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The Effect of Regulations on Port Efficiency: An Empirical Study using Regulatory Quality and Control of Corruption Index

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ABSTRACT

A key determinant influencing port performance is the governance aspect. Since the port plays a crucial role in logistics supply chain systems, its performance determinants should be evaluated. Data from 57 ports worldwide was analysed to investigate how regulations affected their efficiency. First, we utilised the Data Envelopment Analysis (DEA) to obtain the measurement of the port's technical efficiency. Then, the econometric estimation is used to examine the role of regulation on port's technical efficiency. The findings from the econometric estimation suggests that Regulatory Quality (REGQ) and Control of Corruption (CORR) were positively correlated with the port's technical efficiency One important contribution of the study is the implementation of DEA-L in the DEA measurement as to include the external variables in the analysis. This study suggests the government should improve the process by enhancing the application of high-technology items and digitisation that are able to ease the bottleneck at port.

Keywords: DEA; ports;efficiency; logistics; regulation

INTRODUCTION

Sea freight trading accounts for around 80% of the global trading (UNCTAD, 2019). Because the port is the main gateway for international business trading, it had an important effect on sea freight. With the port as the main gateway, it plays a crucial role in determining the performance of the logistics and supply chain systems. Its efficiency is crucial in ensuring that the logistics and supply systems operate efficiently. Several studies highlight the factors influencing port efficiency. Additionally, the port's characteristics significantly contribute to the port's technical efficiency, which is normally measured by various methods, such as Data Envelopment Analysis (DEA). However, any external factors affecting port efficiency are not normally considered by the measurement and, instead, could be due to several reasons, such as data limitation, lack of expertise, or the challenges of the study. The technical efficiency measurement based on internal factors is used by various research in port efficiency, such as the recent studies by Nguyen, Woo, Beresford, & Pettit (2020), Yang & Yip (2019) and Venkatasubbaiah, Rao, Rao, & Challa (2018). However, there are some researchers focused on external factors influencing port efficiency such as by Ren, Dong, & Sun (2018); Tsai & Tai (2019); and Kavirathna, Kawasaki & Hanaoka (2018).

The technical efficiency of measuring port via the DEA commonly attends to its internal characteristics: length of berth, number of cranes, size of storage area and size of container yard, etc. as an input. Thus, the result of the DEA represents the actual technical efficiency of the port facilities and infrastructures. However, other factors affecting the port performance must also be studied. For example, regulations imposed on the port operators may affect port operations in many ways; for example, delaying the documentation clearance adds extra cost to the port operators and shippers. A study by Jamain, Zakaria & Mohd Satar (2022) found that 37 ports, or more than 66% of the total studied ports, faced significant change after the external variables such as logistics performance were deleted from the measurements of the DEA. Some scholars are exploring more options on external variables including the geographical location of ports that may have influence on port performance, such a recent study by Nguyen, Nguyen, & Zhang (2021) which explored the importance of layout of logistics centers in ASEAN countries towards the logistics network efficiency and logistics cost. Ghiara & Tei (2021), has revealed that other than technological advances at

port, external factors such as port membership are more important factors for port performance. A more extreme external factor which is weather, was found to be significant on port technical efficiency in the study by Garcia-Alonso, Moura & Roibas (2020).

An indication of the port logistics performance relies on the regulations or institutional governance aspects known as trade facilitation. In addition, regulations, including operational cost and efficiency, are the primary concern of port stakeholders. Therefore, this study will evaluate how regulations impact port's performance.

LITERATURE REVIEW

The effort to analyse the importance of regulation influence on port performance has been explored by various scholars, for instance Hollweg, Wong, & Kuan (2009) conducted the first study on the restrictiveness index applied to logistics systems in ASEAN+6. Restrictiveness is an element of how the government treats the industries in the business environment context. The research showed Malaysia, China, Indonesia, Lao PDR, the Philippines, and Vietnam as the most restricted countries in this region on logistics, and Singapore, Australia, Japan, and New Zealand as the most open economies. Before the Organization for Economic Co-operation and Development (OECD) reported the Service Trade Restrictiveness Index (STRI), this study was the first to construct the model of the restrictiveness index in 2014. The result showed negative correlations between the logistics restrictiveness index and Logistics Performance Index (LPI). Therefore, allowing the regulation of trade caused the logistics sector to improve.

