCE was statistically significant at a 5% level of significance. Also, the posterior tail-area probability value of 0.001 indicates a 0.1% chance that the PCE would have a negative effect on the GPD performance in Jamaica.

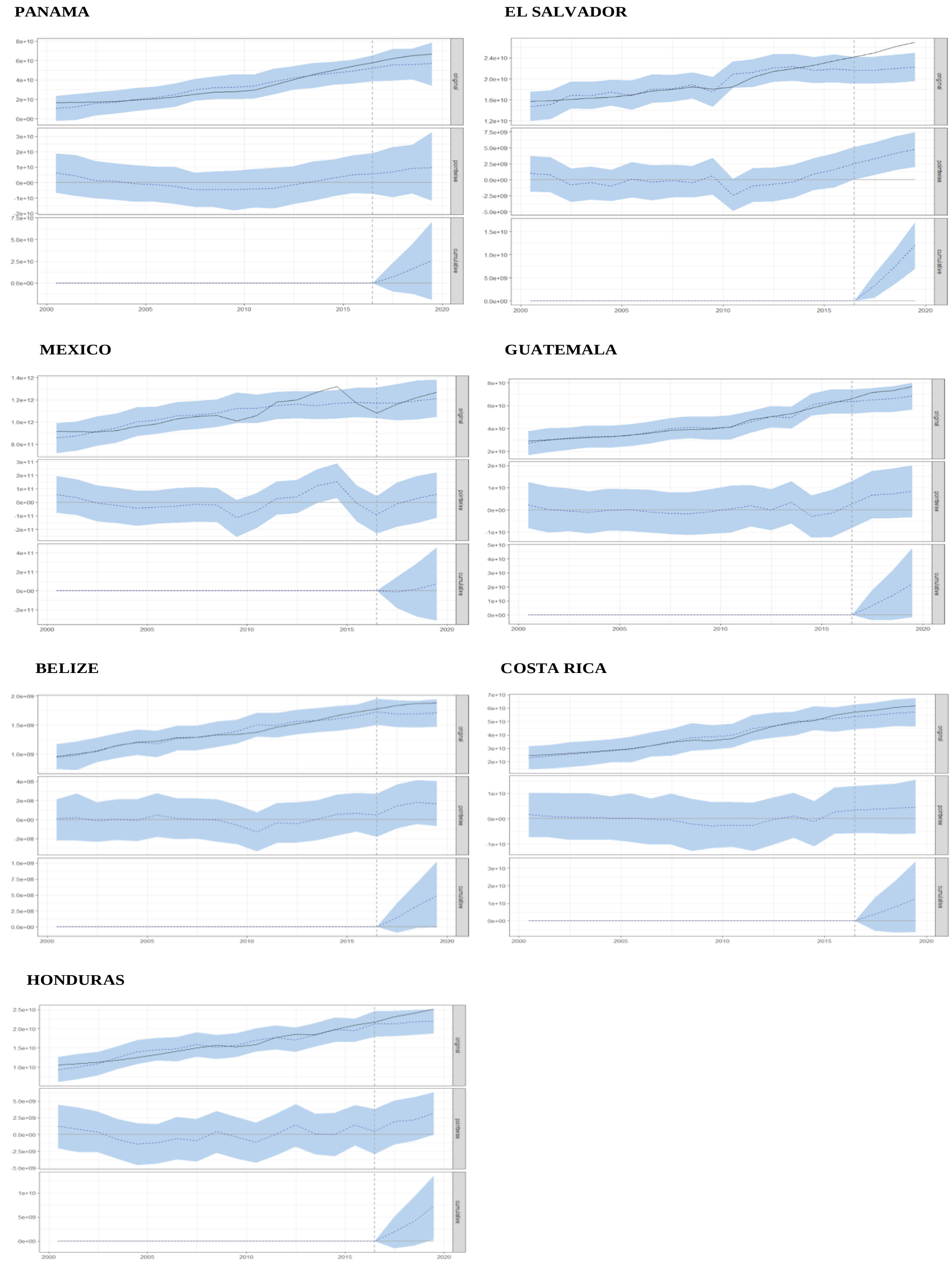
Trinidad and Tobago, during the post-PCE-era, the economic performance had an average of approximately US$ 23.52 Billion. This effect is negative US$2.7 Billion with a 95% interval [-5.4e+09, 6.0e+07]. In relative terms, GDP performance decrease by approximately 10% percent with a 95% confidence interval [-20%, 0.23%]. This negative effect observed during the PCE and advent of Neo-Panamax is statistically significant at a 5% level of significance. Also, the posterior tail-area probability value of 0.001 indicates a 0.1% chance that the PCE would have a negative effect on the GPD performance in Trinidad and Tobago.

Bahamas, during the post-PCE-era, the economic performance had an average of approximately US$ 13.03 Billion. This effect is US$1.1 Billion with a 95% interval [0.56B, 1.73B]. In relative terms, GDP performance increased approximately 5.7% percent. The 95% interval of this percentage is [0%, 11%]. This positive effect was statistically significant at the 5% level with a posterior tail-area probability value of 0.001 indicates a 0.1% chance that the PCE would have a negative effect on the GPD performance in the Bahamas.

4.4 BAYESIAN POSTERIOR DISTRIBUTION GRAPHS

This section discusses the impact of PCE on economic performances (GDP) on LAC countries by analysing the posterior distribution graphs. Here we will assess the time path of the effect of the PCE.

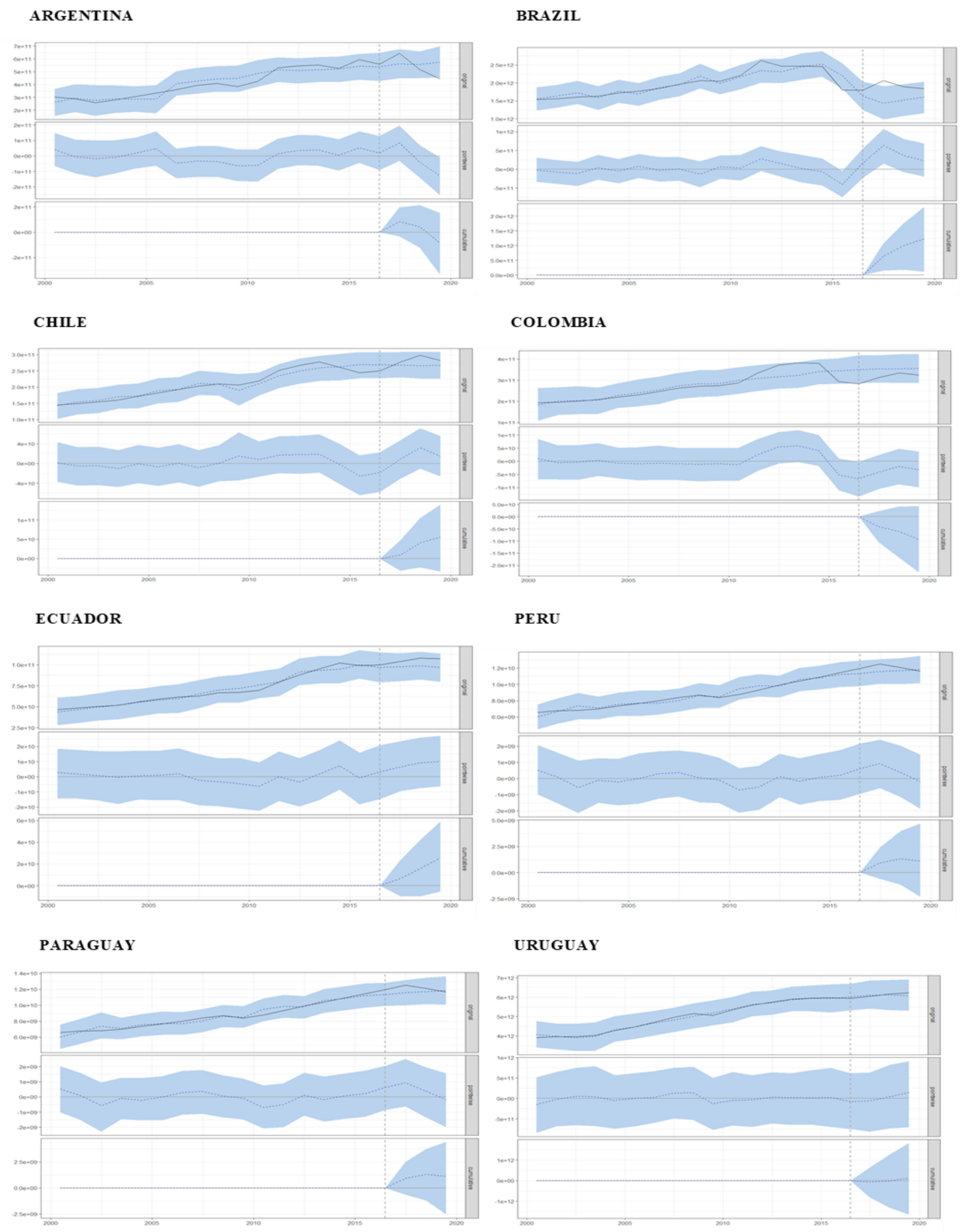
4.4.1 Central America GDP.



