JDE Journal of Developing Economies

JDE (Journal of Developing Economies)
https://e-journal.unair.ac.id/JDE/index

TECHNICAL EFFICIENCY ANALYSIS OF CONTAINER TERMINALS IN TANJUNG PERAK, SURABAYA, EAST JAVA

Bambang Eko Afiatno[1]

Karno Dwi Joyoutomo*[2]

[1,2] Department of Economics, Universitas Airlangga, Indonesia

ABSTRACT

Container Terminals in Tanjung Perak Port is a trading center in the Eastern Indonesia Region (KTI) with a total throughput of 3.6 million TEUs in 2020. The utility/level of use of terminal facilities, consisting of the pier/berth occupancy ratio (BOR), has reached 60%. The field/yard occupancy ratio (YOR) is 65%, while the maximum utility is 70% (UNCTAD). It is necessary to explore the technical efficiency of each container terminal using the stochastic frontier analysis (SFA) because it can also capture the inefficiency effects. This study is built from the analysis of production factors in the period of 2009-2020, where the variables used are capital (k) using company asset data, labor variable (l) using data on the number of human resources, energy variable (e) using energy cost data (fuel oil/fuel, electricity, and water). The inefficiency variables are port draught (d) and loading and unloading productivity (p). The container terminal in Tanjung Perak has a relatively high technical efficiency value of 0.94. This shows that the terminal operation is quite optimum and is approaching the maximum point. The overall average elasticity is 2.01, which can be categorized as an increasing return to scale. The elasticity of assets has the most significant proportion, so it can be concluded that the port is capital intensive. Next, it's found that the higher productivity 1% increase in loading and unloading productivity, the more inefficiency with a relatively minimal value of 0.11%. Finally, an increase of 1% in depth will increase efficiency by 10.89%.

Keywords: *Technical Efficiency, Elasticity, Inefficiency*

JEL: O3; R4; C3; C5; D2

ARTICLE INFO

Received: April 9th, 2022
Revised: May 22nd, 2022
Accepted: May 25th, 2022
Online: June 28th, 2022

*Correspondence:
Karno Dwi Joyoutomo
E-mail:
karno_dj@yahoo.com

To cite this document: Afiatno, Bambang E. & Joyoutomo, Karno D. (2022). Technical Efficiency Analysis of Container Terminals in Tanjung Perak, Surabaya, East Java. JDE (Journal of Developing Economies), Vol. 7(1), 156-179.

Introduction

The world has acknowledged Indonesia as an archipelagic country through UNCLOS 1982, which has a total of 13,466 islands and a beach length of around 54,716 km (BIG, 2015). Indonesia also has a water area of 3,257,483 km2 and a land area of 1,922,750 km2. Thus, Indonesia is called a maritime continent. Therefore, the maritime sector (fishery sector, maritime manufacturing industry/shipbuilding, water transportation, and sea/port supporting services) is a strategic sector in Indonesia's economic development. One supporting infrastructure for international and domestic trade is a port capable of integrating the two trades.

JDE (Journal of Developing Economies) p-ISSN: 2541-1012; e-ISSN: 2528-2018
DOI: 10.20473/jde.v7i1.34928

The port acts as a meeting place between modes of transportation and as one of the strategic gateways for economic activity so that the port becomes an important part of regional economic development on a regional or international scale.

Tanjung Perak Port is the second busiest port in Indonesia after Tanjung Priok Jakarta, where the flow of Tanjung Priok containers is 6.2 million TEUs. In comparison, the flow of Tanjung Perak is 3.6 million TEUs in 2020. Tanjung Perak Port is a trading center in the Eastern Indonesia Region (KTI). Container shipping to and from Java Island for KTI is mostly served by Tanjung Perak Port as shown in Figure 1. This further demonstrates the importance of the role of Tanjung Perak Port in supporting the smooth running of the national logistics system, especially for KTI (Achmadi & Hadi, 2012).

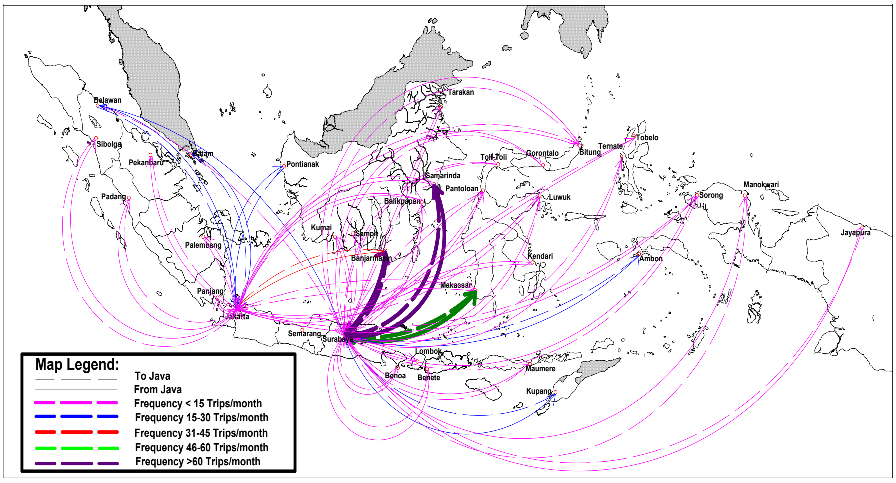


Figure 1: Domestic Shipping Route

Source: (Achmadi & Hadi, 2012)

Non-container cargo, general cargo, dry bulk, and liquid bulk have relatively fluctuating growth, which is indicated by the standard deviation of >10%, while the growth of container cargo is relatively stable with a standard deviation of <10% with an average growth of 7.47% annually. On average, container loads have the most dominant proportion, as many as 73.08%, while non-containers are 26.92%. The next thing that needs to be considered is the utility/level of use of terminal facilities which consists of the pier/berth occupancy ratio (BOR) and the field/yard occupancy ratio (YOR). Based on data in 2019 it shows that BOR has reached around 55%-60% and YOR is around 50%-65% (Kemenhub, 2019). This shows that the port utility in Tanjung Perak has almost fulfilled its installed capacity, where the limit/ maximum utility is 70% (UNCTAD, 2016).

The container port is a gateway for domestic and international trade (Akhavan, 2020). Therefore, in the condition of the port which is almost full of installed capacity, it is necessary to explore the technical efficiency of each container terminal, whether the performance of the terminal has reached the optimum point for production/carrying out loading and unloading services from existing inputs (berth, stacking yards, loading and unloading equipment, and human resources). Furthermore, another factor that needs to be considered from the port's performance from the internal side is depth, which can affect the size of ships visiting the terminal/port and loading/unloading speed/productivity. Therefore, the efficiency and performance of containerized goods ports are very influential in supporting the logistics system, which will increase the competitiveness of Indonesian commodities.

From the introduction that has been discussed, the formulation of the problem in this study are:how is the technical efficiency of the container terminal at Tanjung Perak Port, Surabaya, East Java? What is the elasticity of output (flow of containerized goods) to inputs (assets, human resources, and energy)? Do terminal depth and loading/unloading speed/productivity affect efficiency and productivity? The objectives of this study are analyzing the technical efficiency of the container terminal in Tanjung Perak, East Java; calculating the elasticity of output (flow of containerized goods) to inputs (assets, human resources, and energy); and to examine the effect of inefficiency of terminal depth and loading/unloading speed/productivity.

Literature Review

There are 6 points will be discussed in the literature review: container terminal business process, production theory, frontier production function, technical efficiency, elasticity, and previous research.

Container Terminal Business Process

Port terminals are those port facilities that constitute the factual interface between different modes of transport of the cargo. For example, from sea going vessel into inland barges, road or rail transport, pipeline or feeder vessel, and vice versa. There are also IWT (inland water transport) terminals where the cargo is transferred from inland barge or self-propelled vessel to truck or railway wagon, and the other way around. In commercial ports, the terminals are a port's 'raison d'etre'. All other facilities are provided only to enable the terminals to function safely and efficiently. For captive port facilities the terminal is only a necessary element to enable the key process, for instance a refinery or a power plant (Ligteringen & Velsink, 2012).

The primary functions are as a traffic function which the port is a nodal point in the traffic, connecting water and various land modes and as a transport function which ports are turntables for various cargo flows. Besides these, ports can have several other functions, such as industrial activities which often relate to the cargo flows, ship repair and shipbuilding, or offshore-supply. Still, the vicinity of sea transport may in itself be the reason to locate an industry and as a commercial and financial services, including banks (Ligteringen & Velsink, 2012).

The traffic function requires three conditions to be fulfilled, i.e. a good "front door", a good "backdoor" and sufficient capacity and services in the port itself such as entrance from sea, needs to be accessible and safe; port basins and quays, adequate space for manoeuvring and berthing of the ships, capacity for handling and storage; and hinterland connections, road, rail, inland waterways, pipeline, depending on the transport function (Ligteringen & Velsink, 2012).

Several stages in handling container cargo can be said that it is relatively simple compared to other loads. In general, the handling of container cargo at the port can be started from the sea or land side. From the sea side, cargo is unloaded from the ship using stevedoring tools and then transported (haulage) to the stacking yard or can be directly out of the port without going through the truck loosing yard. If the container is brought to the stacking yard, there will be a stacking activity (lift on/lift off). Ship services at the port are carried out at sea and docks. Ship services at sea include scouting, tug, and shipping lane services. Ship services at the pier consist of kepil services, mooring services, ship water services, bunkering services, and ship waste services (Kemenhub, 2015; Ligteringen & Velsink, 2012). Goods services at the port are carried out at the dock and at the stacking yard. Freight services at the dock consist of dock services and stevedoring services. Goods services at the stacking yard consist of haulage services, stacking services, and lift on/off services (Günther, 2005). The gate services consist of receiving/delivery services, scales, and port passes (Notteboom et al., 2021). The summary of the container terminal business process can be seen in Figure 2.

