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Article

The Role of Maritime Logistics in the Local Economy Development in Island Regions of East Indonesia

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Abstract: The study analyzed the role of maritime logistics in the archipelago's economic development and the impact of air externalities arising from the sea transportation sector. The method uses a dynamic system to measure the causality relationship between maritime logistics and regional economic indicators. The maritime logistics economic sub-systems consist of loading and unloading goods, the number of port workers, loading and unloading costs, sea transportation costs, and logistics service activities, namely land connections and expedition services, including stuffing, packaging, and packing. The results of the first scenario showed that reducing sea transportation costs could reduce the inflation rate and encourage an augmentation in the rate of change of GRDP. The second scenario proved that increased economic growth positively affects the monetary value of maritime logistics and promotes the gain in the value of externalities and environmental costs from air emissions generated from the sea transportation sector. The third scenario revealed that the raise in the number of goods in the long term has a negligible effect on reducing sea freight costs.

Keywords: maritime logistics; externality; local economic; islands

1. Introduction

Maritime logistics integrates logistics systems and supply chain management into maritime transportation systems. Maritime logistics is a series of activities from the planning, implementation, and management of the movement of goods and information using sea transportation [1]. The role of maritime logistics in regional economic development is essential in enhancing efficiency, and local economic competitiveness [2]. Transportation in the maritime logistics system functions to carry and handle cargo through the ocean and broadly connect transportation connections between the sender and recipient of the goods. In Indonesia, as many as 88% of goods transported between regions use sea transportation services [3]. Maritime transportation bridges all logistics system entities, namely, customers, distributors, factories, warehouses, and other networks [1]. As the most dominant mode of transportation is used in international trade, port capacity development, and connectivity become essential to reducing logistics costs and efforts to distribute development. Strengthening transportation connectivity impacts trade flow in areas with adjacent and sectoral regional trade relations and benefits from the transportation network in the region [4].

Other studies conducted by [5] revealed several logistical problems, such as the absence of coordinated logistics chains between countries in one region, which caused transportation costs to enlarge due to container charges that returned to empty, the coordination system was not sound, and administrative costs that are not cheap. Besides that, transportation chain efficiency standards are lower than international standards due to inefficient port operations such as maintenance costs, long customs procedural, low participation from the private sector, and high transportation costs between regions. Poor connectivity in Indonesia, is one of the causes of the high logistics cost between regions, so an inter-island connectivity development policy is needed to solve economic development problems in remote areas that are difficult to reach [6]. Disparity of price levels and spatial economic structure gaps is a development constraint in realizing more equitable welfare. Areas that are far from their growth center become backward and underdeveloped areas. Moreover, the area does not yet have good accessibility, minimal transportation facilities, and poor supporting infrastructure.

The development of maritime transportation infrastructure is important for improving services and economic accessibility, especially in the island region. The economic benefits of developing ports in remote areas can reach far beyond the sub-district where the port is located [7]. Apart from having an impact on the local economy [8,9], the development of maritime transportation systems also has an impact on environmental externalities [10]. Therefore, the study aims to measure whether the reduction in maritime logistics costs can decrease the price level of goods in the island's economy and how economic growth impacts environmental externalities caused by economic activities in the maritime transportation sector. The structure of the paper is as follows: the second section describes the data and methodology framework. The next section is the analysis of the results and discussion. Conclusions and policy implications are explained at the end of the paper.

2. Data and Methodology

Dynamic systems are very useful in examining complex problems involving many interacting elements [11]. The use of dynamic system methods in the field of maritime logistics has been carried out by several researchers such as [12–15]. The study of maritime and economic transport causality has been worked by [16,17] by analyzing the linkages of port activities and the economic. However, the study to measure the causality relationship between maritime logistics and ecological economy in the dynamic system model is new. This study describes the relationship between maritime and ecological—economic logistics systems in a dynamic system, including the operational variables of maritime logistics economics, namely gross regional domestic product (GRDP), income per capita, inflation, maritime logistics costs, maritime logistics economics, and marine economics. The environmental externality is a result of all other sub-system activities.

Figure 1 describes the causal loop link of maritime and ecological-economic logistics systems with the following lines of relationships. First, the economic development pictured in the amount of GRDP will positively impact increasing GRDP per capita and afterward affect regional inflation. An increase in GRDP impacts per capita income. Communities with high per capita incomes have strong purchasing power, which contributes to relatively stable prices [18]. The second line depicts a positive relationship between maritime logistics costs and inflation. It has a negative association with GRDP and then positively impacts increasing per capita GRDP and the Maritime Logistics Economy. The link relationship between GRDP and cargo volume, sea transport, and maritime logistics has been measured by [11,12]. The third track represents the positive relationship of GRDP to the sea transportation sector and subsequently positively impacts the aggregates in the maritime economy and environmental externalities [19]. The fourth line outlines a positive relationship between maritime logistics costs on inflation and a negative on GRDP and then positively related to sea transportation, ocean economy, and environmental externalities [10].

Flowchart of Maritime Logistics Economic

Figure 2 displays the interrelated sub-systems of the maritime logistics economic system. The first sub-system is the GRDP stock with the auxiliary variables: economic growth rate and inflation. The second sub-system is the economic stock of maritime logistics. The auxiliary inflow consists of per capita GRDP variables, the number of workers, total throughput, loading and unloading costs, inland connection, and sea transportation costs. The third sub-system is the stock of maritime logistics costs.

The auxiliary inflow consists of variable loading and unloading costs, inland connections, sea freight, expedition, package, port, PBM, and equipment costs. The fourth sub-system is the stock of the sea transportation sector, which is influenced by the auxiliary inflow of variables in the maritime economic sector: fisheries, oil and gas mining, marine industry, marine construction, marine tourism, marine services, and other sectors. The fifth sub-system is the marine economic stock, influenced by the auxiliary inflow output of seven marine sectors and one non-marine sector.

