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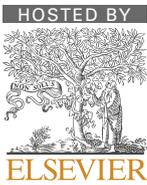
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Original Article

Impact of maritime logistics on archipelagic economic development in eastern Indonesia

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ABSTRACT

The efficiency of logistics is a determinant in developing trade cooperation between regions. Many areas in the eastern part of Indonesia have a flawed logistics system that results in a low level of competitiveness. The paper analyses local ports' performance and maritime logistics impact on the small island economy in East Indonesia, especially in the North Maluku Province. The research method used the survey and the Stochastic Frontier Analysis to measure each local port's performance in which Gross Regional Domestic Product (GRDP) per capita constitutes the output variable. While GRDP, number of cargo throughput, number of port labor, inland connection, loading and unloading tariff, and sea freight cost are input variables. The results show that the loading and unloading tariffs and sea transportation costs harm the GRDP per capita of the respective small island districts. Other findings suggest that the port of Morotai, Central Halmahera, North Halmahera, and Ternate have a higher level of technical efficiency than those in East Halmahera, South Halmahera, Sula, and Tidore. Low port efficiency can disrupt the distribution of goods between islands, resulting in higher logistics costs. The limited data and the small scope of the area is the restriction of the study.

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1. Introduction

Maritime logistics is currently the concern of stakeholders in the logistics field. The evolution of maritime logistics as a new discipline has resulted in profound changes, from increased shipping and customer demands proliferating and the changing role of ports in the context of supply chain and logistics. The port function has evolved from the traditional process of facilitating loading and unloading activities to a link in a more massive logistics chain as a part of global distribution channels. One of the developments of performance and quality of maritime logistics services is improv-

ing port efficiency, such as controlling maritime transport costs (Panayides & Song, 2013).

Indonesia, as an archipelago country, faces a difficult challenge in achieving maritime logistics system efficiency. Indonesia was on the 46th rank for logistics performance in the world or number 4th in Southeast Asia, following Singapore (7), Thailand (32), and Malaysia (41), according to World Bank (2018). It illustrates that logistical problems remain an obstacle in increasing competitiveness and facilitating commodity distribution flow among territories. The average logistics cost in Indonesia was 26.03% of the Gross Domestic Product (GDP), in which transportation cost constituted the largest component, namely 12.04% of the GDP (World Bank, 2013). Inefficient logistics alter trading performance because it generates costs affecting local economic development. High logistics costs occur as a result of high transaction costs at container ports (Cho, 2014). Port development, such as revamping port management and strengthening connectivity between land transportation and sea transportation with supply chains, mainly related to the local economy, is essential in achieving port efficiency (Song & van Geenhuizen, 2014). Other research stated that enhancing port

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efficiency from 25% to 75% may reduce transportation costs by 12% and boost bilateral trade by 25% (Clark, Dollar, & Micco, 2004).

In Indonesia, maritime logistics efficiency has become an important topic among researchers and experts. Sutomo and Soemardjito (2012) measured port efficiency in western Indonesia and found that Tanjung Priok-Jakarta's port was the most effective and efficient. Aqmarina and Achjar (2017) affirm the determinants of port performance in four main ports. Likewise, Fahmiasari and Parikesit (2017) assessed the efficiency of container transport networks and proved that Sea Toll-way was 8% more efficient than Nusantara Pendulum. Gena, Arief, Kusumastanto, and Nimmi (2020) formulate a strategy to strengthen Indonesia's port industry's competitiveness. Mappangara, Adisasmita, Samang, and Sitepu (2015) recommended the necessity for developing a short-distance shipping network in some Sulawesi corridor coastal areas. Kusumastanto (2020), in his paper, estimated logistics cost approximately 20–30% of Indonesia's GDP due to its archipelagic characteristics in which inter-island connectivity induces a higher cost of logistics.

The efficiency of maritime logistics, therefore, is vital for island areas to expand the local economy. There are limited studies on this issue. Thus, this research endeavors to fill the gap by taking North Maluku, an archipelagic province located in eastern Indonesia. North Maluku province faces serious concerns on maritime logistics such as irregular ship schedules, high sea transportation costs, and lack of transportation modes. There are eight main local ports in North Maluku, including Ternate, Tidore, Morotai, Tobelo, Buli, Weda, Babang, and Sanana, directly connected to the central industry, Java Island, in commodity distribution. The ports' existence plays a critical role in facilitating goods flow activity in surrounding areas and periphery islands with poor accessibility. The advance of the maritime logistics efficiency in the islands is an effort to realize the equitable development between territories, particularly in eastern Indonesia.

