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The Efficacy of Maritime Logistics Connectivity in Reducing Regional Price Disparities of Essential Food Commodities across the Indonesian Archipelago

Sri Endang Kornita [1]*, Syarifah Akmal and Rahmah Hamidah

[1] FEB universitas Riau
[2] Universitas Malikussaleh
[3] Politeknik Negeri Sriwijaya
* Correspondence: sri.endangkornita@lecturer.unri.ac.id

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ABSTRACT

The disparity in staple food prices across regions in Indonesia is a structural problem exacerbated by the country's geographical conditions as an archipelago. This study aims to examine the extent to which maritime logistics connectivity can reduce these price disparities. Using a mixed-methods approach, this study analyzed panel data from 34 provinces between 2020 and 2025 combined with semi-structured interviews involving 42 supply chain stakeholders. Estimation results indicate that a one-unit increase in port connectivity scores is associated with a 4.7%-6.2% decrease in the coefficient of variation of inter-island rice prices ($p < 0.01$). The Sea Toll Program has proven successful in narrowing the price gap between Java and Papua, from 47% in 2019 to 31% in 2025. This impact is further reinforced by the implementation of the National Logistics Ecosystem (NLE). The findings indicate that although maritime connectivity is an important prerequisite, intermodal logistics integration remains essential for achieving sustainable food price equity.

Keywords: maritime logistics connectivity; food price disparities; sea toll; Indonesia; National Logistics Ecosystem; archipelagic nation.

1. Introduction

Geographical Context and Food Price Disparities

As an archipelago, Indonesia comprises more than 17,000 islands stretching 5,200 km from west to east. This geographical layout poses significant challenges to the equitable distribution of basic necessities. One consequence is a stark disparity in food prices across regions. According to BPS data, in 2019 the price of medium-quality rice in Papua reached

Rp14,500 per kilogram, while in East Java it was only around Rp9,800 per kilogram a difference of nearly 48% [1]. Such disparities not only burden communities in the eastern regions but also hinder efforts to achieve more equitable prosperity.

Maritime Logistics Connectivity as the Foundation for Market Integration

In the economic structure of an archipelagic nation, maritime transport serves as the primary route connecting dispersed and isolated markets. According to Widodo et al. in the book *Indonesian Logistics: Theory, Policy, and Practice*, the efficiency of the maritime logistics system is a crucial foundation for the integration of the domestic market [2]. A similar view is expressed by Kusuma in *Indonesia's Maritime Toll System Toward the Maritime 5.0 Era*, which emphasizes that ports are crucial nodes in the distribution network, where their design and development strategies significantly influence the smooth flow of supplies and price stability in inland regions (hinterlands) [3]. Taken together, these perspectives indicate that maritime connectivity is not merely a supporting factor but an essential prerequisite for achieving national economic integration.

The Sea Toll Program and Its Integrated Approach to Economic Equality

To address these challenges, the Indonesian government launched the Sea Toll Program in 2014. This policy is not merely a form of freight subsidy but is part of an integrated logistics system that encompasses intermodal transportation, warehousing, cold storage facilities, and the control of staple goods prices at the consumer level. This philosophy is explained in depth in the book *Sea Toll: Connectivity of Indonesia's Maritime Axis Vision*, published by the Directorate General of Sea Transportation [4]. This approach is reinforced by Suhartono et al. in *Indonesia's Maritime Economic Policy*, which states that the development of maritime connectivity is at the core of a strategy for inclusive and equitable economic growth [5].

The Debate Over the Impact and Challenges of Subsidy Sustainability

Although the program has been in place for more than ten years, evaluations of its effectiveness continue to produce mixed findings across studies. On the one hand, a recent study by Sofiyandi, Kurniawan, and Yudhistira [5], which employed the difference-in-differences method, found that maritime logistics subsidies successfully reduced average food prices by 3.2% in recipient regions [6]. However, the same findings also indicate that this price reduction tends to disappear within less than a year after the program is implemented, raising doubts about its sustainability. On the other hand, a Bappenas report (2024) notes that logistics costs in Indonesia remain high, reaching 14.29% of GDP, far above those of Singapore (8%) and Malaysia (13%) [7]. It is this disparity between high expectations and on-the-ground realities that calls for a more in-depth analysis.

