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AN ECONOMETRIC ANALYSIS MODEL FOR IMPROVING SERVICE QUALITY AND CUSTOMER SATISFACTION IN MEXICAN SEAPORTS

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THESIS

AN ECONOMETRIC ANALYSIS MODEL FOR IMPROVING SERVICE QUALITY AND CUSTOMER SATISFACTION IN MEXICAN SEAPORTS

by

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September 2020

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Seaports play a critical role in the Mexican economy, yet their largely decentralized operating systems discourage further national and international maritime trade in the country due to duplicated processes among different Mexican governmental entities. The Mexican Navy and the government have expressed interest in reviewing current procedures aimed at instituting control mechanisms and improving the overall availability, accessibility, and quality of the seaports' data. Their efforts, though, have been hampered by the lack of specific guidance available. To identify particular aspects that better capture customer satisfaction and perceptions of service quality related to maritime ports, this thesis provides an econometrical analysis. Panel data and cross-sectional regressions are implemented using container traffic, median time in port, efficiency in customs, and quality of port infrastructure as response variables. The data and analyses reveal that when a government adopts a specific level of automation and centralized management of maritime port operations, those operations are optimized. That is, such methods must be introduced in harbors judiciously and at the appropriate pace to maintain cooperation and friendly competition among maritime ports.

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LIST OF ACRONYMS AND ABBREVIATIONS

CMAIS	Committee on Maritime Advanced Information Systems
DAI	digital adoption index
DEA	data envelopment analysis
DWT	deadweight tonnage
ESCAP	Economic and Social Commission for Asia and the Pacific
FE	fixed effects
IMO	International Maritime Organization
IT	information and technology
LSCI	liner shipping connectivity index
LSDV	least squares dummy variables
MSW	Maritime Single Window
OECD	Organization for Economic Co-operation and Development
OLS	ordinary least squares
PLSCI	port liner shipping connectivity index
RE	random effects
SCT	Secretariat of Communications and Transportation
TEU	twenty-foot equivalent units
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNECE	United Nations Economic Commission for Europe
USD	United States dollars
WEF	World Economic Forum

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I. INTRODUCTION

"Government does not have an innovation problem; it has an innovation adoption problem."

— Google Chairman Eric Schmidt

Seaports play a critical role in the Mexican economy by facilitating trade and making the logistics cost associated with transportation more competitive. Since 2017, individual port authorities have administered Mexican seaports under the auspices of the Mexican Navy, and their primary functions are vessel inspections, port security, and clearances. Since then, the Mexican Navy has been working to improve the current operational systems in harbors.

One of the challenges that the Mexican Navy faces in maritime ports is the administrative burden arising from duplicative operations among governmental institutions, primarily between the Mexican Navy and the Secretariat of Communications and Transportation. These operations are mostly concerned with trade- and cargo-related issues, and their duplicative nature results in a lack of centralized data management capabilities.

An analysis of the factors that may be significantly correlated with seaport efficiency could provide further information about how the Mexican government can restructure its maritime port operations. According to the United Nations Conference on Trade and Development (UNCTAD, 2019a), one form of analysis is creating a set of performance indicators.

Hence, to accomplish the primary goal of this thesis, which is to identify the factors correlated not only with port performance but also with quality of service and customer satisfaction in maritime ports, I conduct an econometric analysis. In the literature review, I examine the previous empirical studies related with port performance and customer satisfaction, as well as the role of the authorities in maritime ports. Then, I identify those conceptual models that can be used as a reference for further analysis in customer satisfaction.

The model I select from the literature review provides empirical evidence to fill the literature gap about service quality and customer satisfaction. This model consists of five dimensions: resources, outcomes, process management, image, and social responsibility, with each dimension measured by several explaining factors (Thai, 2008). The data collected aims to identify the variables that explain the behavior of such dimensions and therefore create an econometric model to measure the quality of service and customer satisfaction.

To implement this model, I use panel data and cross-sectional analysis. The response variables I use as proxies that explain the dimensions are container throughput, for the management dimension; the port's infrastructure quality, for the resources dimension; efficiency in customs procedures, for the process dimension; and the median time in port for the outcomes dimension. My hypothesis is that a government's adoption of digital methods to centralize and automate port operations has an effect on each of the dimensions.

The analysis shows several significant findings associated with the factors that explain the perception of service quality and customer satisfaction in maritime ports. One of the most notable is the relatively high correlation between the digital adoption by the government index (hereinafter referred to as digital adoption) and better management in maritime ports, holding other factors constant.

This is the most notable finding for multiple reasons. First, among all the regressions run in this thesis analysis, the digital adoption by the government index has the most impact on all the dimensions of the service quality conceptual model. Second, as the fixed effect in panel data controls for variables can be omitted across individual observations, it helps to decrease the bias from privileged geographical location and national stability among ports. The panel data analysis shows a positive correlation between maritime port performance and the government's centralization and automation effort.

The last finding to note is that the digital adoption by the government index shows a quadratic form in some explanatory variables, such as efficiency in customs procedures and port infrastructure quality. A possible explanation for this finding is that the government's effort aims for automation of many port operations now comprising low-skilled jobs, particularly the majority of tasks in customs and infrastructure activities at ports. Those jobs will be at risk while automation will benefit those with higher skilled jobs.

The findings suggest that centralization and automation of the maritime port system can promote a robust network among harbors; however, if implemented too quickly and injudiciously, it may discourage cooperation and friendly competition among ports.

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II. BACKGROUND

In 2002, Mexico started a project to innovate its current operational port system, aiming for centralization and automation. While these innovations were realized individually at some major ports, the intended to facilitate broader cooperation among all ports has not yet extended to port hinterlands. Consequently, this issue generated a domestic legal, economic, and societal crisis, as demonstrated by the fact that only four out of 6,182 offshore vessels operating in Mexico during the last decade were Mexican (Villegas, 2009).

Legally, higher costs burden Mexican ship owners, making it uncompetitive for them compared with foreign ships flagged overseas that are not subject to Mexican taxes. For example, Mexican ships pay 35% for general maritime services, and according to the Mexican income tax law, foreign ships pay just 5% (Ley de impuesto sobre la renta, 2013). Policymakers justify this situation in part because of the international agreements that Mexico has with the Organization for Economic Co-operation and Development (OECD). Nevertheless, this tax law effectively puts Mexican shipowners at a disadvantage.

From an economic perspective, the issue is reflected in the commercial value of global trade, where 29% of international trade was maritime in 2019. Most of this was earned by foreign ships due to Mexico's lack of a proper national nautical fleet. In fact, Mexico's high dependence on an international fleet in most national maritime activities, including the strategic ones, represents a lack of sovereignty and a risk to national security.

From a social perspective, more foreign ships in Mexico mean a missed opportunity for significant employment in the maritime sector for Mexican citizens. The shipbuilding industry in the country is also affected. Domestic shipbuilders tend to find less reason to invest in the shipbuilding industry. There is a tendency for them to focus on secondary activities such as maintenance and assistance. These actions decrease labor opportunities and technological research in Mexico.

Furthermore, Mexican maritime ports have required further improvements as the operating system discourages maritime trade among customers. For that reason, in 2017, the Mexican Government assigned its Navy to take control of the ports' authority after a hiatus of 41 years, during which the ports were managed by the Secretariat of Communications and Transportation (Secretaría de Comunicaciones y Transportes – SCT). Among other things, the Mexican Navy assumed all security functions of the ports, while the SCT remains in charge of all economic aspects.

Effective in June 2017, the Mexican Navy officially introduced the General Directorate of Port and Maritime Affairs (Dirección General de Capitanías de Puerto y Asuntos Marítimos), which is taking charge of the 98 Port Captaincies active on both coastlines of the country — Pacific Ocean and Gulf of Mexico — out of a total of 103 in the process of transfer from the SCT. Since then, the Mexican Navy has been working to find solutions to the previous problems and taking action to address security issues and administrative challenges.

According to the Organization for Economic Co-operation and Development (OECD, 2019a), there are duplicative efforts that create administrative burdens affecting readiness and informed decision making at seaports. These are mostly concerned with trade- and cargo-related issues. In Mexico, the duplication is due in part to policy shortfalls between governmental institutions, primarily between the Mexican Navy and the SCT. This duplication results in a lack of centralized data management capabilities.

The International Maritime Organization's latest Amendment recommends that governments should establish electronic information procedures in harbor operations (IMO, 2019). According to the International Maritime Organization, these actions will prevent poor port management by increasing a broader coordination among ports at both the national and the international level.

Along these lines, Mexico could develop a Maritime Single Window (MSW) that contains the data public port authorities and the government will demand from ships. Improvements in data collection and management will provide broader and faster networking. Since the International Maritime Organization has already offered the basic software for an MSW, implementation would require minimal capital expenditure and offer a significant investment return. Additionally, these actions will enable effective operational decisions within the maritime environment (CMAIS, 1999).

Although the International Maritime Organization has developed recommendations and guidelines for trade facilitation and electronic business, they are limited. The instructions provide only basic definitions, models, data harmonization, or roadmaps towards implementing an innovative ports management system in maritime ports. Implementers may face many difficulties in introducing such innovations because no specific guidelines cover the data management system.

Furthermore, the development timeline for maritime port systems varies from one country to another, and it depends on political will, adequate planning, and funding (Niculescu & Minea, 2016). As a reference, several countries in the European Union have set a target of five year. Nevertheless, this estimation varies depending on current political support.

An innovative Maritime Single Window addresses its financial system by three typical models: 1) Fully operated and funded by public authorities, 2) supported by commercial port companies, and 3) paid for by users as a fee per transaction.