When STRI was launched in 2014, Nordås & Rouzet (2017) were among the researchers who studied the relationship of STRI with trade performance. This study applied the gravity model using the PPML regressions and explored 12 sectors in service sectors. Import sector numbers negatively affect STRI, notably service exports, which are more sensitive to trade restrictions than service imports shown by the results. Moreover, findings also showed regulatory differences as an essential element compared to service trade restrictiveness. Thus, the bilateral agreement between countries with a regulatory difference is significant and impacts trade between countries.

Because of the competitive nature of logistics, it should be regulated. However, in many countries, the government does not regulate logistics services because its disjoint regulatory framework creates poor coordination among the different agencies (ITC, 2017). Regulating treatments improperly by the government will decrease logistics efficiency, such as management costs and time, reducing international trading efficiency. The Ease of Doing Business report shows cost and time as the two indicators associated with exporting or importing goods related to documentary compliance, border compliance, and domestic transport (World Bank Group, 2018). For instance, a bottleneck at the cross border will result in increased storage time and rental cost.

Dappe & Suarez-Aleman (2016) proposed a vital regulation aspect forming part of the policy to enable port efficiency. Additionally, they stated that between 2006 to 2011, the port in South Asia lost its control as the top performer in the region after other ports reduced their turnaround time of container vessels. A considerable amount of literature focuses on port performance determination, outlining the critical role of regulations on port performance. In their studies on 23 container ports in Asia, Yang & Yip (2019) described the regulation aspect as a primary limitation. Along with inputs, Yang *et al.* (2019) claimed that other exogenous factors possibly influence port efficiency, such as transport networks, government regulation and economic trends. Among these several determinants of port efficiency were container mix, work practices, crane efficiency, vessel size, and cargo exchange (Tongzon, 1995). Gumbau-Albert & Maudos (2002) analysed the determinants of port efficiency in the Spanish Industry and finalised the size of the firm, the concentration of the market, the investment, the condition of the market, and location as the independent variables. Whereas, Serebrisky *et al.* (2016) compared determinants of the inefficiency of ports terminal in Latin America and the Caribbean with the following variables: landlord, corruption, income per capita and linear trend. Pérez, Trujillo & González, (2016) analysed several determinants of port efficiency, focusing on Latin America and Caribbean container terminal ports. These factors were pointed out as technology change, location of ports, trade alliance and the number of terminals.

This study extracts information from the aspect of regulations that might be overlooked by various scholars. The enforcement, laws, and

procedures are needed to regulate the industry of port, but certain procedures might be too rigid and need additional facilitation by the government.

METHOD

This study uses the Data Envelopment Analysis or specifically the DEA-CCR model to measure the efficiency of 57 ports. Charnes, Cooper, & Rhodes introduced DEA-CCR in 1978 as an extension of Farrell's (1957) idea, assuming constant returns to scale. Since returns to scale are constant, all production combinations can be proportionally scaled up and down. This research measured the efficiency of the port first by following the DEA-CCR model of Charnes, Cooper & Rhodes (1978) and expressed as follows:

$\theta^* = min\ \theta$

Subject to:

$$\sum_{j=1}^{n} x_{ij}\lambda j \leq \theta x_{i0}\ \ i = 1,2,\ldots,m$$

$$\sum_{j}^{n} Y_{rj}\lambda_j \geq Y_{ro}\ r = 1,2,\ldots,s \sum_{j}^{n} Y_{rj}\lambda_j \geq Y_{ro}\ r = 1,2,\ldots,s$$

$\lambda \geq 0 \qquad j = 1,2,\ldots,n$

Where $y_{r0}y_{r0}$ and $x_{i0}x_{i0}$ stand for the rr^{th} output and ii^{th} input, respectively, and the $\lambda\lambda$ is the decision variable containing the weights that DMUjj assigns to DMU^{00}. For the efficiency analysis in the equation above, n DMUs were assumed. Each DMU generates ss outputs from mm inputs. As a result, $y_{rj} > 0 y_{rj} > 0$ represents the quantity of output r generated by the DMUs, while represents $x_{ij} > 0 x_{ij} > 0$ the amount of Input I consumed by the DMUs. The $\theta\theta^*$ could represent an efficient unit value or an inefficient DMU represented by a value less than unity. The DEA-BCC model was created by adding the convexity criterion $\sum_{j=1}^{n}\lambda_j \sum_{j=1}^{n}\lambda_j$ to the original DEA-CCR model.