The study aims to measure local port performance and maritime logistics impact on the North Maluku province's small island economy. The paper's structure is organized as follows: section two highlights the maritime logistics on economic development and framework of the stochastic frontier model. Section three presents the data and operational model consisting of the input and output variables and works' scope. The next part is an analysis of the results and discussion. The conclusions and policy implications for developing maritime logistics efficiency, especially in islands, are outlined at the end of this paper.

2. Literature review

2.1. Maritime logistics role on economic development

Maritime logistics is a concept that applies the principles of logistics and supply chain management to the maritime transport system (Panayides & Song, 2013). Panayides (2006) outlines three characteristics that form the basis for understanding the maritime logistics' concepts. There are maritime transportation, logistics, and supply chain management. Maritime transportation contains the activity of transporting cargoes or passengers between two ports by sea. Logistics is a function responsible for materials flow from the suppliers into an organization through the operating system and then out to the customer. The supply chain involves activities and organizations that materials move through on their journey from supplier to the end of the customer. Supply chain management integrates all business process across the supply chain. Similarly, Nam and Song (2011) define maritime logistics is the review of the maritime transport (i.e., shipping and ports), traditional logistics functions (e.g., storage, warehousing, and offering distribution

center services), and integrated logistics series (e.g., value-added services, including labeling, assembly, and repairing).

Maritime logistics plays an essential role in local economic development. In maritime logistics systems, transportation is a significant component in helping the distribution and transport of freights by sea. The quality of maritime transport infrastructure is urgent to supporting maritime logistics systems' efficiency to increase economic added value and competitiveness in international trade (Bensassi, Márquez-Ramos, Martínez-Zarzoso, & Suárez-Burguet, 2015). Another statement said that the transportation network connectivity in logistics systems could enhance the industrial commodities' trade flow between countries (Alamá-Sabater, Márquez-Ramos, & Suárez-Burguet, 2013). Using a spatial approach, the authors noted that international trade among regions helps its neighbors' transport networks.

A similar study revealed a significant positive correlation between overall logistics performance with exports and imports in international business. The work extended the analysis by examining six indicators of logistics specificities on trade. Namely the ability to track and trace consignments; competence and quality of logistics services; ease of arranging competitively priced shipments; efficiency of customs clearance process; the frequency with which shipments reach consignee within scheduled or expected time; and quality of trade and transport-related infrastructure. All indicators confirmed a positive and statistically significant correlation with exports (Gani, 2017).

Further, Mohamed-Chérif and Ducruet (2016) indicate several logistical problems in the Maghreb region, such as the absence of a coordinated logistics chain between countries, causing transportation costs to increase due to returning containers empty, a flawed coordination system, and administrative expenses are not cheap. Besides, the transportation chain efficiency standards are lower than international standards due to inefficient port operations such as maintenance costs, lengthy customs procedures, low participation from the private sector, and high inter-regional transportation costs.

Another issue associates with the role of maritime logistics infrastructure investment in the regional economy. Song and van Geenhuizen (2014) examined how port infrastructure investment affects China's local economy. The results display that port infrastructure investment positively impacts regional growth in China with differences at the regional and provincial levels. This difference is related to the difference between the seaports to inland ports, the difference in density of land transport infrastructure, economic development stages, and port's advantages in the neighboring area.

The increasing of maritime logistics infrastructure investment will contribute massive loading and unloading activities at the port. Augmented economic activity in the harbor accelerates the advance of the local economy. The research worked by Park and Seo (2016) shows that the extension in loading and unloading activities has a significant and positive impact on local economic development in South Korea. In contrast, ports that do not have adequate loading equipment can hamper economic growth in a region. Bottasso, Conti, Ferrari, and Tei (2014) examined how port activities impact local development in the European area. The results exhibit that ports tend to raise GDP in districts that directly own ports and have a large and positive impact on their immediate neighborhoods' GDP. The area closest to port activity has a real economic advantage. Economic expansion in the non-port regions may result in high demand in areas with ports. In other words, ports tend to escalate GDP in zones that directly have ports and significantly impact GDP in the surrounding area. The competition from neighboring ports also helps boost the regional economy (Shan, Yu, & Lee, 2014).

All the studies above discussed the role of maritime logistics on continental or land areas' economic development. Few studies

Table 1
General information of local ports.

Local ports	Average (2016–2018)						
	GRDP ($t - 1$) (\$USD)*	GRDP/Capita (\$USD)*	Cargo throughput (Ton)	Port labor	Load and unload cost (\$USD)* /Ton	Inland connection (\$USD)* /Trip	Sea.transcost from T.Perak (\$USD)* /Ton
Ternate Island	405,465,652.00	1960.62	469,132	460	7.59	21.01	59.54
Tidore Island	118,680,478.20	1263.50	26,065	50	6.35	7.36	39.4
South Halmahera	235,015,681.30	1163.23	60,476	107	6.23	4.2	63.48
Center Halmahera	87,180,618.80	1781.01	270,352	130	5.6	7	59.54
East Halmahera	131,686,840.10	1566.26	2,586,914	27	8.1	10.51	48.16
North Halmahera	236,853,319.00	1321.34	408,216	600	6.1	14.39	83.18
Morotai Island	61,241,305.20	1017.58	81,421	247	7.99	10.51	39.4
Sula Island	97,808,012.50	1037.09	70,873	96	6.3	10.51	42.03

*Currency on January 2, 2020.