Note: On the original panel, the blue-dotted and the solid black lines horizontal indicate the time path of predicted series and actual series, respectively.

Fig.4.3 the economic performance (GDP) of seven (7) Central American countries during the period 2000 to 2019.

4.4.3 South America GDP.

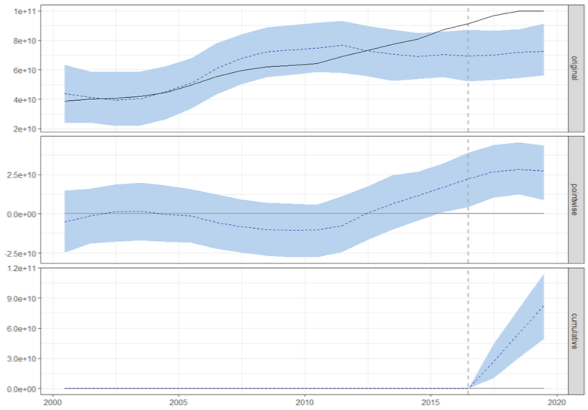


Note: On the original panel, the blue-dotted and the solid black lines horizontal indicate the time path of predicted series and actual series, respectively.

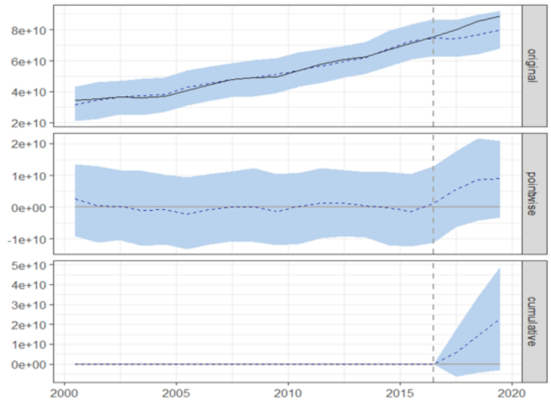
Fig. 4.4 the economic performance (GDP) of eight (8) South American during the period of 2000 to 2019.

4.4.5 Caribbean GDP.

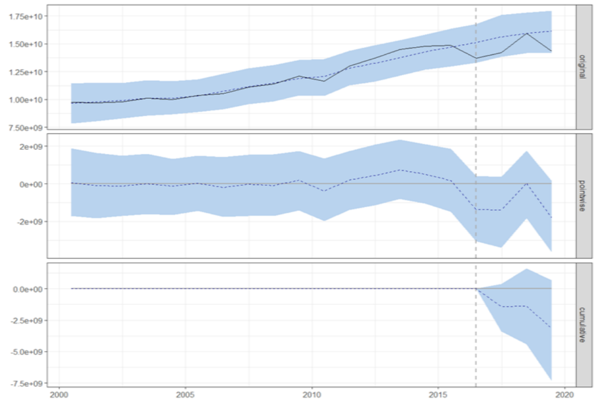
CUBA



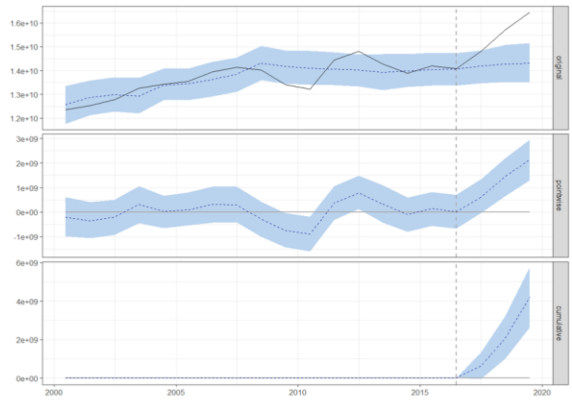
DOMINICAN REPUBLIC (DR)



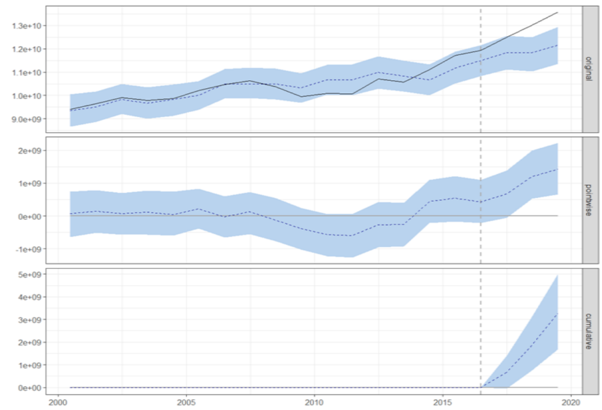
HAITI



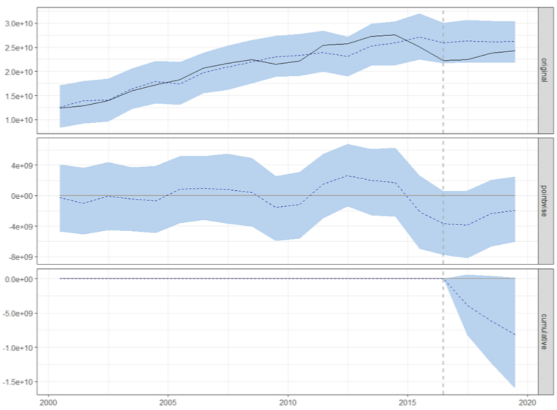
JAMAICA



TRINIDAD &TOBAGO



THE BAHAMAS



Note: On the original panel, the blue-dotted and the solid black lines horizontal indicate the time path of predicted series and actual series, respectively.

In Fig.4.5, shows the economic performance (GDP) of Six (6) Caribbean during the period of 2000 to 2019.

4.5 ROBUST CHECKS

Note that the definitions of all the variables and the parameters in Eqs. (4)–(6) are the same as those in Eqs. (1)–(3) with the introduction of an additional explanatory variable (GNI) and parameter β.

$$4)\ y_t = \mu_t + \tau_t + \beta^T(GNI) + \varepsilon_t , \quad \varepsilon_t \sim N(0, \sigma_t^2)$$

$$5)\ \mu_t = \mu_{t-1} + \delta_{t-1} + u_t , \quad u_t \sim N(0, \sigma_u^2)$$

$$6)\ \tau_t = -\sum_{s=1}^{s-1} \tau_{t-s} + w_t , \quad w_t \sim N(0, \sigma_w^2)$$

For tables; 4.9, 4.10, and 4.11. Displays the results of the above equations. It can be seen that there were statistical significances for the PCE impact for explanatory variables of GDP and GNI and covariates of HDI and rate of Unempl for all countries within the three sub-regions except for Honduras, Chile, Colombia, Paraguay, and Uruguay results showed that PCE impact for economic growth was statistically insignificant. However, the robustness of the results was confirmed based on the similar statistical significance of the impact for each country for the GNI and GDP.

Table 4.9, Robustness checks results of posterior estimates of the PCE on Central America's Gross National Income (GNI) comparison to GDP.