Evaluation Framework for the National Logistics and Ecosystem Performance Index

The Logistics Performance Index (LPI) is widely used to assess logistics system effectiveness through six aspects: customs efficiency, infrastructure quality, ease of shipment arrangements, logistics service competence, shipment tracking, and delivery timeliness [8]. This framework enables a more comprehensive evaluation of logistics performance beyond physical infrastructure alone. In response to logistics inefficiencies, the Indonesian government launched the National Logistics Ecosystem (NLE) through Presidential Instruction No. 5 of 2020 to strengthen infrastructure, improve connectivity, and synchronize the flow of goods and documents [9]. By the end of 2024, NLE implementation had covered 97% of maritime cargo flows across 53 ports and 7 airports [10].

Research Gaps and Study Objectives

The review above reveals a significant gap in current understanding. Most previous studies have only evaluated the impact of maritime logistics policies in isolation, without comprehensively examining how factors such as port connectivity, intermodal transport efficiency, and digital ecosystems like the NLE interact to influence price disparities for specific commodities. Furthermore, the perspectives of on-the-ground actors particularly supply chain operators in remote areas who are most acutely affected by price disparities are often not adequately captured in quantitative analyses.

To address this gap, this study aims to comprehensively analyze the role of maritime logistics connectivity in reducing food price disparities across Indonesia's archipelago. In summary, the findings indicate that improved maritime connectivity does reduce price disparities by 4.7% to 6.2%, but this effect is limited without support from intermodal integration and the strengthening of the digital logistics ecosystem. This means that physical connectivity is a critical prerequisite, yet the sustainability of price equity requires a robust digital ecosystem and supporting infrastructure.

2. Materials and Method

Research Design

This study employs a mixed-methods approach using an explanatory sequential design, where quantitative findings were subsequently explored through qualitative interviews, combining quantitative analysis of panel data with qualitative in-depth interviews. This design was chosen based on the need to first identify robust statistical patterns and then explore the mechanisms behind these findings through narrative data [14]. The initial stage involved econometric estimation of the relationship between maritime logistics connectivity and food price disparities. The results of this stage then served as the basis for conducting

semi-structured interviews in the second stage, to deepen the understanding of the detected causal relationships.

Data Sources and Types

This study used secondary quantitative data obtained from public databases managed by Indonesian government agencies, without involving primary data collection or experiments. To ensure transparency, the authors will provide the complete dataset and analysis syntax during the review process. Food price data for eight major commodities across 34 provinces from January 2020 to December 2025 were sourced from Bapanas and BPS. Data on Sea Toll routes, ship frequency, cargo volume, and port waiting times were obtained from the Directorate General of Sea Transportation. Regional data, including GRDP per capita, road density, and the number of traditional markets, were collected from BPS and the Ministry of Public Works and People's Housing. Information on National Logistics Ecosystem (NLE) implementation, including port coverage and service digitization, was gathered from DJBC and LNSW reports.

Variable Definitions and Operationalization

The dependent variables in this study are food price disparities, measured by the coefficient of variation (CV) of commodity prices across districts/cities and the price difference of medium-grade rice between western Indonesia (Java) and eastern Indonesia (Papua, Maluku, and East Nusa Tenggara). The main independent variable is the Maritime Logistics Connectivity Index (MLCI), which measures physical connectivity, operational efficiency, and transportation affordability on a 0–100 scale. The moderation variable is the implementation level of the National Logistics Ecosystem (NLE), also measured on a 0–100 scale based on logistics service integration. To isolate the effect of the Maritime Logistics Connectivity Index (MLCI), the model includes several control variables such as per capita GRDP, road density, the number of traditional markets, and annual provincial inflation.