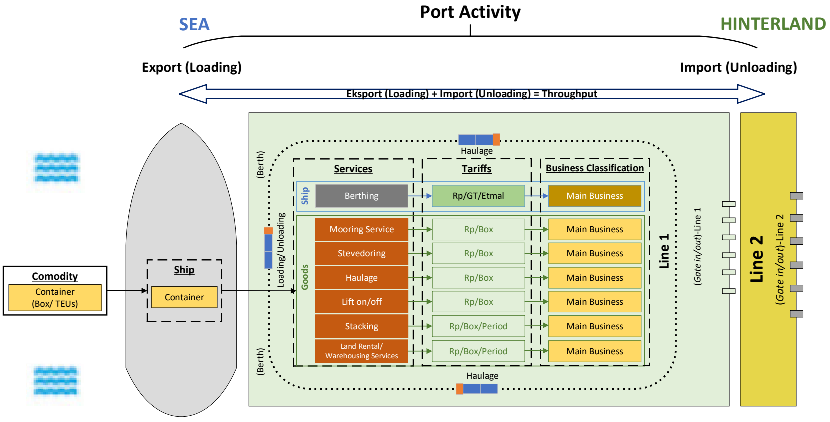


Figure 2: Container Terminal Business Process

Source: Author's Illustration

Production Theory

The activity of converting inputs into outputs that is run by a business unit is a major part in the establishment of a business unit. This activity is carried out to meet consumer needs with available production factors to produce goods and services. Business units can use various combinations of inputs to carry out these activities so that they run optimally (Pindyck & Rubinfeld., 2018). In line with this, Perloff (2020) said that in a production process, business units use technology to carry out these activities. This is important because in order to get maximum profit, the business unit must try to maximize production with certain cost constraints. In production, business units use many types of inputs, which are capital (k) is a long-term input, labor (l) is the number of workers and hours worked, energy (e) is the fuel used in the operation of production activities, and raw materials (m) is the raw materials/materials used during the production process.

Production factor is a base for obtaining the best combination or ratio of inputs that must be used to produce products in accordance with the law of diminishing returns which provides the basis for effective use of inputs in a production system. The use of factors of production can be described by an isoquant curve which the combination of inputs in the production process will involve various skills of labor, and various natural resources. All these elements are summarized in terms of factors of production.

Nicholson & Snyder (2012) stated that the production function which accommodates many inputs is the Cobb-Douglass and Translog production function. Mathematically the Cobb Douglas function is more widely used in economic studies because the simplicity in its formula. In addition, the input coefficient used as a measure of elasticity that interprets the changes in output due to changes in inputs of the production process. On the other hand, the sum of all the input coefficients in the Cobb-Douglas function has the meaning of return to scale which is the magnitude of the rate of change in output as much as proportional changes in input. If the change in output is greater than the change in input, it is called increasing return to scale. If the change in output is the same as the change in input, it is called a constant return to scale and if the change in output is smaller than the change in input, it is called a decreasing return to scale. This scale is important to understand as an evaluation material in planning business activities to produce optimum profits.

Adopting a flexible form of function can reduce the risk of model specification errors. Furthermore, the translog model is a development of the Cobb-Douglass production function which has a more flexible functional form of the frontier production function (Sari et al., 2016). The translog production function explains how the model uses different variables by considering the interaction factors between variables. This stochastic translog model considers error terms (inefficiency and noise), a form of statistical model (Aigner et al., 1977). In addition, the translog form can be used to describe the growth of total factor productivity (Suyanto & Bloch, 2009). The Cobb-Douglas production function (Equation 1), translog (Equation 2), and the inefficiency model (Equation 3) are written as follows:

$$\ln y_i = \beta_0 + \sum_n \beta_n \ln x_{ni} + v_i - u_i \quad (1)$$

$$\ln y_i = \beta_0 + \sum_n \beta_n \ln x_{ni} + \frac{1}{2} \sum_n \sum_k \beta_{nk} \ln x_{ki} + v_i - u_i \quad (2)$$

$$u_i = \delta_0 + \sum_j \delta_j z_{ji} + w_i \quad (3)$$

where is the output; x is an input variable (Capital, Labor and Material); i is a business unit. and are the intercepts of the production function and the inefficiency function. β and δ are parameters to be estimated, is technical inefficiency and is error term in inefficiency equation.

Frontier Production Function

The frontier production function is a description of technical knowledge to measure the efficiency of how the company produces maximum output using certain inputs at the existing technological level (Coelli et al., 2005). The frontier production function is usually used to estimate the real optimum standard that forms the frontier of the average production function, therefore it can be said that technically efficient is achieved when a company with certain inputs produces output right on the frontier line (see Figure 3).

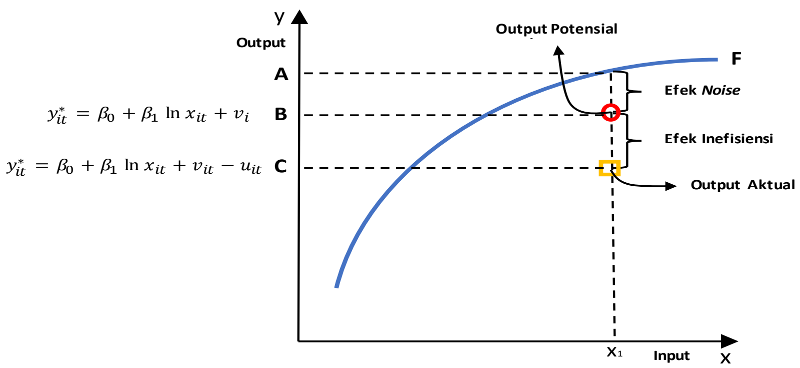


Figure 3: Frontier Production Function

Source: (Coelli et al., 2005)

Furthermore, Figure 3 depicts the stochastic production frontier, where the F line is the frontier production line. The point (X1, A) is where the company can be said to be technically efficient because it is right on the frontier production line. Meanwhile, the point (X1, C) as the actual output is referred to as technically inefficient because with the input (X1, C) the company should be able to produce right on the frontier line, which is the point (X1, A) as the potential output. Along (X1, C) to (X1, A) are error terms which can be positive or negative. Furthermore, specifically for the error term in the stochastic production frontier approach, it has an inefficiency effect (independent) and a noise effect (random variable) which can cause the company not to be right on the frontier line (Coelli et al., 2005). It can simply be explained in the following equation 4:

($y_{it} = f(x_{it}; t, \beta) \exp(v_{it} - u_{it}) = f(x_{it}; t, \beta) \exp(\varepsilon_{it})$ (4)

In equation 1, there are characteristics of the stochastic production frontier approach such as ε_it, which is the error term consisting of v_{it} (random variable) and u_{it} (inefficiency) so that $\varepsilon_{it} = v_{it} - u_{it}$, which is independent and in year t is used to capture progress technology. The advantage of SFA is that hypotheses can be tested with the relationship between inputs and outputs following a known functional form. This approach was first developed by Aigner et al. (1977), Farrell (1957) in Coelli et al., (2005) suggesting a method of measuring technical efficiency by estimating the production function of a fully efficient company. The weakness of the fully efficient frontier production function is that it is not known in practice, so it must be estimated from observations of samples, especially container terminals.

Technical Efficiency

The concept of efficiency in economics including technical efficiency has been described by Arunsawadiwong (2007), Assaf (2007), Coelli et al. (2005), Badunenko & Stephan (2006), and Herrero & Pascoe (2002). Technical efficiency is described as the maximum amount of output in a production produced from certain inputs, so simply technical efficiency is the ratio of inputs per output of a company. The company's output is usually measured in terms of units or value added, while the input consists of reprocessing resources and capital a company can be called technically efficient if it produces maximum output with existing technology from a certain number of inputs (Coelli et al., 2005). The concept of technical efficiency shows the level of success in the resources from inputs to produce outputs. Therefore, inefficiency is simply the difference between the values of production and the maximum value that can be achieved by the use of a particular technology. TAn exponential factor can represent the difference between maximum and actual output in the frontier production function, namely exp (u_{it}). The actual output can be expressed as a function of the stochastic frontier output level or Equation 5 can be written as follows:

$$y_{it} = y_{it}^{*} \exp(-u_{it}) \quad (5)$$

The container terminal operates optimally or can be said to be technically efficient when it is precision at the frontier. The technical efficiency, TE_{it}, for the i-th company in the t-th period is the ratio between the actual output and the maximum achievable output which can be written in Equation 6 as follows:

$$TE_{it} = \frac{y_{it}}{y_{it}^{*}} \quad (6)$$

The level of company efficiency can be measured from two things, such as: technical efficiency as a form of the company's ability to achieve maximum output from a combination of input forms and allocative efficiency as the company's ability to optimally proportion inputs by considering minimum prices and production technology (Farrell, 1957). When these two measures are combined, they can explain the overall measure of economic efficiency (Coelli et al., 2005). The technical efficiency literature review is often used by researchers using the Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) methods. This comprehensive DEA and SFA was initiated by Kumbhakar & Lovell (2000) and Coelli et al. (2005). The DEA approach has more shortcomings than the SFA approach. The DEA approach is deterministic so that it does not consider exogenous factors that affect the model. On the other hand, SFA considers error terms which indicate the influence of exogenous factors that can affect the model. In addition, another difference is that the SFA estimation results in a technical efficiency standard error whereas the non-parametric approach (DEA) cannot give an efficiency standard error.

