

## The Impact of Non-Tariff Measures on Indonesian Seaweed Exports to the International Market

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### ABSTRACT

With the increasing global demand for seaweed and Indonesia's position as one of the world's largest producers, understanding the barriers to export growth has become increasingly urgent. This study investigates the impact of Non-Tariff Measures (NTMs) on Indonesia's seaweed exports to six major destination countries—Chile, China, Denmark, Japan, Spain, and the United States—over the period 2012 to 2022, using annual panel data. A panel data regression analysis with the Random Effect Model (REM) is employed to examine the influence of various factors, including import prices, population, GDP per capita of the importing countries, and NTMs in the form of Sanitary and Phytosanitary (SPS) standards and Technical Barriers to Trade (TBT). The findings show that import prices, GDP per capita, and the implementation of SPS and TBT measures negatively affect Indonesia's seaweed export volume, while population growth in the importing countries has a positive and significant impact. Key challenges hindering Indonesia's seaweed exports include stringent SPS requirements, food safety regulations, and product rejections due to contamination and non-compliance with international standards. To improve the competitiveness of Indonesian seaweed in the global market, it is essential to strengthen product quality, comply with international regulations, promote technological innovation, and provide targeted support for exporters.

**Keywords:** *export, seaweed, panel data regression, non-tariff policy, product quality*

### BACKGROUND

Seaweed is one of the primary commodities in the fisheries sector, contributing significantly to Indonesia's aquaculture production. In 2022, seaweed production accounted for 70.47% of the total national aquaculture output, supported by Indonesia's vast aquatic potential and favorable environmental conditions for seaweed cultivation (Fatonny et al., 2023). An increase in production was observed in the fourth quarter of 2022 compared to the previous quarter, particularly in key production centers such as South Sulawesi, Maluku, East Java, and East Kalimantan. The main factors driving this increase were stable climatic conditions and the use of higher-quality tissue-cultured

seedlings. Additionally, the rise in seaweed prices in the second half of 2022 further encouraged cultivators to expand production.

Table 1 shows that, in terms of exports, seaweed is one of Indonesia's leading commodities, with export value growth reaching 32.67% over the same period. The export volume of seaweed increased by 11.74%, with China as the primary destination, followed by South Korea and Vietnam.

**Table 1.** Growth in Export Volume and Value of Fishery Products by Main Commodities, Q4 2021 – 2022

Main Commodity	Volume (Ton)		Value (000 USD)		Growth (%)	
	2021	2022	2021	2021	2022	2021
Shrimp	66.332	61.069	615.338	504.637	-7,93	-17,99
Tuna-Skipjack-Scad	49.902	63.542	215.072	280.739	27,33	30,53
Rumput Laut	65.355	73.030	108.969	144.569	11,74	32,67
Squid-Cuttlefish-Octopus	58.459	48.837	217.504	228.063	-16,46	4,85
Blue Swimming Crab-Crab	7.987	5.892	165.973	96.936	-26,24	-41,60
Others	96.848	97.137	343.665	375.061	0,30	9,14
Total	344.884	349.508	1.666.522	1.630.004	1,35	-2,19

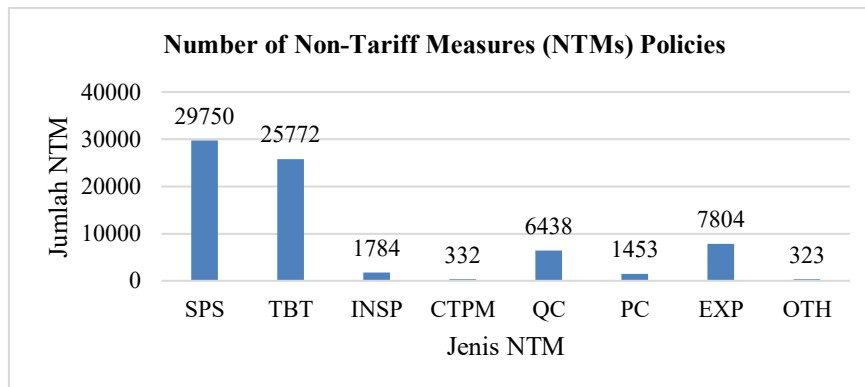
Source: Direktorat Jenderal Pengawasan Sumber Daya Kelautan dan Perikanan (2022)

However, despite continuous export growth, Non-Tariff Measures (NTMs) imposed by importing countries have the potential to hinder Indonesia's seaweed exports. The International Trade Centre (ITC, 2013) reported that 60% of 1,000 fresh food companies in Indonesia face regulatory challenges related to NTMs, with 66% of the applied regulations considered burdensome. The primary obstacles include technical requirements, such as stringent product specifications and high-quality standards.