Econometric Analysis Model

The analysis model follows the standard approach for panel data. Based on the Hausman test, which rejected the null hypothesis, the fixed-effects model was chosen as it is more suitable for controlling for unobserved inter-provincial heterogeneity. The main model is formulated as:

$$CV_{it} = \alpha + \beta_1 IKLM_{it} + \beta_2 NLE_{it} + \beta_3 (IKLM \times NLE)\, it + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where:

- CV_{it} is the coefficient of price variation in province i in month t
- $IKLM_{it}$ and NLE_{it} are the main and moderator variables

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- X_{it} is the control vector
- μ_i and λ_t are the fixed effects for province and time (month-year)
- ε_{it} is the stochastic error term

To address potential endogeneity between connectivity and prices, this study applied a two-stage Instrumental Variables (IV) approach (2SLS) using the historical distance of each province's main port from the colonial administrative center as the instrument. Instrument validity was tested with the Kleibergen-Paap rk Wald F statistic to detect weak instruments. Estimations used cluster-robust standard errors at the provincial level to account for heteroscedasticity and serial correlation. In addition, the impact of the Sea Toll program was analyzed using the difference-in-differences (DiD) method by comparing price disparities between served and unserved districts before and after program implementation. All analyses were conducted using STATA 18.0, with do-files provided as supporting materials.

Qualitative Approach

To support the quantitative findings, this study conducted semi-structured interviews with 42 key informants selected through purposive and snowball sampling, all of whom had at least five years of experience in inter-island food logistics. Respondents included officials from the Directorate General of Sea Transportation, port managers, wholesalers, regional distributors, logistics academics, and provincial Trade Office officials. Interviews were conducted in person or online, recorded with verbal consent, and transcribed verbatim. The interview guide focused on transportation costs, ship schedule reliability, port and road infrastructure constraints, and the impact of NLE digitization on logistics operations. Data were analyzed thematically using NVivo 14 following Braun and Clarke's six-stage approach, with reliability ensured through member checking and independent coding by two researchers. The study followed the ethical principles of the Declaration of Helsinki, and the Hasanuddin University Research Ethics Committee granted an exemption from formal ethical approval because the research involved only voluntary adult interviews with anonymized data.

3. Result

Descriptive Statistics on Food Price Disparities

An analysis of monthly panel data from January 2020 to December 2025 reveals persistent price disparities across various provinces. Table 1 presents the coefficient of variation (CV) of prices for eight major food commodities across districts/cities, grouped by region.

The CV for medium-grade rice ranges from 0.089 (in East Java in 2025) to 0.347 (in Papua in 2020). Fresh horticultural commodities, particularly red chili peppers and red onions, consistently exhibited the highest levels of disparity. On the other hand, wheat flour exhibits the lowest disparity (average CV of 0.142), likely due to its nature as a processed product with a more standardized and regulated supply chain. Seasonal patterns are also evident: there is a 23% average increase in the coefficient of variation in the fourth quarter compared to the second quarter, in line with a surge in year-end demand that is not offset by an increase in maritime transport capacity.

Table 1. Coefficient of Variation in Prices of Staple Food Commodities Across Districts/Cities (Average for 2020–2025)

Commodity	Indonesia West	Indonesia Central	Indonesia East	National
Medium Rice	.112	.187	.289	.196
Granulated Sugar	.098	.156	.234	.163
Cooking Oil	.087	.142	.218	.149
Wheat Flour	.079	.127	.221	.142
Broiler Chicken Meat	.134	.203	.312	.216
Broiler Eggs	.118	.178	.267	.188
Red Onions	.243	.367	.546	.385
Red Chili	.278	.398	.561	.412

Note: Western Indonesia (Sumatra, Java, Bali), Central Indonesia (Kalimantan, Sulawesi), Eastern Indonesia (Nusa Tenggara, Maluku, Papua).