A port authority with the overall responsibility for the smooth functioning of the ports is the correct logical organization to maintain a set of performance indicators (United Nations, 1976). Nevertheless, such an authority faces a large amount of data from individual ports that is not thoroughly analyzed. Data managed effectively and efficiently from a unique seaport system will facilitate the required reporting of information to all authorities that need access to it (Maritime Executive, 2014). Consequently, effective data management can facilitate improved collaboration among institutions, resulting in a reduction in inventories and costs, improved speed and service levels, and increased customer satisfaction (Vargas et al., 2018).

For these reasons, Mexico should consider innovation of the current system of operations for its maritime ports to support the national interest. This innovation process would target the entire maritime industry, including all commercial and shipbuilding activities, and would formalize maritime commerce and improve its quality service.

It is important to note, however, the innovation process will likely face resistance by ship owners or even some areas of government, because such an undertaking requires an initial and significant investment in new technology and personnel training. With that in mind, there is a risk of unsuccessful implementation of an innovative Maritime Single Window in Mexico. Thus, it is necessary to identify and address any potential resistance as early as possible in the implementation project. According to the National Single Window Guidelines provided by the European Commission in 2015, well-planned training, awareness, and communication strategies often reduce this resistance. The planning should include project goals, objectives, targets, progress, and difficulties (European Commission, 2015).

III. LITERATURE REVIEW

Assessing service quality and customer satisfaction at Mexican seaports requires drawing on numerous research areas in the literature. This chapter first discusses the many definitions of service quality and customer satisfaction as they relate to seaports. This study then explores how these services are related to seaport authorities and how they can be improved by using quantitative performance indicators.

A. SERVICE QUALITY AND CUSTOMER SATISFACTION IN SEAPORTS

Although the literature relating to the measurement of port efficiency and port choice has been well developed, what constitutes port service quality and customer satisfaction has not been deeply analyzed.

From the seaport performance perspective, relevant studies have concluded that data envelopment analysis is the most frequently used performance evaluation technique. Additionally, these studies demonstrated that the most common performance indicators are based on operational aspects (Ensslin et al., 2018).

Several studies mention what quality means in the industrial and commercial sectors. Yet, few of them are seaport related (Anderson et al., 1993; Bolton et al., 1991; Van Doorn & Verhoef., 2008). Various scholars agree that a successful service quality model consists of five dimensions: tangibles, reliability, responsiveness, assurance, and empathy (Datta & Vardhan, 2017).

By contrast, Thai developed a model to explore the same concept of service quality but focused solely on maritime transport (Thai, 2008). The structure of Thai's model includes the following dimensions: resources, outcomes, process, management, image, and social responsibility. Compared with previous quality service models, Thai's model is more applicable to harbors, particularly because it considers of the importance of social responsibility (Yeo et al., 2015).

This aspect of social responsibility and maritime port management is relevant to other studies. Previous research showed a high correlation between environmentally responsible operations and enhanced customer satisfaction (Yeo et al., 2015). Nevertheless, another research mentioned that port authorities usually lack power in the administration of environmental and sustainability regulations in harbors (Lee, 2014). For that reason, port authorities seek to cooperate with the private sector to make their respective country's ports more competitive.

The other aspect studied, service quality, has a significant positive impact on customer satisfaction. This means that this satisfaction is related to the quality of the products or services provided to shipping lines, cargo owners, and their representatives (Yeo et al., 2015). Customer satisfaction comes from consumers' experience, comparing the expected level of service and the level of service delivered (Ghotbabadi et al., 2015). Thai states that resources, outcomes, process, management, image, and social responsibility positively influence customer satisfaction.

The service quality models reviewed agree that customer satisfaction is related to service quality. Nevertheless, the concept of service quality differs from one model to another within the various industrial sectors. Additionally, although these models identify the factors relevant for better quality service at ports, such models do not provide quantifiable indicators that help seaport managers measure or improve their service quality. It is possible, though, to establish a connection between the empirical indicators of the previous models and quantifiable performance indicators through econometric analysis, which this thesis undertakes as described in the following chapters.

B. SERVICES THAT PORT AUTHORITIES PROVIDE

The definition and role of a port authority varies from one country to another. According to the U.S. Department of Transportation, port authorities supervise harbor operations according to procedures that conform to national and international maritime laws (Bureau of Transportation Statistics, 2017).

In Mexico, the maritime ports law describes the port authority as a representative of the federal government responsible for Mexican maritime ports that conducts programs for the development of the national port infrastructure system, while encouraging participation from the public and private sectors (Ley de puertos [Ports

Law], 1993). Additionally, the same law mentions that the port authority's role is to ensure that protocols at seaports meet the statutory standards while verifying and participating in the improvement of processes and quality of customer service.

Although the management style among port authorities differs depending on their respective habors' specific model, all port authorities share the same goal of serving the public interest (Sherman, 1999). Mexico falls in the category of a Landlord port (World Bank, 2007). This type of port gives the port authority the right to act as a regulatory body, while private companies manage the logistic operations of the port (Van Hooydonk, 2013).

Although the landlord port is the most common port model worldwide, its structure differs from country to country. These differences correspond to the tools that both government and privatized companies employ according to their specific port. These tools include price strategies, access regulation, and environmental management systems (Lam & Notteboom, 2014). Ports adopt different policies depending on their geographical, economic, and political conditions. Hence, it is challenging to determine whether one model is better than another. This thesis aims to develop a model that can control for relevant factors and compare performance indicators between ports.

C. MARITIME PORT PERFORMANCE INDICATOR MEASURES

Seaport terminals use various performance models and indicators to measure their cost effectiveness and quality. The efficiency of ports is measured primarily by operational productivity and customer satisfaction (Tongzon, 2009). From the operational perspective, key measures are associated with labor and capital performance whereas customer satisfaction derives from direct costs, service speed, and safety and security.

The most utilized methods to evaluate productivity in harbors have been data envelopment analysis and stochastic frontier analysis (Cullinane, 2006). It is challenging to obtain port performance with a direct method because of logistic complexity. For that reason, data envelopment analysis estimates port performance using a relative approach while comparing different harbors' components and characteristics (Farrell, 1957; and Charnes et al., 1978).

One component of a port's performance may be competitiveness. Population growth, urbanization, and industrialization accelerate commercial trade, especially sea shipping. As a consequence, maritime trade competitiveness encourages the building of larger containers and deep-sea container carriers. In turn, terminals invest more in the capital and fulfill broader requirements from shippers as a result (Wiegmans & Dekker, 2016. Furthermore, according to a study of ports commissioned by the European Commission, port labor actively impacts harbor competition (Van Hooydonk, 2013). For that reason, most port authorities invest in safer operations and better infrastructure quality, which may increase a port's reputation and performance (Gimenez et al., 2012).

Administrative operations such as commercial, financial, and transport and insurance documents operations play a vital role in seaport efficiency (Tijan, Agatic, Jovic, & Aksentijevic, 2019; Tijan, Jovic, Jardas, & Gulic, 2019). While countries belonging to the Organization for Economic Co-operation and Development recorded 35.4 USD on average for documentary compliance related to exporting a shipment of goods, some countries in Africa, due to underdevelopment, recorded more considerable costs (215.1 USD on average) (OECD, 2019a). The United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) and United Nations Economic Commission for Europe (UNECE) mentioned that continuous simplification of import, export, and transit procedures and documentation would reduce administrative burden and improve seaport performance (UNECE, 2010).

Overall, port performance can be positively influenced by a port's convenient geographical location, reduced port costs, quality infrastructure, and worldwide connectivity (Tongzon, 2001). Nevertheless, some of the research that focused on a determined cargo type (bulk, container, carrier, cruiser) showed that such specialization requires the use of several different performance indicators (Ha et al., 2019; Dayananda & Dwarakish, 2020). Similarly, the studies reviewed that focused on a specific region, such as Southeast Asia and Europe, may have led to possible geographical bias (Lee, 2014; Yeo et al., 2015).

It is also important to note that the dependent variable in the models reviewed also varied. On the one hand, Cullinane considered the container throughput (TEU) as an indicator measure (Cullinane, 2006). On the other hand, other authors argued that net income and berth occupancy revenue per ton of cargo are better performance indicators (Ibrahimi, 2009).

D. SUMMARY

The academic literature shows that port performance research has been well developed, yet what constitutes port service quality and customer satisfaction have not been deeply analyzed. The current research on the quality of service at maritime ports is based on surveys only and requires additional methodologies to produce more robust analysis. The most relevant model related to service quality in maritime ports explores six dimensions: resources, outcomes, process, management, image, and social responsibility. Though the structure and roles of port authorities vary depending on geographical and political factors, these authorities share the common purpose of serving the public interest of a state or region. Additionally, is the research reflected a significant correlation between environmentally responsible operations for enhancing customer satisfaction and the encouragement of collaborative actions between port authorities and the private sector. The subsequent chapters examine the dimensions of service quality from the econometrical perspective, aimed at the development of models that describe the behavior that will result in better service quality and increased customer satisfaction in maritime ports.

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IV. DATA AND METHODOLOGY

A. DATA SOURCES

As described in the literature review, not much research exists specifically on service quality and customer satisfaction in maritime ports. The few existing publications, as mentioned in the previous chapter, are based mostly on surveys and bring an empirical approach, but they identify variables that explain the behavior affecting the perception of service quality in maritime ports.

The conceptual model developed in this thesis consists of the following dimensions: resources, outcomes, process, management, image, and social responsibility, with each dimension measured by several explaining factors. The data collected aims to identify the variables that explain the behavior of such factors and therefore create an econometric model that measures service quality and customer satisfaction.