Elasticity

Elasticity is useful for measuring how much the percentage of output increases from the percentage of input used in the company. It can estimate changes in production factors (capital, labor, energy and raw materials) that have an impact on changes in output. Furthermore, the production function's elasticity supports the varying substitution elasticity of the various input functions. In addition, the translog form can also relax the homogeneity of the input. The substitution elasticity occurs in the curve of the isoquant curve which the isoquant curve is a curve that describes the combination of several inputs with a single output so that from this elasticity it can be seen whether the loading and unloading activity of a container terminal includes increasing, constant or decreasing returns to scale (Coelli et al., 2005). The return to scale can be interpreted as the proportion of changes in output that occur as a result of the proportion of changes in all inputs.

Nicholson & Snyder (2010) explains that along an isoquant, the rate of technical substitution will decrease as the capital-labour ratio decreases (that is, as k/l decreases). If the RTS does not change at all for a change in k/l, it can be said that substitution occurs because the ratio of the marginal productivity of the two inputs does not change as the input combination changes. Alternatively, if the RTS changes rapidly for small changes in k/l, then substitution is difficult to occur because small variations in input combinations will have a substantial effect on input productivity. Nicholson & Snyder (2010) explains the form of elasticity with Equation 7 as follows:

$$\varepsilon = \frac{percentage\ of\ \Delta(k/l)}{percentage\ of\ \Delta RTS} = \frac{\partial(k/l)}{\partial\ RTS} \times \frac{RTS}{k/l} = \frac{\partial \ln(k/l)}{\partial \ln\ RTS} \tag{7}$$

Equation 2 cannot be directly interpreted economically, but this interpretation can be obtained by calculating the elasticity of output for each input (Sari et al., 2016). The elasticity calculation is calculated in Equation 8 as follows:

$$\varepsilon_{ni} = \frac{\partial y_i}{\partial xn_i} = \beta_n + \frac{1}{2}\sum_{n=1}^{4}\sum_{m=1}^{4}\beta_{nm}xm_i + \beta_n t, \tag{8}$$

Estimation Techniques of Stochastic Frontier Analysis

In general, data processing and analysis techniques can be seen in Figure 6. In the first stage, the value of the company's efficiency is obtained from the estimation of panel data (cross section and time series) using SFA (stochastic frontier analysis). The general form of stochastic frontier analysis (SFA) according to Equation 9 is as follows:

$$Q_{it} = fX_i, t, \beta \exp \epsilon\ it\ ; \epsilon it = v_{it} - u_{it} \tag{9}$$

Description:

Q_{it} = output value of company i on t period

X_{it} = input value of company i on t period

β = estimated coeficient

t = time trend

ϵ_{it} = error term

v_{it} = random error of company on t period

u_{it} = inefficiency of company on t period

The stochastic frontier production function model is also known as the composed error model because it has two error terms, where $\epsilon it = v_{it} - u_{it}$. The v_{it} variable is a random error variable which is normally distributed and has an average value of 0 and a constant variance or , symmetrical and free from u_{it}. The variable u_{it} is a non-negative variable and is assumed $N(0, \sigma v^2)$ to have a truncation distribution (normal or exponential) or $N(u_{it}, \sigma v^2)$. The u_{it} variable is also called the one-side disturbance which is used to capture the effect of inefficiency. For company i in year t, the distribution parameter value (u_{it}) of technical efficiency can be formulated in Equation 10 as follows:

$$(u_{it} \sim N\delta_0 + \delta_k Z_{kit}, it, \sigma^2) \quad (10)$$

For δ is the vector of the parameters to be estimated and Z_{it} is the vector of the explanatory variables that affect the technical efficiency and is constant (Khalifah et al., 2008). The coefficient value of the SFA model can be estimated using the maximum likelihood (ML) or ordinary least square (OLS). Coelli et al., (2005) stated that meyide ML is more efficient than OLS. Empirical evidence shows that the ML method is significantly better than the OLS method when the contribution of the effect of engineering efficiency to the total variance is large. In addition, ML estimation is better than OLS for large sample sizes. There are two methods to estimate the factors that become sources of inefficiency, namely by using the two-step or one-step production frontier method. The two-step production frontier method consists of two steps. The first step is to estimate the production function equation model first to get the value of u_{it}. The second step is to regress the value of u_{it} with the independent variable using the simultaneous method to capture the effect of the independent variable on u_{it}. According to Kumbhakar et al. (2000) there are two problems in using the two-step production frontier method. First, there is the possibility of technical inefficiency related to the input, causing the estimation to be inconsistent on the production frontier. Both OLS methods are not appropriate because the technical inefficiency is assumed to be one-sided. The one-step production frontier method is carried out by simultaneously estimating the relative production function model and the engineering efficiency equation. However, the one-step production frontier method can be said to have better results than the two-step production frontier which has biased results so it is not good for explaining the source of inefficiency (Wang & Schmidt, 2002).

Previous Research

In this previous research, there are 20 studies related to technical efficiency in container terminals. In general, all these studies have the same objectives, in which the methods used vary widely. Some important studies from previous research related to this study can be seen in Appendix 1.

In the study of technical efficiency and productivity, it is necessary to pay attention to inputs and outputs. Efficiency is input per output, while productivity is output per input. Both have the same meaning in the assessment of production activities, both are goods and services. As for the previous research, there are several gaps in the research. A study on technical efficiency and productivity in general was carried out by Chang & Tovar (2014), Ding et al. (2015), Kim (2012), and López-Bermúdez et al. (2019).

In this case the previous researcher that specifically discusses about efficiency are Iyer & Nanyam (2021), Kutin et al. (2017), Munim (2020), Mustafa et al. (2021), and Zarbi et al. (2019). Then the discussion specifically for productivity is carried out by Odeck and Schøyen (2020) and Song & Cui (2014). Furthermore, the analysis of efficiency can be analyzed more deeply/specifically. As done by Cheon et al. (2010) which discusses the evaluation of port institutional reforms that can affect efficiency improvements. Furthermore, the discussion of operational efficiency is carried out by Dinu et al. (2018) and from this discussion can be grouped as written by Wu & Goh (2010), but it is different from Hung et al. (2010), where efficiency operational scale efficiency targets are carried out.

Furthermore, Odeck and Schøyen (2020) analyzed the efficiency of container terminals based on the delivery of logistics services in the hinterland. Continuing Pérez et al. (2020) examines whether port specialization and size can have an impact on port efficiency. In contrast to Yuen et al. (2013) who reviewed efficiency through Foreign Direct Investment (FDI). Finally, the discussion of efficiency specifically concerns business competition, where the level of competition between ports/container terminals can affect the efficiency of the port, as reviewed by Cabral & Ramos (2014) and Figueiredo De Oliveira & Cariou (2015). The research gap between authors can be seen in Figure 4.

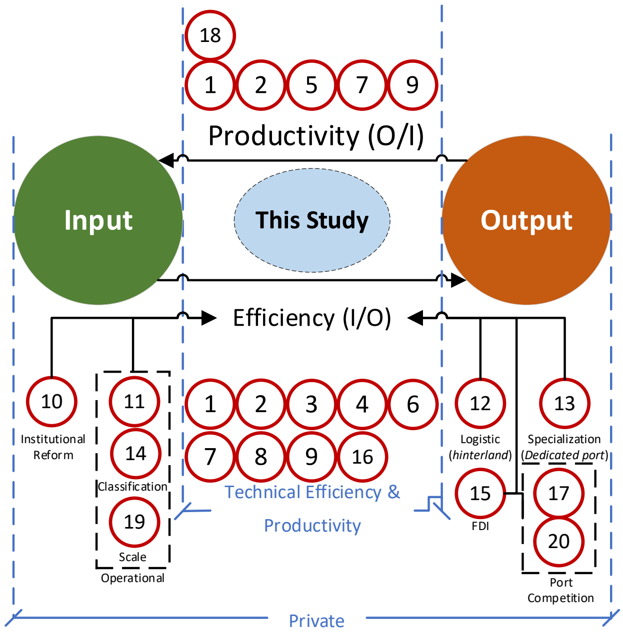


Figure 4: Research Gap Source: Author's Illustration

Data and Research Methods

This study is built from the analysis of production factors, where the variable used is capital (k) using company asset data, for labor variable (l) using data on the number of human resources, for energy variable (e) using material/energy cost data (fuel oil/fuel, electricity, and water). In the output variable, container revenue (nominal - not affected by the increase in tariffs / purely on the increase in quantity) on average at BJTI terminals is Rp655.75 million, at TPS is Rp2,079 million, at TTL is Rp465.28 million, and Tanjung Perak amounting to Rp361.33 million. Please note that TTL has only been operating since 2014 until now. Then for the input variables, assets at the BJTI terminal is Rp1.11 trillion, at TPS is Rp2.6 trillion, at TTL is Rp1.97 trillion, and Tanjung Perak is Rp1.21 trillion. Furthermore, on human resource data, at the BJTI terminal there are 357 people, at TPS it is 419 people, at TTL it is 327 people, and Tanjung Perak is 769 people.

Finally, for the inefficiency variable, the port depth at the BJTI terminal is -9.17 mLWS, at TPS it is -12.18 mLWS, at TTL it is -13.55 mLWS, and Tanjung Perak is -8.24 mLWS. The average loading and unloading productivity at the BJTI terminal is 150 TEUs per hour, at TPS is 200 TEUs per hour, at TTL is 80 TEUs per hour, and at Tanjung Perak is 90 TEUs per hour. Furthermore, average output, input, and inefficiency variables can be seen in Table 1.