Source: Compiled from the Bapanas Food Price Panel and BPS (2025).

Development of Maritime Logistics Connectivity

During the study period, maritime logistics connectivity at the national level showed planned expansion. The number of Sea Toll routes increased from 18 in 2019 to 39 in 2025, with the number of ports of call expanding from 31 to 114 [3]. Quantitatively, transport volume is projected to reach 1,440.82 thousand tons and 35,391 TEUs by 2025 [11].

Nevertheless, operational efficiency continues to face challenges due to an imbalance in backhaul capacity, with the average backhaul capacity reaching only 32% of the outbound cargo capacity during the observation period. The Maritime Logistics Connectivity Index (MLCI) developed in this study ranged from 18.2 in mountainous Papua to 87.4 in East Java in 2025. Overall, the national average MLCI rose from 42.6 in 2020 to 54.3 in 2025, indicating significant progress despite the persistence of a fairly wide spatial disparity gap.

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3.3. Econometric Estimation of the Effect of IKLM on Price Inequality

The fixed-effects model with cluster-robust standard errors shows that a one-unit increase in the IKLM significantly reduces rice price disparity by 5.2% ($p < 0.01$). The IV (2SLS) endogeneity test confirms the reliability of the model, with a Kleibergen-Paap rk Wald F statistic of 16.78 indicating no weak instrument problem. Model 2 further reveals that the interaction between IKLM and the National Logistics Ecosystem (NLE) is negative and significant ($\beta = -0.031$, $p < 0.05$), meaning that NLE implementation strengthens the effect of maritime connectivity in reducing price disparities. In provinces with NLE implementation above 75%, the impact of IKLM is nearly 2.3 times greater than in provinces below 25%, with a moderate interaction effect size ($\eta^2 = 0.09$).

Table 2. Fixed-Effects Panel Estimation Results — Dependent Variable: Rice Price CV

Variables	Model 1	Model 2	Model 3
IKLM	-.052** (.018)	-.047** (.017)	-.051** (.019)
NLE	—	-.028* (.012)	-.031* (.013)
IKLM × NLE	—	-.031* (.014)	—
GRDP per capita (ln)	-.018 (.023)	-.015 (.021)	-.017 (.022)
Road Length (km/km²)	-.041 (.036)	-.038 (.034)	-.039 (.035)
Total Traditional Markets	-.008* (.003)	-.007* (.003)	-.007* (.003)
Provincial Inflation (%)	.012* (.005)	.011* (.005)	.011* (.005)
R^2 (within)	.487	.523	.519
Observation	2,448	2,448	2,448

Note: $p < .05$; $p < .01$. Cluster-robust standard errors in parentheses. All models include fixed effects for province and month-year. Model 3 excludes interactions.

Impact Analysis by Commodity

Disaggregation by commodity type (Table 3) reveals substantial heterogeneity in the responses. Maritime connectivity had the greatest impact on fresh horticultural commodities: red chili peppers ($\beta = -.078$, $p < .01$) and shallots ($\beta = -.069$, $p < .01$). In contrast, wheat flour, as a processed commodity, showed the lowest response ($\beta = -.023$, $p < .10$). These findings confirm that price sensitivity to improvements in connectivity is directly proportional to the level of perishability and supply volatility of the commodity.

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Table 3. Impact Coefficients of IKLM on Price CV by Commodity (Fixed-Effects Model)

Commodity	β IKLM	Std. Error	Significance
Medium Rice	-.052	.018	**
Granulated Sugar	-.038	.016	*
Cooking Oil	-.034	.015	*
Wheat Flour	-.023	.013	†
Broiler Chicken Meat	-.057	.019	**
Broiler Eggs	-.043	.017	*
Red Onion	-.069	.022	**
Red Chili	-.078	.024	**

Note: *p* < *.01; p* < *.05;* †p < .10. The model includes all control variables as in Table 2, Model 2.