Central America	Actual		Predicted (s.d.)		Absolute effect (s.d.)		Absolute effect (s.d.)		Posterior tail-area probability	
	GNI	GDP	GNI	GDP	GNI	GDP	GNI	GDP	GNI	GDP
Panama	2.9e+11	6.5e+10	2.8e+11 (3.5e+10) [2.1e+11, 3.5e+11]	5.6e+10 (7.6e+09) [4.1e+10, 7.1e+10]	1.5e+10 (3.5e+10) [-5.4e+10, 8.2e+10]	8.6e+09 (7.6e+09) [-6.4e+09, 2.4e+10]	5.3% (13%)	15% (14%)	0.351	0.122
El Salvador	2.5e+10	2.6e+10	2.1e+10 (1.1e+09) [1.9e+10, 2.3e+10]	2.2e+10 (8.5e+08) [2.0e+10, 2.4e+10]	3.3e+09 (1.1e+09) [1.1e+09, 5.6e+09]	4.1e+09 (8.5e+08) [2.3e+09, 5.7e+09]	15% (5.4%) [5.3%, 26%]	18% (4%) [11%, 27%]	0.005**	0.001**
Mexico	1.2e+12	1.2e+12	1.2e+12 (9.3e+10) [1.1e+12, 1.4e+12]	1.2e+12 (6.6e+10) [1.1e+12, 1.3e+12]	-5.2e+10 (9.3e+10) [-2.3e+11, 1.3e+11]	2.5e+10 (6.6e+10) [-9.9e+10, 1.5e+11]	-4.2% (7.6%) [-18%, 11%]	2.1% (5.6%) [-8.3%, 13%]	0.282	0.356
Honduras	2.2e+10	2.4e+10	2.1e+10 (1.4e+09) [1.8e+10, 2.4e+10]	2.2e+10 (1.1e+09) [2.0e+10, 2.4e+10]	1.3e+09 (1.4e+09) [-1.4e+09, 4.4e+09]	2.4e+09 (1.1e+09) [2.1e+08, 4.6e+09]	6.2% (6.8%) [-6.4%, 21%]	11% (5.2%) [0.95%, 21%	0.190	0.018**
Guatemala	7.2e+10	7.4e+10	6.5e+10 (5.5e+09) [5.4e+10, 7.6e+10]	6.6e+10 (4.2e+09) [5.8e+10, 7.4e+10]	7.1e+09 (5.5e+09) [-3.7e+09, 1.9e+10]	7.4e+09 (4.2e+09) [-5.7e+08, 1.6e+10]	11% (8.5%) [-5.7%, 28%]	11% (6.4%) [-0.86%, 24%]	0.096	0.035**
Costa Rica	5.9e+10	6.0e+10	5.8e+10 (4.7e+09) [4.9e+10, 6.7e+10]	5.6e+10 (3.4e+09) [4.9e+10, 6.3e+10]	9.4e+08 (4.7e+09) [-8.1e+09, 1.0e+10]	4.1e+09 (3.4e+09) [-2.4e+09, 1.1e+10]	1.6% (8.1%) [-14%, 18%]	7.4% (6%) [-4.3%, 20%]	0.436	0.112
Belize	1.8e+09	1.9e+09	1.6e+09 (9.7e+07) [1.4e+09, 1.8e+09]	1.7e+09 (8.6e+07) [1.5e+09, 1.9e+09]	1.3e+08 (9.7e+07) [-6.8e+07, 3.2e+08]	1.6e+08 (8.6e+07) [-3078306, .4e+08]	8% (5.9%) [-4.2%, 20%]	9.6% (5%) [-0.18%, 20%]	0.081	0.029**

Note: The values in the brackets show 95 % confidence interval, while those in the parentheses are standard deviations. ** represent 5% significance level and p stands for Posterior tail-area probability.

Table 4.10, Robustness checks results of posterior estimates of the PCE on South America's Gross National Income (GNI) comparison to GDP.

South America	Actual		Predicted (s.d.)		Absolute effect (s.d.)		Absolute effect (s.d.)		Posterior tail-area probability	
	GNI	GDP	GNI	GDP	GNI	GDP	GNI	GDP	GNI	GDP
Argentina	5.2e+11	5.40E+11	5.8e+11 (6.4e+10) [4.5e+11, 7.1e+11]	5.6e+11 (4.2e+10) [4.9e+11, 6.5e+11]	-6.1e+10 (6.4e+10) [-1.9e+11, 6.9e+10]	-2.9e+10 (4.2e+10) [-1.1e+11, 5.1e+10]	-10% (11%) [-34%, 12%]	-5.1% (7.4%) [-20%, 9%]	0.152	0.252
Brazil	1.9e+12	1.9e+12	1.4e+12 (3.9e+11) [6.2e+11, 2.2e+12]	1.5e+12 (1.9e+11) [1.2e+12, 1.9e+12]	5.3e+11 (3.9e+11) [-2.6e+11, 1.3e+12]	4.1e+11 (1.9e+11) [3.9e+10, 7.7e+11]	39% (28%) [-19%, 93%]	27% (13%) [2.6%, 51%]	0.083**	0.024**
Chile	2.7e+11	2.9e+11	2.6e+11 (2.3e+10) [2.2e+11, 3.1e+11]	2.7e+11 (1.3e+10) [2.4e+11, 2.9e+11]	9.3e+09 (2.3e+10) [-3.3e+10, 5.2e+10]	1.9e+10 (1.3e+10) [-8.0e+09, 4.3e+10]	3.5% (8.8%) [-13%, 20%]	6.9% (5%) [-3%, 16%]	0.364	0.089
Colombia	3.2e+11	3.2e+11	3.7e+11 (3.6e+10) [3.0e+11, 4.4e+11]	3.2e+11 (2.8e+10) [2.7e+11, 3.7e+11]	-5.7e+10 (3.6e+10) [-1.3e+11, 1.2e+10]	5.5e+09 (2.8e+10) [-4.8e+10, 5.7e+10]	-15% (9.6%) [-34%, 3.3%]	1.7% (8.7%) [-15%, 18%]	0.054	0.425
Ecuador	1.0e+11	1.1e+11	1e+11 (8.4e+09) [8.3e+10, 1.2e+11]	9.8e+10 (5.6e+09) [8.7e+10, 1.1e+11]	4.3e+09 (8.4e+09) [-1.2e+10, 2.1e+10]	8.6e+09 (5.6e+09) [-2.3e+09, 1.9e+10]	4.4% (8.4%) [-12%, 21%]	8.8% (5.7%) [-2.3%, 20%]	0.326	0.066
Peru	2.1e+11	2.2e+11	2.1e+11 (2e+10) [1.7e+11, 2.4e+11]	2.1e+11 (1.6e+10) [1.1e+10, 1.3e+10]	4.5e+09 (2e+10) [-3.4e+10, 4.3e+10]	3.8e+08 (6.1e+08) [-7.7e+08, 1.6e+09]	2.2% (9.7%)	3.2% (5.2%) [-6.6%, 13%]	0.402	0.271
Paraguay	3.8e+10	1.2e+10	4.1e+10 (4.4e+09) [3.3e+10, 5.0e+10]	1.2e+10 (5.9e+08) [1.1e+10, 1.3e+10]	-3.5e+09 (4.4e+09) [-1.3e+10, 5.1e+09]	3.8e+08 (5.9e+08) [-7.3e+08, 1.5e+09]	-8.4% (11%) [-31%, 12%]	3.2% (5.1%) [-6.3%, 13%]	0.199	0.252
Uruguay	6.0e+10	6.1e+12	5.7e+10 (6.3e+09) [4.5e+10, 7.0e+10]	6.1e+12 (3.0e+11) [5.5e+12, 6.7e+12]	2.8e+09 (6.3e+09) [-1e+10, 1.4e+10]	4.1e+10 (3.0e+11) [-5.5e+11, 6.1e+11]	4.9% (11%) [-17%, 25%]	0.68% (4.9%) [-9%, 10%]	0.337	0.441

Note: The values in the brackets show 95 % confidence interval, while those in the parentheses are standard deviations. ** represent 5% significance level and p stands for Posterior tail-area probability.

Table 4.11, Robustness checks results of posterior estimates of the PCE on Caribbean's Gross National Income (GNI) comparison to GDP.