The data collected for this model comes from the United Nations Conference on Trade and Development (UNCTAD), the World Bank, the OECD, and the National Geospatial-Intelligence Agency. I gathered the data at both the national and the individual port level to identify the correlation between port performance and the country's governance at the respective ports.

B. DATA MANAGEMENT

At the national level, the variables considered in the model are container traffic in twenty-foot equivalent units (TEU), national port liner shipping connectivity index, digital adoption by government index, quality of port infrastructure, and burden of customs procedures. At the port level, the variables are port liner shipping connectivity index (PLSCI), the median time in days that a ship spends in a specific port, the average cargo capacity, and the average container capacity in TEUs, and variables about the port's features.

1. National Level Data

The national level data provides the information that differentiates port performance from one country to another, and it may reduce geographical location and political bias.

a. Container Port Traffic

The container port traffic or container throughput uses TEUs as a unit measure. This unit is widely applied in ground and maritime shipping transportation networks (UNCTAD, 2019b).

b. Quality of Port Infrastructure

The port's infrastructure quality refers to the customer's perception of port facilities; this data was gleaned from 144 countries. The data was gathered from a survey administered by the World Economic Forum (Schwab, 2019). The sample selection was based on company size and business sector using a weighted average approach (World Economic Forum, 2019). The World Economic Forum survey set lower rates for poor infrastructure and higher rates for harbors meeting better international requirements in their facilities.

c. Digital Adoption Index by the Government

The Digital Adoption Index measures a country's relative progress in adopting technology for the public sector in comparison to others worldwide (World Bank, 2019a). The index is measured on a zero to one scale. That is, early adopter countries aim for an index ranking close to one whereas those economies that have struggled to incorporate new technologies show a lower index.

d. Liner Shipping Connectivity Index

The United Nations Conference on Trade and Development (UNCTAD) jointly developed the Liner Shipping Connectivity Index (LSCI) with MDS Transmodal. This index allows us to understand the factors affecting a port's competitiveness, depending on the port's country (UNCTAD, 2019b). MDS Transmodal is a freight transport consultancy specializing in the maritime sector; has been working jointly with the United Nations Conference on Trade and Development since 2006, with the common goal of providing data quality toward the achievement of the sustainable development objectives (Benamara et al., 2019).

e. Median Time at Port

For the present analysis, I use the median time in days a container ship spends at a port in contradistinction to the average time (UNCTAD, 2018). My rationale for doing so is that the average time containers spend in port is longer due to different trading reasons. The statistical distribution for average time has a "long tail" mostly because vessels arrive at a specific port for maintenance or major repairs, which may take weeks or months depending on the size and repair requirements.

Furthermore, along with the median time in port, I include the number of arrivals, which is the port calls captured per country per year; the average size of vessels, considered the average gross tonnage of the vessels that have called in the country's ports during the year; the average deadweight tonnage (DWT) of the vessels that have called in the country's ports during the year; the average capacity to carry TEUs of the container ships; and the maximum size that has called.

Additionally, using the World Port Index generated by National Geospatial-Intelligence Agency (2018), I collected information about the characteristics of the ports. This publication contains the location and physical features of the facilities and services offered by major ports and terminals worldwide.

The term "harbor" is used for the principal water area of the port. The variables that classify harbors are the harbor size, which is based on facilities and wharf space, and harbor type, as illustrated in Figure 1.

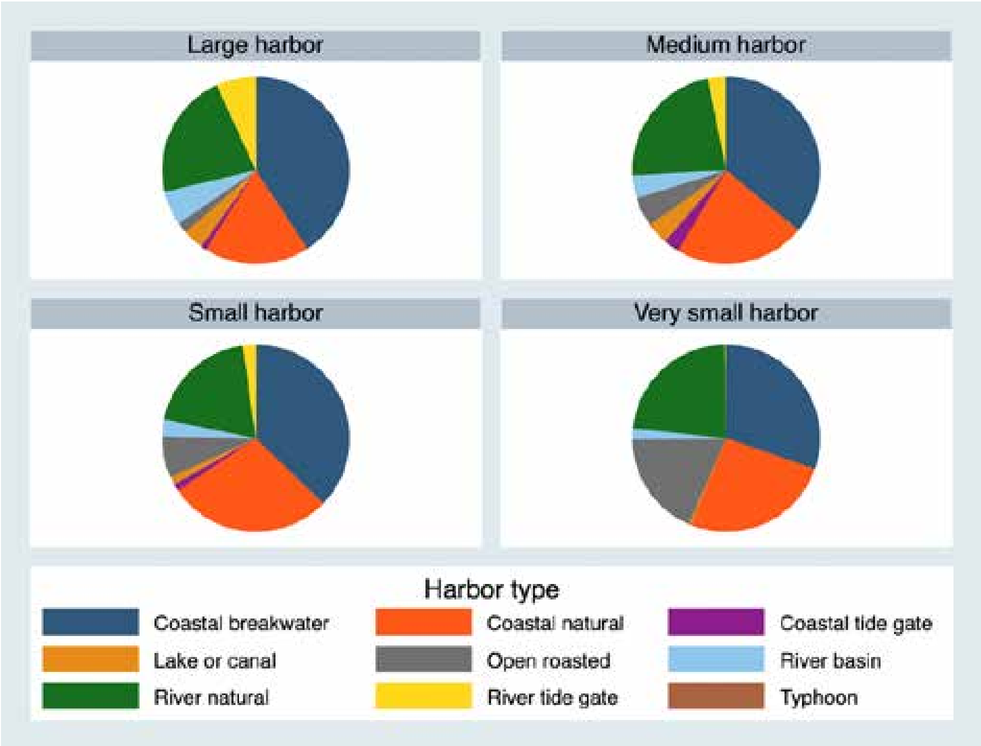

Figure 1. Maritime ports by type and size included in the analysis.

f. Customs Procedures

The customs procedures variable ranges from one to seven and determines the efficiency in terms of service quality and service in customs in a specific country. The methodology used for this variable is similar to that for the quality of port infrastructure (World Bank, 2019b).

2. Port Level Data

The port level data provides information that differentiates one port to another regardless of which country it belongs to. The data may reduce infrastructure characteristics bias.

a. Port Features

Using the World Port Index publication, I collected the physical characteristics of harbors from more than 800 ports (National Geospatial-Intelligence Agency, 2018). The more relevant variables used for the present analysis are the following:

- Bay characteristics. This variable includes the shelter quality, entrance restrictions, overhead limitations, depths, and tide range. Such indicators are relevant for customers in deciding to whether to select determined ports while protecting the ship's safety.

- Ship's size vessel. This is a binary variable where one indicates that the port can receive a ship over 500 feet or 152.4 meters long and zero otherwise.

- Pilotage and tug services. These indicators are represented in a binary form to specify whether the port can supply pilotage and / or tug assistance. These services could not actually be stationed at the harbor in question but may be docked somewhere close to it.

- Communications. This indicator includes the type and number of communication resources that the harbor uses for its operations.

- Load/offload. This variable indicates the area where transshipment operations are handled. Typically harbors load and offload their commerce at the wharf, but ports can also support such operations either anchoring in the bay or mooring at the beach or ice due to lack of space or coast conditions.

- Medical facilities. This indicator is represented in a binary form to specify whether the port has medical facilities.

- Garbage disposal. This indicator is represented in a binary form to specify whether the port provides garbage disposal that meets international standards.

- Cranes/lifts. This variable indicates whether there are cranes available, what type, and their lifting power in tons.

b. Port Liner Shipping Connectivity Index

Similar to the national LSCI, the port liner shipping connectivity index (PLSCI) variable reflects a port's position in the global liner shipping network. A higher value is associated with better connectivity. The variable base is set at 100 for the top-ranked port in 2006, Hong Kong, and all other observations concerning this value.

The index is generated for more than 900 container ports globally and consists of the number of port calls, average container capacity per ship, number of shipping companies, and worldwide port accessibility without requiring transshipment.

This indicator helps to reduce the service quality and geographical location bias. For that reason, this index can be used as a proxy for connectivity to the global maritime commerce (Rodrigue, 2010).

C. KNOWN DATA LIMITATIONS

Global statistics depend on individual countries' data quality, and some governments may not be staffed appropriately or sufficiently to ensure that quality. The collection of accurate data, especially in developing countries, is often difficult and relatively expensive. Lack of technical capacity, competency, policy, or politics is the main challenge that prevents some countries from keeping an accurate track of data and high-quality analysis.

Another limitation is that working with several data set sources differs not only in quality but also in the data time. Some data sets were provided fully in year-to-year statistics from 2010 to 2019, but some covered limited years and contained fewer observations, bringing an unbalanced panel data set. Such limitations constrained the analysis, especially when working in panel data analysis. Some other data sets were provided in cross-sectional form only, so they were not considered for panel data regressions considering that the data given changes over time.

The variables used in the regression models used in this thesis are described in Table 1.

Table 1. Descriptive statistics from the variables used in the regression models.