Impact of the Sea Toll Program Through Difference-in-Differences Analysis

The difference-in-differences (DiD) analysis shows that districts served by Sea Toll routes experienced a significant reduction in price disparities between Java and Papua. The price gap for medium-grade rice fell from 47% in 2019 to 31% in 2025, equivalent to a 34% relative decrease, with a treatment effect of -11.4 percentage points ($p < .01$, Cohen's $d = .42$). However, the impact varied across regions, as Papua and East Nusa Tenggara recorded the largest reductions (18–25 percentage points), while North Maluku and Southeast Sulawesi experienced smaller decreases (5–8 percentage points). These differences were strongly linked to the quality of supporting infrastructure, especially refrigerated storage facilities and road access from ports to distribution centers ($r = .64$, $p < .01$).

Qualitative Findings on Supply Chain Actor Perspectives

A thematic analysis of interviews with 42 key informants identified four main themes. First, transportation costs were seen as the main driver of inter-island price disparities, with shipping costs from Surabaya to Jayapura reaching Rp18 million per container compared to Rp5 million for the Surabaya–Banjarmasin route. Second, respondents highlighted schedule uncertainty and limited facilities in eastern Indonesia, where delayed ship arrivals often disrupt supply chains. Third, the digitization of the National Logistics Ecosystem (NLE) improved administrative efficiency by reducing document processing time from three to four days to only one day, lowering cargo waiting and storage costs. Finally, many informants

emphasized that inadequate land infrastructure remains a major challenge, as high trucking costs from ports to markets often reduce the benefits of maritime transport subsidies.

4. Discussion

Maritime Connectivity as a Driver of Price Convergence

The econometric analysis shows that a one-unit increase in the Maritime Logistics Connectivity Index (IKLM) reduces rice price variation by 5.2% ($p < .01$), confirming the important role of maritime logistics accessibility in harmonizing prices across Indonesia's archipelagic regions. These findings support Sofiyandi, Kurniawan, and Yudhistira [5], who reported a 3.2% decrease in food prices in areas receiving maritime logistics subsidies, while also showing that the effects of connectivity vary across commodities and can persist for up to six years. This longer-term impact is likely driven by accumulated port infrastructure investments and increased shipping frequency. The results also strengthen the argument of Pratikto et al. [19] that domestic port connectivity is essential for integrating markets across geographically dispersed regions.

The Role of the National Logistics Ecosystem as a Driver of Digital Transformation

The significant negative interaction effect between IKLM and the National Logistics Ecosystem (NLE) ($\beta = -0.031$, $p < .05$) shows that simplifying procedures and digitizing logistics systems can strengthen the impact of physical infrastructure development. This finding supports Presidential Instruction No. 5 of 2020 and indicates that port development and shipping route expansion will be less effective without integrated digital logistics systems. It also complements the perspective of Widodo et al. [2] by emphasizing that the digital aspect of the NLE is as important as physical infrastructure. Therefore, these results support accelerating NLE implementation across all Sea Toll ports, especially in eastern Indonesia where price disparities remain high.

Differing Responses Across Commodities and Their Impact on Policy

The impact of IKLM varies across commodities, with red chili peppers ($\beta = -0.078$) and shallots ($\beta = -0.069$) showing the strongest response, while wheat flour ($\beta = -0.023$) showed the weakest. Perishable commodities and those vulnerable to supply fluctuations benefit most from improved maritime connectivity, as transit time and delivery reliability are critical to supply chain efficiency. These findings align with those of Karimah, Sastiono, and Yudhistira [13], who found that maritime logistics subsidies not only lower prices but also alter food consumption patterns in recipient regions. Therefore, national food distribution

policies should focus more on fresh commodities on routes with the highest price gaps, while processed commodities with more stable supply chains can be left to rely more on market mechanisms. This differentiation-based approach will make the allocation of public resources more efficient.