Next, the resulting efficiency will be analysed on the variables of regulations through the relationship between the regulations and the port efficiency. Therefore, to analyse the second-stage analysis and evaluate the relationship between the variables, the Robust Fixed Effects (FE) approach will be applied. The Robust FE is robust against both the serial correlation and heteroscedasticity. Thus, to explore the regulatory impact on port efficiency, the baseline equation shown in the following equation (1.0) is provided:

$$TE_{it} = \beta_0 + \beta_1 REGQ_{it} + \beta_1 CORR_{it} + \beta_2 PLSCI_{it} + \beta_3 COSTEXBORDER_{it} + \beta_4 TIMIMBORDER_{it} + \beta_5 TIMIMDOC_{it} + \mu_{it} \quad (1.0)$$

Where,

TE_{it} = ports efficiency as dependent variable (DV)
β_0 = constant
$REGQ_{it}$ = regulatory quality
$CORR_{it}$ = control of corruption
$PLSCI_{it}$ = port liner connectivity index
$COSTEXBORDER_{it}$ = cost export at border
$TIMIMBORDER_{it}$ = time import at border
$TIMIMDOC_{it}$ = time import documentation
μ_{it} = errors

Equation 1.0 represent various variables as dependent variable used in the model, inclusive of Regulatory Quality (REGQ), Control of Corruption (CORR), Port Liner Shipping Connectivity Index (PLSCI), Cost Export Border (COSTEXBORDER), Time Import at Border (TIMIMBORDER), and Time Import Documentation (TIMIMDOC). REGQ and CORR are two government regulations to be verified in this study. REGQ is the status of regulation quality in the country, whereas the CORR emphasized on the status of government action towards corruption. Both variables are important, as the CORR is the most serious matter influencing the country in many aspects. Study by Dauda, Zaki Ahmad, & Keling (2020), showed the severity of corruption in Nigeria, until the country had to introduce the whistle-blowing law as a mechanism to combat the corruption.

As for the data, 57 strategic ports around the world were selected. The selected ports are the most strategic ports representing most of their individual regions, and all the ports possess similar operational standards as importer, exporter, and transshipment ports. Those ports are listed in the 100 Ports Lloyd's List (2020) ranking, the most up-to-date list of the best performing ports in the world ranking. All 57 ports as listed in Table 1.

Table 1: List of Ports and Countries (Source by author)

No	Name of Country	Name of Port
1.	Algeciras	Spain
2.	Ambarli	Turkey
3.	Antwerp	Belgium
4.	Balboa	Panama
5.	Barcelona	Spain
6.	Bramen	Germany
7.	Busan	Korea
8.	Cartagena	Spain
9.	Colon	Panama
10.	Dalian	China
11.	Durban	South Africa
12.	Felixstowe	United Kingdom
13.	Genoa	Italy
14.	Guayaquil	Ecuador
15.	Ho Chi Minh	Vietnam
16.	Hong Kong	China
17.	Houston	USA
18.	Incheon	Korea
19.	Jeddah	Saudi Arabia
20.	Kaohsiung	Taiwan
21.	Karachi	Pakistan
22.	Khorfakkan	United Arab Emirates
23.	Kobe	Japan
24.	Laem Chabang	Thailand
25.	Lianyungang	China
26.	Long Beach	USA
27.	Los Angeles	USA

28.	Manila	Philippines
29.	Manzanillo	Mexico
30.	Melbourne	Australia
31.	Mersin	Turkey
32.	Mundra	India
33.	New York/New Jersey	USA
34.	Ningbo-Zhousan	China
35.	Osaka	Japan
36.	Piraeus	Greece
37.	Port Klang	Malaysia
38.	Port Said	Egypt
39.	Qingdao	China
40.	Rizhao	China
41.	Rotterdam	Netherlands
42.	Salalah	Oman
43.	Santos	Brazil
44.	Shanghai	China
45.	Singapore	Singapore
46.	Southampton	England
47.	St Petersburg	Russia
48.	Taichung	China
49.	Tanger Med	Morocco
50.	Tanjung Pelepas	Malaysia
51.	Tanjung Priuk	Indonesia
52.	Tianjin	China
53.	Tokyo	Japan
54.	Valencia	Spain
55.	Vancouver	Canada
56.	Xiamen	China
57.	Yokohama	Japan