Caribbean	Actual		Predicted(s.d.)		Absolute effect(s.d.)		Absolute effect (s.d.)		Posterior tail-area probability	
	GNI	GDP	GNI	GDP	GNI	GDP	GNI	GDP	GNI	GDP
Cuba	9.0e+10	9.9e+10	7.0e+10 (6.4e+09) [5.8e+10, 8.3e+10]	7.1e+10 (5.5e+09) [6.1e+10, 8.2e+10	2e+10 (6.4e+09) [7.4e+09, 3.2e+10]	2.7e+10 (5.5e+09) [1.7e+10, 3.8e+10]	29% (9.1%) [11%, 45%]	38% (7.7%) [23%, 53%]	0.003**	0.001**
Dominican Republic	8.1e+10	8.5e+10	8.0e+10 (6.2e+09) [6.7e+10, 9.2e+10]	7.7e+10 (4.5e+09) [6.9e+10, 8.7e+10]	1.2e+09 (6.2e+09) [-1.1e+10, 1.4e+10]	7.7e+09 (4.5e+09) [-2e+09, 1.6e+10]	1.6% (7.8%) [-14%, 17%]	10% (5.9%) [-2.6%, 21%]	0.422	0.050**
Haiti	1.5e+10	1.5e+10	1.7e+10 (1.3e+09) [1.5e+10, 2e+10]	1.6e+10 (6.9e+08) [1.5e+10, 1.7e+10]	-2.5e+09 (1.3e+09) [-5.0e+09, 1.4e+07]	-1.1e+09 (6.9e+08) [-2.5e+09, 2.3e+08]	-2.5e+09 (1.3e+09) [-5.0e+09, 1.4e+07]	-6.6% (4.3%) [-15%, 1.4%]	-15% (7.5%)	0.052
Jamaica	1.5e+10	1.6e+10	1.3e+10 (7.1e+08) [1.2e+10, 1.4e+10]	1.4e+10 (2.7e+08) [1.4e+10, 1.5e+10]	2.1e+09 (7.1e+08) [6.8e+08, 3.5e+09]	1.4e+09 (2.7e+08) [8.8e+08, 1.9e+09]	16% (5.5%) [5.3%, 27%]	9.8% (1.9%) [6.1%, 13%]	0.003**	0.001**
Trinidad &Tobago	2.3e+10	2.4e+10	2.6e+10 (2.0e+09) [2.2e+10, 3.0e+10]	2.6e+10 (1.4e+09) [2.3e+10, 2.9e+10]	-3.0e+09 (2.0e+09) [-6.8e+09, 8.2e+08]	-2.7e+09 (1.4e+09) [-5.4e+09, 6.0e+07]	-12% (7.6%) [-26%, 3.2%]	-10% (5.5%) [-20%, 0.23%]	0.065	0.031**

Bahamas	1.3e+10	1.3e+10	1.3e+10 (4.8e+08) [1.2e+10, 1.4e+10]	1.2e+10 (2.9e+08) [1.1e+10, 1.2e+10]	-7.9e+07 (4.8e+08) [-1.0e+09, 8.8e+08]	1.1e+09 (2.9e+08) [5.6e+08, 1.7e+09]	-0.63% (3.8%) [-8.1%, 7%]	5.7% (2.7%) [0%, 11%]	0.407	0.025**

Note: The values in the brackets show 95 % confidence interval, while those in the parentheses are standard deviations. ** represent 5% significance level and p stands for Posterior tail-area probability.

CHAPTER 5

5.0 DISCUSSION

The DID Model results revealed that PCE (Intervention) positively impacted container port throughput (TEUs) within the LAC region. All estimated coefficients δ in the model were statistically significant at 1%, 5%, and 10%. The findings from the model revealed that the average container port throughput for Treated ports (DTrp) was more than that of Controlled ports (CONTp) for Transhipment hub, Central America, and South America having 20%, 12%, and 34% growth since the canal expansion, except for the Caribbean ports (DTrp) that experienced losses of 8 %. These DID results were expected and supported by several authors and data resources such as Rodrigue and Ashar (2016), CEPAL (2020), World Bank (2021), UNCTAD (2014), Martinez et al. (2016), and Singh et al. (2015). For the positive impact of PCE (Intervention), Martinez et al. 2016, studies revealed that the PCE would generate significant transit time saving and shifting container traffic from West Coast to East Coast ports. Rodrigue and Ashar (2016) forecast increases in both transshipment activity and container throughput through the PCE. However, the Caribbean Treatment (DTrp) ports have experienced decreases in container port throughput based on the DID model's findings. This decline may be largely influenced by port infrastructural development and improvement of the US East and Gulf coast, increasing competition among US ports and regional ports (Van Hassel et al., 2018; Martinez et al., 2016). Ports that lack or delayed port modernization investments will experience losses in container throughput (TEUs) and changes in liner shipping routes (Talley, 2006; Sarriera et al., 2015; Kendrick, 2020). The DID results revealed that major Caribbean ports (DTrp) such as Kingston, Freeport, San Juan, and Caucedo had experienced losses in container throughput (TEUs) since the PCE. Reyes et al. (2019) and Park et al. (2020) supported this finding; Reyes et al. (2019) revealed that the short-term impact of Caribbean ports would decrease transshipment volume because port modernization investment among US ports will impact liner shipping routes.

The Canal expansion has reshaped US and LAC ports' economic and environmental geography beyond this research scope. However, other factors were considered, such as Quality of Port Infrastructure (QPI), Foreign Direct Investment (FDI), and Trade Freedom (TRFR) (Bhadury, 2016; Prozzi and Overmyer, 2018; Ashley and Dettoni, 2016; United Nations, 2005, Carral et al., 2018). These data were not included in the model but were considered supporting graphs to justify the expansion's pre- and post-era impact. Fig.3.1 shows that the overall QPI scores have improved from 3.6 to 3.96. Fig.3.2 shows FDI rebounded in 2017 from US$2.22 Billion to US$2.59 Billion in 2019. Fig.3.3 reveals that TRFR improved from 74.6 in 2014 to 74.74 in 2018; simultaneously, it may be said that these variables may have influenced container port throughput (TEUs) growth. However, The PCE had impacted liner shipping routes, cargo tonnage growth, and port investment within LAC and US East and Gulf ports that resulted in water channel investments and improvement of policies to foster economic growth in anticipation of the PCE (Prozzi and Overmyer, 2018; Bhadury, 2016; Carral et al., 2018; Sarriera et al., 2015; Kendrick, 2020; Rodrigue, 2020).

The dynamics of trade globalization, development of transport technology, application of cargo-handling technology, and cargo unitisation are keen attributes that will determine regional ports' competitiveness (ICS, 2020; Park et al., 2020; Nicholson and Boxill, 2017). The Caribbean region (DTrp) ports' finding was unexpected because of the Transshipment history and strategic location of these ports being a part of the "Transshipment triangle" of the LAC region (Notteboom et al., 2021). These results also revealed that Mega-ships' introduction to the Caribbean region does not necessarily benefit transshipment ports due to the following: the inability to accommodate Neo-Panamax, lack of proactiveness to global changes, poor port infrastructure, and competition from regional ports, especially the US and Gulf Coast port (Merk, 2018; Kapoor, 2016; Bhadury, 2016; Park et al., 2020).

The 21st century shows that radical changes in the maritime trade will impact port operations' dynamics and their capability to compete for container traffic. Impact evaluation such as DID enables ports to assess an intervention's impact and efficiently make adjustments in trade policy reforms, port infrastructure, and most importantly, prepare them to be more resilient towards sustainable developments for the present and future dynamism in global trade.

5.1 DISCUSSION

The SFA model results showed that the four (4) output variables, Berth Length (B_{it}), Area of port (A_{it}), Cranes (C_{it}), and the number of berths (Q_{it}) used in the model, were all statistically significant, as shown in Table 4.3. All four (4) output variables, had significant increases from 2000 to 2010, as shown in Table A.3. However, in Table A.1 from 2010 to 2016, only the variable; Cranes (C_{it}) had established considerable increases among the 19 major regional ports. During the period 2016 to 2018 as shown in Table A.2, all variables had no changes except for the deepening of the harbor for the Port of Kingston; this variable was excluded from the model.

The keen factors in improving port productivity and efficiency are the improvements of port and logistics infrastructures, reducing shipping and handling costs, and lowering DT, which will eventually improve a port's trade volumes and competitiveness (Clark, Dollar, and Micco, 2004; Töngür et al., 2020; Gani, 2017; Merk and Dang, 2012; Blonigen and Wilson, 2007; Figueiredo de Oliveira and Cariou, 2015). Interestingly, the SFA results showed that the coefficient for the crane was 0.2719, which constituted as having the largest impact than the other variables (Hassan et al., 2017; Suarez-Aleman et al., 2015; Talley, 2017; Serebrisky et al.,2013). The PCE had spurred the LAC region towards port investment (Labrut, 2013; Suarez-Aleman et al., 2015; Notteboom et al., 2021). These investments were largely focused on the acquisition of STS gantry and neo-Panamax cranes, port hinterland expansion, and for some ports; the deepening of waterways or harbor to accommodate ships with a draft of 15m and more (Mudronja et al., 2020; Munim and Schramm,2018; Rodrigue and Notteboom, 2021; Serebrisky et al.,2013). Therefore, the utilization of the four (4) output variables (B_{it} , A_{it} ,C_{it} , and Q_{it}) were important components for improving PE and regional competitiveness (Suarez-Aleman et al., 2015; Talley, 2017; Rodrigue and Notteboom, 2021; Töngür et al, 2020; Gani, 2017, Serebrisky et al., 2013).