Source: Regional Statistical Agent, Local Port Labor Association, 2019.

elaborate on the maritime logistics issues in archipelagic or small island regions. For instance, [Tovar, Hernández, and Rodríguez-Déniz \(2015\)](#) explored the competitiveness and connectivity in Canary Islands’ container port. Some other investigations only depict the nature of small islands’ vulnerability and development related to logistics maritime circumstances. [Kerr \(2005\)](#) notice high transport costs, unreliability, and irregularity of sea transport, making the ‘just in time’ demands of the modern supply chain challenging to satisfy. A similar study conducted by [Fernandes and Pinho \(2015\)](#) describes the accessibility problems reliance on sea transport services. Other works mentioned insularity and remoteness give rise to transport and communication problems (high external transport costs, time delays and high cost in accessing external goods, delays and reduced quality in information flows) ([Briguglio, 1995](#); [Pelling & Uitto, 2002](#)). The reviews do not detail measuring maritime logistics’ efficiency and role in advancing small islands’ economy. Therefore, this research is critical to complement previous studies related to maritime logistics’ efficiency in remote island areas.

2.2. General framework of stochastic frontier analysis

The Stochastic frontier production function was first introduced by [Aigner, Lovell, and Schmidt \(1977\)](#), which assumed a parametric operation of the input and output production models. The SFA model offers information about technical inefficiencies and recognizes that random effects outside the production control variable can impact output. Therefore, the stochastic frontier is divided into two random units, one non-negative random that captures the stochastic frontier function’s inefficiency effect – another random which calculates the effects of other estimation errors ([Coelli, 1995](#)).

In general, the stochastic frontier approach is based on a production function (1) in which the technical efficiency of region i is u_i , and it must be positive. At the same time, the statistical mark of noise v_i can be positive or negative.

$$y_i = x_i\beta + v_i - u_i, \quad i = 1, 2, \dots, N \tag{1}$$

Y_i is the output, x_i is the input vector, and β is an unknown vector parameter. Random error v_i calculates for error measurement and other random factors for input variables that are not specified in the production function. The v_i value is independent and represented as normally distributed with a mean of zero and a constant variance of $N(0, \sigma^2_v)$ ([Aigner et al., 1977](#)). Whereas u_i is an independent non-negative random variable and is assumed as half-normal distribution.

To quantify the standard error and hypotheses test, the stochastic frontier model generally uses the maximum likelihood method since it is more efficient for measuring the effects of technical inefficiencies in the stochastic frontier ([Coelli, 1998](#)). This method

computes the value of the technical inefficiency parameter. The random variable u_i is assumed to be truncated distributed over $N(0, \sigma^2)$ independent of v_i , which is supposed to be normally distributed. In this case, [Aigner et al. \(1977\)](#) described the likelihood function in the form of two variant parameters, namely $\sigma_s^2 = \sigma^2 + \sigma_v^2$ and $\lambda = \sigma/\sigma_v$, where [Battese and Corra \(1977\)](#) explain the likelihood function parameter in its mathematical equation. Furthermore, the technical efficiency of the SFA function, $TE = \exp(-u_i)$, can be computed using the assumption of a random variable technical inefficiency in a half-normal distribution:

$$TEi = \frac{y_i}{\exp(x_i\beta)} = \frac{\exp(x_i\beta - u_i)}{\exp(x_i\beta)} = \exp(-u_i) \tag{2}$$

This formula is an output-oriented measure of technical efficiency, which takes a value between zero and one ([Coelli, 1998](#)). As for the frontier model hypothesis test for Eq. (1), the null hypothesis (H_0) i.e., there is no effect of technical inefficiency in the model, can be done by testing the alternative hypothesis of the likelihood ratio, $H_0: \sigma^2 = 0$ and $H_1: \sigma^2 > 0$.