The last sub-system is inflation stock, where the input variables are maritime logistics costs and the inflation rate resulting from the transportation sector. Meanwhile, the externality stock of each pollution component is influenced by the ecological multiplier value obtained from the analysis of input-output table calculations.

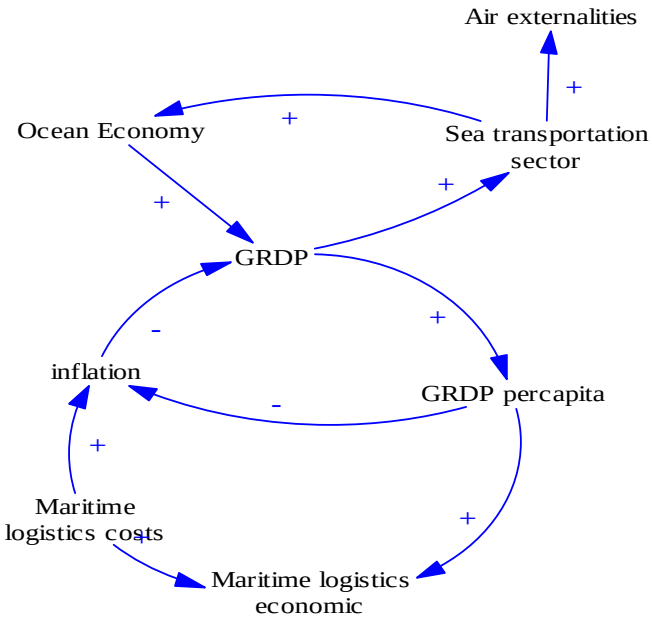

Figure 1. Causal Loop of Maritime Logistics Economic.

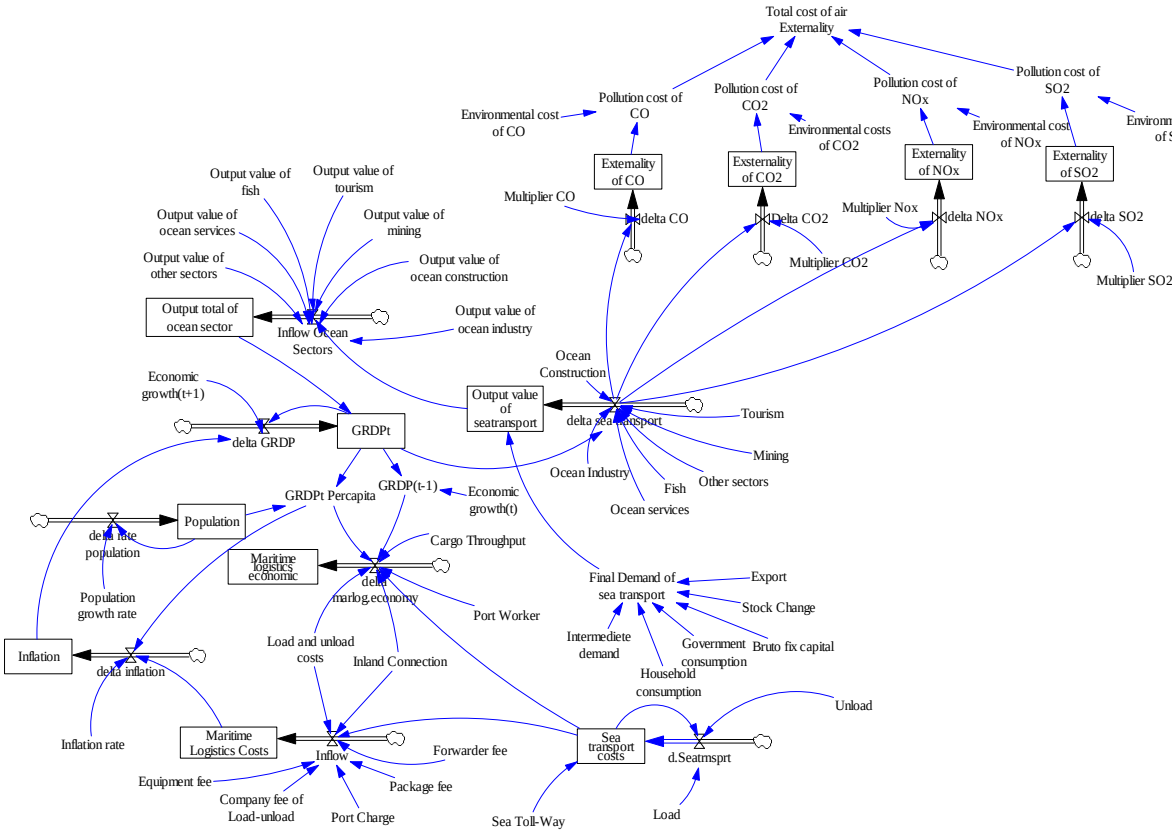

Figure 2. Stock Flow Diagram of Maritime Logistics Economic and Air Externalities.

3. Variables and Stock Parameters

The maritime logistics economic subsystem variable uses data collected from direct investigations at the port, the results of econometric calculations from statistical data, the calculation results of the North Maluku Province Ecological-Economic Input-Output table (I-O), and the Regional Statistics Agency. The data in Table 1 outlines the

main parameters of the maritime logistics economic system with a case study at the port of Ternate Island. This port is a maritime logistics center that serves all the economic needs of the island communities in North Maluku Province.

Table 1. Main Parameters of Ternate Island's Maritime Logistics Economic Model System.