Table 4.2, shows that PE results for ports within the LAC vary depending on two factors; (1) a port's ability to handle larger container vessels, and (2) the surge in container throughput (TEUs) due to increases in transshipment activities (Talley, 2017; Mudronja et al., 2020; Suarez-Aleman et al., 2015; Clark, Dollar, and Micco, 2004). On the other hand, some ports especially traditional transshipment ports such as Kingston (Jamaica) and Freeport (the Bahamas) encounter a decline in TEUs due to port proximity, and inefficiencies (Figueiredo de Oliveira and Cariou, 2015; Perez et al., 2016; Clark et al., 2004).

The PCE may play a major role in maritime activities among regional ports however, it is not the only influencing factor for PE improvement (Merk and Dang, 2012; Suarez-Aleman et al., 2015; Talley, 2017; WorldBank, 2020; UNCTAD, 2021; CDB, 2017). Several other factors such as port privatization, trade policy, global economic growth, port liner connectivity, infrastructure, and the culture of corruption, can affect port productivity and efficiency (Tongzon and Heng, 2005; Tongzon, 1995; Serebrisky et al., 2015; Shetty and Dwarakish, 2018; Park, 2020; and Celebi, 2017; WorldBank, 2020; UNCTAD, 2021). Moreover, port efficiency (PE) in relation to throughput also depends on the port location, frequency of ship calls, port charges, economic activity, and terminal efficiency (Tongzon,1995; Talley, 2017; Figueiredo de Oliveira and Cariou, 2015; Suarez-Aleman et al., 2015; Jung, 2012). For example, the efficiency of a container port depends on the crane efficiency, economies of scale (Vessel size and cargo exchange), work practices, and mixed container (Tongzon,1995; Shetty and Dwarakish, 2018). These PPIs are frequently used to determine PE. Nevertheless, exogenous factors such as governmental trade policies, liner connectivity, economic growth, trade, intermodal connectivity, and logistics infrastructure have impacted regional port performance (Merk and Dang, 2012; Serebrisky et al., 2015; Shetty and Dwarakish, 2018, 2018; Park, 2020; and Celebi, 2017).

The TE results shown in Table 4.2; revealed that ports within the region experience different levels of growth in TEUs that depend on their scale of operation (Hassan et al., 2017; Harrera and Pang, 2006). PPIs improvements enhance the quality of service to the port users, reduce technical and cost inefficiencies, and increase the port's compatibilities (Talley, 2017; Mellalla et al., 2016; Shetty and Dwarakish, 2018; Hassan et al., 2017). As shown in Tables 3.6 and 3.7, Panama has the highest port infrastructure index and container throughput within the region. The results from the SFA revealed that both the ports of Colon and Balboa showed TE values of 100 percent from 2010 to 2018. Argentina has a quality of QPI recorded rank of 3.7, and port of Buenos Aires, TE was 54 percent.

A shorter time at a port is a positive indicator of the port's efficiency and trade competitiveness (UNCTAD, 2019; Aminatou et al., 2018; Hassan et al., 2017; PortStrategy, 2020). Therefore, reducing vessel time at the port will accommodate more vessel calls (Tongzon and Heng, 2005; Talley, 2017; Notteboom et al., 2021). Fig. 2.1; shows the median time vessel spent on region ports. Panamanian and Colombian ports displayed the shortest at 0.67 and 0.6, respectively. These values correlate to the high level of TE of 100 and 87.5 percent, respectively. The results clearly, revealed that ports with the shortest time median (dwell time) normally displayed larger TE values.

Port is the gateway to trade and economic growth (Talley, 2017; Notteboom et al., 2021). Therefore, improving PE is a necessary component for enhancing a port's productivity and competitiveness for developing countries (Tongzon and Heng, 2005; Talley, 2017; Serebrisky et al., 2013; Shetty and Dwarakish, 2018; Park, 2020; and Celebi, 2017). The results revealed that for the LAC region four (4) PPIs were significant for PE during the pre and post-PCE era. However, factors such as trade and port policy, liner shipping connectivity, and the utilization of technological innovation can be essential tools to alleviate port congestion and improve dwell time (PortStrategy, 2020).

5.2 DISCUSSION

This research investigates six (6) LPI components' relationship to LAC exports and income classifications. It will also evaluate the Panama Canal expansion (PCE) influence of Logistics performance on Latin American exports.

The main findings from the HLM results, as shown in Table 4.5, revealed that for 2016, LP-Customs accounted for 10.1% of the variance to exports, whereby economic variable IND was positive and statistically significant to export. For 2018, LP-Customs model 2 accounted for 7.0% of the variance in exports. In Table 4.6, the HLM regression results revealed that among three (3) categories of income in LAC; High-income, Upper-middle income, and lower-middle-income countries; LP-Custom for High-income countries in the LAC region accounts for 1.2% of the variance in exports. However, for Upper-middle and Lower-middle income countries, all components of LPI were insignificant. For Pre-PCE and Post- PCE era, LP-Customs was 1.3% and 8.3% respectively of the variance to exports. The economic variables in Table 4.7 for the Pre-PCE era were GDP, and TRFR was positively related to exports, and the post-PCE era was TRFR, and IND were positively significant to exports. The overall OLPI results from the HLM showed that for the Pre and Post PCE era, the overall or general logistics performance Index (OLPI) was statistically significant for only the post-PCE era accounting for 7.3% of the variance to export.

Most authors agree that all six (6) components of LPI improvements is necessary for trade and economic growth; therefore, all LPI components from the Pearson's results for LAC showed a positive and significant relationship to exports except for LP-Custom that had a negative relationship (Rezaei et al. 2018; Ekici et al., 2016; World Bank, 2019; Yang and Chen, 2016). The negative relationship for LP-Custom to Export; agreed with Seabra et al. (2016) on the inefficiency of customs procedures and corruption in LAC. Therefore, a negative relationship was expected.

The HLM results revealed that for periods; 2010, 2012, 2014, 2016, and 2018, LPI components influence on exports within the LAC region seemingly changes over Time. For instance, in 2010, LP-QLS (3.051) showed a positive relationship to export while LP-Infrastructure (-7.212) was a negative relationship (Töngür et al., 2020; Gani, 2017; Ho and Chang, 2015). None of the LPI components were significant in 2012. However, TRFR (30.79) had the most influence on exports among LAC countries. This result was in agreement that TRFR has a positive impact and relationship with exports (Hausman et al., 2012; Naanwaab and Diarrasouba, 2013). In 2014, LP-QLS (-6.960), LP-TT (6.872), and LPTL(-3.633), the HLM results revealed that only LPTT had a positive relationship to exports (Shamsuzzoha and Helo, 2011). In 2016, only LP-Customs (-2.206) was significant yet a negative relation to exports. This result was expected because Customs procedures within LAC countries are affected by inefficient customs procedures and corruption, which has become a barrier to trade (Seabra et al., 2016; Gani,2017; Cosco, 2017). Furthermore, the economic variable, IND (11.669), had a positive relationship to exports (Rezaei et al., 2018; Cosco, 2017; Gani, 2017). Likewise, in 2018, only LP-Customs was a significant component of LPI and displayed a negative relationship to exports (Seabra et al., 2016). On the other hand, TRFR (14.91) and IND (10.41); economic variables, have a positive relationship with exports (Index of Economic Freedom (IEF), 2020; Rezaei et al., 2018; Naanwaab and Diarrasouba, 2013; Cosco, 2017; Gani, 2017).