RESULTS AND DISCUSSION

Since the current study measures the effect of regulations on port

performance, the logistical aspects must be included. Therefore, the logistics performance was a prominent variable determining the port's time-consuming operation. Moreover, Table 2.0 shows the descriptive analysis of the 57 ports from 2015 to 2019. First, the minimum value of the TEU is 1447390, the maximum is 43303000 and the mean is 7154974.25. Next, the CWT minimum value is 12.89, the maximum is 9223.37, and the mean is 1128.21. Finally, the PLSCI minimum value is 1.51, the maximum value is 134.32, and the mean is 51.83.

Table 2: Descriptive Statistics of Logistics Variables for 57 Ports (2015–2019)

Variables	N	Minimum	Maximum	Mean	Std. Deviation
TEU (Port Throughput)	285	1447390	43303000	7154974.25	7459006.630
CWT (Container Waiting Time)	285	12.89	9223.37	1128.21	2326.71
PLSCI (Port Liner Shipping Connectivity Index)	285	1.510	134.32	51.83	27.17

The purpose of investigating how the regulation influences the technical efficiency of ports is shown in Table 3.0, where the variable details are used in the econometric estimations. The dependent variables consist of the DEA's first stage analysis variables, technical efficiency (TE), which are endogenous. The second stage analysis shows the exogenous variables as the focal point. They measure the regulatory impact towards TE, the regulatory quality (REGQ) and control of corruption (CORR). The REGQ and CORR report the aggregate and individual governance indicators of most countries from an index developed by the World bank. The REGQ and CORR are appropriate regulatory proxies since the quality of regulation by good governance practices is the best option to assist the industries related to port services. Regulatory quality deals with the measurement of government participation, entry for business and investment, and the regulated prices by the government (Zhuo, O, Muhammad, & Khan, 2020). As for the CORR, this study analyses the corruption factors in determining port performance. Corruption significantly determines the flexibility and neutrality of the government's decision on the governance aspect.

In addition to the endogenous and exogenous variables, two important variables of port performance are also incorporated into the model. These

variables are highly close to facilitation issues in the aspect of logistics. Port services are the time constraint at the border during the export and import process; hence the time constraint at the border was the most suitable variable to influence the port performance. Therefore, cost of export (COSTEXBORDER), time to import (TIMIMBORDER) and time of import documentation (TIMIMDOC) are essential variables defining the effectiveness of the government process at the border.

The diagnostics test of the Breusch–Pagan Lagrangian multiplier test suggested that the RE model is preferred to OLS, thus the Null hypothesis of the Breusch-Pagan LM test was rejected. Next, the Hausman test suggested that the FE model is preferred to the RE model. Hence, findings from the FE model will be interpreted. However, the modified Wald test suggested that the model presented heteroscedasticity. The Wooldridge test suggested no autocorrelation. Therefore, econometric approaches were conducted to diminish heteroscedasticity. Moreover, the Robust FE model was applied since this estimator can handle heteroscedasticity. The final result of Robust FE is shown in Table 3.

The results of REGQ are significant at 1 percent, revealing that it positively correlates with technical efficiency. This correlation implies that an increasing 1 percent in the REGQ will increase the port technical efficiency by 0.000013 percent. These outcomes result from the improved regulator quality, possibly causing the specific procedures to ease, strengthening the enforcement of illegal activities, and reducing the bureaucracy. Thus, the outcome will improve the overall activities at the port and create better facilitation for the industries. However, the processing delay can increase the time consumption at the port because government activities, such as customs clearance, border inspection, and documentation preparation, will reduce the performance. As referred to a previous study by Núñez-Sánchez, Jara-Díaz, & Coto-Millán (2011), regulation significantly impacted the Spanish ports reforms between 1986 and 2012. The study found that port autonomy and decentralisation are the most important regulatory factors in enhancing port efficiency. It is significantly related to logistics issues, as explained in the earlier chapter, where excellent governance can reduce the delay in the logistics, reducing the trade cost, respectively, the critical point for port efficiency. The International Trade Centre in 2017 described how several factors influence logistics service providers, causing delays and,