Variable	Obs	Mean	Std.Dev.	Min	Max
Container throughput	5576	2.09e+07	4.28e+07	48735	2.26e+08
Digital adoption	5576	.695	.163	.166	.992
Port connectivity index	5576	12.876	16.946	.479	133.583
Customs efficiency ranking	5576	4.644	.935	1.7	6.47
Port quality ranking	5576	4.785	.896	1.9	6.8
Total median time at port (days)	5576	1.159	.513	.41	4.12
Container median time at port (days)	5576	.916	.525	.33	3.8
Number of services at port	5576	6.406	2.894	0	11
Wharf operations available	5576	.944	.23	0	1
Mooring operations available	5576	.169	.375	0	1
Average cargo capacity (thousands of tons)	5576	27.375	18.26	6.874	95.784
Average container capacity (thousands of TEUs)	5576	3.273	1.539	.783	7.297
Tug service available	5576	.919	.272	0	1
Pilot available	5576	.914	.281	0	1
Sanitation service available	5576	.968	.177	0	1
Total arrivals	5576	120.262	121.887	.24	524.469
Railway logistics network	5576	.734	.442	0	1
Airport nearby	5576	.794	.404	0	1
Excellent shelter at port	5576	.212	.409	0	1
Number of restrictions	5576	1.936	1.009	0	5
Fixed crane available	5576	.706	.456	0	1
Mobile crane available	5576	.853	.354	0	1
Float crane available	5576	.395	.489	0	1

D. METHODOLOGY AND REGRESSION MODELS

This thesis's main objective is to determine which factors are correlated with service quality and customer satisfaction, using panel data analysis. I use a regression for each of the variables related to the dimensions of service quality discussed in the literature review. The response and control variables relationship is illustrated in Figure 2. The response variables used as proxies that explain the dimensions are container throughput, for the management dimension; port infrastructure quality, for the resources dimension; efficiency in customs procedures, for the process dimension; and the median time in port for the outcomes dimension.

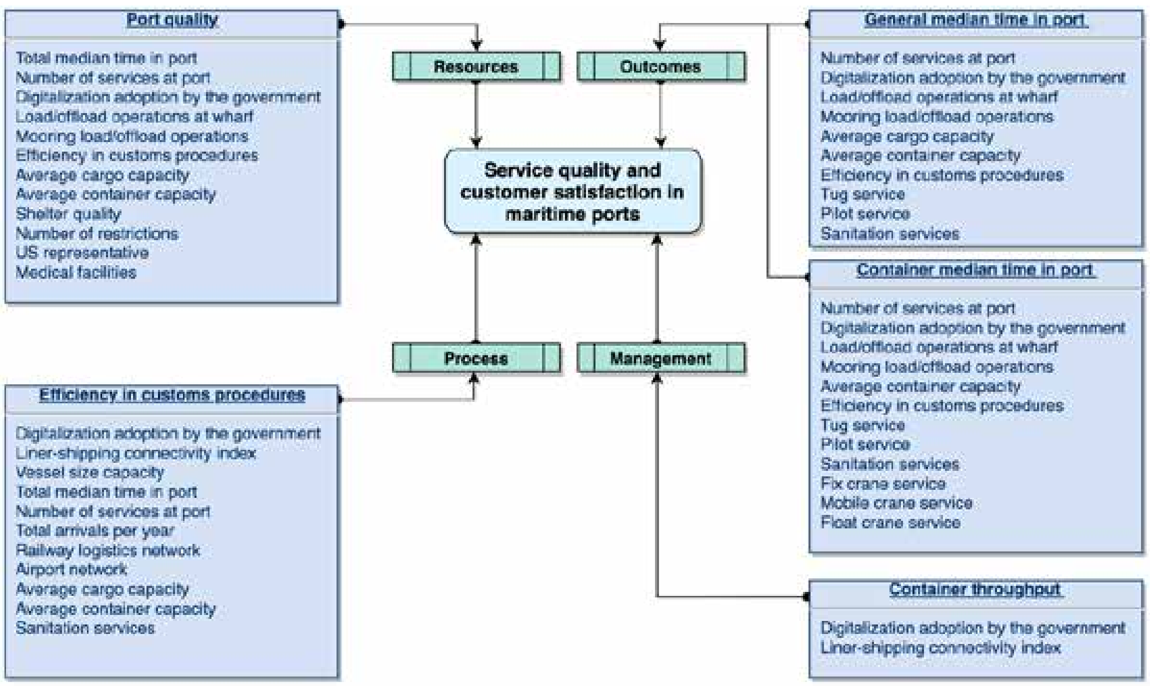

Figure 2. Relationship of the control and response variables to the service quality at maritime ports model.

First, I use a scatter plot to provide an overview of the relationship of the container throughput (TEU), port liner shipping connectivity (PLSCI), quality of port infrastructure (port_quality), and digital adoption by the government (dai_gov) variables.

Then, I use the panel data methodology to address how the digital adoption by the government index explains the container throughput. I control for the number of port calls, port physical infrastructure, and geographical advantage by including the port liner shipping connectivity in this model.

I hypothesize that a government's adoption of digital methods to manage port operations has an effect on the container throughput by holding constant the liner shipping connectivity index from 2011 to 2019, taking 2010 as a base year. This model helps identify the relationship between the digital adoption by the government index and the country's maritime logistics network. To measure the factor determining the effect of the digital adoption index in container throughput with panel data, I use the following equation:

$$y_{it} = \beta x_{it} + a_i + \varepsilon_{it}$$

where

i = Maritime ports considered in the model

t = Years 2010 to 2018

The response variable y_{it} is the volume of trading in the selected ports in TEUs (container throughput), and x_{it}, is the independent variable considered in the model. The term a_i, represents unobserved state-specific factors that explain TEUs other than digital adoption and liner shipping connectivity.

Because the panel data does not reflect unobserved state-specific factors that are also changing over time, I created dummy variables from 2011 to 2018. I considered the year 2010 as a base year to avoid perfect collinearity. With these specifications, the regression model is shown in following equation:

$$log(TEU)_{it} = \beta_0 + \delta_1 d11 + \delta_2 d12 + \delta_3 d13 + \delta_4 d14 + \delta_5 d15 + \delta_6 d16 + \delta_7 d17 + \delta_7 d18 + \beta_1\, dai\_gov_{it} + \beta_2 log(plsci)_{it} + a_i + \varepsilon_{it}$$

where

log(TEU) = Logarithmic function of container throughput in TEUs

$\delta_1 d11 - \mathrm{d}18$ = Dummy variables for years 2011 to 2018

dai_gov = Digital adoption by the government index

$log(plsci)$= Logarithmic function of port liner shipping connectivity index

a_i = Other unobserved specific factors that explain TEUs

I use Ordinary Least Square, Fixed Effects (FE), and Random Effects (RE) regressions for the present analysis. A Hausman-Taylor specification test is used afterwards for best model testing.

E. SUMMARY

I use econometric analysis to identify the models that better explain the service quality and customer satisfaction in maritime ports. Variables from national and port level are used as proxies for the dimensions related to the service quality conceptual model discussed in the literature review. The response variables used for the current analysis are container throughput, for the management dimension; port infrastructure quality, for the resources dimension; efficiency in customs procedures, for the process dimension; and the median time in port for the outcomes dimension. I use panel data analysis for container throughput because of the extended data available to control for unobserved factors among ports and nations. For infrastructure quality, customs procedures, and median time in port, I use cross-sectional analysis that creates a model for the latest updated data provided.

V. ANALYSIS

A. CONTAINER THROUGHPUT

In this section I use panel data analysis to identify characteristics that explain the container throughput. The data I select explains the number of TEU's based on port liner shipping connectivity and digital adoption by the government. This data is from 2010 to 2018.

1. Scatter Plot Overview

Figures 3 and 4 show a positive correlation between liner shipping connectivity and the digital adoption by the government index in 2010 and 2018, respectively. The balloons' sizes represent the yearly container throughput in TEUs, the higher (larger) the balloon, the more container trade a particular country had in that year. The balloon's color represents the perception of the port's quality based on customers' responses to a survey conducted by the World Economic Forum (WEF, 2019a). Colors range from green for high quality to red for countries whose ports are perceived to have poor quality. The countries represented are China (CHN), Great Britain (GBR), the United States (USA), Singapore (SGP), Mexico (MEX), and Colombia (COL).

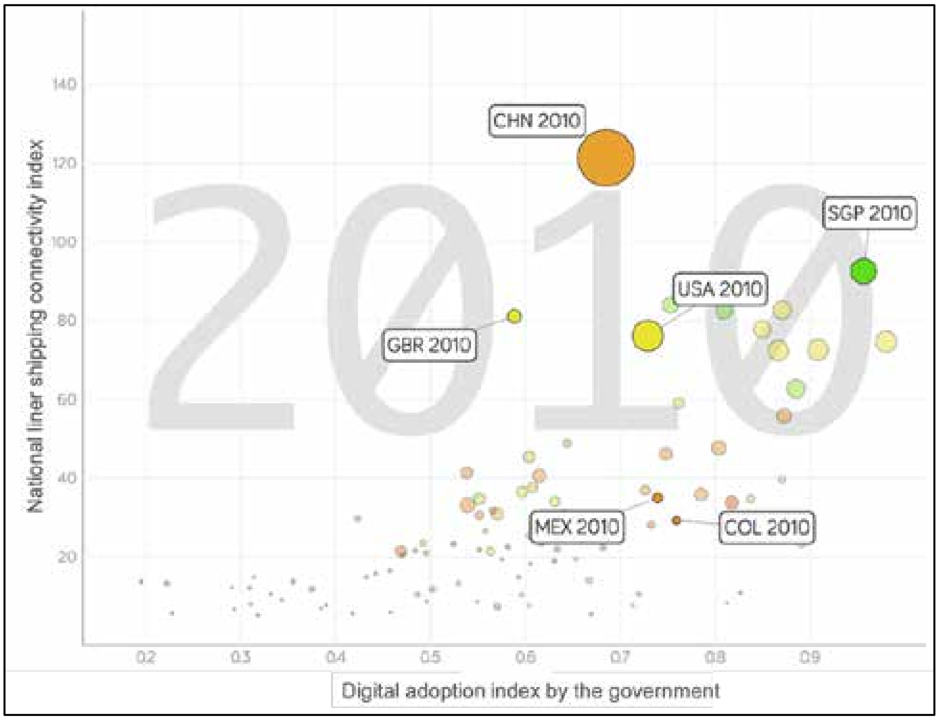

Figure 3. Relationship between digital adoption by government index and national port connectivity scatter plot for 2010.