Table 1: Average Output, Input, and Inefficiency Variables (2009-2020)

id	Output	Input			Inefficiency	
	Revenue-Nominal (Rp-Million)	Assets (Rp-Million)	Labor (Person)	Energy (Rp-Million)	Depth of Port (mLWS)	Load/unload productivity (TEU/hour)
Terminal Berlian Jasa Terminal Indonesia (BJTI)	655,751	1,116,382	357	458,232	-9.17	150.00
Terminal Petikemas Surabaya (TPS)	2,079,368	2,603,507	419	898,170	-12.18	200.00
Terminal Teluk Lamong (TTL)	465,283	1,970,140	327	261,761	-13.55	80.00
Pelabuhan Tanjung Perak (Terminal Nilam, Mirah, & Jamrud)	361,331	1,219,246	769	194,785	-8.241	90.00

Source: Tanjung Perak Port, 2009-2020

In identifying the object of this study, it is necessary to know the profile of the port/terminal under review, such as the size of the berth, the area of the stacking yard, the depth of the port, equipment, human resources (HR), and the flow of container goods in 2009-2020 period. Furthermore, at the modeling and data analysis stage, it is necessary to pay attention to the business processes in the container terminal so that the overall mechanism of the container handling flow is in accordance with field conditions. This will mention how the linkage of infrastructure (piers, stacking yards, and warehouses) and equipment (cranes, trucks, rubber tire gantry cranes/RTGCs, reach stackers, and forklifts) from a terminal will affect efficiency and productivity in port services (mooring services, dock services, stevedoring services, lo-lo services, stacking services, and warehousing services). In the end, all will lead to a maximum occupancy/utility level of 70% (UNCTAD, 2016), where production can no longer grow.

Furthermore, from the entire series of business processes, technical efficiency will be analyzed using the stochastic frontier analysis (SFA), which consists of Cobb-Douglas, Hick's Neutral, No Technical Progress, and Translog production functions. All production functions will be tested for likelihood ratio (LR test) and maximum likelihood. From these results can be seen and the elasticity of each variable. The framework of this study can be seen in Figure 5.

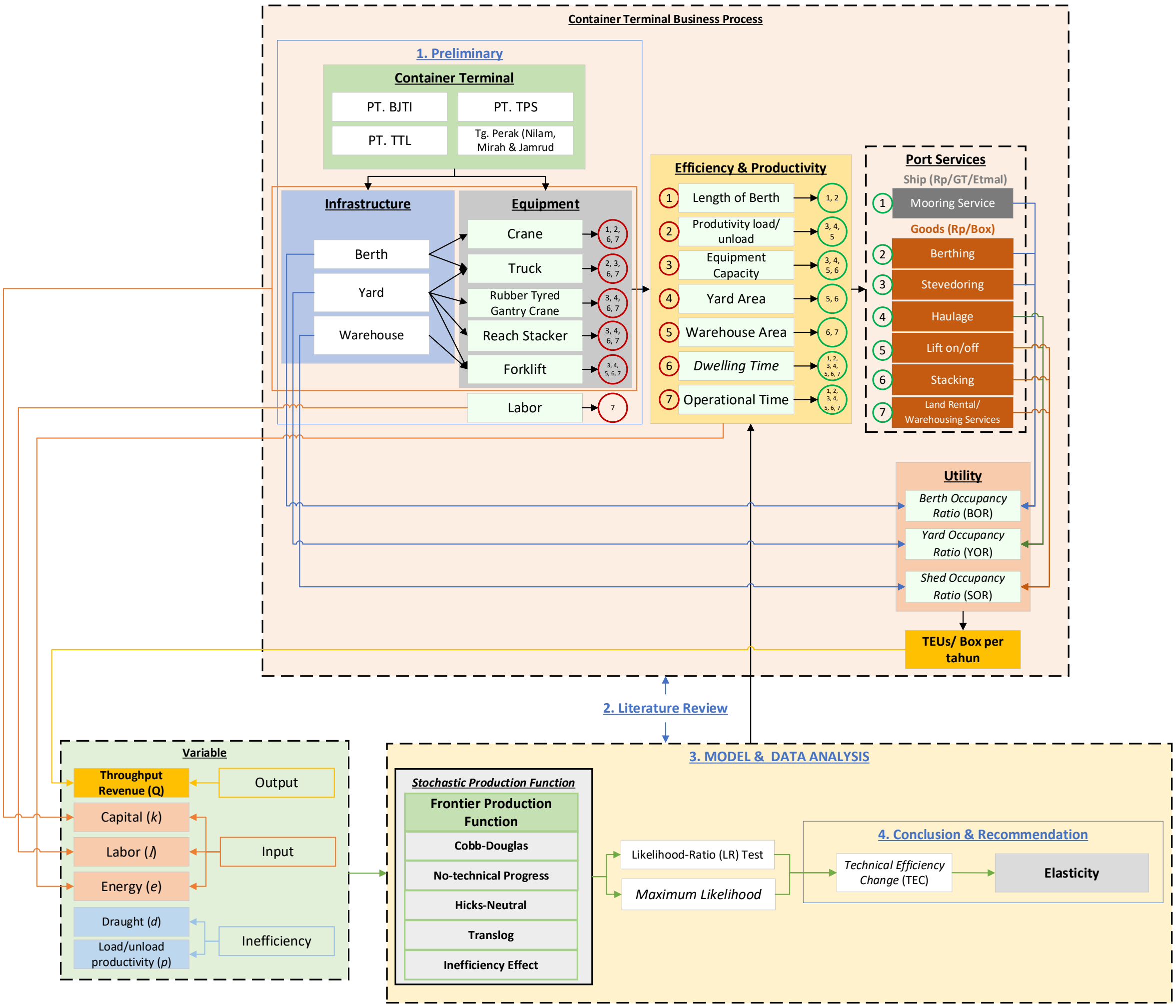


Figure 5: Study Framework

Source: Author's Illustration

The inefficiency variables used are port draught (d) and loading and unloading productivity (p). The selection of these variables in the inefficiency variable is because the depth of the port will affect the size of ships visiting the terminal/port (Lu & Wang, 2017). Productivity of loading and unloading will affect the speed of loading and unloading of containers, where this can determine how much container flows through the port. All of these inefficiency variables can indirectly affect the production of loading and unloading containers and further affect the efficiency level of the container terminal (Lun et al., 2010).

The calculation step for the analysis of the frontier production function is to use one step, where exogenous variables have been included in each production function. The subscript i denotes the i-th company, the t subscript represents the t-th year for each company, where u_{it} is the value of technical inefficiency and ε_{it} is the error term in the technical inefficiency function. For xn_{it}, it shows each input variable in a production function. The analysis of the study consisted of many relatively long stages. To make it easier to understand the calculation process, Figure 6 is a flow chart for calculating the efficiency and productivity of a container terminal in Tanjung Perak, East Java.