For High-income LAC countries, the HLM results revealed that LP-Custom was the only significant component; however, it has a negative relationship to exports. All LPI components were insignificant for both upper-middle and lower-middle-income countries. Although, findings from Gani (2017) and Cosco (2017) agreed that logistics performance positively impacted exports. Nevertheless, as shown in Fig.2.3, the LPI ranking also depends on a country's level of income, in which there is a widening gap between developed and developing countries (Gani, 2017; Budkin, 2018; Celebi, 2017; World Bank, 2020; Rezai et al., 2018; Cosco, 2017; Martin et al., 2017; Seabra et al., 2016).

The HLM regression revealed that for the post-PCE era, TRFR, IND, and LP-Cust were statistically significant than for the pre-PCE era, whereby only TRFR and GDP were significant, revealing that the post-PCE era influenced TRFR, IND, and LP-Customs relationship between exports (Behar, Manner and Nelson, 2009; Liu et al., 2016; Seabra et al., 2016; Hausman, Lee, and Subramaniam, 2013; Arteaga et al., 2020).

The research shows that the HLM is an effective assessment tool for a hierarchical model that determines which components of LPI had the highest variance and significant predictor of exports within Latin America. The results showed that customs had the highest variance to exports. Therefore, policymakers within the region must address these issues, such as corruption and inefficient customs procedures. All income classifications must improve logistics performance in order to improve exports. Celebri (2017) findings revealed that low-income countries' exports are impacted more by logistics performance than high and upper-income countries. Therefore, future studies are recommended to assess the holistic relationship among LPI components relationship on imports and trade deficits.

5.3 DISCUSSION

Overall, the BSTS model revealed that for the three (3) regions of LAC; Central America, South America, and the Caribbean. The impact of the PCE on GDP using covariates of HDI and UNEMPL. All three variables used within the model were statistically significant for all countries except for Argentina, Bahamas, Chile, Colombia, and Haiti in which the UNEMPL covariate was were statistically insignificant. The BSTS results revealed that for all three (3) sub-regions of the LAC, the PCE had a positive causal effect on all countries except for Trinidad & Tobago, Haiti, and Argentina. However, the overall causal effect for countries within the three (3) sub-regions was statistically insignificant: For Central America, Panama, and Mexico. For South America, all other countries except for Brazil. Moreover, for the Caribbean, only Haiti had statistically insignificant values.

For Central America, it was expected that countries would benefit economically from the PCE because of increased seaborne trade (Kreishan, 2010; Lim,1998; Rodrigue and Notteboom, 2021; Gross, 2008; Munim and Schramm, 2018). However, it was entirely unexpected that the positive causal effect of the PCE was statistically insignificant for Panama since the PC primarily impacts Panama's economy in Toll fees, logistics, and transshipment among its major ports(World Bank, 2020; OECD, 2021). Interestingly, Panama's economy has had sustainable positive growth even before the PCE (World Bank, 2020; OECD, 2021; Rodrigue and Notteboom, 2021). Therefore, the apparent effect could be the result of random fluctuations that are unrelated to the intervention. These effects may result from fiscal imbalance, Government final consumption expenditure (GFCE), and policy changes that could significantly impact Panama's economy than the PCE during that era. For Mexico and Costa Rica, similar views may be shared regarding fiscal imbalance and GFCE; however, the nature of trade, port proximity, and shift in trade routes; can affect the causal effect and statistical significance (Rodrigue and Ashar, 2016; Sing et al., 2015; Bhadury, 2016; Park et al.,2020). Regarding Fig. 3.18, for Central America, except for Panama, the ship segments are predominantly passenger ships (Tourism), dry bulk, and liquid carrier (UNCTAD, 2021, Barleta and Sanchez, 2020). Therefore, in Fig 3.17, the Panamax vessels were dominant than neo-Panamax in those market segments; therefore, no major changes in port throughput would significantly impact GDP during the PCE era (Panama Canal Authority, 2021).

Moreover, for Mexico and Costa Rica, the shift in trade due to the PCE will negatively impact the country's West Coast ports due to expansion that caused a shift in the supply chain from the West to the east coast (Gooley, 2018; Rodriguez, 2020). In addition, port proximity and competition within the region will contribute to the statistical insignificance of economic growth during the PCE era (Lim, 2011; Rodrigue and Notteboom, 2021). For central American countries such as El Salvador, Honduras, Guatemala, and Belize that revealed positive and a statistically significant impact in economic growth during the PCE era; maybe a result of the increase in maritime trade, traffic, and transshipment activities that are the by-product of seaborne trade (Lane and Pretes, 2020; Osadume and Blessing, 2020; Rodrigue and Notteboom, 2021; Jouili, 2016; Michail, 2020). However, the PCE may not be singled out as the only contributory factor to the positive GDP growth. Most countries within that region have diverse exports trade that can impact GDP through trade agreements such as Central America Free Trade Agreement (CAFTA) and GFCE (CEPAL, 2019).

For South America, the causal effect was positive for all countries. However, the effect of PCE was statistically insignificant for all countries within this region except for Brazil. This result may be due to several factors such as policy change, recession, market segment, and trade routes. Table 3.6; revealed that the top 15 users of the PC, predominantly the USA account for 72.5 % of cargo tonnage transiting the PC. Table 3.6 clearly, reveals that not all South American countries use the PC as a trade route. The market segment of ships in Fig. 3.17 reveals that only container, LPG, and LNG carriers are predominantly Neo-Panamax vessels that use the third lock of the PC. Therefore, PCE will have little to no effect on economic performance for these countries because most trades within that region mainly use Panamax vessels (Panama Canal Authority, 2021; Rodrigue and Notteboom, 2021). Economic endogenous and exogenous factors include policy changes, inflation, fiscal imbalance, GFCE, and free trade agreement (Mercosur) (UNCTAD, 2021; Panama Canal Authority, 2021; Rodrigue and Notteboom, 2021).

BSTS revealed that only Haiti and Trinidad& Tobago (T&T) had a negative causal effect since the PCE era in the Caribbean region. However, only Haiti's values were statistically insignificant. T&T is a small economy impacted by exogenous changes within the maritime market. In addition, the country's port proximity may be negatively impacted by regional port competition (Transshipment) and oil prices volatility will affect trade volumes that will influence GDP growth (World Bank, 2021; UNCTAD, 2021; Nicholson & Boxill, 2017; Rodrigue, 2021; McCalla et al., 2005).

Although there has been increasing competition for traditional transshipment ports, especially for those within the "Caribbean Transhipment triangle" from US East and Gulf coast ports (Prozzi and Overmyer, 2018; Bhadury, 2016; Carral et al., 2018; Sarriera et al., 2015; Kendrick, 2020, Rodrique, 2020). In Fig.3.21., the decline in container throughput for top transshipment ports such as Bahamas and Jamaica are mainly a result of regional competition and port proximity. However, these ports' geographical location within the transshipment triangle will benefit trade and economic growth because of increased traffic and transshipment activities, as shown in Fig.3.21, which relates to the increasing number of container ships from 2018 to 2020.

On the other hand, although the positive causal effects were during the PCE era. However, these findings may not be a true reflection of the PCE impact. The Caribbean region is mainly renowned for tourism; therefore, during the PCE era, GDP growth could be affected by tourism, trade agreement, and policy changes such as GFCE.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 The research questions #1 were evaluated, and the following conclusion was derived:

1. What is the causal effect of the PCE on container throughput among LAC ports since the advent of mega-ships (Neo-Panamax)?

This study examined the impact of PCE on 100 ports within the LAC region from 2000 to 2019. The DID model was used to assess the causal effect of the PCE on container throughput (TEUs) among ports within the LAC region which includes the three (3) subregions and major transshipment ports. This method was significant for analysing the Pre and Post PCE era's impact on regional ports since the advent of Neo-Panamax and Post-Panamax vessels (Mega-ships) transiting the PCE in 2016. The DID model's finding revealed that PCE has positively impacted container throughput volumes among LAC regional ports except for the Caribbean regional transshipment ports (DTrp) that experienced TEUs' losses since the PCE (Intervention). The findings were important in evaluating the PCE's causal effect on container throughput volume among LAC ports and determining endogenous factors that may affect regional port competitiveness. Despite its limitations, the DID model is an alternative approach in impact evaluation that can be used to assess the effectiveness of governmental policies, environmental policies, and socio-economic programs (Hawkins et al., 2015). The DID model can also be used as a guide for policymakers to improve or adjust an intervention's outcome for regional ports. Limited studies were conducted on the DID approach in the maritime sector; therefore, it is recommended that future studies use the DID approach with other variables such as GDP, DFI, and environmental policies (MARPOL Annex VI), to determine the holistic impact of the PCE on the ports within the LAC region. In general, the maritime sector is volatile and sensitive to the dynamic changes within global trade. Therefore, ports that are proactive in assessing the effectiveness of a policy or intervention will have a competitive edge in adjusting or improving endogenous factors (e.g., policies, infrastructure, and trade) to remain sustainable in the maritime industry.