Variables	Value	Unit	Source
Economic Growth (t + 1)	7.6	Percent	Statistical agent
GRDPt (Province) 2016	21,556.7	Million IDR	Statistical agent
Population (Province) 2016	1,185,910	People	Statistical agent
Port Workers	460	People	TKBM *
Inland Connection	300,000	IDR	TKBM *
Cargo Throughput	517,664	Ton	Local port
Load and unloading costs	108,287	IDR	TKBM *
Sea transport costs	850,000	IDR	Forwarder
Port service charge	210,000	IDR	Local port
Charge of load and unload company	225,000	IDR	Local port
Equipment fee	325,000	IDR	Local port
Package fee	100,000	IDR	Local port
Forwarder fee	723,982	IDR	Local port
Inflation in Transport sector	0.01	Percent	Statistical agent
Coefficient Backward of Fish sector	0.374	-	Table I-O 2016
Coefficient Backward of Mining, oil, and gas sector	0.544	-	Table I-O 2016
Coefficient Backward of Ocean Industry sector	0.661	-	Table I-O 2016
Coefficient Backward of Ocean construction	0.433	-	Table I-O 2016
Coefficient Backward of tourism sector	0.463	-	Table I-O 2016
Coefficient Backward of ocean service sector	0.261	-	Table I-O 2016
Coefficient Backward of other sectors	0.488	-	Table I-O 2016
GRDP of sea transport, north Maluku province 2016	319.9	Million IDR	Statistical agent

Source: Data analysis (* TKBM: man power company for loading and unloading).

This study calculates environmental costs using the assumption of emission costs caused by ships using the standard air externality costs of the sea transportation sector [20,21]. The measured air externality values are NO_x, CO, CO_2, and SO_2, as shown in Table 2.

Table 2. Environmental costs of Ship emissions.

Pollutant	NO_x	CO	CO_2	SO_2	Source
Emission multiplier	0.065672	2.121222	0.005574	0.110781	Table I-O
Environmental costs ($/ton)	4992	3	26	13.96	(Brechemen 2012)

Source: data analysis.

4. Policy Scenario and Validation

Policy simulation in a dynamic system aims to measure the impact of specific policies on targeted output by changing several policy variables in the dynamic system model. The assumptions are based on three indicators: sea freight costs, economic growth, and the number of goods loaded. A study by [6] explained sea freight costs as an indicator of maritime logistics costs harming the island's economy. Meanwhile, economic growth indicates an increment in sectoral economic activity that contributes to an increase in the rate of environmental damage [22–24]. This study improves three policy scenarios, namely, sea transport cost decrease by 20%, 30%, and 50%; the economic growth rise to 8.5%; and the number of cargo enhance to 20%, 30%, 50%, and 100%. The scenario selection focused on understanding how changes in transportation costs and cargo volume could impact the price of goods and maritime transportation costs. The economic growth scenario, meanwhile, aimed to measure the impact of increased environmental externalities from maritime transportation activities.

The model requirement is valid if it is scientifically proven to resemble the actual system performance. The validity value of a model is based on the results of the validation tests performed on the simulation results that have been carried out. Ref. [25] explained that the simplest and most straightforward technique to use is the absolute mean error (AME) method with the formulation AME = [S − R]/R. S is the simulated variable value, and R is the value based on actual data. Based on the simulation results, the AME calculation results for the maritime logistics economic model are shown in Table 3.

Table 3. Absolute Mean Error (AME) of Gross Regional Domestic Product (GRDP).

Year	GRDP Simulated	Real GRDP (Million/IDR)	Ratio AME
2016	21,556,700	21,556,700	0.000
2017	23,389,000	23,210,090	0.007
2018	25,377,100	25,050,100	0.013

Source: Data Analysis.

The results of the AME calculation show that the simulated value of the GRDP model is 0.00 in 2016 and 0.013 in 2018. A model can be said to be valid if the results of calculating statistical validity are ≤0.10 [25]. Thus, the ecological-economic model of maritime logistics with the GRDP stock variable can be declared valid because it is less than 0.10. 2016 was used as the base year to adjust to the availability of existing data, especially the Input-Output table which was last released by the regional statistics agency in 2016.

5. Results

The port has a strategic role as a ship berth in serving the process of loading and unloading goods and providing other services that support the activities of the maritime transport sector in an area. Integrating intermodal transport services requires increasing the quality of services available at ports. The ability of ports and inland connections to accommodate the rise in maritime transport volume can develop if it is supported by the ability to provide good logistics services. The economic contribution of maritime logistics in regional development not only depends on the scale of economic activity, maritime infrastructure, human resources, market environment, and institutional factors but is also influenced by the integration of supply chain flows and the performance of maritime logistics. According to [26], the critical concept in maritime logistics is identifying optimal transportation routes, network development, and door-to-door service facilities. The development of ship shipping networks is one of the functions of maritime logistics where regions become interrelated and globally integrated into a complex maritime network system. An essential aspect of the shipping service system is determining which ports serve large-sized ship calls and which ports serve feeder vessels and function as liaison and transshipment. The integration of the maritime logistics system has good advantages for remote and hard-to-reach areas where the movement of the distribution of goods and services can develop so that economic benefits in the form of regional income can broaden.

The GRDP growth rate of North Maluku Province has a strong influence on increasing the economic value of maritime logistics. Figure 3 displays the GRDP value in the initial 2016 measurement year of IDR 21,556,700 million, resulting in an economic value of maritime logistics 11,882,900,000. In 2017, the GRDP value escalated to IDR 23,195,000 million, resulting in an economic value of 23,765,800,000 maritime logistics. Until 2035, it can be concluded that with the increase in the level of GRDP in current conditions or normal conditions without any policy intervention, the economic value of maritime logistics will experience positive linear growth with the GRDP growth rate of North Maluku Province.