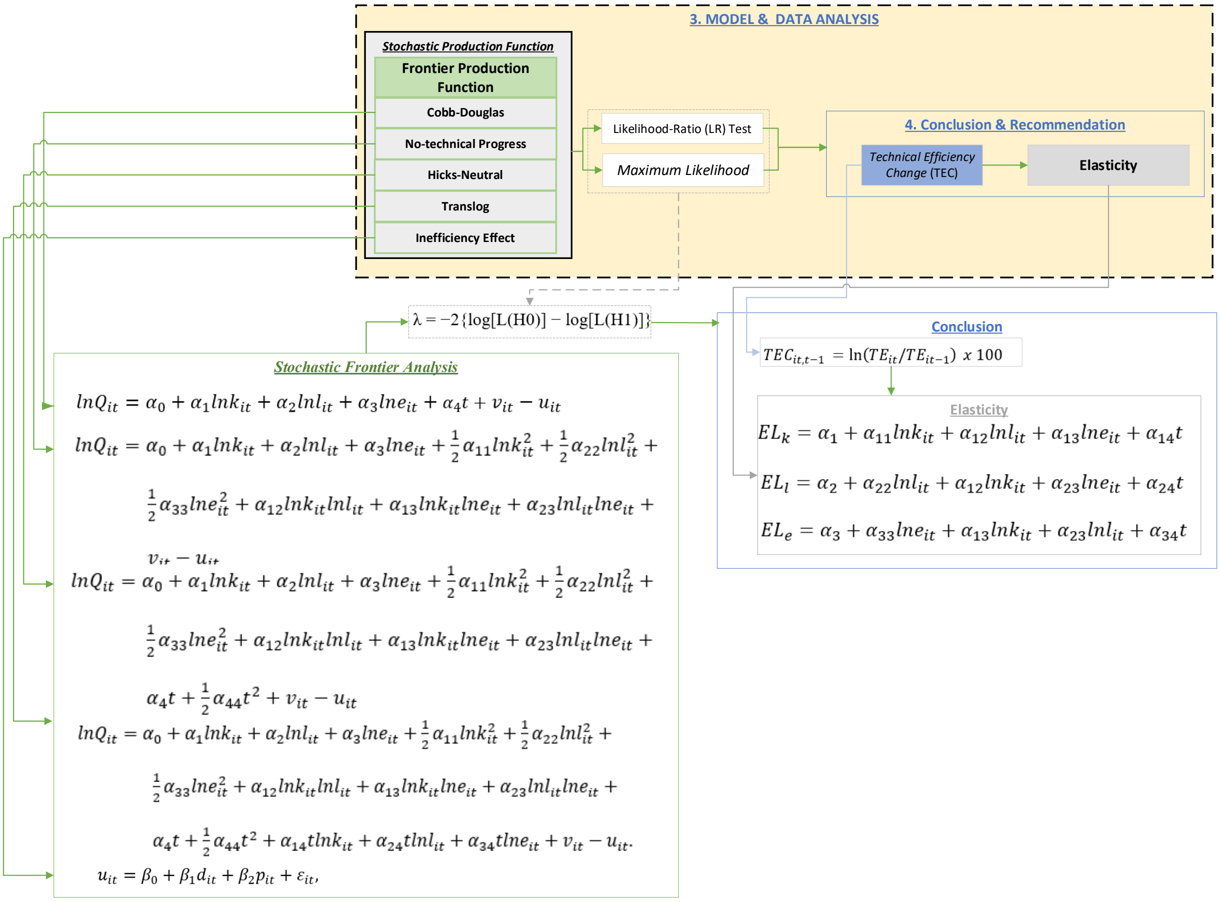


Figure 6: Flow of Calculation of Efficiency and Productivity

Source: Author's Illustration

Finding and Discussion

From the available data, the next step is to estimate the regression to see the relationship between variables, where the regression is carried out through several production functions, including Cobb-Douglas, Hicks-Neutral, No-Technical Progress (NTP), and Translog. In general, the Cobb-Douglas production function consists of input variables (k, l, and e). Then for the Hicks-Neutral production function, the input variable has a quadratic factor, the interaction between variables, and the time variable (t) is added. Furthermore, the No-Technical Progress production function is almost like the Hicks-Neutral production function, but without the addition of a time variable. Finally, the production function of Translog is from all interactions between variables plus interactions with the time variable (Kumbhakar & Lovell, 2000). Furthermore, TE can be estimated from t xn_{it} his year to the next year as in Equation 11.

$$
\begin{aligned}
TE &= -\frac{\partial u_{it}}{\partial t} \\
&= \exp(-u_{it}) \\
&= \delta \exp\{-\delta(t-T)\} u_{it} \\
&= \delta \eta_t u_i
\end{aligned} \tag{11}
$$

$$TEC_{it,t-1} = \ln(TE_{it}/TE_{it-1}) \times 100$$

For , it shows each input variable in a production function. In detail the elasticity of each input variable can be seen in Equation 12, Equation 13, and Equation 14.

$$EL_k = \frac{\delta \ln Q_{it}}{\delta \ln k_{it}} = \alpha_1 + \alpha_{11} \ln k_{it} + \alpha_{12} \ln l_{it} + \alpha_{13} \ln e_{it} + \alpha_{14t} \quad (12)$$

$$EL_l = \frac{\delta \ln Q_{it}}{\delta \ln l_{it}} = \alpha_2 + \alpha_{22} \ln l_{it} + \alpha_{12} \ln k_{it} + \alpha_{23} \ln e_{it} + \alpha_{24t} \quad (13)$$

$$EL_e = \frac{\delta \ln Q_{it}}{\delta \ln e_{it}} = \alpha_3 + \alpha_{33} \ln e_{it} + \alpha_{13} \ln k_{it} + \alpha_{23} \ln l_{it} + \alpha_{34t} \quad (14)$$

Regression estimation is carried out using Frontier 4.1, where the use of these tools shows a comparison of the estimation results of each production function and the inefficiency effect. The estimation results can be seen in Table 2.

Table 2: The Estimated Coefficient of Inputs on Production Functions

	Cobb-Douglas	Hicks-Neutral	NTP	Translog
beta 0	0,1837*	0,1424	0,3209*	0,4403*
K	0,9108*	0,9020*	0,8300*	0,6966*
L	-0,103*	0,1755	0,1852	-0,346*
E	0,9523*	0,8225*	0,2915*	0,9008*
K^2	-0,017*	1,4487*	0,4864	-1,312
L^2	-	-0,420	0,1383	-1,626*
E^2	-	-0,076	-0,202*	-0,044*
K*L	-	0,6708	0,6898*	0,3297
K*E	-	0,2649	0,7600*	0,8406*
L*E	-	0,3155	0,1137	-0,762*
t	-	-0,013	-	-0,038*
t^2	-	-0,001	-	0,0057
K*t	-	-	-	0,0308*
L*t	-	-	-	0,1270*
E*t	-	-	-	-0,047*
delta 0	-0,092	-0,054	1,2798*	-0,114
p	-0,000	0,0009	-0,007*	0,0011*
d	0,2781*	-0,058	-1,166*	-0,108*
sigma-squared	0,0131	0,0055	0,0048	0,0039
gamma	0,1603	0,9991	0,9674	0,9999

Note: * is significant at 5%

Source: Author's Calculation

From Table 2, Translog as the selected production function can be seen that all variables (assets, human resources, and energy) have a significant effect on the production output/flow of containerized goods. Likewise for the effect of inefficiency, where all inefficiency variables, namely productivity/loading and loading speed and port depth, have a significant effect. The next stage is to do the Likelihood-Ratio (LR) Test of each production function as a parameter hypothesis test in the frontier production function. There are three kinds of tests on the frontier production function: LR test; Wald; and the Lagrange Multiplier (Coelli et al., 2005). Generally, Coelli et al., (2005) only describes the LR test because it is easier to estimate the translog model. Furthermore, the technical inefficiency effect model was tested using the LR test where the hypothesis in this test was that there was a technical inefficiency effect or no technical inefficiency effect. In detail, it can be explained in Equation 15 as:

$$\lambda = -2\left(\log\left[L\left(H_0\right)\right] - \log\left[L\left(H_1\right)\right]\right) \quad (15)$$

$[L(H_0)]$ and $\log[L(H_1)]$ is the value of the log-likelihood function for the stochastic frontier model with the exposure that the null hypothesis (H0) has a technical inefficiency effect and the alternative hypothesis (H1) has no inefficiency effect (Kodde & Palm, 1986). Each production function is tested through the Likelihood-Ratio (LR) Test as shown in Table 3

Table 3: Likelihood-Ratio (LR) Test and Maximum Likelihood

		Log Likelihood Function	Lambda	Chi Square Table (Alpha 1%)	Degree of Freedom	Number of Parameter	Decision
H1	Translog	93.01				14	
H0	Cobb-Douglas	29.46	127.09	23.21	10	4	Translog
	Hicks Neutral	69.87	46.28	11.34	3	11	Translog
	NTP	71.38	43.26	15.09	5	9	Translog

From Table 3 it can be seen that the selected production function is the translog production function. The next stage is to see the inefficiency effect of the selected production function, where the method is to eliminate the inefficiency variable from the selected production function (H0) and compare it with the selected production function using the inefficiency variable (H1). The inefficiency effect can be seen in Table 4.

Table 4: Inefficiency Effect

		Log Likelihood Function	Lambda	Chi Square Table (Alpha 1%)	Degree of Freedom	Number of Parameter	Decision
H1	Translog	93.01				14	
H0	No-Inefficiency	75.15	35.71	9.21	2	14	Translog

Source: Author's Calculation

Translog is selected as production function, then the inefficiency coefficients in Table 2 can be described. As for the productivity variable, it affects the inefficiency of the container terminal, where the higher productivity/1% increase in loading and unloading productivity the more inefficiency, but with a relatively very small value of 0.11%. This is because all container terminals in Tanjung Perak generally still use relatively old equipment and the loading and unloading speed is not high yet, such as at BJTI and Tanjung Perak Port. If loading and unloading productivity is to be increased, it is often done by adding equipments that have the same capacity as the previous tool and not increasing the loading and unloading speed of the previous tool. This reflects that the increase in loading and unloading speed will increase capital costs, operational costs, and human resources whose additions are not proportional to output expectations. Furthermore, all container terminals in Tanjung Perak generally have not been able to improve their technological capabilities to support higher productivity.

Furthermore, on the port depth variable, the deeper the port, the more efficient it will be, where an increase of 1% in depth will increase efficiency or reduce inefficiency by 10.89% at the port/terminal. A further explanation is that a deep harbor pool is an important facility for shipping that berthing ships at the terminal, where the deeper the pool, the larger size of the berthed ship with a larger draft (Meisel, 2009). Furthermore, in logistics, the larger size of the visiting ship, the lower unit price of an item (economics of scale). This has an impact on the efficiency of the container terminal, where the larger the size and number of ships visiting, the larger flow of containers through the terminal.

The results of the Frontier4.1 program in addition to producing coefficient estimates also produce TE, where the TE value is 0 – 1. The average TE value of the container terminal in Tanjung Perak is 0.94. In detail, the highest average TE is at TPS with a value of 0.98. TPS has the highest TE due to several things, which are having the most assets (unloading equipment, docks, and stacking yards), which of these assets can make loading and unloading productivity the fastest with an average of 200 TEUs per hour. Iyer & Nanyam (2021); Munim (2020); and Kim (2012) stated that the factors that affect technical efficiency are the size and facilities and equipment of the terminal (piers, stacking yards, and loading and unloading equipment).

In terms of human resources, TPS has a number of human resources that on average are not much different from other terminals, so it can be said that the operation of the terminal with the most assets does not require much more human resources than other terminals. The same thing also happened to the energy costs required for the operation of container terminals, where TPS only required Rp. 16,137 per TEU on average, while the average energy demand for all container terminals in Tanjung Perak was Rp. 17,210. This shows that the energy demand at TPS has a fairly good energy efficiency, which is 6.24% of the average in all container terminals in Tanjung Perak.