NTMs, which encompass Sanitary and Phytosanitary Measures (SPS) and Technical Barriers to Trade (TBT), are implemented to ensure the safety and quality of imported products. The agri-food sector, including seaweed, is among the most affected by these policies (Ghodsi et al., 2017; Kareem et al., 2016; Kuenzel, 2020; Marette, 1995). SPS measures are applied to protect human health and the environment from potential risks associated with international trade, including biological, chemical, and physical hazards. For instance, SPS policies for seaweed often set maximum limits for heavy metal contamination such as lead (Pb), cadmium (Cd), and mercury (Hg), commonly at thresholds such as 0.5 mg/kg for lead, 0.2 mg/kg for cadmium, and 0.1 mg/kg for mercury. In addition, microbiological standards may require the absence of pathogenic bacteria like Salmonella in 25 grams of sample and limits for E. coli at less than 100 CFU/g. These specific standards are intended to ensure that exported products conform to the food safety regulations of importing countries (Winchester, 2009).

As a major exporting country, Indonesia must ensure the quality and safety of its seaweed products to meet these global standards. Although seaweed is not subject to export trade restrictions, strict quality control from upstream to downstream is essential to enhance competitiveness in

international markets. One crucial aspect that requires attention is the availability of quality testing laboratories, managed by both the government and the private sector, to ensure compliance with global export standards (Ministry of Industry and Trade, 2010).



**Figure 1.** Seaweed and Other Algae Exports by Main Destination Countries

With the increasing global demand for seaweed, Indonesia has a significant opportunity to strengthen its position as a leading exporter. However, the tightening of NTM regulations may affect the competitiveness and demand for Indonesian seaweed products. Various studies have discussed the effects of NTMs on trade performance—Ghodsi et al. (2017), Kareem et al. (2016), and Kuenzel (2020) examined their broad impacts on agricultural and food exports. Meanwhile, research more specific to Indonesia, such as by Denantica (2012) and Hakim and Puspa (2019), has analyzed the effect of NTMs on Indonesia’s overall fishery exports. However, few studies have focused specifically on seaweed as a commodity, particularly using a cross-country panel approach over an extended period.

The novelty of this study lies in its focus on analyzing the impact of SPS and TBT measures on Indonesia’s seaweed exports, disaggregated by major destination countries (China, Chile, Denmark, Japan, Spain, and the United States) using annual panel data from 2012 to 2022. By integrating econometric analysis with descriptive policy mapping, this study provides more specific and actionable insights into how NTMs influence seaweed trade patterns—something that previous literature has not explored in depth. Therefore, this study aims to analyze the impact of NTM policies on Indonesia's seaweed exports and formulate sustainable strategies to enhance competitiveness in the global market.

**RESEARCH METHODS**

This study was conducted using secondary data collected from various sources, focusing on Indonesia's seaweed commodities in the international market. The data covers six major importing countries—China, Chile, Japan, Denmark, Vietnam, and Spain—over the period from 2012 to 2022. A quantitative approach was employed using panel data analysis, which combines cross-sectional data (six countries) and time-series data (eleven years). This approach allows for capturing variations across both countries and time, increasing the robustness of the analysis.

The variables analyzed in this study include import volume as the dependent variable, while import price, GDP per capita, population, nominal exchange rate, and non-tariff measures (NTMs) in the form of SPS and TBT policies are the independent variables. The selection of these variables is based on previous empirical literature that identifies them as major determinants of international trade performance (Denantica, 2012; Ghodsi et al., 2017; Khaldun, 2017). Import price affects cost competitiveness; GDP per capita and population represent purchasing power and market size; the nominal exchange rate influences trade flows via currency valuation; and SPS/TBT capture institutional and regulatory barriers that affect import demand.