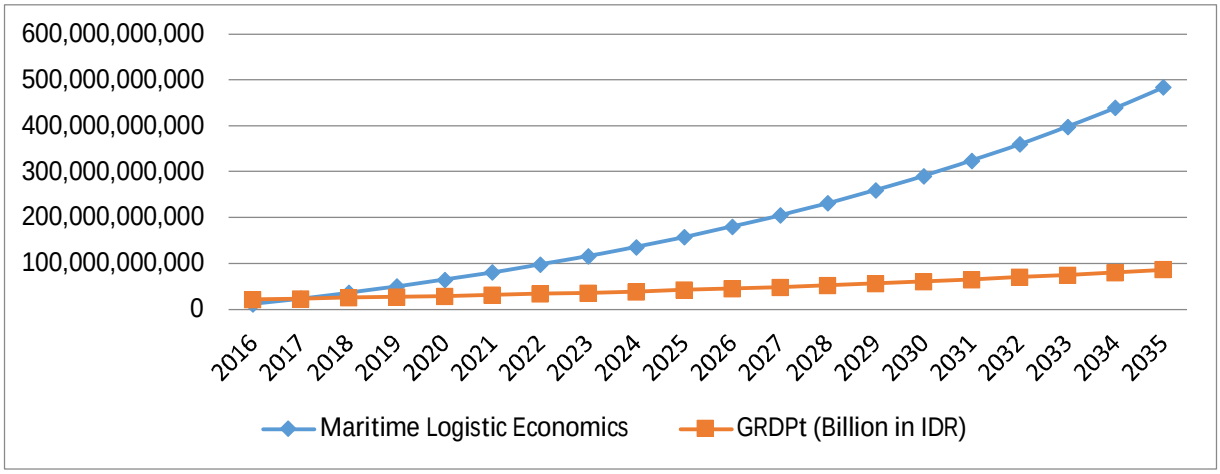

Figure 3. Current Condition of Maritime Logistics Economic.

(a) Reduction in Sea Freight Costs

The role of sea freight costs in the maritime logistics system is a significant component of goods loading and distribution activities since they are loaded at the port of origin and then unloaded at the destination port. Ref. [27] described geographical factors, transport insurance, trade imbalances, economies of scale, construction of container transport, number of maritime passages, port efficiency, and illegal cost practices that affect maritime transportation costs. The distance between the port of origin and destination is significant. The farther the distance between the two markets, the higher the transportation costs incurred. Therefore, policy simulations carried out in this scenario are carried out with the assumption that there is a reallocation of market centers that are close to the islands and the provision of subsidies for ship operations through the mechanism of the Sea Toll program.

The expected effect of reducing the cost of sea transportation through this policy scenario could have an impact on reducing the price of goods and further boosting the performance of the island's economy. Figure 4 reflects the simulation results from various scenarios if sea transportation costs are reduced by 20%, 30%, and 50% of the inflation rate in North Maluku Province.

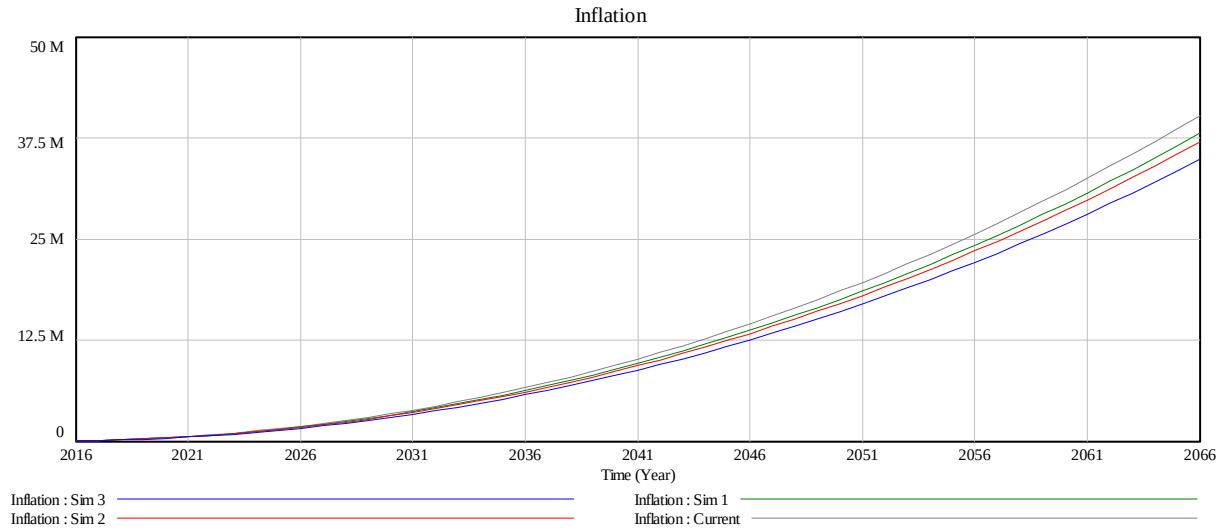

Figure 4. Simulation Results of Reducing Sea Freight Costs to Inflation Rate.

The simulation results for the inflation indicator present that a reduction in sea transportation costs from IDR 850 thousand per ton to IDR 680 thousand/ton or around 20% can reduce the price level of goods caused by the sea transportation sector in 2016 by −3.65% assuming an inflation rate for the transportation sector and other maritime logistics cost components are constant. Likewise, if there is a decrease in sea freight costs by 30% and 50%, the contribution to the price reduction resulting from the transportation sector is 5.68% and 9.12%, respectively. Conversely, if there is an increase in the cost of sea transportation, it will undoubtedly impact the rising prices of goods. These results confirm that sea freight logistics costs have an impact on price levels in the island and archipelago areas of North Maluku Province.