In competitive analysis, efficiency and productivity between ports cannot be separated from the scope of linkage and nodes (Antapassis et al., 2009; Geerlings et al., 2018), regarding transportation analysis at ports, where there is an analysis of land and sea transportation. The analysis is described through a cost approach, both from the land and sea side. In the analysis of transportation costs on land, TPS on average has a cost of 5.46% more expensive than the average logistics costs of all container terminals because in terms of location the terminal is slightly further away from the nearest hinterland zone, but this is not the most significant in cost efficiency. Furthermore, the cost of transportation at sea, TPS has a cost efficiency that is 37.94% cheaper than the average cost of transportation at sea at other terminals.

Therefore, the technical efficiency of TPS from all aspects is relatively the highest or furthermore the use of inputs is relatively optimum in producing output/conducting loading and unloading activities of containers compared to other terminals. Then TTL with a TE value of 0.97; BJTI with a TE value of 0.94, and Tanjung Perak Port with a TE value of 0.88. Furthermore, changes in the TE value at each container terminal in Tanjung Perak from 2009-2020 can be seen in Figure 7.

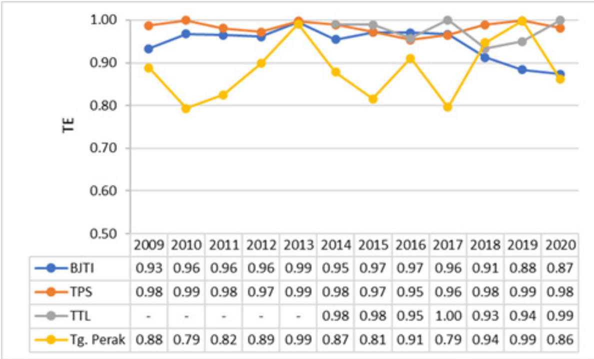


Figure 7: Technical Efficiency in Container Terminals in Tanjung Perak

Source: Author's Calculation

In summary, the growth in technical efficiency (TEC) was positive and negative. The positive growth is due to evaluations and improvements in port services, both in terms of providing facilities, improving equipment performance, and increasing human resource capabilities so as to facilitate the main activity, which is loading and unloading goods. On average, BJTI has positive growth of 2.97% and negative growth of -1.74%. Then at TPS positive growth of 1.7% and negative growth of -1.28%. Continuing on TTL positive growth of 2.94% and negative growth of -2.49%. Finally, at the Port of Tanjung Perak positive growth of 9.86% and negative growth of -11.08%. In detail, the TEC of the container terminal in Tanjung Perak can be seen in Table 5.

Table 5: Technical Efficiency Change in Container Terminals in Tanjung Perak

Δ	id	year	TEC	Δ	id	year	TEC
2009-2010				2015-2016			
	1	2	0.04		1	8	-0.00
	2	2	0.01		2	8	-0.02
	4	2	-0.11		3	8	-0.03
2010-2011					4	8	0.12
	1	3	-0.00	2016-2017			
	2	3	-0.02		1	9	-0.00
	4	3	0.04		2	9	0.01
2011-2012					3	9	0.04
	1	4	-0.00		4	9	-0.13
	2	4	-0.01	2017-2018			
	4	4	0.09		1	10	-0.06
2012-2013					2	10	0.02
	1	5	0.03		3	10	-0.07
	2	5	0.03		4	10	0.19
	4	5	0.10	2018-2019			
2013-2014					1	11	-0.03
	1	6	-0.04		2	11	0.01
	2	6	-0.01		3	11	0.02
	3	6			4	11	0.05

Δ	id	year	TEC	Δ	id	year	TEC
	4	6	-0.11	2019-2020			
2014-2015					1	12	-0.01
	1	7	0.02		2	12	0.02
	2	7	0.02		3	12	0.05
	3	7	0.00		4	12	-0.14
	4	7	0.07				

Source: Author's Calculation

The last step, the elasticity of output to input is calculated. The indicators in this elasticity are if $EL_{xn} > 1$, then it is classified as increasing return to scale (IRS); if $EL_{xn} = 1$, then it is classified as constant return to scale (CRS); and if $EL_{xn} < 1$, then it is classified as decreasing return to scale (DRS). The calculation of the elasticity of output to input is based on the derivative of output to input $\left(\delta \ln Q_{it} / \delta \ln xn_{it} \right)$ following the mathematical formula in Equation 3, Equation 4, and Equation 5. On average, the elasticity of assets is 0.91, the elasticity of human resources is 0.53, and the elasticity of energy is 0.57. Thus, the overall average elasticity is 2.01. From the elasticity results, the elasticity of assets has the largest proportion, so it can be concluded that the port is capital intensive. The value of the elasticity of output to these inputs can be categorized as increasing return to scale (IRS), where the addition of 1 percent of inputs can increase > 2.01% of output. The elasticity results are similar to previous research by Hung et al. (2010), where 70% of container ports in Asia operate at IRS.The results of the calculation of the elasticity of output to input at each container terminal in Tanjung Perak from 2009-2020 can be seen in Table 6.

Table 6: Output Elasticity

Δ	id	year	dQ/dK	dQ/dL	dQ/dE	εtotal	Δ	id	year	dQ/dK	dQ/dL	dQ/dE	εtotal
							2015-2016						
			1.08	0.61	0.89	2.57		1	8	1.70	0.48	0.46	2.64
			0.10	0.15	1.40	1.65		2	8	0.80	0.33	0.99	2.12
			1.38	-0.92	-0.44	0.03		3	8	-0.22	2.10	0.86	2.74
2009-2010								4	8	1.78	0.92	0.45	0.41
	1	2	1.17	0.57	0.78	2.51	2016-2017						
	2	2	0.22	0.17	1.35	1.74		1	9	1.75	0.52	0.37	2.64
	4	2	1.32	-1.24	-0.04	0.04		2	9	0.86	0.40	0.92	2.19
2010-2011								3	9	0.09	1.72	1.00	2.81
	1	3	1.25	0.52	0.66	2.43		4	9	1.55	0.60	0.16	2.31
	2	3	0.36	0.17	1.28	1.80	2017-2018						
	4	3	1.25	-1.06	-0.10	0.09		1	10	1.87	0.37	0.30	2.54
2011-2012								2	10	0.97	0.42	0.86	2.26
	1	4	1.37	0.31	0.57	2.21		3	10	0.17	1.64	1.05	2.86
	2	4	0.40	0.20	1.26	1.93		4	10	1.43	1.17	0.30	2.90
	4	4	1.39	-1.06	-0.18	0.22	2018-2019						
2012-2013								1	11	1.92	0.35	0.20	2.47
	1	5	1.49	0.24	0.48	2.21		2	11	1.00	0.53	0.80	2.33

Δ	id	year	dQ/dK	dQ/dL	dQ/dE	εtotal	Δ	id	year	dQ/dK	dQ/dL	dQ/dE	εtotal
	2	5	0.48	0.26	1.19	1.93		3	11	0.28	1.63	1.00	2.92
	4	5	1.53	-1.07	-0.25	0.22		4	11	1.51	1.22	0.22	2.95
2013-2014							2019-2020						
	1	6	1.51	0.50	0.66	2.67		1	12	1.97	0.34	0.09	2.40
	2	6	0.59	0.28	1.12	1.99		2	12	0.98	0.66	0.73	2.38
	3	6	-4.50	5.88	1.08	2.46		3	12	0.27	1.78	0.94	2.98
	4	6	1.56	-0.96	-0.31	0.28		4	12	1.38	1.46	0.17	3.01
2014-2015													
	1	7	1.58	0.50	0.55	2.63							
	2	7	0.70	0.31	1.05	2.06				Average			
	3	7	-0.79	2.58	0.90	2.68				dQ/dK	dQ/dL	dQ/dE	εtotal
	4	7	1.61	-0.88	-0.37	0.35				0.91	0.53	0.57	2.01

Source: Author's Calculation

Conclusion

This paper examines how the container terminal in Tanjung Perak, East Java works in the 2009-2020 period from the point of view of technical efficiency at each terminal. Furthermore, this study also examines how the terminal works in carrying out the main activity, namely loading and unloading containers by paying attention to the elasticity of output to input. The inputs are based on the theory of the production function which consists of capital, labor, and energy, where capital is represented by assets, labor reflects the number of human resources, and energy is based on the costs needed to operate the terminal. Finally, this study reviews the factors that influence the occurrence of terminal inefficiency, in this case using the variables of productivity/unloading speed and port depth.

In general, it can be concluded that the container terminal in Tanjung Perak has a relatively high technical efficiency value of 0.94. This shows that the operation of the terminal is quite optimum and is approaching the maximum point. Furthermore, this condition is in line with the berth occupancy ratio (BOR) which is close to the maximum limit set by UNCTAD, which is 70%. In detail, the highest average TE is at TPS with a value of 0.98, which has the most assets (unloading equipment, docks, and stacking yards) that can make loading and unloading productivity the fastest with an average of 200 TEUs per hour. Then TPS does not require much more human resources than other terminals. Furthermore, TPS only requires Rp16,137 per TEU on average, which has a fairly good energy efficiency of 6.24% above the average of all container terminals in Tanjung Perak.

The container terminal in carrying out its main activity, which are loading and unloading, cannot be separated from paying attention to the elasticity of output to input. On average, the elasticity of assets is 0.91, the elasticity of human resources is 0.53, and the elasticity of energy is 0.57. Thus, the overall average elasticity is 2.01. From the elasticity results, the elasticity of assets has the largest proportion, so it can be concluded that the port is capital intensive. The value of the elasticity of output to these inputs can be categorized as increasing return to scale (IRS), where the addition of 1 percent of inputs can increase > 2.01% of output.