as a result, rising costs: weakened coordination between the government regulatory bodies, a lack of public and private sector discussions, and complex compliance requirements for government agencies. Delay severity results when each delay day reduces at most miniscule 1 percent of its trade, impacting and destroying itself, as explained by Djankov *et al.* (2010). Clark, Dollar, & Micco (2004) empirically explain how port efficiency negatively correlates with trade costs, where a more efficient port results in lower trade costs. Another study shows how Mexican ports affected port operational costs; for instance, reducing moving containers by 5.6 percent between January 1995 to December 1998 increased the TFP by 4.1 percent between 1996 to 1999 (Estache, de la Fé, & Trujillo, 2004).

This study points to a second regulation variable: CORR. The relationship between the regulations and the technical efficiency of ports shows that CORR is significant at 1 percent, correlating positively with the port technical efficiency, having a coefficient of 0.2510363. Respectively, an increase of 1 percent in CORR will increase the technical efficiency by 0.25 percent. Similarly, Dappe & Suarez-Aleman (2016) replicated this result, where reducing public sector corruption increased port efficiency. Additionally, Sebra, Flores & Gomes (2016) explained how Latin America's port found corruption as a significant variable for its performance. Thus, the government's efforts to reduce the corruption rate in the country is a vital approach to improving the process efficiently in government-related activities. Furthermore, because corruption can be manipulated, bureaucracy will increase. Thus, controlling or eliminating corruption can enhance the process and, respectively, increase the time of the port's performance.

Table 3: Econometric Estimation Results

Variables	Fixed Effect (FE)	Random Effect (RE)	Pooled OLS	Fixed Effect Robust
CORR	0.2393187***	0.0939737***	0.0192389	0.2510363***
	(0.016)	(0.018)	(0.369)	(0.015)
REGQ	0.0000109	0.00001	4.81e-06	0.0000131***
	(0.434)	(0.489)	(0.882)	(0.000)
PLSCI	-0.0118609***	-0.0032155***	0.0020613***	-0.0112387***
	(0.000)	(0.004)	(0.001)	(0.000)
COSTEXBORDER	0.0002042	0.0001645	0.0001792***	0.0001392
	(0.359)	(0.249)	(0.025)	(0.458)

TIMIMBORDER	-0.0007845 (0.083)	-0.0006343 (0.140)	-0.000423 (0.365)	-0.0008188*** (0.011)
TIMIMDOC	0.0006028 (0.397)	0.00067 (0.273)	-0.0001257 (0.815)	0.0005603 (0.198)
R-Squared	0.2244	0.1781	0.0669	0.2150
Adj. R-Squared			0.0328	
Number of OBS	285	285	285	285
Number of Group	57	57		57

Notes: Numbers in parentheses are *p*-values
***Indicates statistical significance at 1% level, ** 5%
Source: Author's calculations

CONCLUSION

The study confirms that regulations are positively correlated with technical efficiency. Two regulation variables, REGQ and CORR, appeared to correlate positively with the port's technical efficiency. Likewise, several previous studies on regulation impacts on port performance also proved similar results. Since regulatory quality is a standard indicator managed by governments, the inclusive enforcement regulations on certain port operational acts and laws require a high quality of regulation control and implementation. The positive influence of regulation on technical efficiency can be translated into the need of proper guidelines that should be implemented to ensure that controlling regulation does not reduce the port performance. Regulation controls the market and enforces the laws. However, improper management might cause it to become vulnerable. Certain regulations, such as high-technological equipment, might need improvement to accelerate the process and reduce human error. Custom clearance, for instance, is primarily handled by enforcement officers; however, the ICT innovation might escalate the process, reducing the waiting time due to human error. Thus, before introducing new policies, the government should measure current policies through the impact on the port performance. Coglianese (2012) explained that the government should select an appropriate research design and a reliable indicator, ensuring that

the policy is marketed efficiently. One important contribution of this study, where it empirically showed the importance of government function in facilitating the industry and business environment to be more competitive and efficient via the proper regulations. Since the study only focused on 57 ports with limited data, in the future there might be enormous data based on big data analysis that can expand the study to be more comprehensive via logistics data such as time to load and unload containers for instance.

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