Further, the stochastic frontier method’s applications are handy and already widely helpful in measuring maritime logistics system performance. For instance, [Hai-Bo and He-Zhong \(2009\)](#) employed the stochastic frontier analysis models assessing the influences of a net permanent asset and total employees to the central business revenue of 13 port companies in China. The finding suggested the internal incentive system of port influencing Chinese port X-efficiency. Besides, [Tongzon and Heng \(2005\)](#) applied the SFA model to investigate port competitiveness determinants. The result presents that private sector participation in the port industry can improve port operation efficiency, which will increase port competitiveness. In another case, [Medda and Liu \(2013\)](#) evaluated how terminal efficiency operation is affected by terminal type, operation type, scale efficiency, and return to scale. The authors demonstrate that container terminals are more efficient than multi-purpose terminals. Similarly, [Trujillo, González, and Jiménez \(2013\)](#) explore the evolution of port efficiency during the port reform process using a stochastic production frontier. The result emphasizes the importance of legal framework reform expanding and facilitating the private sector’s entry.

3. Data and operational model

3.1. Input and output variables

Most of the studies on maritime logistics performance measurement with port Decision-Making Units (DMU) used the indicator of the number of throughputs as output variables. In contrast, the input variables are the length of the berth, the number of cranes, the stockpile area, and the number of stevedoring labors ([Cullinane, Song, Ji, & Wang, 2004](#); [Cullinane & Wang, 2010](#); [Tongzon, 2001](#)).

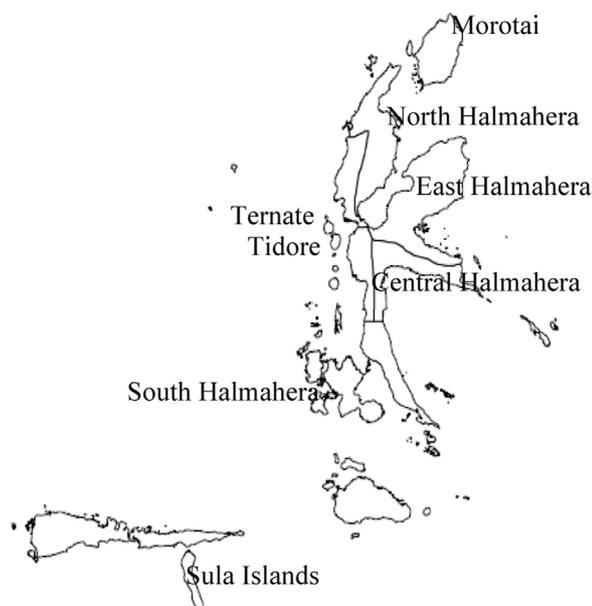


Fig. 1. Port districts of North Maluku Province.

Due to the data limitation and characteristics of the port, especially for small local ports, this study combines regional economic indicator (i.e., $GRDP_{(t-1)}$), economic activities at the port (i.e., number of throughput and port workers), and maritime logistics features such as inland connection, loading and unloading cost, and sea freight cost as the input variables in the model. Whereas the output variable is the region's Gross Regional Domestic Product (GRDP) per capita. The DMU analysis consists of eight areas with district port, namely Ternate, Tidore, South Halmahera, Central Halmahera, East Halmahera, North Halmahera, Morotai, and Sula Islands (Fig. 1).

GRDP per capita as an output variable is one indicator to predict the success of a region's economic development performance (Park & Seo, 2016; Shan et al., 2014). The GRDP variable in the previous year, the number of throughputs, and port labor are the determinant that acts as an input to stimulate the raise of output (Bottasso, Conti, Ferrari, & Tei, 2014; Park & Seo, 2016; Shan et al., 2014; Tongzon, 1995). Tables 1 and 2 feature general information and summary statistics on data.

3.2. Scope of work and data

Since the vast scope of maritime logistics and insufficient data availability, this study limits the measurement of maritime logistics performance, including freights transported from the original port, unloaded at the port of destination until it reaches the owner's warehouse. Efficiency assessments include sea transportation costs, loading and unloading costs, and inland connection services as inputs that can affect maritime logistics performance (Panayides & Song, 2013). The loading and unloading tariffs are incurred from the ship to the truck and unloaded at the owner's warehouse. Sea transportation costs are charges imposed by shipping service companies from the port of origin to the destination port. The measured route is transportation costs from the Tanjung Perak port in Surabaya, East Java Province, to the ports in each regency of North Maluku Province. Inland connection services use a proxy of land transportation rates charged by service providers at the port when loading cargoes from the ship or container field to the owner's warehouse.

The pooled data of eight districts of North Maluku province for 2016–2018 obtained by conducting a direct survey at each local port. Data on the number of cargo throughput was collected from

the port operator unit office, and the Gross Regional Domestic Product (GRDP) data was available at the regional statistics agency. Simultaneously, data on load-unload costs and port labor were accessed from the local organization of port labor. The data on inland connection and sea transportation costs were received from the Indonesian forwarder logistics (ALFI) services of North Maluku province.