Finally, in summary, terminal inefficiencies are viewed from an internal perspective, namely productivity/loading and loading speed and port depth. In the productivity variable, the higher productivity/1% increase in loading and unloading productivity the more inefficiency with a relatively very small value of 0.11%. In general, the container terminal in Tanjung Perak has not been able to improve its technological capabilities to support higher productivity. Furthermore, on the port depth variable, an increase of 1% in depth will increase efficiency or reduce inefficiency by 10.89% at the port/terminal. This has an impact on the efficiency of the container terminal that the larger the size and number of ships visiting, the larger the flow of containers through the terminal.

Fundamentally, in designing a port/terminal, it is necessary/ recommended to pay attention to several aspects, including technical aspects (size and strength of the berth, field area, depth of the port pool, and equipment requirements) and economic aspects (flow of goods, hinterland conditions, and production projections). From these two aspects, it can be estimated that the optimum capacity of a terminal can operate sustainably. The implementation of this for the Container terminal in Tanjung Perak, Surabaya, East Java is with a limited area, but still able to update technology by adding high-capacity equipment (loading and unloading speed of more than 25 TEUs per hour).

There are several limitations in assessing the efficiency and productivity of container terminals, such as observation data on the number of terminals are relatively limited; availability of data/observations that is relatively short (12 years); the data does not include the transit of goods because the data is not yet available. So this flow of goods is only available as a final port; this study analyzes all goods or does not differentiate between international and domestic goods so that the role of Customs and Excise is not calculated in influencing the productivity and efficiency of the container terminal at Tanjung Perak Port, Surabaya, East Java.

Reference

Achmadi, T., & Hadi, F. (2012). Connectivity Report on Domestic Sea Transport. Surabaya: LPPM-ITS & The World Bank Group Indonesia.

Aigner, D., Lovell, C. A. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. . Journal of Econometrics, 6(1), 21–37. Retrieved from https://doi.org/10.1016/0304-4076(77)90052-5

Akhavan, M. (2020). Port Geography and Hinterland Development Dynamics: Insights from Major Port-cities of the Middle East. Cham: Springer International Publishing.

Antapassis, A., Athanassiou, L., & Rosaeg, E. (2009). Competition and Regulation in Shipping and Shipping Related Industries: Brill | Nijhoff.

Arunsawadiwong, S. (2007). Productivity Trends in the Thai Manufacturing Sector : the Pre- and Post-Crisis Evidence Relating To the 1997 Economic Crisis. (In Doctoral dissertation, University of St Andrews.). University of St. Andrew.

Assaf, A. G. (2007). Modelling the Efficiency of Health Care Foodservice Operations : A Stochastic Frontier Approach.: March.

Badunenko, O., Fritsch, M., , & Stephan, A. (2006). What Determines the Technical Efficiency of a Firm ? The Importance of Industry, Location, and Size.: December, 34.

Badan Informasi Geospasial (BIG). (2015). *Peta Kelautan [Marine Map]*. Retrieved from Badan

Informasi Geospasial.

Cabral, A. M. R., & Ramos, F. d. S. (2014). Cluster analysis of the competitiveness of container ports in Brazil. Transportation Research Part A: Policy and Practice, 69, 423-431. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S096585641400216X

Chang, V., & Tovar, B. (2014). Efficiency and productivity changes for Peruvian and Chilean ports terminals: A parametric distance functions approach. Transport Policy, 31, 83-94. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S0967070X1300173X

Cheon, S., Dowall, D. E., & Song, D.-W. (2010). Evaluating impacts of institutional reforms on port efficiency changes: Ownership, corporate structure, and total factor productivity changes of world container ports. Transportation Research Part E: Logistics and Transportation Review, 46(4), 546-561. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S1366554509000416

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). An Introduction to Efficiency Analysis. Uniter State of America: Springer.

Ding, Z.-Y., Jo, G.-S., Wang, Y., & Yeo, G.-T. (2015). The Relative Efficiency of Container Terminals in Small and Medium-Sized Ports in China. The Asian Journal of Shipping and Logistics, 31(2), 231-251. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S2092521215000322

Dinu, O., Rosca, E., Dragu, V., Rosca, M., & Ilie, A. (2018). Optimization of the transfer function through handling productivity control in port container terminals. Procedia Manufacturing, 22, 856-863. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S2351978918304177

Farrell, M. J. (1957). The measurement of productive efficiency. J. R. Stat. Soc, 120(3).

Figueiredo De Oliveira, G., & Cariou, P. (2015). The impact of competition on container port (in)efficiency. Transportation Research Part A: Policy and Practice, 78, 124-133. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S0965856415001202

Geerlings, H., Kuipers, B., & Zuidwijk, R. (2018). Ports and networks: strategies, operations and perspectives. Abingdon, Oxon ; New York, NY: Routledge.

Günther, H.-O. (2005). Container terminals and automated transport systems: logistics control issues and quantitative decision support. Berlin Heidelberg: Springer.

Herrero, I., & Pascoe, S. (2002). Estimation of technical efficiency: a review of some of the Stochastic Frontier and DEA software (15th ed.): CHEER Virtual.

Hung, S.-W., Lu, W.-M., & Wang, T.-P. (2010). Benchmarking the operating efficiency of Asia container ports. European Journal of Operational Research, 203(3), 706-713. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S0377221709005669

Iyer, K. C., & Nanyam, V. P. S. N. (2021). Technical efficiency analysis of container terminals in India. The Asian Journal of Shipping and Logistics, 37(1), 61-72. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S2092521220300420

Kementerian Perhubungan (Kemenhub). (2015). Peraturan Menteri Perhubungan RI No. 51 tentang Penyelenggaraan Pelabuhan Laut [Regulation of the Minister of Transportation of the Republic of Indonesia No. 51 concerning the Operation of Seaports.]. Jakarta:

Kementerian Perhubungan RI

Kementerian Perhubungan (Kemenhub). (2019). Rencana Induk Pelabuhan (RIP) Tanjung Perak dan Sekitarnya Secara Terintegrasi Provinsi Jawa TImur. Surabaya: Kementerian Perhubungan [Integrated Port Master Plan (RIP) of Tanjung Perak and Around East Java Province. Surabaya: Ministry of Transportation]

Khalifah, N. A., Talib, B. A., & Amdun, P. Z. (2008). Are foreign multinationals more efficient? A stochastic production frontier analysis of Malaysia's automobile industry. International Journal of Management Studies, 15, 91-113.

Kim, D.-j. (2012). A Comparison of Efficiency with Productivity Criteria for European Container Ports. The Asian Journal of Shipping and Logistics, 28(2), 183-202. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S2092521212000181

Kodde, D. A., & Palm, F. C. (1986). Wald criteria for jointly testing equality and inequality restrictions. Econometrica, 54(5), 1243–1248.

Kumbhakar, S., & Lovell, C. A. K. (2000). Stochastic Frontier Analysis. Cambridge Cambridge University.

Kutin, N., Nguyen, T. T., & Vallée, T. (2017). Relative Efficiencies of ASEAN Container Ports based on Data Envelopment Analysis. The Asian Journal of Shipping and Logistics, 33(2), 67-77. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S2092521217300226

Ligteringen, H., & Velsink, H. (2012). Ports and terminals (First edition ed.). Delft, the Netherlands: VSSD.

López-Bermúdez, B., Freire-Seoane, M. J., & González-Laxe, F. (2019). Efficiency and productivity of container terminals in Brazilian ports (2008–2017). Utilities Policy, 56, 82-91. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S0957178718302406

Lu, B., & Wang, S. (2017). Critical Factors for Berth Productivity in Container Terminal. Singapore: Springer Singapore.

Lun, Y. H. V., Lai, K.-H., & Cheng, T. C. E. (2010). Shipping and Logistics Management. London: Springer London.

Meisel, F. (2009). Seaside operations planning in container terminals. Dordrecht ; New York: Physica-Verlag.

Munim, Z. H. (2020). Does higher technical efficiency induce a higher service level? A paradox association in the context of port operations. The Asian Journal of Shipping and Logistics, 36(4), 157-168. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S209252122030016X

Mustafa, F. S., Khan, R. U., & Mustafa, T. (2021). Technical efficiency comparison of container ports in Asian and Middle East region using DEA. The Asian Journal of Shipping and Logistics, 37(1), 12-19. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S2092521220300250

Nicholson, W., & Snyder, C. (2010). Microeconomic Theory Basic Principles and Extensions. In Journal of Materials Processing Technology (Vol. 1, Issue 1). Nelson Education, Ltd.

Nicholson, W., & Snyder, C. (2012). Microeconomic Theory : Basic Prinsiples and Extensions.

In IEEE Transactions on Information Theory (11th ed., Vol. 58, Issue 3). South-Western: Cengage Learning.

Notteboom, T., Pallis, A., & Rodrigue, J.-P. (2021). Port Economics, Management and Policy (1 ed.). London: Routledge.

Odeck, J., & Schøyen, H. (2020). Productivity and convergence in Norwegian container seaports: An SFA-based Malmquist productivity index approach. Transportation Research Part A: Policy and Practice, 137, 222-239. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S0965856420305760

Pérez, I., González, M. M., & Trujillo, L. (2020). Do specialisation and port size affect port efficiency? Evidence from cargo handling service in Spanish ports. Transportation Research Part A: Policy and Practice, 138, 234-249. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S0965856420306042

Perloff, J. (2020). Theory And Applications With Calculus (5th ed.): Pearson Media Company.