The following table presents each variable, its proxy, and the source of the data used in this study:

**Table 2.** Operational Definitions of Variables and Data Sources

Variable	Proxy/Unit	Source
Import Volume	Kilograms (kg)	UN Comtrade
Import Price	USD per kg	Trade Map
GDP per Capita	USD	World Bank
Population	Number of people	World Bank
Nominal Exchange Rate	Local currency per USD	World Bank
SPS Measures	Number of SPS notifications	WTO I-TIP Database
TBT Measures	Number of TBT notifications	WTO I-TIP Database

Data on SPS and TBT regulations specific to seaweed commodities (HS Code 121221) were obtained from the WTO I-TIP (Integrated Trade Intelligence Portal). The search was filtered based on product code (HS 121221) and reporting/importing country, ensuring that only NTMs directly associated with seaweed were included, rather than general fisheries or food categories. This level of specificity enhances the relevance and accuracy of the analysis. The software used in this research is EViews 12, which was utilized to estimate the panel regression model and perform the necessary classical assumption tests. The panel data regression model was selected based on the results of the Chow, Hausman, and Lagrange Multiplier (LM) tests, leading to the use of the Random Effect Model (REM). The SPS and TBT variables were operationalized as the annual cumulative count of notified regulations per country that specifically target seaweed commodities under HS 121221. These values were compiled from the WTO notification system and cross-checked against relevant national regulatory documents when available.

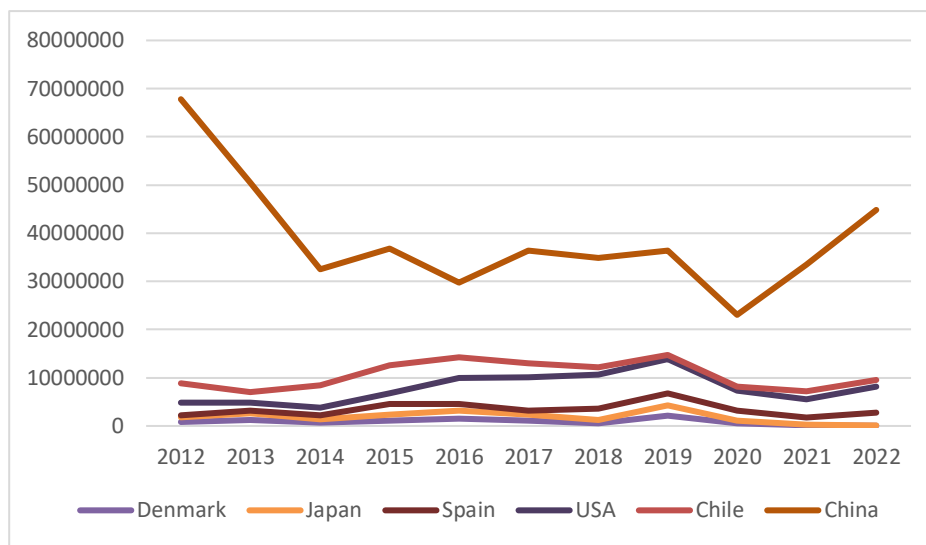
## RESULT AND DISCUSSION

### Indonesia's Seaweed Trade Performance

Seaweed has emerged as a globally significant commodity, serving not only as a food source but also as a key input in various industries. According to (Ferdouse et al., 2018), approximately 40% of hydrocolloids used in the global food, cosmetics, and pharmaceutical industries are derived from seaweed extracts, particularly from *Eucheuma* spp., *Kappaphycus* spp., and *Gracilaria* spp. Indonesia is one of the world's leading seaweed producers, contributing 63.28% to the global hydrocolloid

seaweed supply, with production primarily focused on these three species (FAO, 2021). As a major exporter of raw seaweed materials, Indonesia plays a critical role in fulfilling the demands of international industries (Stieваны & Jalunggono, 2022).

Despite its strong production capacity, Indonesia's domestic seaweed processing industry remains underdeveloped. As a result, a significant portion of seaweed production is exported to countries with more advanced processing technologies, such as China, Chile, Denmark, Japan, Spain, and the United States. In global trade classification, raw seaweed intended for industrial processing is categorized under HS Code 121221. The leading export destinations for Indonesian seaweed under this HS code are illustrated in Figure 2.