3.3. Stochastic frontier models

The SFA model allows inefficiency models from frontier observation and the form of errors or noise variables. The identification of the dependent and the independent variable is the first step in model formation. The dependent variable is the GRDP per capita (y_{it}), while the independent variable (x_{it}) is determined by assuming the variables influencing the district or city GRDP. Using the equation functions of double-log specification (Cobb Douglas) as follows:

$$\begin{aligned} \ln(y_{it}) = & \beta_0 + \beta_{1i(t-1)} \ln X_{1i(t-1)} + \beta_{2it} \ln X_{2it} \\ & + \beta_{3it} \ln X_{3it} + \beta_{4it} \ln X_{4it} + \beta_{5it} \ln X_{5it} \\ & + \beta_{6it} \ln X_{6it} + v_{it} - u_{it} \quad i = 1, 2, \dots, N \quad t = 1, 2, \dots, T \end{aligned} \quad (3)$$

Where y_{it} is the output of GRDP per capita from district/city i , X_{it} is a predictive factor for the production frontier. There are six production input factors, namely X_1 : regency/city GRDP in the previous year; X_2 : total cargo; X_3 : number of port labors; X_4 : inland connection; X_5 : loading and unloading cost; X_6 : sea freight cost. β_0 intercept; i is district/city; t is time, and β is the estimated parameter; $v_{it} - u_{it}$ is the specific error term of the i th observation and time t . Random variable v_{it} is useful for calculating the size of the error and factors outside the control. It is also called statistical noise in the output variable's value and the combined effects of the input variable that is not specified in the production function where random normally distributed or $N(0, \sigma^2 v)$. Whereas the u_i variable is one side disturbance, which functions to capture the effects of inefficiency. This study applies a time-invariant inefficiency model to count the value of technical inefficiency where the u_i variable is a non-negative variable ($u_i \geq 0$) and is assumed to be truncated normally distributed $N(\mu, \sigma^2)$ (Kumbhakar, Wang, & Horncastle, 2015).

In this model, the first three independent variables are expected to contribute positively to increasing GRDP per capita, and the coefficient β should be positive and significant. For example, assume there is an increase in the throughput at the port. In that case, it is supposed that the GRDP per capita of the island will increase; the β coefficient relationship should be positive and significant. Meanwhile, two other input variables illustrate the effect of the maritime logistics cost component on the GRDP per capita so that the β coefficient should be negative and significant. In this case, if there is an increase in sea transportation costs and loading and unloading tariffs, the GRDP per capita could potentially reduce. While the inland connection variable is required to increase the GRDP per capita, the β coefficient value should be positive and significant.

4. Result and discussion

4.1. Result

Before analyzing the SFA results, the step was to assess the model's feasibility by calculating the gamma parameter (Υ). The gamma parameter calculation result was 0.99, which featured that the model's variant strongly supports stochastic frontier technical efficiency since the gamma value approaches the number 1. It also

Table 2
Summary statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
GRDP per capita	24	1.98E+07	4,840,738	1.40E+07	2.95E+07
GRDP _(t-1)	24	2,451,771	1,575,738	821,322	6,222,453
Cargo	24	496,681.4	1,063,537	18,345	4,567,869
Labor	24	214.7083	199.4055	25	600
Inland Connection	24	153,333.3	69,245.42	60,000	300,000
Load-Unload cost	24	96,826.5	13,035.57	80,000	115,600
Sea Freight cost	24	775,781.3	206,594	562,500	1,187,500

Table 3
Frontier production function of local port performance.

Variables	OLS	MLE
Log GRDP _(t-1)	0.099 (0.385)	0.585** (0.000)
Log CARGO	0.054 (0.319)	0.001 (0.725)
Log LABOR	-0.085 (0.299)	-0.354** (0.000)
Log LOAD-UNLOAD cost	-4.434 (0.408)	-1.502** (0.002)
Log INLAND Connection	(0.209) (0.226)	0.110 (0.182)
Log SEA Freight cost	0.180 (0.688)	-0.8729** (0.007)
.cons	15.159 (0.143)	38.156** (0.000)
σ^2_u	-	8.86912
σ^2_v	-	0.0002118
Υ	-	0.9999
Unrestricted log-likelihood function	-	38.953685
Restricted log-likelihood function	-	8.783100
LR	-	60.34117

Note: ** 1% significance test, *p*-value in brackets.

means that the stochastic frontier model is applicable to evaluate the production function (Battese & Corra 1977; Hai-Bo & He-Zhong, 2009). Similarly, in using the MLE model procedure, a sign on the skewness value can also be employed to test the SFA model's feasibility that the results from the OLS residual should mark a negative skewness sign (Kumbhakar et al., 2015). Based on OLS's calculating, the skewness -1.04 ; thus, the model is appropriate and can continue in the stochastic frontier analysis.