Pindyck, S. R., & Rubinfeld., D. L. (2018). Microeconomics (9th ed.): Pearson Media Company.

Sari, D. W., Khalifah, N. A., & Suyanto, S. (2016). The spillover effects of foreign direct investment on the firms' productivity performances. . Journal of Productivity Analysis, 46(2–3), 199–233. . Retrieved from https://doi.org/10.1007/s11123-016-0484-0

Song, B., & Cui, Y. (2014). Productivity changes in Chinese Container Terminals 2006–2011. Transport Policy, 35, 377-384. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S0967070X14000985

Suyanto, S., R., & Bloch, H. (2009). Does Foreign Direct Investment Lead to Productivity Spillovers? Firm Level Evidence from Indonesia. 37(12).

UNCTAD. (2016). Port Management Series. Switzerland: United Nation.

Wang, H. J., & Schmidt, P. (2002). One-step and two-step estimation of the effects of exogenous variables on technical efficiency levels. Journal of Productivity Analysis, 46(2–3), 199–233.

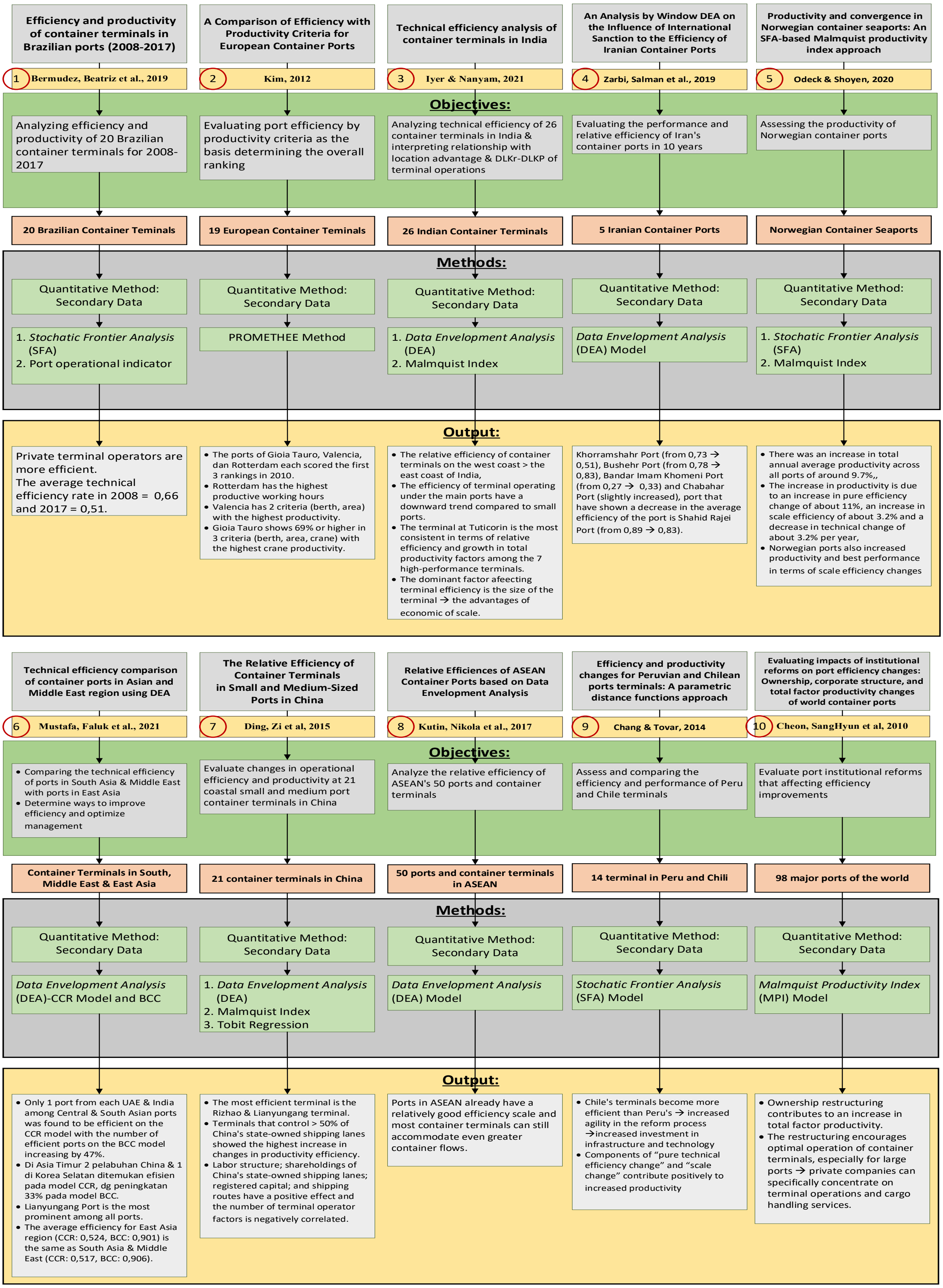
Wu, Y.-C. J., & Goh, M. (2010). Container port efficiency in emerging and more advanced markets. Transportation Research Part E: Logistics and Transportation Review, 46(6), 1030-1042. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S136655451000013X

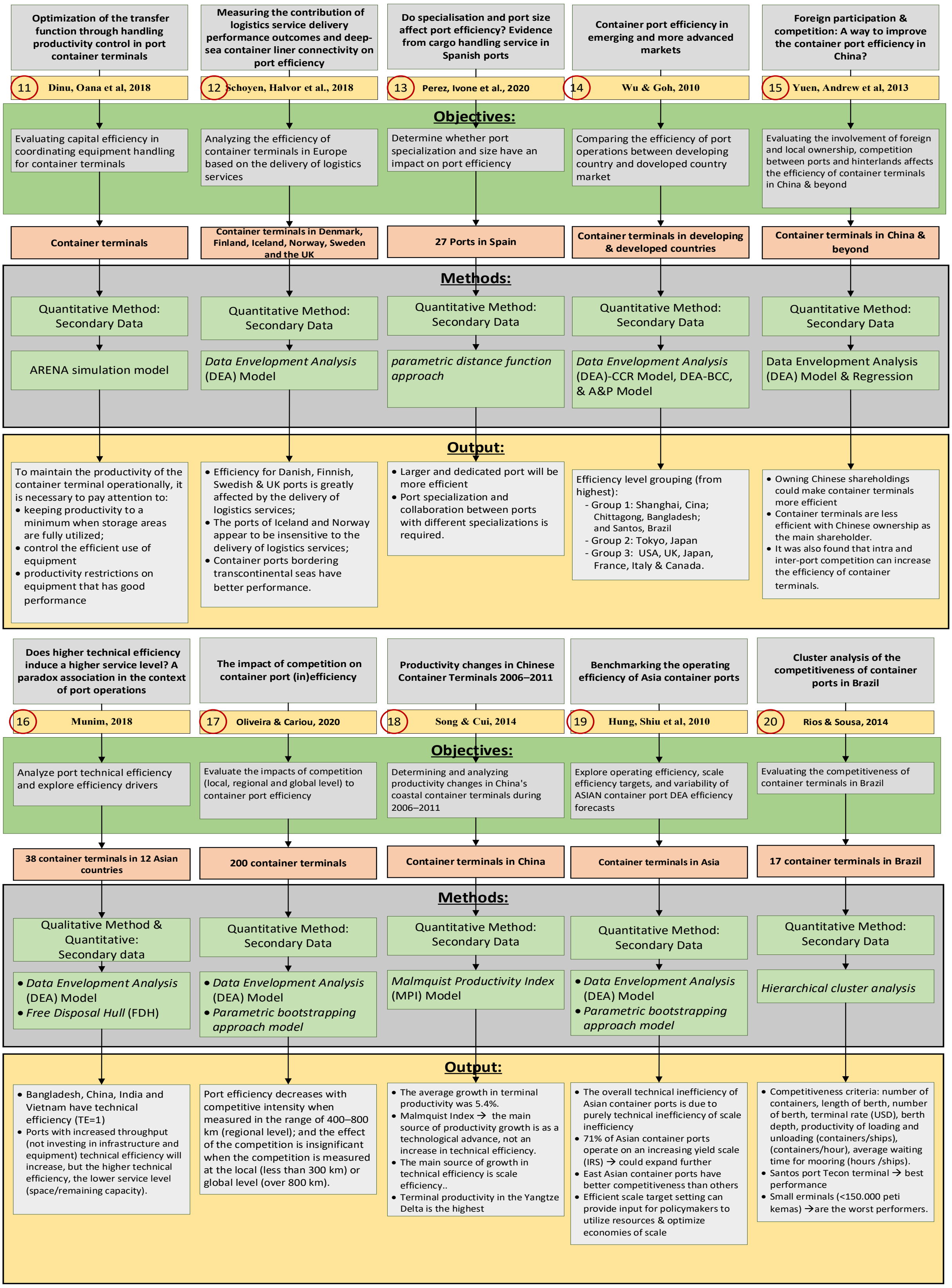
Yuen, A. C.-l., Zhang, A., & Cheung, W. (2013). Foreign participation and competition: A way to improve the container port efficiency in China? Transportation Research Part A: Policy and Practice, 49, 220-231. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S0965856413000335

Zarbi, S., Shin, S.-H., & Shin, Y.-J. (2019). An Analysis by Window DEA on the Influence of International Sanction to the Efficiency of Iranian Container Ports. The Asian Journal of Shipping and Logistics, 35(4), 163-171. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/S2092521219300719

Appendix

Appendix 1 Previous Research





Source: Author's Illustration