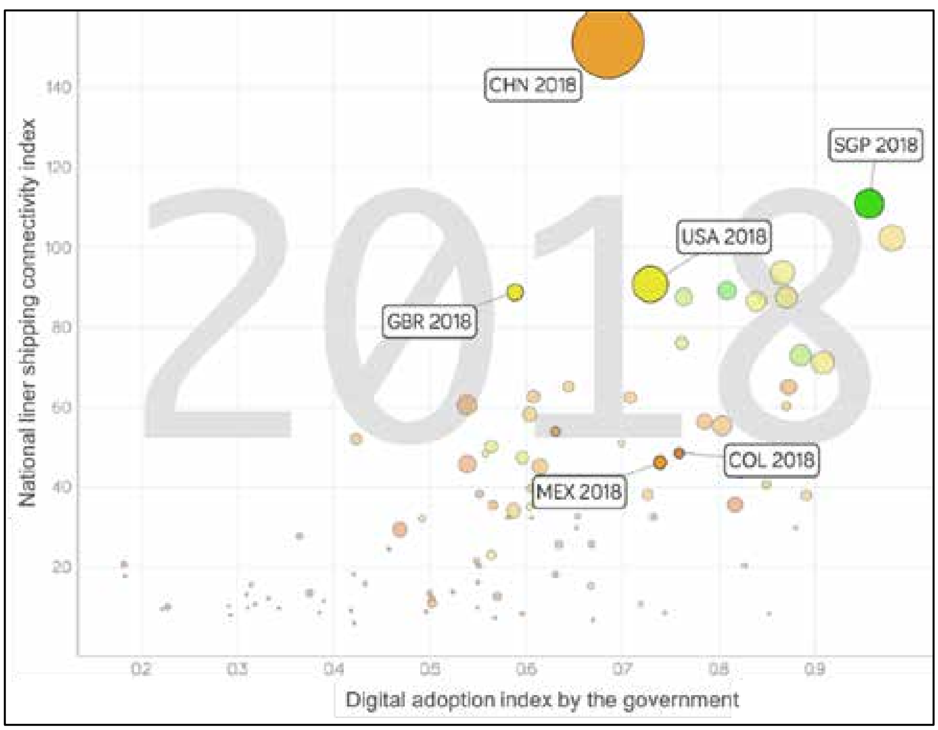

Figure 4. Relationship between digital adoption by the government index and national port connectivity scatter plot for 2018.

2. Outlier

Most of the observations show a similar response to the effect of the variables represented in the scatter plots, with China as a clear exception. I use a box plot to examine this particular case.

a. China

The box plot in Figure 5 shows the worldwide distribution of the total maritime container throughput in TEUs for the years 2010 and 2018. The orange boxes represent the combined nations comprising the 25th through 75th percentile. The line inside the orange box represents the median; the closer to the middle line, the more normally distributed the data. That is, 2018 shows a more normal distribution of the container trade among nations than in 2010.

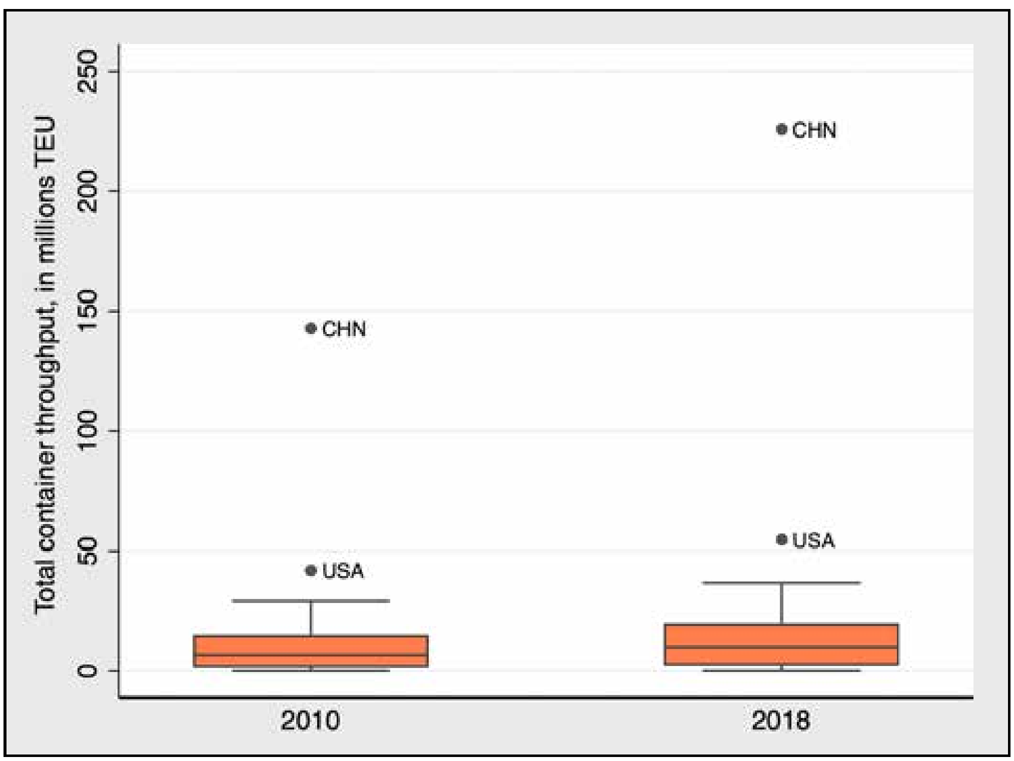

Figure 5. 2010 and 2018 box plots of container throughput worldwide.

China has led in the level of shipping connectivity by sea, regardless of its government’s adoption of digital port operations and the quality of its ports. The country has shown a rapid rise in maritime trade by the increasing number of port calls and customers. Yet, the main reason for Chinese ports’ increase in capacity—and its position as an outlier—is China’s large-scale port construction, which focused on quantity rather than quality. China has constructed more ports than any other country and has increased its cargo throughput by 1,434 times since 1949 (Zhu, 2019).

Although China is by far the leader in maritime trade, partly because of the government’s main goal to build more maritime ports, the relatively poor quality of the ports¾indicated by the orange color in the scatter plots¾has led to overcapacity and disorderly competition (Zhu, 2019). Ports with the same services located closer to each other lead to poor resource allocation, contributing to a lack of coordination and conflicts of interest among harbors.

Figure 7 shows the more recent Chinese maritime governance system under which local government authorities manage their own maritime ports. This system, named the “one city, one port, and one administration,” motivates the development of the high-speed port (Xu & Chin, 2012). The lack of existing cooperation among Chinese local governments and their maritime ports, however, has contributed to a rethinking of this current policy.

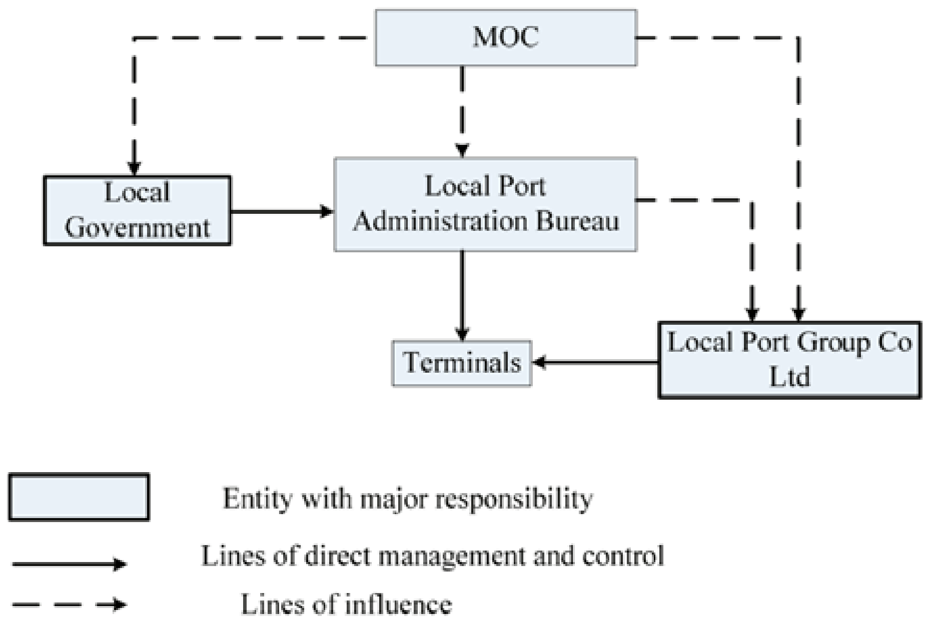

Figure 6. China's main seaports and river ports governance model. Source: Xu and Chin (2012).

In other words, centralized data management should not be so extensive and complex as to discourage the ports from cooperating with one another. That is, ports must cooperate and compete simultaneously (Zhuang et al., 2014).

Observations about outliers such as China can cause anomalies in the regression analysis; the smaller the data set, the more sensitive it is to outliers. In addition to the data set used for the present analysis being relatively large, the logarithmic transformation for the container throughput variable also de-emphasizes outliers. Hence, it potentially allows us to obtain a bell-shaped distribution.

b. A Comparison of Countries with Similar Liner Shipping Connectivity

Figures 4 and 5, shown previously, highlight the United States and Great Britain as two countries showing similar liner shipping connectivity. Both countries had similar capacity vessel size, number of port services, and number of companies that deploy container ships. However, from 2010 to 2018, the United States surpassed Great Britain in port connectivity. Similarly, Colombia and Mexico were positioned close to each other in 2010, with Colombia showing a slightly lower value. Nevertheless, by 2018 Colombia had surpassed Mexico.