The cost of sea transportation to ports in the North Maluku province is expensive due to the potential for empty return cargo. This problem causes the burden of shipping or transportation costs charged at the time of delivery from the port of origin compared to the return costs. The effect of high transportation costs on the economy, apart from the inflation in the price of goods, also impacts decreasing regional revenue receipts in the form of GRDP. Conversely, if there is a decrease in the cost of sea transportation, the inflation rate can decrease and have an impact on increasing the regional GRDP value.

In the long term, the simulation results show that the impact of reduced sea transportation costs on the GRDP of North Maluku Province at the port of Ternate Island, as well as regional revenues for the Province's GRDP, has increased. At an economic growth rate of 7.6%, reducing sea transportation costs by 20% can boost GRDP revenues for North Maluku Province by 0.000007% in 2020, 2021, and 2022 by 0.000012%. The small economic contribution of reducing sea transportation costs to North Maluku Province's GRDP is due to the relatively low inflation rate caused by the transportation sector, which is only 0.01% compared to the change in GRDP value. The food and beverage group is the component that has the highest contribution to the inflation rate in North Maluku Province. Thus, the high cost of sea transportation directly impacts the inflation rate caused by the transportation sector on the regional economy.

The reduction in sea transportation costs also has a long-term positive impact on increasing the economic value of maritime logistics for North Maluku Province. In simulation 1, if there is a 20% reduction in sea freight costs, the economic value of maritime logistics from 2016 to 2021 will not change or be constant. The economic value of maritime logistics will enhance in 2023, namely 0.000007%, and then continue to deepen. Likewise, in other simulation results where sea transportation costs fell by 30% and 50%, maritime logistics economic value will extend in 2022 by 0.000008%, respectively. The magnitude of the economic value of maritime logistics illustrates the economic aggregate obtained from logistics activities at ports influenced by input factors, namely logistics costs (loading and unloading costs, sea freight costs), inland connections, cargo throughput, and the number of port workers.

(b) Increasing of Economic Growth

Economic growth indicators in the dynamic system model act as input controls that can control the dynamic changes of other subsystems. In this case, the policy simulation is carried out by assuming that a boost of economic growth to 8.5%, will affect the maritime logistics economic subsystem and impact on environmental externality costs. The assumption of economic growth increasing by 8.5% can produce a GRDP value in 2018 of IDR 25,377,073,152 and affect the economic value of maritime logistics to IDR 36,647,551,819,264 or an increment of 0.29% from the current condition of IDR 36,551,819,264.

The positive correlation between the growth in GRDP and the economic value of maritime logistics indicates that the rate of change in GRDP dramatically influences the escalation in the rate of change of the maritime logistics economy, assuming the input variables are constant (Figure 5). Compared with the scenario of reducing sea freight costs, the economic value of maritime logistics resulting from the increasing economic growth illustrates a more significant economic value of maritime logistics. It indicates that economic growth policy interventions have more effect on changes in maritime logistics' economic value than policies to reduce sea freight costs.

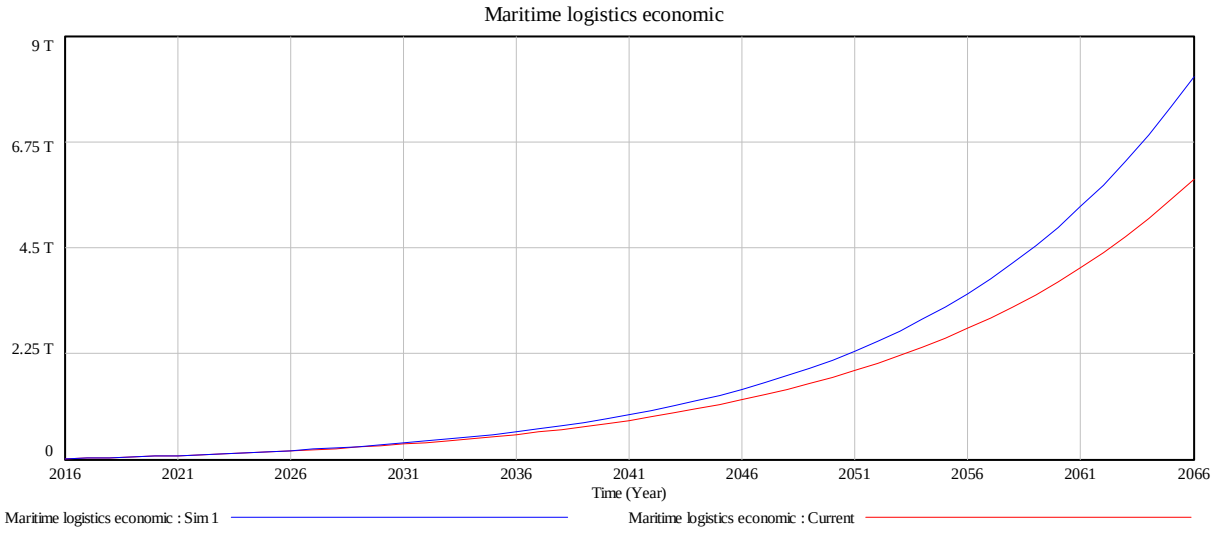

Figure 5. The dynamic of Maritime Logistics Economic.

The environmental externality values depict that if there is the rise in economic growth, the impact of environmental pollution on the air components of CO and SO_2 will grow. In 2016 and 2017, the air externality value stayed the same. A hike in the rate of environmental pollution for the CO and SO_2 components occurred in 2018 by 0.79%, respectively, 250.16 mg/m^3 and 13.04 mg/m^3, with the resulting externality costs of IDR 10,670,400/ton and IDR 2,593,120/ton. Until 2035, the upturn in the value of externalities and environmental costs resulting from CO and SO_2 air components is 20.33%.