In addition to checking the gamma parameter (Υ) and the skewness sign, the likelihood ratio (LR) statistical test is often also carried out after estimating the maximum likelihood (Coelli, 1995). The statistical test results of the likelihood ratio obtained by using the formula $-2 [L(H_0) - L(H_1)]$ where $L(H_0)$ is the log-likelihood value of the restricted (OLS) model and $L(H_1)$ is the log-likelihood value of unrestricted stochastic frontier model (Kumbhakar et al., 2015). The likelihood ratio value of 60.34 means that the results reject H_0 , and there is no technical inefficiency, so the H_1 model is acceptable. The next step is to compute the technical efficiency value where $TE_{it} = \exp(-u_{it})$ in line with the mathematical equation formulated by Jondrow, Knox, and Schmidt (1982).

4.2. Discussion

The SFA model (Table 3) displays that the input variables positively correlate to the output variables: GRDP, number of throughputs, and inland connection. In contrast, the number of port laborers has a negative sign and significant relationship to the output of GRDP per capita. This result emphasizes that the existence of a large number of workers is disadvantageous. It is often, when the cargo throughput in small amounts, many workers are unemployed. The imbalance of the amount of cargo with the number of workers induces the income earned by workers so that it makes

the labor organization of the port restricts the recruitment of new workers.

Characteristics of the regional economic structure determine the level of port throughput so that it affects the absorption of the number of port workers. Bottasso et al. (2013) affirmed that more excellent labor absorption in the port area relies more on the manufacturing sector than the service industry sector. In North Maluku Province, the municipality of Ternate and North Halmahera districts that depend on trade and service sectors have a relatively higher number of ship visits and cargo throughputs. On another side, Morotai, Tidore, South Halmahera, and Sanana districts rely on the plantation industry as the leading sector has lower ship and throughput. The number of laborers working in the ports of Ternate and Tobelo, North Halmahera, is larger than that of other ports. Meanwhile, East Halmahera and Central Halmahera districts that rely on the plantation and mining sectors for nickel ore as a regional economic base are relatively less absorbing dockworkers (Table 1). This condition justified that the port's economic activity on the island based on the agricultural sector is unbeneficial for improving the dockworkers' welfare.

The inland connection variable based on the calculations using the MLE method confirms a non-significant positive relationship to the GRDP per capita. The positive outcome of the availability of trucking services in the island logistics system enhances the smooth distribution of payloads to consumers and the market. The distance traveled from the port to the owner's warehouse is quite close, 3–5 km. Consequently, the costs charged to consumers are relatively low. In this case, the most expensive truck costs only occur in Ternate, which is \$21 per trip, whereas, for other areas, the average cost of trucks is \$7–\$10 per trip. As for land transportation outside the port city, the number of transportation costs adjusted to the distance. The farther from the city, the more expensive the truck costs to pay.

Variable loading and unloading tariffs and sea transportation costs have a negative relationship and significantly affect the GRDP per capita. In other words, it is unprofitable for the island's economy. An increase of \$0.72 per ton of loading and unloading cost will reduce the GRDP output per capita of North Maluku province by \$107. Likewise, an increment of \$7.2 cost of sea transportation will decrease GRDP per capita by as much as \$62.35.

The loading and unloading tariffs for each port varies according to the loading and unloading aids, the wages of loading and unloading labor, and port operator fee. For ports that lack the means of unloading equipment, the process of transporting goods from ships to trucks at the docks uses human where the laborers physically bear the goods. This process brings the cost of labor per unit/ton to be relatively more expensive. Labor wages are estimated based on several elements: district or municipality minimum wages, transportation allowances, food, and rice. These features correlate to the level of prices of essential goods that apply on the island. If inflation on the island is hard to handle, it will react to demands to raise port workers' wages. Consequently, the increment in port labor wages will enlarge logistics costs, promoting price rise at the consumer level. Such a circumstance generates complexity in responding to inflation.

Table 4
Cargo throughput of residence ports (Ton) 2016–2018.

Port regions	Average throughput (2016–2018)		Container port
	Unloading (Ton)	Loading (Ton)	
Ternate Island	498,064	19,600	Yes
Tidore Island	16,860	9204	Yes
South Halmahera	41,526	18,950	Yes
Center Halmahera	96,228	174,124	No
East Halmahera	2562	2,584,352	Yes
North Halmahera	131,795	276,420	Yes
Morotai Island	71,822	9599	Yes
Sula Island	50,538	20,335	No

Source: Local Port Office, 2019.

The island's geographical circumstance of island, which is far (average 1871 km) from the center of its market, mostly located in Java, creates isolation, which leads to the high cost of sea transportation. The island's remoteness encourages transportation and communication difficulty. The transportation cost per unit to build trading relations with outside districts is relatively higher since the islands are separated by the sea (Briguglio, 1995). It seems to become a challenge to the transportation process for export and import. The supply chain movement of goods is not satisfactory due to the isolation making the 'just in time' demands of the modern supply chain troublesome (Kerr, 2005).