Countries such as Mexico and Great Britain that were surpassed by their counterparts in 2018 showed a lower digital adoption index than their counterparts. Both cases also show a homogeneous port quality infrastructure, with green for the developed countries and dark orange for Mexico and Colombia.

In the particular case of Colombia, one of the reasons it shows a relatively high digital adoption index is its open data initiative, which aims to promote the accessibility, availability, and reuse of government data by both public and private users (OECD, 2019b). Mexico has also implemented open data initiatives that have had impacts within the public sector in Mexico as well as at the international level. So far, however, they lack scale. Only a limited number of public services have adopted these solutions, and the maritime sector is not fully included. Additionally, these strategies do not provide customers the use and sharing of personal data by public institutions, which still causes administrative burden in the maritime sector (OECD, 2020).

Investing in physical infrastructure is necessary and is encouraged by competitiveness among maritime ports since this logistics network benefits from economies of scale. Yet, the present scatter plot analysis shows that there are also intangible factors that need to be considered in seaports, such as digital services supplied by the government. These intangible factors are relevant not only for port performance but also for better service quality. Omitting such characteristics could erode economies of scale and make physical infrastructure investments worthless.

The scatter plot overview serves to identify the relationship between the variables of interest used in the panel data regression model. The plot shows a robust tendency for liner shipping connectivity and digital adoption by the government index to rise above their means or fall below their means at the same time. The trend line has a positive slope, which shows a positive correlation between the variables. The scatter plot also shows a relative growth of container trade with higher shipping connectivity and digital adoption values, with China as a clear outlier. I use the logarithmic transformation for the container throughput throughout the regression to reduce the influence of those observations.

3. Panel Data Analysis

In the previous section, I analyzed the correlation between the liner shipping connectivity, digital adoption index, container throughput, and the quality of port infrastructure. I briefly analyzed specific cases of interest such as China, the United States, Great Britain, Colombia, and Mexico. China was analyzed further to identify the reasons for its position as an outlier in both the scatter plot and the box plot. The logarithmic function for the container throughput variable helps generate a better regression that includes outliers.

Table 2 shows the regressions of pooled ordinary least squares (OLS), and random and fixed effects, respectively, using panel data analysis.

Table 2. Panel data regressions on container throughput (TEUs).

	(1) Pooled OLS log (TEU)	(2) Fixed effects log (TEU)	(3) Random effects log (TEU)
Digital adoption by the government	5.076***	0.586***	1.461***
	(0.096)	(0.164)	(0.149)
log (PLSCI)	0.135***	0.040***	0.042***
	(0.017)	(0.007)	(0.007)
2011	0.071	0.078***	0.078***
	(0.081)	(0.007)	(0.007)
2012	0.116	0.125***	0.125***
	(0.081)	(0.007)	(0.007)
2013	0.173*	0.160***	0.160***
	(0.081)	(0.007)	(0.007)
2014	0.199*	0.187***	0.186***
	(0.081)	(0.007)	(0.007)
2015	0.188*	0.190***	0.189***
	(0.082)	(0.007)	(0.007)
2016	0.219**	0.212***	0.212***
	(0.081)	(0.007)	(0.007)
2017	0.274***	0.270***	0.269***
	(0.082)	(0.007)	(0.007)
2018	0.325***	0.319***	0.318***
	(0.082)	(0.007)	(0.007)
_cons	11.661***	14.966***	14.359***
	(0.096)	(0.115)	(0.117)
N	5578	5578	5578
R^2	0.263	0.374	

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

a. Pooled OLS Model

I pooled the model and employed an OLS regression. If the variables used in the model are assumed to be constant across time and individuals, there is no significant individual or temporal effect. For that reason, the pooled OLS panel regression takes the form presented in the following equation, where the fixed effect is not considered:

$$ln(TEU)_{it} = \beta_0 + \delta_1 d11 + \delta_2 d12 + \delta_3 d13 + \delta_4 d14 + \delta_5 d15 + \delta_6 d16 + \delta_7 d17 + \delta_7 d18 + \beta_1\, dai\_gov_{it} + \beta_2 ln\,(plsci)_{it} + \varepsilon_{it}$$

I expect a positive correlation of port liner shipping connectivity on container throughput, as liner shipping accounts for the number of port calls, size of the harbor, and maximum ship size capacity (deeper channels and berths). Holding constant for such factors helps identify what factors other than continuous physical infrastructure growth facilitates shippers and carriers doing business in a maritime port. My expectations for the digital adoption by the government index are uncertain, as the government strategy varies from one country to another, depending on geographical and political situations.

The table shows that a government fully implementing centralization and automation (dai_gov = 1) will increase container throughput by 500%, holding the size of port physical infrastructure, connectivity, and port calls constant. This is a considerable effect, and for that reason, I am also analyzing these panel data.

The model also states that for every 1% increase in port liner shipping connectivity, there is an effect of 0.13% in container trading growth. The dummy variables explain how container growth has increased over time, although some are not statistically significant at a 95% confidence interval.

b. Fixed Effects Model

The fixed effects model¾also called as the Least Squares Dummy Variables (LSDV)¾allows for different constants for each group by including dummy variables. The estimation of the digital adoption by government index and liner shipping connectivity were found to be positive influences as they were in the pooled OLS model, but with a significantly lower coefficient. This was especially true for digitalization adoption. The fixed effects model shows that the digitalization adoption effect on container throughput is ten times lower when controlling for omitted variables across ports. In this model, the government's total implementation of digital methods increases the container throughput by 58.6% in a specific port, compared to a port with zero support for digitalization adoption by the government, and holding the physical infrastructure capabilities and port calls constant.

c. Random Effects Model

The random effects method is similar to the fixed effects model, differing in that the random effects method handles the constants for each section as random rather than fixed parameters rather. The model shows no significant changes in the liner shipping connectivity coefficient, with a similar effect of 0.042% growth in container throughput for each 1% increase in the size of the physical infrastructure, and the number of port calls.

The digital adoption by the government index's coefficient is powerfully influential here compared to the one in the fixed effects model, but lower than for the pooled OLS regression. In this model, the complete implementation of digital methods in services provided by the government increases the container throughput to 146%.

d. Hausman–Taylor Specification Test

The Hausman test provides a guide for discriminating between the fixed effects and the random effects estimators. The fixed effects model is consistent in both the null and the alternative hypothesis whereas the random effects model is only constant under the null hypothesis. That is, when the null hypothesis is true it means that there is no difference between random and fixed effects (Wooldridge, 2015. The null hypothesis tested is that the difference in coefficients for the two models is not systematic:

$$H_o: \beta_{FE} = \beta_{RE} \ \ vs \ \ H_a: \beta_{FE} \neq \beta_{RE}.$$

With a p-value < 0.001, the null hypothesis that the difference in coefficients is not systematic is rejected. Therefore, I reject the random effects equation according to the Hausman-Taylor test. That is, the model is better explained with a fixed effects approach (Wooldridge, 2015.

From the preceding analysis, it is found that both variables, the digitalization adoption by the government index, and the port liner-shipping connectivity index, show a positive influence in terms of container throughput growth under all models. I applied the Hausman-Taylor test, which strongly supports the fixed effects model.

As opposed to the pooled OLS regression, the fixed effects model controls for variables that can be omitted across individual observations, ports in this case. By controlling for the omitted factors, the digitalization adoption coefficient from the fixed effects model shows a significantly lower impact on the percentage growth in container throughput (TEU), compared to the pooled OLS regression. Although this difference indicates there are omitted factors across ports, the digitalization adoption index keeps a significant effect on container throughput, with a p-value of 0.05. That is, considering the different factors that make worldwide ports different from each other, the digitalization adoption index remains significant, with a 95% confidence interval.

With a p-value < 0.001, the pooled OLS model is biased upward, so either:

$$p\left(a_i,\ dai_{gov}\right) > 0\ and\ (a_i,\ lteu) > 0,$$

or

$$p\left(a_i,\ dai_{gov}\right) < 0\ and\ (a_i,\ lteu) < 0.$$

There are possible characteristics of ports captured consistently with this bias, such as a privileged geographical situation and the governmental policy approach from both the national and local levels towards ports management and operations.

Panel data analysis pointed out that there should be equilibrium balance in the degree to which the government inserts itself in maritime port operations from the digitalization perspective. Next, I use a cross-sectional analysis to identify the effect of digitalization adoption in the Resources, Outcomes, and Process dimensions.

B. PORT INFRASTRUCTURE QUALITY

In this section, I use the quality of the port infrastructure variable as a proxy for the resources dimension. This dimension refers to the port facilities' condition and availability.

Figure 7 shows that a government's adoption of digitalization has a decreasing positive effect on port infrastructure quality. In this case, I am using a quadratic function to identify the decreasing marginal effect on the response variable. Also, variables other than digitalization adoption are included to hold constant factors that otherwise would bias the real effect of a government's digitalization adoption on the quality of port infrastructure.