Limitations of Supporting Infrastructure and Reloading Issues

Qualitative findings and DiD analysis show that maritime connectivity alone is insufficient to reduce price disparities. Supporting infrastructure such as access roads and storage facilities has a strong positive relationship with lower price disparities ($r = 0.64$, $p < .01$), confirming that ports can only operate effectively when integrated with adequate land transport and logistics systems. In addition, the low backhaul rate of only 32% creates major inefficiencies, as empty return cargo increases operational costs and contributes to higher prices. Long-term solutions therefore require cross-sector collaboration, including the development of local industries in eastern Indonesia to generate return cargo for western regions.

Broader Implications and Directions for Future Research

This study shows that price disparities in archipelagic nations are influenced not only by distance, but also by logistics systems and institutional support. While maritime connectivity helps overcome physical barriers, its impact remains limited without strong institutions. These findings are relevant for Indonesia as well as other archipelagic countries such as the Philippines and Pacific Island nations, supporting UNESCAP [20] recommendations on the importance of maritime connectivity for sustainable development in the Asia-Pacific region. Future research may focus on developing more detailed connectivity indices, expanding price data to remote areas, applying spatial econometric models, and exploring IoT and blockchain technologies to improve the transparency and efficiency of food supply chains in island regions. These studies will contribute to more targeted and sustainable maritime logistics policies.

5. Conclusion

This study confirms that maritime logistics connectivity plays an important role in reducing staple food price disparities in Indonesia. A one-unit increase in the Maritime Logistics Connectivity Index (IKLM) reduces regional rice price variation by 4.7%–6.2% ($p < .01$). The Sea Toll Program also reduced the Java–Papua price gap from 47% in 2019 to 31% in 2025, supported by the National Logistics Ecosystem (NLE) through digitalization and streamlined procedures. However, the benefits are uneven, with greater impacts on perishable commodities and regions with adequate infrastructure. The findings show that

maritime connectivity alone is insufficient to achieve sustainable food price parity, particularly in regions with limited supporting infrastructure and weak intermodal integration, as intermodal integration, infrastructure availability, and backhaul issues remain key challenges. Academically, this study enriches understanding of maritime connectivity and market integration in an archipelagic country through an integrated empirical framework combining physical, operational, and institutional dimensions.

Limitations of the Study

Several limitations should be noted when interpreting the results.

First, the IKLM developed does not yet fully reflect service quality aspects such as vessel schedule accuracy and cargo security, which qualitative respondents identified as important factors. Second, the price data used at the district/city level may not fully represent conditions in remote areas not covered by the BPS's routine surveys. Third, the analysis has not considered the possibility of spillover effects between regions, which could affect the accuracy of policy impact estimates. Fourth, the small number of qualitative respondents (42 people) spread across many provinces limits the depth of analysis for each local context. These limitations provide opportunities for future studies to further refine and expand the current findings.

Recommendations

Based on these findings, several steps are recommended. The government should continue and expand the Sea Toll Program by prioritizing routes with high price disparities, particularly in eastern Indonesia, while developing a systematic backhaul cargo strategy. The implementation of the National Logistics Ecosystem (NLE) should also be accelerated across all Sea Toll ports, including the integration of cold chain systems for fresh commodities. In addition, coordination among the Ministry of Transportation, the Ministry of Public Works and Public Housing, and local governments is needed to improve port infrastructure, access roads, and storage facilities. To enhance operational efficiency, the government should provide incentives such as reduced port fees or partial subsidies to encourage backhaul cargo utilization. Furthermore, the Ministry of Transportation and Bapanas should establish a data-driven monitoring system integrating food price and port operational data. Future research is encouraged to develop more detailed connectivity models, examine price dynamics in remote areas, apply spatial econometric approaches, and explore IoT and blockchain technologies for optimizing food supply chains in island regions.

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