The increased environmental externalities illustrate that the potential for disruption to environmental externalities cannot be avoided, especially in ports. Activities related to transporting goods by ships and trucks produce pollution to the surrounding environment, which impacts the sustainability of the environmental ecosystem in coastal areas. Advancing the area of the terminal container field and increasing the capacity of docks, warehouses, and trucks affects the density of goods transport activities so that the value of environmental externalities related to air pollution has the potential to widen. Carbon dioxide emissions resulting from maritime transport activities are estimated at 3.3% of global emissions, while NO_x emissions are around 10% to 15% [28]. A study by [29] found that ships arriving and departing from ports produced around 1,725,000 tons of NO_x and

1,246,000 tons of SO_x. The social impact on health if the SO_x emission component is more than 0.06 mg/m^3 and NO_x exceeds 100 mg/m^3 can interfere with the human respiratory system, causing severe damage to bronchitis and respiratory infections [30].

Figure 6 highlights that the four components of air externalities resulting from sea transportation sector activities in the long term can harm the social conditions and health of the island community. The selected variables are CO, CO_2, NO_x, and SO_2. The NO_x emission value in 2022 under normal conditions without an increase in economic growth is above the threshold of the health standard, which is 145.04 mg/m3, so it has the potential to affect the health quality of the surrounding community. One of the findings proves that most or about 70% of ship emissions within 400 km of coastal communities cause nearly 60 thousand deaths yearly in coastal marine areas in East Asia, South Asia, and Europe [31].

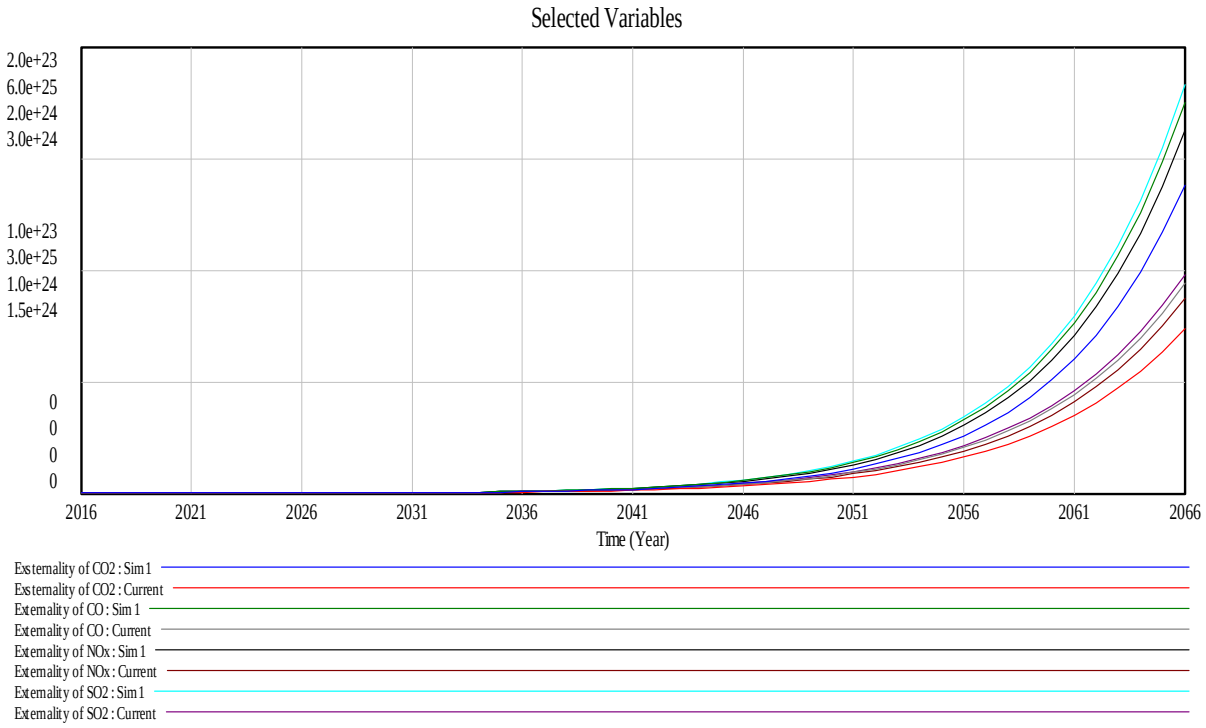

Figure 6. Environmental Externalities of the Sea Transportation Sector.

The environmental costs that must be replaced due to the emission externalities of sea transportation activities are high. In 2016 and 2017, the environmental costs for normal conditions did not change, namely IDR 15,247,532 and IDR 30,495,064. Estimated environmental costs began to increase in 2018, namely by 0.79%. If economic growth were 8.5%, the value of environmental costs for air emissions would expand to IDR 563,191,744 from the initial condition of IDR 558,773,120. Along with the increment in GRDP, the cost value of environmental externalities has also enlarged. Until 2035, the estimated environmental costs based on the ecological multiplier figure in Table IO amount to IDR 425,730,473,984, or an increase of 20.33% if economic growth is 8.5%.

(c) Rising the number of islands cargo

The trade imbalance between regions is one of the factors triggering high sea transportation costs [27]. The imbalance showed by the number of goods transported to the destination area, which is more than the number of goods loaded back. Shipping companies generally lowered meager freight costs of up to a third of the inbound rates when transporting goods back. For example, the City of Ternate, the cost of transportation from the port of Tanjung Perak in Surabaya to the port of Ahmad Yani Ternate is IDR 13 million/container or IDR 850 thousand per ton/m^3. In contrast, the return transport costs IDR 6 million/container. High sea freight costs can harm the regional economy by triggering inflation.