**Figure 2.** Export Volume of Major Seaweed Exporting Countries

Among these destinations, China has consistently been the largest importer of Indonesian seaweed, primarily due to its highly developed carrageenan extraction industry. China's domestic supply of carrageenan-rich seaweed is insufficient to meet industrial demand, making imports from Indonesia essential. Additionally, Indonesia's proximity and lower production costs further enhance its competitiveness in the Chinese market. However, a notable decline in Indonesia's seaweed exports to China was observed between 2012 and 2016. This downturn can be attributed to several key factors. First, China significantly tightened its Sanitary and Phytosanitary (SPS) regulations during this period, leading to an increase in product rejections due to contamination with heavy metals, microbial hazards, and other quality concerns. Second, trade disruptions caused by fluctuating international prices and logistics issues temporarily reduced Indonesia's competitiveness. Lastly, China began diversifying its sourcing strategies by increasing seaweed imports from other producers such as the Philippines and Malaysia, thereby reducing its reliance on Indonesia. Indonesia's fisheries trade performance is influenced not only by market-driven factors but also by regulatory policies in international trade, particularly in terms of product safety standards. To ensure product quality and safety, Indonesia must align its quality assurance systems with those of its export destinations, especially countries with fisheries cooperation agreements such as China, Chile, Denmark, Japan, Spain, and the United States. Rejections of Indonesian fishery exports are predominantly linked to

the implementation of SPS and Technical Barriers to Trade (TBT) policies—both of which were institutionalized during the GATT Uruguay Round in 1986. These policies aim to safeguard human, animal, and plant health, while also addressing market inefficiencies (Lim, 2024).

According to (Denantica, 2012), the key determinants of Indonesia’s seaweed exports include export prices, national seaweed production, revitalization policies (captured through dummy variables), the GDP of importing countries, export volume, and real exchange rates. The study found that national seaweed production, importer GDP, revitalization efforts, and export volume exert a positive and significant influence, whereas export prices and exchange rates have a negative and significant impact. Supporting this view, (Khaldun, 2017) emphasized that implementing the blue economy concept, particularly through upstream revitalization, industrial development, and the enforcement of the Indonesian National Standard (SNI) for seaweed, can significantly boost the competitiveness of Indonesia’s seaweed in global markets.

**The Impact of NTMs on the Demand for Indonesian Seaweed Imports**

**1. Model Specification Test**

To determine the most appropriate panel data estimation model, this study compared two primary alternatives: the Fixed Effect Model (FEM) and the Random Effect Model (REM). The comparison was conducted using the Hausman test, a standard procedure for model selection in panel data analysis. As shown in Table 2, both models yield statistically significant results for several variables. However, there are notable differences in coefficient magnitude and significance across models. For example, the import price variable (*ln\_p*) has a coefficient of -0.344 (significant at 1%) under REM and -0.451 (significant at 5%) under FEM. Similarly, GDP per capita (*ln\_g*) is negative and significant in both models, with a larger effect under FEM (-2.601) compared to REM (-0.972). Meanwhile, the SPS and TBT variables remain negative and statistically significant in both models, confirming their consistent impact on import demand. Despite these similarities, the Hausman test result indicates that the p-value is 0.6108, which is greater than the conventional 5% threshold. This means that the null hypothesis—stating that the individual effects are uncorrelated with the regressors—cannot be rejected. In this case, the Random Effect Model is preferred because it is more efficient, assuming that the unobserved heterogeneity across countries is random and not correlated with the explanatory variables. Therefore, based on the results of both the regression outputs and the Hausman test, the Random Effect Model (REM) is deemed the most appropriate and efficient model for estimating the impact of Non-Tariff Measures (NTMs) and other economic variables on the import demand for Indonesian seaweed.

**Table 3.** Panel Data Regression Estimation Results – Random Effect Model & Fixed Effect Model

<i>ln_v</i>	(1) Random Effect (RE)	(2) Fixed Effect FE
<i>ln_p</i>	-0.344*** (0.0975)	-0.451** (0.209)
<i>ln_pop</i>	0.546* (0.287)	7.282 (6.263)
<i>ln_e</i>	0.125	-1.778

ln_v	(1) Random Effect (RE)	(2) Fixed Effect FE
	(0.228)	(1.210)
ln_g	-0.972**	-2.601***
	(0.474)	(0.840)
sps	-0.342***	-0.280*
	(0.106)	(0.167)
tbt	-0.325**	-0.292*
	(0.155)	(0.171)
Constant	14.34	-91.69
	(10.72)	(112.3)
Observations	66	66
R-squared	0.705	0.237
Number of country	6	6

Source: Penulis (2025)

## 2. Classical Assumption Tests

Heteroskedasticity refers to a condition in regression analysis where the variance of errors differs across observations. When the p-value for a heteroskedasticity test (such as the Breusch-Pagan test or White test) falls below a predetermined threshold, such as 0.05, it provides strong evidence against the null hypothesis of homoskedasticity (constant variance). A Chi-square ( $\chi^2$ ) statistic of 6.89 indicates the model's degree of fit with the assumption of constant residual variance, and a probability of 0.0087, which is lower than the 5% significance level. Consequently, the null hypothesis ( $H_0$ ) is rejected, indicating statistical evidence of heteroskedasticity in the model.