More specifically, the quadratic regression model estimates the following equation:

$$log(\,port\ quality) \ = \ \beta_0 \ + \beta_1\, daigov + \beta_2\, daigov^2 + \ \beta_3 C \ + \varepsilon$$

where

log($port\ quality$) = Logarithmic function of port infrastructure quality

$daigov$ = Digitalization adoption index by the government

$daigov^2$ =Squared digitalization adoption by the government index

C = Control variables (total median time, services, wharf and mooring operations, customs efficiency, average cargo and container capacities, shelter quality, restrictions, U.S. representative, and medical facilities)

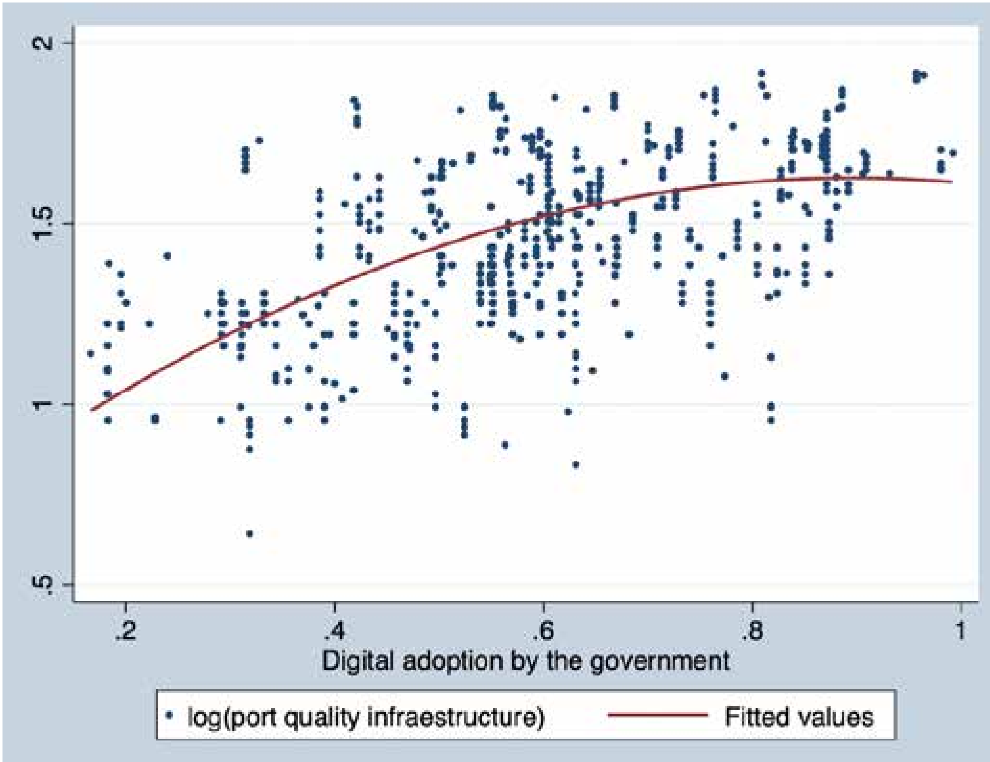

Figure 7. Relationship between port infrastructure quality and digital adoption by the government index scatter plot.

Figure 7 shows a statistically positive correlation between the digital adoption index and the logarithmic function of the quality of port infrastructure, in a quadratic function, with other factors held constant. Yet, the digital adoption index's quadratic function shows a decreasing marginal effect on the quality of port infrastructure. Government efforts to use digital methods for centralized data and port operations management have a greater effect in low-quality ports than in high-quality ports, holding other factors constant.

With the derivative of the quadratic function, I seek to determine whether the digital adoption index shows a real turning point, using the following function,

$$daigov = \frac{\beta_1}{2\beta_2}.$$

From the data provided in the Table 3, it can be seen that the derivative Equations 1, 3, and 4 (identified in the column headings of the table) show a positive relationship between the digital adoption index and the logarithmic function of port quality. Yet, those equations do not show a significant turning point effect from the digital adoption index on port infrastructure quality. Equation 2 of the Table 3, however, does show a turning point of 0.823 in the digital adoption index variable. To maximize customers' perceptions of port infrastructure quality, the government should implement digital methods in no more than 82.34% of operations at all ports, holding other factors constant. Exceeding this level of control through more centralized maritime port management would lead to a decreasing effect in the quality of port infrastructure.

Table 3. Port infrastructure quality regression models.

	(1) log (port quality)	(2) log (port quality)	(3) log (port quality)	(4) log (port quality)
Digital adoption	0.306***	1.535***	0.306***	0.341***
	(0.053)	(0.074)	(0.053)	(0.053)
Squared digital adoption	-0.102**	-0.932***	-0.102**	-0.127***
	(0.037)	(0.054)	(0.037)	(0.038)
Median time	-0.039***	-0.168***	-0.039***	-0.038***
	(0.004)	(0.006)	(0.004)	(0.004)
Services	0.006***	0.014***	0.006***	0.005***
	(0.000)	(0.001)	(0.000)	(0.001)
Wharf operations	0.008	-0.009	0.008	0.009
	(0.006)	(0.008)	(0.006)	(0.006)
Mooring ops	-0.018***	-0.055***	-0.018***	-0.017***
	(0.003)	(0.006)	(0.003)	(0.003)
log (customs)	0.650***		0.650***	0.656***
	(0.010)		(0.010)	(0.010)
Avg. cargo	-0.002***	-0.001***	-0.002***	-0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
Avg. container	0.008***		0.008***	0.007***
	(0.001)		(0.001)	(0.001)
Excellent shelter		0.029***		0.011***
		(0.005)		(0.003)
Restrictions		-0.009***		-0.011***
		(0.002)		(0.001)
US representative				0.011***
				(0.003)
Medical facilities				0.035***
				(0.006)
_cons	0.418***	1.106***	0.418***	0.387***
	(0.023)	(0.030)	(0.023)	(0.024)
N	5576	5576	5576	5576
R^2	0.785	0.471	0.785	0.789

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

C. EFFICIENCY IN CUSTOMS PROCEDURES

The efficiency in the customs procedure variable serves as a proxy for the process dimension of the service quality conceptual model. This dimension refers to the interaction between employees and customers during the operations at the port. The efficiency in customs procedures, particularly in maritime ports with international trade, plays a vital role in customers' perception of the service process.

Similar to the findings for quality of port infrastructure, Figure 8 shows a decreasing marginal effect in the logarithmic function of customs procedures for the digital adoption variable. The scatter plot also shows a more obvious turning point compared to the port quality analysis. For that reason, I am using a quadratic function as well as follows,

$$log(\,customs\;procedures) \;=\; \beta_0 \;+ \beta_1\, daigov + \beta_2\, daigov^2 + \;\beta_3 C \,+ \varepsilon$$

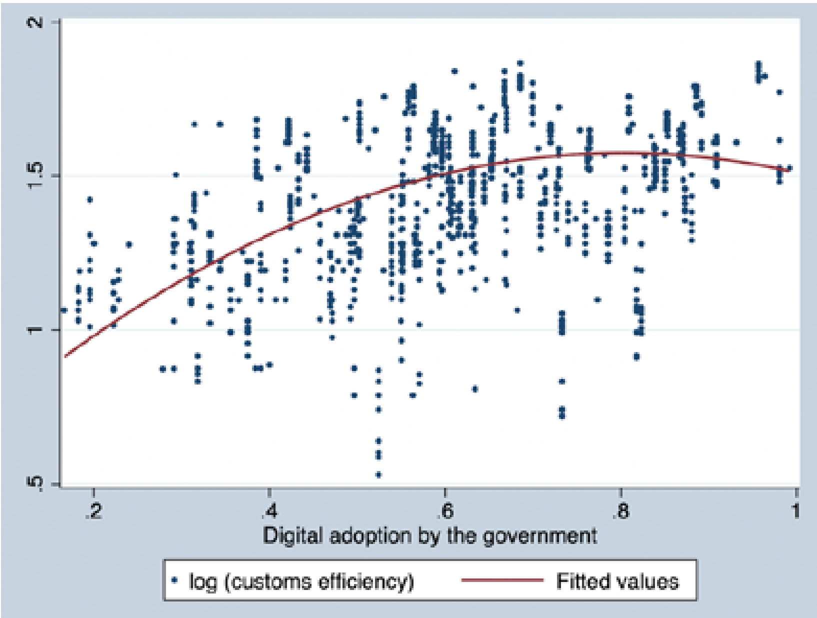

Figure 8. Relationship between customs efficiency procedures and digital adoption by the government index scatter plot.

Table 4 shows the regressions using the control variables of the logarithmic function of efficiency in customs procedures.

Table 4. Customs efficiency regression models.

	(1) log (customs efficiency)	(2) log (customs efficiency)	(3) log (customs efficiency)	(4) log (customs efficiency)
Digitalization adoption	1.927***	1.938***	1.626***	1.603***
	(0.077)	(0.076)	(0.082)	(0.080)
Squared digitalization	-1.203***	-1.226***	-1.040***	-1.028***
	(0.058)	(0.058)	(0.061)	(0.060)
Log (PLSCI)	-0.005*	-0.001	-0.010***	-0.011***
	(0.002)	(0.002)	(0.002)	(0.002)
Large vessel	-0.055***	-0.056***	-0.057***	-0.061***
	(0.005)	(0.005)	(0.005)	(0.005)
Services	0.010***		0.008***	0.005***
	(0.001)		(0.001)	(0.001)
Total arrivals (thousands)	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Railway comm		0.055***		0.040***
		(0.006)		(0.007)
Airport		0.024***		0.011
		(0.006)		(0.006)
Avg. cargo capacity			-0.002***	-0.002***
			(0.000)	(0.000)
Avg. container cap			0.036***	0.036***
			(0.002)	(0.002)
Sanitation services			-0.002	-0.016
			(0.009)	(0.010)
_cons	0.685***	0.684***	0.772***	0.777***
	(0.024)	(0.024)	(0.023)	(0.023)
N	5576	5576	5576	5576
R^2	0.345	0.346	0.378	0.383

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Using the data provided in Table 8, all the models show a significant turning point in the digital adoption index variable. In order to maximize the efficiency in customs procedures, the government should implement digital methods in no more than 80.1% of these procedures, holding other factors constant.