The scenario of a rise in the amount of cargo is based on the assumption that if there is an increase in load at island ports that will be marketed outside the region, it is hoped that this will impact reducing sea transportation costs. The simulation results show that the expansion in loading goods by 20% and 50% can reduce the cost of sea transportation in 2035 by 0.24% and 0.28%, respectively. If the number of goods loaded enhances by 100%, sea freight costs decrease by 0.38% in 2035 (Figure 7).

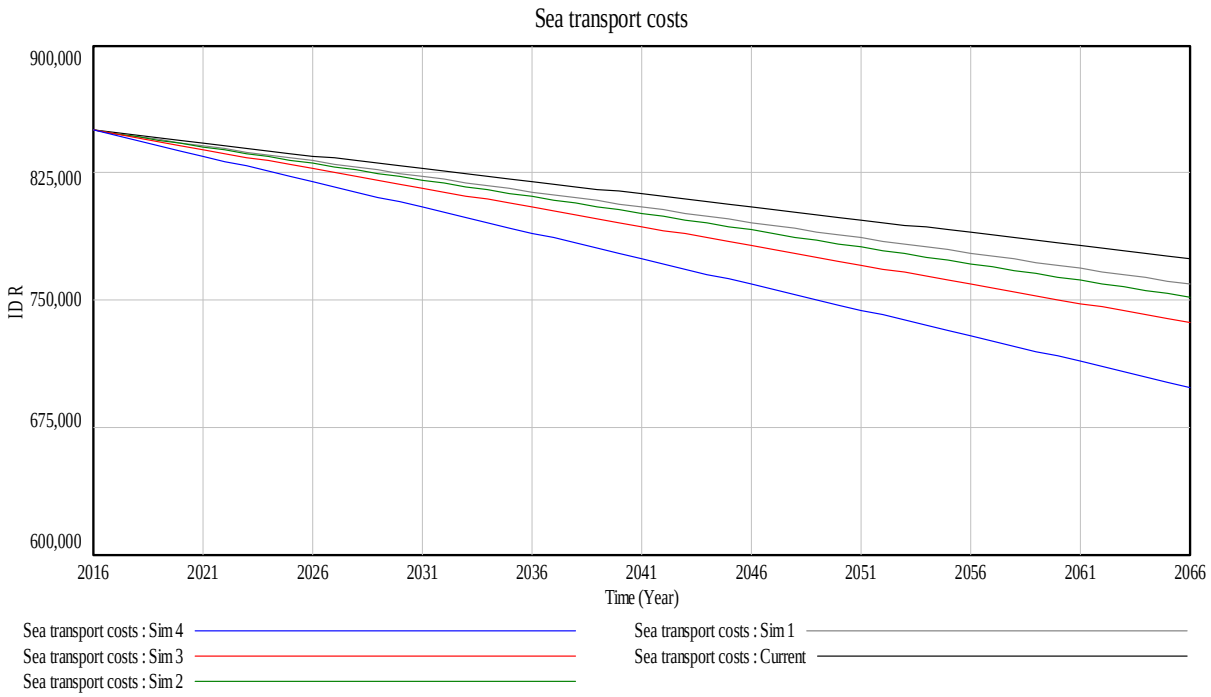

Figure 7. Sea Transport Costs.

6. Air Externality of Sea Transportation

Ports are essential to link land and sea activities, acting as entry points and transportation corridors that affect trade flow and communication between regions. The effects of port externalities on the environment, especially the atmosphere and human health, are significant, and these impacts can be calculated by measuring air pollution emissions. Ports affected by maritime emissions contribute specifically to air pollution in the surrounding area [32]. Suppose the environmental conditions around the port are polluted due to pollution emissions. In that case, the losses incurred are significant for the company and the national economy. All communities related to the area's supply chain of goods distribution are affected [33].

The results of measuring the estimated value of air externalities using the ecological input-output table analysis approach of North Maluku Province display that the emission value of the CO component is higher than the emission value of the SO_2 and NO_x components. Based on the results, the value of environmental damage obtained from air emission components can potentially disrupt the health of the environment and surrounding communities in the long term. The adverse effects arising from air pollution emissions are not only detrimental to the port's economic activity but also have an impact on the economic activity of the tourism sector. The negative externalities effect on tourism is a serious health threat to visiting tourists, such as lung cancer, liver disease, and congenital disabilities [34].

Table 4 outlines the environmental costs of air emissions that occur at the Ahmad Yani port on Ternate Island can affect the health level of the surrounding environment. The social costs of emissions that should be borne present an increasing trend from year to year. In 2016, the total environmental costs of Ternate port activities amounted to IDR 15,247,562. The social costs of emissions from loading and unloading activities amounted to IDR 29.45 per ton, and the social costs of emissions from ship visits amounted to IDR 7020.06 per call. In 2017, the estimated social costs increased to IDR 30,495,024, where the environmental costs for loading and unloading activities amounted to IDR 103.01 per ton, and the social costs of emissions from ship visits amounted to IDR 13,994.96.

The changes in the economic growth has encouraged an increase in the activity of loading and unloading goods at ports, and it has an impact on increasing levels of air pollution emissions both from container ships, people's ships, heavy vehicles, trucks, and loading and unloading equipment. To control the potential for environmental pollution due to increased port economic activity, port managers can reward the cleanest ships in their operational activities at sea and while in port and impose penalties in fines or additional environmental costs to the dirtiest ships. In addition, the option of rejuvenating goods transport trucks operating at ports can also be implemented. Old and old trucks must be replaced with new vehicles to reduce air pollution. Port managers can provide grants or loans to transport service companies as an incentive to replace trucks.

Table 4. Performance of Eco-Port in the Ternate Island.