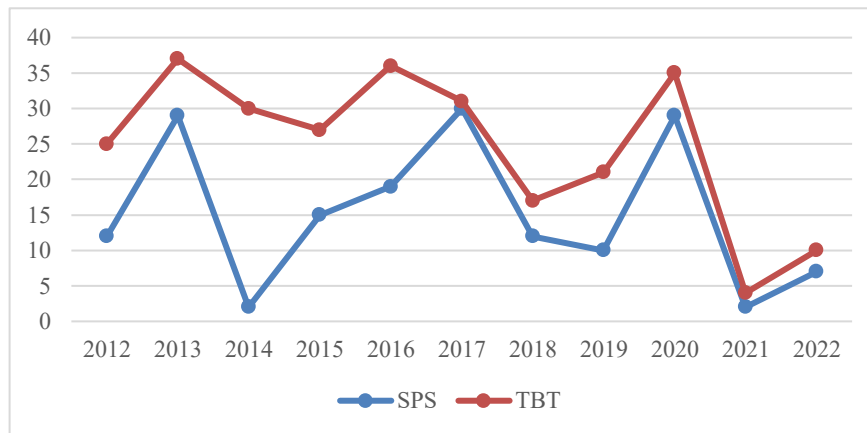
Based on the analysis conducted, the regression model satisfies the necessary assumptions to produce the Best Linear Unbiased Estimator (BLUE). The multicollinearity test indicates no issues, while the results of the heteroskedasticity and autocorrelation tests confirm that the model meets these assumptions. Additionally, the residuals do not exhibit serious normality issues. Therefore, it can be concluded that this model generates unbiased, efficient estimators with the smallest variance among possible alternatives.

### The Impact of SPS and TBT on Indonesia's Seaweed Import Demand

Based on the estimation results, the probability value of the SPS regulation variable is 0.00, with a coefficient of -0.342 (Table 2). This indicates that a 1% increase in the number of SPS policies leads to a 0.342% decrease in the volume of Indonesian seaweed imported by the six destination countries. Similarly, the coefficient for TBT is -0.325, which also reflects a significant negative relationship. These findings suggest that both Sanitary and Phytosanitary (SPS) and Technical Barriers to Trade (TBT) regulations function as trade barriers for Indonesian seaweed exports. This result is consistent with the study by Hakim and Puspa (2019), which found that SPS measures negatively and significantly affect Indonesia's marine exports.

The negative impact occurs because SPS and TBT regulations often impose strict safety and quality requirements on imported products, including limits on chemical residues, microbial

contamination, heavy metals, and specific packaging or labeling formats. Indonesian seaweed products are frequently rejected for failing to meet these standards—often due to issues such as contamination by mercury or cadmium, poor post-harvest handling, inadequate cold chain infrastructure, or insufficient documentation.



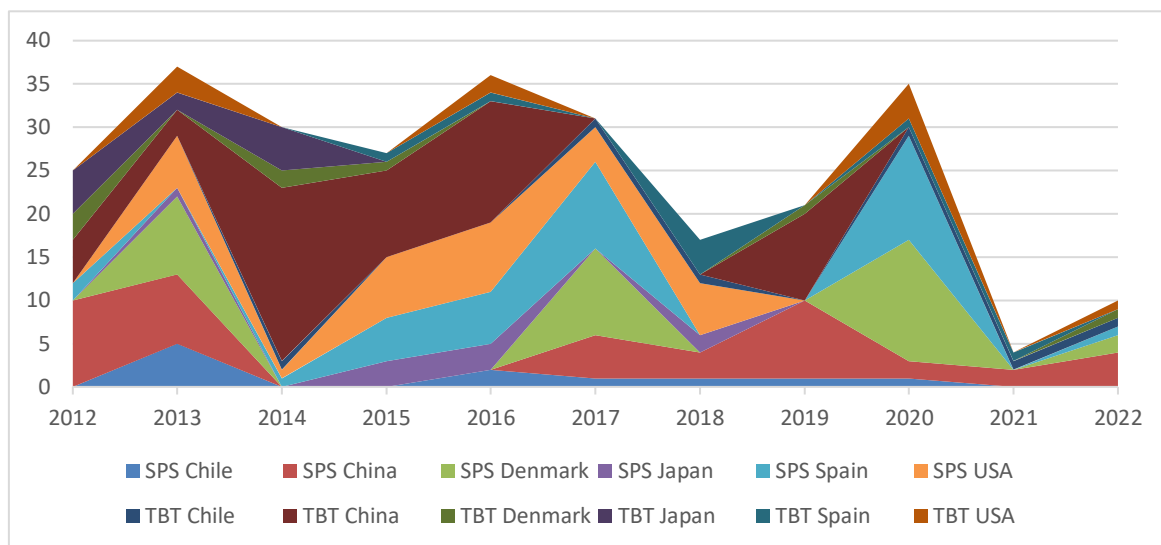
**Figure 3.** Cumulative Trend of SPS and TBT Implementation on Indonesia's Seaweed (2012–2022)