The low number of cargo that indicates the smallness of the island's economies of scale induces the high transport costs per unit. The carriage rates are higher when carrying cargo from the origin port to the island destination port than when returning. For example, the transportation cost to the port of Bacan, South Halmahera district, from Surabaya is \$1035 per container and \$535 for going back. The sea transportation cost from Surabaya to Ternate route is \$928 per container, while the cost of transporting goods from Ternate to Surabaya is cheaper at \$500 per container. Local governments cannot regulate sea transportation rates among areas. The shipowner unilaterally decided the transportation costs' determination based on the component of the ship's operational costs while at sea and the port.

The high cost of sea transportation pertains to the island's economy inefficiently. The economic inefficiency of the island significantly correlated to the vulnerability of the small islands. The small size possessed by the island encourages several economically disadvantageous such as scarcity of natural resources and high imports, limitations on substitute imports, small domestic market and dependence on export, reliance on finite goods commodities, weak ability to change domestic prices, low ability to grow economies of scale, limitations on domestic competition, and public administration issues (Briguglio, 1995). The small island population sets the low demand level so that commodities consumption testes tend to be homogeneous. Fernandes and Pinho (2015) mentioned the smallness and the periphery of the economic center make small islands high dependent on other regions' aid. Therefore, strengthening connectivity is a solution for small islands to prevent isolation from having economic efficiency.

In the maritime sector, the island's economic inefficiency is observed from the supply side's limitations and uncertainties. The inability of island communities to intensify the superior local product's economic added value has a consequence on the number of throughput of goods loaded for sale outside the island. The number of goods loaded is relatively smaller than the number of goods unloaded (Table 4). Fernandes and Pinho (2015) note that small domestic markets and difficulties in generating economies of scale in production and service providers supporting the vulnerability of small islands. Notably, for North Halmahera, East Halmahera, and Center Halmahera, these three regencies have large mining in nickel and gold. Thus load more generous than unloading.

Many shipments unloaded compared to the goods loaded depicts that most of the community's economic needs must be imported and transported from outside their region. It is in line with McElroy's statement that the island communities produce what they do not consume and consume what they do not make (Kerr, 2005). Uncertainty of the number of goods loaded contributes to the arrival time of the ship to be tentative. The ship cargo is often empty, leading to the transportation costs for goods imported from outside become more expensive. The local entrepreneurs and traders have to buy merchandize in large quantities; consequently, the logistics costs enlarge for renting warehouses and laborers.

The SFA models' technical efficiency values (Table 5) clarify that maritime economic activity on the islands is relatively inefficient. The average stochastic frontier values for all districts of the North Maluku province are less than 1.00.

Port of Morotai has the highest efficiency value because the sea-freight cost is cheaper than the others. The presence of the subsidized sea toll ship that offers low transportation costs is sufficient to help distribute the island community's food and logistical needs. The sea transportation cost from the Surabaya in Java Island to Morotai is \$642 per container, while the return cost is \$285 per container. The low cost of sea transportation benefits the island's economy, primarily to curb inflation rates.

Furthermore, the port of Ternate and North Halmahera has a high-efficiency value because port infrastructure is quite good, such as the availability of crane and extended Beth facilities for ships so that the activity of loading and unloading can run sufficient. Although the cost of sea transportation in the two regions is relatively more expensive, the determinant of large throughputs and high gross regional domestic product causes the value of the island economy's efficiency to be greater (Table 5).

As for Tidore, Sula, and East Halmahera, which have low technical efficiency values due to port infrastructures such as limited loading and unloading aids, and short berth lengths, push the loading-unloading activities are slow and inefficient. Besides, the small GRDP factor and the low amount of cargo create little technical efficiency in Tidore City and Sula Regency. Similarly, in East Halmahera district, as shown in Table 5, although this area has many loading cargoes, the high cost of loading and unloading labor and small GRDP contribute to the low technical efficiency value.

Low average SFA technical efficiency is a convergence to the reality of the island's economic issues. The low-efficiency value is not only due to the small number of cargo, low GRDP, and the high cost of sea transportation, but also it is stimulated by the high cost of loading and unloading labor of port. Sometimes, unloading costs are higher than the local government's price and the port service stakeholders. Some consumers or traders paid the adding fee if they want their consignment unloaded and safely delivered to the warehouse. The additional costs vary between \$14 to \$35, depending on the volume and type of shipment. Illegal levies are still often practiced by port authorities against port service actors. For example, a fee of \$0.04 per ton is imposed on expedition service companies when carrying out unloading goods. There were also administrative costs paid by the shipping company agent, which were not regulated in the rules. For instance, the administration charge is \$25 per trip; the ship document fee is \$71 per trip.