Year	Emission	Social Cost (IDR)	Social Cost of Emissions Per Throughput (IDR/Ton)	Emission Social Cost Per Ship Trip (IDR/Call)
2016	CO	288,883	0.56	133.00
	CO_2	6574	0.01	3.03
	NO_x	14,881,900	28.75	6851.70
	SO_2	70,205	0.14	32.32
	Total	15,247,562	29.45	7020.06
2017	CO	577,767	1.95	265.15
	CO_2	13,148	0.04	6.03
	NO_x	29,763,700	100.54	13,659.34
	SO_2	140,409	0.47	64.44
	Total	30,495,024	103.01	13,994.96
2018	CO	10,586,700	17.83	2982.17
	CO_2	240,924	0.41	67.87
	NO_x	545,373,000	918.60	153,626.20
	SO_2	2,572,770	4.33	724.72
	Total	558,773,394	941.18	157,400.96

Source: Data Analysis.

7. Discussion

The volume capacity and value of traded goods strongly influence maritime transportation costs. Remote countries or regions with small markets face high maritime transportation costs. Small economies of scale in island regions produce relatively small amounts of cargo, increasing transport costs per unit [35]. The availability of infrastructure and poor services has led to port inefficiencies, which also impact the high costs of sea transportation in the archipelago area of North Maluku Province. Ref. [36] stated the island's vulnerabilities including the limited infrastructure development, uneconomical provision of services and administration, high transport and manufacturing costs, and irregular transportation, makes timely demands in modern supply chains unsatisfactory.

The long inter-island supply chain causes high maritime logistics costs for goods. Farmers' crops and fishermen's catches in areas or islands with limited transportation access must wait for the arrival of ships for 4–5 days. Irregular boat arrival schedules can prevent fish caught by fishermen from being damaged due to limited ice supplies. Farmers' crops in the form of copra, nutmeg, or cloves from the island must be transported to a ship and then unloaded at the regency/city port for further transport by truck or pick-up to be taken to the distributor's collector's shop or warehouse. After all these commodities have been collected, they are sent via containers or cargo ships to be sold to Surabaya or Bitung. The logistics activities between islands and the market center creates much uncertainty in its economic activities, resulting in significant transaction costs such as coordination, information, and negotiation costs. Maritime uncertainty in the islands impacts several indicators of the economic value of island maritime logistics, namely GRDP, loading and unloading charges, transportation costs, land connections, total throughput, and labor force.

Maritime logistics economic indicators in the dynamic model reveal that the scenario of reducing sea freight costs positively affects in reducing the price of goods. The relatively high price level of goods due to the small scale of the island's economy causes most of the goods the people's economy needs be imported from outside the region. Therefore, the problem of inflation on the island can be overcome through policies regulating sea transportation costs or tariffs set by ship operators who tend to be unilateral and do not prioritize the interests of consumers and island communities.

Providing the budget allocation for subsidies for the operational costs of ships serving shipping routes to the islands. It is crucial to consider that maritime logistics costs that companies and ship owners must bear are expensive. The fuel cost component for ships on national shipping routes in Indonesia can reach 94.39%, while the capital cost is 4.63% [37]. However, the policy of subsidized sea-highway ships to serve the outermost and remote islands in the North Maluku Province, namely Morotai Island, Tidore Island, Buli, and Gebe Island, has yet to solve the inflation problem. Even though the distribution of goods for the economic needs of the island community is smooth, the price level for goods has stayed the same due to the relatively high costs of loading and unloading at the port and truck rental services.

8. Conclusions

The results of the first policy scenario prove that reducing sea transportation costs by 20%, 30%, and 50% can reduce the inflation rate so that, in the long run, it can encourage the boost in the rate of change of GRDP in North Maluku Province. Besides that, reducing sea freight rates also positively impacts increasing the economic value of maritime logistics. The second scenario model suggests that the rate of change of GRDP positively affects growing changes in the maritime logistics economy and encourages an increase in externality values and environmental costs from air emissions generated from the sea transportation sector. This expansion triggers environmental and social costs that harm the island's environmental and community health levels. The results of the third scenario prove that the gain in the number of goods in the long term has a negligible effect on reducing sea transportation costs.

Policy Implication

Based on the simulation results to reduce the cost of sea transportation, it explains that the scenario with the policy of equitable distribution of industrial development spatially adjacent to the island and the policy of providing subsidies for ship operations has a more significant effect on the island's economy to reduce the inflation rate. The market center relocation closer to the islands will decrease the ship's operational costs for fuel because distance and travel time are more efficient. Likewise, the policy of providing subsidies for sea toll-way programs can directly reduce ship operational costs. Increasing the capacity of the number of goods loaded will have a negligible effect on reducing the cost of sea transportation. On this basis, providing subsidies for ship operations, especially the sea highway program and developing industrial centers adjacent to island areas, is the right policy to improve the island's economic performance.

This study contributes to the empirical application of the IO method combined in a dynamic system related to the maritime logistics system and the impact of pollution produced by the maritime transportation sector on the environment. However, the study has weaknesses in the use of environmental cost rates that are not based on direct measurement results at the research location, so that cost assumptions need to be strengthened with real data using more accurate economic valuation method. Further studies can also develop the dynamic I-O or multi-regional I-O methods to capture a wider range of interactions and economic dependencies in the maritime logistics sector.

Author Contributions

C.A.: Conceptualization, Methodology, Formal Analysis, Writing—Original Draft. P.C.H.R.: Data Curation, Writing—Original Draft, Conceptualization. H.M.: Investigation, formal analysis, Writing—Review & editing, Supervision. E.A.: Writing—review & editing, supervision. T.K.: Supervision, validation. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

This study was conducted as internal organizational research and did not require IRB approval under institutional policies.

Informed Consent Statement

Verbal informed consent was obtained from all subjects involved in the study.

Conflicts of Interest

The authors declare that they have no known competing financial interest or personal relationship that could appear to influence the research reported in this paper.

Use of AI and AI-assisted Technologies

No AI tools were utilized for this paper.

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