6.2 The research questions #2 were evaluated, and the following conclusion was derived:

2. What effect has the PCE had on regional port performance, and how has this effect improved regional ports' technical efficiency (TE)?

In order to assess port efficiency (PE) in Latin America and the Caribbean (LAC), Stochastic Frontier Analysis (SFA) was used to determine the technical efficiency (TE) for 19 ports from 2010 to 2018. Container throughput (TEUs) was used as the output variable, whereas Berth length (B_{it}), Port Area (A_{it}), Cranes (C_{it}), and Number of Berths (Q_{it}) were input variables.

The estimation from the SFA indicates productivity from cranes, ship-to-shore (STS) gantry, and berth length had the largest impact and are positively significant. Findings also revealed that LAC countries with low QPI rankings displayed low TE. The pre and post PCE Era highlighted that 'timely' investment towards port development and infrastructural improvements increases productivity and efficiency which is partly influenced by the privatization of ports (Tongzon and Heng, 2005; Nogue-Alguero, 2019; Notteboom et al., 2021; Munim et al., 2018; Rodrigue et al., 2020; Talley, 2006; Talley, 2017; Serebrisky et al., 2013). For instance, Caucedo (Dominican Republic) and Buenaventura (Colombia) were good examples of these findings; they showed significant improvements in TE because of the regional port administration's initiatives towards the improvement and development of ports before the completion of the PCE. Furthermore, most of the top and emerging regional ports executed the long-term strategy of improving port competitiveness through port privatization and policies (Rodrigue and Notteboom, 2021; Tongzon and Heng, 2005; Merk and Dang, 2012; Serebrisky et al., 2013). For instance, CMA-CGM signed a $509 million, 30-year concession with the Port Authority of Jamaica in 2015. Likewise, APM Terminal signed a $992 million, 33-year concession with the government of Costa Rica in 2011.

Improvements in PE for the LAC region were not solely influenced by the PCE. Other factors such as trade agreements among Latin American countries were implemented during the pre and post PCE era, for example, the Central America Free Trade Agreement (CAFTA) and Free Trade Area of the Americas (FTAA) (CEPAL, 2019). Liner consolidation, port privatization, and the growth of the seaborne trade have certainly had a positive impact on regional port development (Nogue-Alguero, 2019; Notteboom et al., 2021; Munim et al., 2018; Rodrigue et al., 2020; Talley, 2006; Talley, 2017; Shetty and Dwarakish, 2018).

The results, as shown in Table 4.4 also, revealed that South America's TE has improved since the PCE, while Central America and the Caribbean have experienced a reduction in TE influenced by the regional port competitions (Bhadury, 2016; Park et al., 2020). This reduction could be a result of both port inefficiency and proximity. Take, for instance, Freeport (Bahamas); one of the significant transshipment hubs have experienced TEUs losses due to the port's proximity to US East coasts ports such as Miami, Everglades, and Charleston (Notteboom, Coeck, and Broeck, 2000; Merk and Dang, 2012; Bhadury, 2016; Park et al., 2020).

Assessing TE using PPIs can guide port seeking to improve productivity, cost reduction, and competitiveness (Blonigen and Wilson, 2007; Serebrisky et al., 2013). PPIs such as berth length (B_{it}), terminal Area(A_{it}), (STS gantry and mobile) cranes (C_{it}), and the number of berths (Q_{it}) are crucial areas that investors should focus on to improve productivity. However, other variables such as corruption, type of ownership, added-value services, port proximity, and income classification could further validate the TE results. These variables were not considered within this research. Further studies on these variables may be considered for future research. Overall, the SFA model can be an effective tool for assessing port productivity within the LAC region.

6.3 The research questions #3 were evaluated, and the following conclusion was derived:

3. How has the relationship between logistics performance and export within the region been affected by the PCE, and how has this relationship impacted LAC countries as per income classification?

This study examines the relationship between exports and the six (6) LPI components among LAC countries regarding income classification and its influence on exports during the pre-and post- PCE era. The Hierarchical Linear Model (HLM) assessed this relation among 20 Latin American countries for 2010, 2012,2014,2016, and 2018. The HLM results revealed that for 2016 and 2018, the LP-Customs model had accounted for 10% and 7.0% of the variance in exports. The findings also revealed that LP-Customs had a significant and negative relationship to Higher-income exports accounting for 1.2% of the variance to exports and was statistically insignificant for both Upper-middle and Lower-income countries. For the pre-PCE and post-PCE era, LP-Customs were 1.3% and 8.3% of the variance to exports.

Logistics performance is important for improving trade and economic growth, which has benefited several developed countries. Therefore, assessing the relationship between LPI components and exports was a key indicator of the region's logistics performance to improve trade since PCE. This study highlights the importance of promoting policies within LAC that will focus on reforming and facilitating trade by improving logistics infrastructure and systems defined by the LPI indicators.

6.4 The research questions #4 were evaluated, and the following conclusion was derived:

4. What is the causal effect has the PCE had on the LAC economy since the advent of neo-Panamax and port development?

This paper seeks to analyze the causal effect of the PCE on economic growth among twenty-one (21) countries within Latin America and the Caribbean region (LAC). The Bayesian Structural Time Series (BSTS) was applied to evaluate the PCE impact on the GDP for each country using the covariates of HDI and the rate of unemployment.

The findings revealed that PCE had positive and statistically significant relative effects for Central American countries such as El Salvador, Honduras, Guatemala, and Belize had 18%,11%,11%, and 9.6%, respectively. For South America, Brazil had a relative effect of 27%. For the Caribbean region, Cuba, Dominican Republic, Bahamas, and Jamaica, have 38%, 10%, 5.7%, and 9.8%, respectively. However, findings also revealed that countries that were statistically insignificant but positive relative effect by various factors such as Fiscal imbalance, GFCE, trade route, market segment, port proximity, and trade agreement during the pre-and post-era; therefore, the PCE would have little to no effect on economic performance for these countries.

The conclusions from this study contribute to academic research in assessing the PCE impact on economic growth in the LAC. Assessing the causal effect of a program or intervention is important for developing and implementing policies that address factors that contribute to economic changes. This research also revealed that the Bayesian Structural Time-series (BSTS) model could effectively assess the causal effects of PCE on the LAC region's economic growth.

CHAPTER 7

LIMITATIONS

The study has the following limitations:

7.1 THE DID MODEL APPLICATION

The sample size was taken from ECLAC and World Bank from 31 countries and 118 ports and port zones from 2010 to 2019. The nine (9) timestamps may not fully justify the Parallel trend Assumption (PTA) of the DID model. However, the container throughput (TEUs) of 100 LAC ports gives a clearer perspective on the PCE's causal effect. Some regional ports, mostly Caribbean ports, were excluded from the model because of limited and missing data. Each of the 100 regional ports' profile and characteristics were difficult to obtain because of limited data. However, Digital Logistics Assessment, Marine Traffic database, and World Port Source (WPS) websites helped retrieve data such as the number of terminals, berth length, port area, number of gantries, and draught for major ports within the region but were limited for small ports. The classification of 100 ports in the category of treated (DTrp) and Control (CONTp) ports was classified according to CEPAL and UNCTAD container throughput data. Port ratings were divided into transshipment hubs and ports that improved infrastructural development for mega-ships; therefore, some deep-water ports (mainly Pacific coast) accommodated post-Panamax before PCE were not classified as treatment (DTrp) ports.

Limited research articles were published on DID application within the Maritime field. The main limitation to this technique is the non-verifiability of its assumptions (Schiozer et al., 2020). This model's application to assess causal effects of endogenous and exogenous variables associated with the maritime industry may be proven challenging and may require additional methods to evaluate an intervention's impact. The maritime industry's volatility triggered by exogenous factors such as oil prices, freight rates, natural and economic disasters, wars, etcetera., can create limitations to the DID applications. The parallel trend assumption (PTA), although one of the most popular used methods for determining the DID model's internal validity, as shown in figure 7, was the method used to validate the model in this research. However, Kahn-Lang et al. (2018) believe that the PTA is insufficient to establish the DID's validity. Therefore, other procedures such as the Robustness test and reformulating the model to allow non-parallel pre-period trends can be applied to test the model's validity (Bilinski and Hatfield 2018; Rambachan and Roth 2019).