The high cost of sea transport, loading and unloading tariffs, therefore, can hamper economic development, especially investment expansion in island regency. Inefficient port management accelerates the cost of carriage. Expensive transportation costs can negatively influence the islands' ability to conduct trade cooperation with other lands. The flow of commodity trade will flow to areas that offer maritime logistics services at lower costs. Conversely, areas with inefficient maritime logistics service systems will tend to be abandoned by markets where commodities flow will not flood into the area. Bensassi et al. (2015) said that the availabil-

Table 5
Efficiency ranks of regional ports in North Maluku Province.

Port regions	Technical efficiency	Ranking	Parameter
Morotai Island	0.984	1	Low sea transport cost
Central Halmahera	0.983	2	Low loading and unloading cost, large cargo
North Halmahera	0.981	3	Low loading and unloading cost, high GRDP, large cargo
Ternate Island	0.957	4	High GRDP, large cargo
East Halmahera	0.539	5	High loading and unloading cost, small GRDP
South Halmahera	0.438	6	High sea transport cost, small cargo
Sula Island	0.405	7	Small GRDP, low cargo
Tidore Island	0.344	8	Small GRDP, low cargo
Average	0.704		

Source: Data Analysis, 2019.

ity of transportation infrastructure and good logistics performance drive increasing the flow of a country's export trade.

Finite port infrastructures such as a short length of the berth and no available tools like cranes discourage the effectiveness of loading and unloading from the ship to the truck and then continued to the stacking field, making the cost of dockworkers quite expensive. The port labor usually asks for a higher salary because they have to unload goods without the proper unloading tools. It needs two or three days to unload and load goods from/to the ship. Besides, the unavailability of a suitable warehouse for a commodity that requires special handling, such as meat, chicken, vegetables, fish, pushes the risk of a relatively high level of damage. High levels of damage to products can affect the availability of goods sold in the market. Suppose the stock of goods in the market is relatively small. In that case, it is inevitable that prices will rise so that inflation will be higher, the island's economic inefficiency is getting worse.

5. Conclusion

The paper revealed the high maritime logistics costs harm the island's economic performance. The SFA model results exhibit that expensive loading and unloading tariffs and sea transportation costs can reduce the island's GRDP per capita. The low average of technical efficiency illustrates that the port performance in most small-island areas supporting the regional economy is relatively unsuitable. The study also extended the determinant of a small quantity of cargo, and inadequate port facilities are the leading causes that shape small-island maritime logistics inefficiency. Besides, the structure of the plantation sector's small-island-based economy is less favorable for improving labor welfare in the port industry sector.

5.1. Policy implications

The finding stresses the importance of increasing port efficiency for the small-islands province to strengthen the regional economy. Maritime logistics costs, the number of throughputs, and the ability to generate featured value-added products that can be marketed outside the islands positively determine the port efficiency. Government intervention is required to facilitate the expansion of inter-island industrial that export-oriented, evaluate regional regulations that hamper business and investment, and regulate the center of distribution and transport process of goods within the territory efficiently. Fair enforcement of port rules and management may augment the island's maritime logistics system's performance. Port infrastructures such as broaden the berth, technology for handling cargo throughputs, cooling warehouses, and reliable maritime human resources are urgent to decrease inefficiencies so that the islands' economy can improve and be competitive.

Islands development policies should maintain the strength of local resources owned, reduce transportation costs, derive a high diversification product. Thus, trade transactions occur with the

diversity of brands with other lands, produce the commodities based on the community and local knowledge to build an interdependent island economy. Indeed, to anticipate the empty backhaul problem, good coordination among the maritime stakeholders (i.e., port authority, businessman, shipping, and forwarder) is necessary to have information about the number of cargoes shipped. Therefore, the policymaker should upgrade the logistics information system based on digitalization among the island ports integrated with the local industry center. Collaboration and cooperation between island ports can be through interconnected digital information systems. Transaction costs such as coordination and communication costs will decrease; the maritime logistics system becomes efficient.

5.2. Limitations and future research

Since the limited data mainly in the time series and the small scope of the area, the findings are the only depiction of cases in the North Maluku province. The lack of data is due to the data of time series for variable sea transportation costs, especially for the ports of Tidore Island and Morotai, which have only been available since 2016. Previously, the two ports did not directly yet connected with the Tanjung Perak port in Surabaya as the central economy to serve all logistics needs in the Eastern Part of Indonesia. Therefore, future studies for broader area coverage with many harbor units of the island is needed.

Declaration of interest

The authors report no conflict of interest. The authors alone are responsible for the content and writing of this article.

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