D. MEDIAN TIME IN PORT

The median time in port serves as a proxy to represent the speed of service performance, a variable belonging to the outcomes dimension. This dimension refers to whether the service is being provided in a considered manner. Additionally, I use the container's median time due to the available data that this specific transportation type provides.

The scatter plot in Figure 9 shows a negative correlation between the median time in port and the digital adoption by the government index. That is, the more extensively the government implements digital methods to centralize port operations, the more rapid those operations become. Table 5 shows that full digital implementation by the government would decrease the median time in port by one day, assuming I control for the efficiency of customs in the analysis. Also, the digital adoption index's effect is higher for maritime ports that have a relatively longer median time compared to those with fewer days. The figure also shows that there is no turning point associated with the digital adoption by the government index.

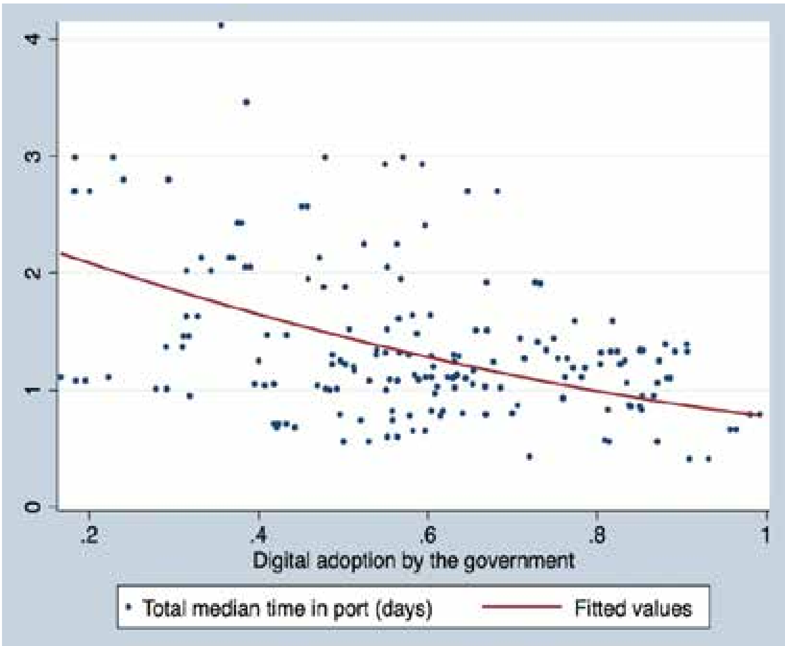

Figure 9. Relationship between total median time in port and digital adoption by the government index scatter plot.

Table 5. Total median time and container median time in port regressions.

	(1) Total median	(2) Total median	(3) Container median	(4) Container median
Digital adoption by the government	-1.432***	-1.029***	-1.561***	-1.120***
	(0.044)	(0.040)	(0.045)	(0.040)
Services	0.008***	0.017***	0.016***	0.027***
	(0.002)	(0.002)	(0.002)	(0.002)
Operations at wharf	-0.027	-0.037		
	(0.029)	(0.026)		
Avg. cargo capacity	0.010***	0.008***		
	(0.000)	(0.000)		
Avg. container cap.	0.004	0.028***	0.019***	0.023***
	(0.005)	(0.004)	(0.005)	(0.004)
log (customs efficiency)		-0.917***		-0.872***
		(0.025)		(0.034)
Tug service		-0.040*		-0.118***
		(0.019)		(0.024)
Pilot service		-0.102***		-0.117***
		(0.020)		(0.021)
_cons	1.844***	3.010***	1.841***	2.979***
	(0.046)	(0.065)	(0.043)	(0.075)
N	5576	5576	5576	5576
R^2	0.382	0.510	0.236	0.356

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

E. IMPLICATIONS

The analysis shows several significant findings associated with the factors affecting customers' perception of service quality and customer satisfaction in maritime ports. One of the most notable is the relatively high correlation between a government's adoption of digital methods to centralizeand improve management of operations in maritime ports, holding all other factors constant.

This is the most notable finding for multiple reasons. First, among all the regressions made, the digital adoption by the government index had the most impact on all proxy variables from each dimension of the service quality in the conceptual model. Second, as the fixed effects in panel data controls for variables that can be omitted across individual observations, it helped decrease the bias from privileged geographical location and national stability among ports. The panel data model shows a positive correlation between maritime port performance and the government's adoption of digital methods to centralize management of port operations.

The last occurrence to note is that the digital adoption by the government index showed a quadratic form in some explanatory variables, such as efficiency in customs procedures and port infrastructure quality. The reason this might occur is that the adoption of digital methods to centralize port operations aims for automation, and therefore, it can threaten low-skilled jobs, such as customs and infrastructures activities, while benefiting higher-skilled jobs.

Those findings suggest that the maritime port system should become centralized carefully to promote not only a robust network among harbors, but also continued friendly competition and cooperation among them, and with a consideration of the anticipated impact on the workforce employed at these ports.

F. RECOMMENDATIONS

I recommend that governments, especially in developing countries, implement a more centralized digital network among their respective ports to ease the current bottleneck some ports are facing. That would strengthen the logistics network and improve customer satisfaction and enable the collection of high quality, accurate, timely, and comprehensive data about port operations.

One of the challenges many countries face in developing a maritime data management system, however, is the lack of specific guidelines to accomplish this task. Thus, the regression models developed in this thesis can help implementers define and narrow the priorities to work on in the improvement of service quality and customer satisfaction in maritime ports.

In Mexico's specific case, the government should increase the centralization of data management among its privatized maritime ports, without sacrificing competitiveness. According to the model, the effort to digitalize data management should be focused primarily on centralized automation of port calls and container trade information.

Centralizing information on port calls, time in port, arrivals, departures, and container and cargo information related to all maritime ports in a single national network will increase quality of service, especially for clients that interact with several logistic platforms.

In July 2020, the President of Mexico, Andres Manuel Lopez Obrador, decided to give full control of maritime ports to the Mexican Navy, including customs, an area previously managed by the Secretariat of Communications and Transportation. Lopez Obrador mentioned that the reason for this drastic change was that corruption reigns in the ports, and specifically in customs (Stevenson, 2020). This policy change in port operations has brought the Mexican Navy the opportunity to implement further improvements to the current customs operations in harbors.

According to the econometric model presented in this thesis, the Mexican government should implement regulations restricting access to customs procedures data. Public access to such information discourages competitiveness among maritime ports, threatens low-skilled jobs, and affects customer satisfaction. Additionally, by gathering data management within a single organization, and controlling data sharing among users, the government can certainly prevent unnecessary duplicative efforts and administrative burdens.

In a nutshell, the models suggest that port authorities in Mexico should cooperate in sharing container trade data in a more detailed way, whereas customs and infrastructure data sharing should be restricted to superior levels and only for the purpose of preventing corruption.

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VI. CONCLUSION

The purpose of the presented analysis has been to identify the factors that better explain how to increase service quality and customer satisfaction in Mexican maritime ports. By identifying the conceptual models and applying an econometric approach, it has been possible to address the resources that maritime ports need to provide better service.

As the literature review showed, the depth of knowledge about these areas in the maritime domain is lacking compared to other logistics sectors, either public or private. In addition, there is no specific guidance regarding the design and implementation of a centralized data management system for a network of maritime ports. Such challenges discourage the government from undertaking efforts to improve customer satisfaction in harbor operations. Government and maritime port managers by themselves cannot bring about the level of success required without stable cooperation and system implementation that allows smoother procedures among customers.

As the results show, the government must adopt digital methods to centralize port operations in a controlled and judicious way that optimizes maritime port operations. That is, there is an optimal degree for how quickly these efforts should be introduced in harbors. The models showed that the full and rapid implementation of centralized management of port calls and container trade information improves customer service and satisfaction. On the other hand, a more gradual introduction of these methods should be applied in customs procedures and infrastructure operations because port operations will require a smooth transition from low-skilled jobs to automation and more skilled jobs. It is also important to note that this implementation depends mainly on the national government controlling the ports involved and their geographical position, which can be customized by applying the econometric models implemented in this thesis.

Successful automation and centralization of port operations will prevent duplicative efforts that create administrative burdens affecting readiness and informed decision making at maritime ports. Nevertheless, success should not lead to complacency, as experience has proved that digital initiatives often fail and the implementation of digital strategies does not always lead to the desired results (Bughin et al., 2018).

APPENDIX. HAUSMAN-TAYLOR SPECIFICATION TEST ON CONTAINER THROUGHPUT

	Coefficients (b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
dai_gov	-.5015336	.5929622	-1.094496	.0680308
lplsci	.0402401	.0423952	-.0021551	.
d11	.0787737	.0785297	.000244	.
d12	.1253469	.1255294	-.0001825	.
d13	.1599403	.1596813	.000259	.
d14	.1875736	.1875988	-.0000252	.
d15	.1899834	.1894646	.0005188	.
d16	.2120525	.2117237	.0003287	.
d17	.2709679	.2688719	.002096	.
d18	.318767	.3187735	-6.48e-06	.

```
                     b = consistent under Ho and Ha; obtained from xtreg
      B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test:  Ho:  difference in coefficients not systematic

             chi2(10) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                      =      256.07
            Prob>chi2 =      0.0000
            (V_b-V_B is not positive definite)
```

Figure 10. Hausman-Taylor specification test on container throughput using digital adoption by the government index and port liner shipping connectivity.

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