Economic and environmental variables such as Gross Domestic Product (GDP), Direct Foreign Investment (FDI), maritime pollution, Carbon and Green gas emission from Neo-Panama and Post-Panama vessels were not covered within the scope of this research. Excluding these variables may limit the full justification of the PCE to the region from an economic and environmental perspective.

7.2 SCHOLASTIC FRONTIER ANALYSIS APPLICATION

The sample size of this research was taken from the ECLAC, World Port Source, and port website. This sample was among 19 top regional port consisting of transshipment hubs that accounts for over 80 percent of container throughput. The limited sample size resulted from the exclusion of smaller ports that provided limited data on berth length, port area, number of gantries, and depth of harbor. In addition, most small ports cannot accommodate Neopananax and post-Panamax vessels; therefore, throughput volume will be lower than large ports. Thus, the generalization of the findings is constrained to major ports.

7.3 HIERARCHICAL LINEAR MODEL (HLM) APPLICATION

The data was sourced from the Logistics Performance Index (LPI), World Bank for 2010, 2012, 2014, 2016, and 2018. This data was sourced for 33 LAC countries; however, only 20 countries were successfully assessed based on research objectives. The thirteen (13) other countries were excluded from the model because of missing and limited data. The limited sample size has created a noticeable discrepancy in generalizing the research findings for the region. Import data was not included within the model because of the trade deficit within the region, especially among smaller states. Imports and Logistics performance may have statistical significance. However, exports which are a significant contributor to economic growth was the main focus of this research.

7.4 BSTS MODEL APPLICATION

The sample size was taken from the World Bank from 33 countries within the LAC from 2000 to 2019. However, 12 countries were excluded from the BSTS model because of limited GDP, HDI, and Unemployment data. Therefore, more data would be needed to improve the generalization of the research findings. The BSTS is a popular model used for nowcast forecasting and finding the causal effect of a program or intervention. While it is popular within the economic and marketing sector, limited research articles were published on the BSTS application within the maritime field. The LAC region is a diverse export-driven economy affected by exogenous and endogenous factors unique to each region based on economic policy and trade agreement. Therefore, economic variables such as GFCE and Fiscal imbalance were not included within the model.

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APPENDIX

Table A.1: Port Characteristics of LAC Average between 2014–2016 (Pre- PCE-Era)

Country /ports	Ave. Annual Throughput (TEU) 2014-2016	Ave. Berth Length (m)	Ave. Area (m^2)	Ave. Mobile Crane with Capacity>1 4t(No.)	Ave. STS Gantry Cranes (No.)	Ave. Depth (m)	Ave. Container (No.)	Ave. Berth (No.)
Colon, Panama	3377515	1258	384000	33	8	16.5	1258	4
Santos, Brazil	3359757	1980	597000	46	13	16	1980	65
Manzanillo, Mexico	2496234	380	437000	8	9	16.5	1240	13
Cartagena, Colombia	2328538	270	225000	2	28	21	225000	8
Balboa, Panama	3250753	442	300000	8	17	16.5	5	7
El Callo, Peru	1982629	183	441080	6	3	16	24300	4
Guayaquil, Ecuador	1713675	1320	228273	3	6	10.5	228273	4
Kingston, Jamaica	1619609	138	1037671	5	13	14	2400	11
Buenos, Aires, Argentina	1395294	500	220000	8	12	10.7	220000	5
San Antonio, Chile	1183822	537	495000	6	13	15	495000	9
San Juan, Puerto Rico	1271083	610	287273	0	6	17	287273	46
Buenaventura, Colombia	902841	440	68500	3	8	15	68500	14
Caucedo, Dominican Repulic	886859	922	800000	2	6	15.2	800000	15
Limon Moin, Costa Rica	1056951	210	677276	1	1	10.2	4930	6
Veracus, Mexico	1128491	507	402909	1	5	14	402909	11
Freeport, Bahamas	914825	1294	320125	0	13	16	57000	3
Itajai, Brazil	1333333	1035	180000	3	2	14	180000	4
Valparado, Chile	1058139	740	280710	5	3	14	280710	3
Altamica, Mexico	932258	973	396570	1	4	12	600	12

Source: Own elaboration based on data from World Port Source.

Table A.2: Port Characteristics. Average between 2017–2018 (Post-PCE-Era)

Country /ports	Ave Annual Throughput (TEU) 2017-2018	Ave. Berth Length (m)	Ave. Area (m^2)	Ave. Mobile Crane with Capacity>1 4t(No.)	Ave. STS Gantry Cranes (No.)	Ave. Depth (m)	Ave. Container (No.)	Ave. Berth (No.)
Colon, Panama	4107844	1258	384000	33	8	16.5	1258	4
Santos, Brazil	3707340	1980	597000	46	13	16	1980	65
Manzanillo, Mexico	2954438	380	437000	8	9	16.5	1240	13
Cartagena, Colombia	2371143	270	225000	2	28	21	225000	8
Balboa, Panama	2753602	442	300000	8	17	16.5	5	7
El Callo, Peru	2295441	183	441080	6	3	16	24300	4
Guayaquil, Ecuador	1967936	1320	228273	3	6	10.5	228273	4
Kingston, Jamaica	1696527	138	1037671	3	19	15.5	2400	11
Buenos, Aires, Argentina	1633457.5	500	220000	10	13	10.7	220000	5
San Antonio, Chile	1478861	537	495000	6	13	15	495000	9
San Juan, Puerto Rico	1302253	610	287273	0	9	17	287273	46
Buenaventura, Colombia	1144570	440	68500	3	8	15	68500	14
Caucedo, Dominican Repulic	1283854	922	800000	2	6	15.2	800000	15
Limon Moin, Costa Rica	1231939	210	677276	0	6	10.2	4930	6
Veracus, Mexico	1193694	507	402909	1	5	14	402909	11
Freeport, Bahamas	1146779	1294	320125	0	16	16	57000	3
Itajai, Brazil	950283	1035	180000	3	2	14	180000	4
Valparado, Chile	1022545	740	280710	5	3	14	280710	3
Altamica, Mexico	988515	973	396570	1	7	12	600	12

Source: Own elaboration based on data from World Port Source.

Table A.3: Port Characteristics. Average between 2000–2016

Country /ports	*Ave. Annual Throughput (TEU) 2010-2016*	*Ave. Berth Length (m)*	*Ave. Area (m^2)*	*Ave. Mobile Crane with Capacity>1 4t(No.)*	*Ave. STS Gantry Cranes (No.)*	*Ave. Depth (m)*	*Ave. Container (No.)*	*Ave. Berth (No.)*
Colon, Panama	3258381	1258	384000	33	8	16.5	1258	4
Santos, Brazil	3393593	1980	597000	46	13	16	1980	65
Manzanillo, Mexico	2578822	380	437000	8	9	16.5	1240	13
Cartagena, Colombia	2323787	270	225000	2	28	21	225000	8
Balboa, Panama	2989860	442	300000	8	17	16.5	5	7
El Callo, Peru	2054970	183	441080	6	3	16	24300	4
Guayaquil, Ecuador	1814915	1320	228273	3	6	10.5	228273	4
Kingston, Jamaica	1567442	138	1037671	5	13	14	2400	11
Buenos, Aires, Argentina	1352068	500	220000	8	12	10.7	220000	5
San Antonio, Chile	1287658	537	495000	6	13	15	495000	9
San Juan, Puerto Rico	1270210	610	287273	0	6	17	287273	46
Buenaventura, Colombia	869061	440	68500	3	8	15	68500	14
Caucedo, Dominican Repulic	918542	922	800000	2	6	15.2	800000	15
Limon Moin, Costa Rica	1115452	210	677276	1	1	10.2	4930	6
Veracus, Mexico	1177385	507	402909	1	5	14	402909	11
Freeport, Bahamas	965294	1294	320125	0	13	16	57000	3
Itajai, Brazil	1200000	1035	180000	3	2	14	180000	4
Valparado, Chile	1104143	740	280710	5	3	14	280710	3
Altamica, Mexico	884030	973	396570	1	4	12	600	12

Source: Own elaboration based on data from World Port Source.

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