Figure 3 illustrates the cumulative implementation trends of SPS and TBT policies targeting Indonesian seaweed between 2012 and 2022. SPS implementation fluctuated significantly, peaking in 2013, declining sharply in 2014, and rising again in 2017. It reached its lowest point in 2021 before slightly increasing in 2022. TBT regulations, by contrast, were more consistently applied and generally more dominant than SPS throughout the period, with notable spikes in 2013 and 2020.

These fluctuations can be explained by external shocks such as disease outbreaks, contamination cases, or updated international standards that require exporting countries to comply with new regulations. For example, a surge in SPS may be a response to increased health concerns or stricter food safety monitoring in importing countries. Meanwhile, the relatively steady application of TBT measures reflects a systematic effort to align imported products with established technical standards—including labeling, traceability, and testing protocols. TBT measures often impose higher compliance costs than SPS due to more complex technical documentation, broader conformity assessments, and frequent product reformulations. Both SPS and TBT share core procedural elements such as regulation publication, enquiry points, and notification requirements. However, while SPS focuses on public health protection related to food safety and the environment, TBT addresses broader product characteristics and technical specifications.

To overcome these trade barriers, Indonesian exporters must improve product quality and ensure full compliance with the regulatory frameworks of destination countries. This includes investing in laboratory testing, certification, traceability systems, and standardization processes. Furthermore, the government should expand access to accredited testing facilities, provide training to seaweed producers, and strengthen monitoring systems throughout the supply chain. Long-term strategies should also involve harmonizing domestic regulations with international standards and enhancing exporter readiness through targeted capacity-building programs.

**Implementation of SPS and TBT on Indonesian Seaweed by Importing Country**



**Figure 4.** Implementation of SPS and TBT on Indonesian Seaweed by Importing Country (2012–2022)

The implementation of Sanitary and Phytosanitary (SPS) and Technical Barriers to Trade (TBT) measures on Indonesian seaweed varies significantly across importing countries, not only in terms of the number of regulations but also in their technical specifications. These differences have direct implications for exporters, especially regarding contamination thresholds, labeling requirements, and certification standards. China applies one of the highest contamination limits under its SPS framework, with a maximum allowable contamination level of approximately 5%. Its SPS regulations typically focus on the presence of additives, heavy metals, microbial content, and pesticide residues. Imported seaweed must also be accompanied by specific certificates, such as inspection or quarantine approvals, to ensure compliance with food safety protocols. In contrast, the United States enforces much stricter SPS requirements through the Food Safety Modernization Act (FSMA), which mandates a maximum contamination threshold of around 1%. Furthermore, U.S. authorities such as the Food and Drug Administration (FDA) require that products be certified under the Generally Recognized as Safe (GRAS) framework and include complete disclosure of ingredients, potential allergens, and production processes. Japan enforces an almost zero-tolerance policy regarding contamination in imported seaweed, particularly concerning microbial and toxic substances. Products must be certified with a Phytosanitary Certificate under the Plant Protection Act and comply with the Food Sanitation Act, which regulates food additives, genetically modified organisms, and allergens. Additionally, seaweed packaging must be labeled in Japanese, indicating the product name, origin, composition, expiration date, and storage method. This ensures transparency and protects consumers from potential health hazards. Chile, while being a significant importer of Indonesian seaweed, implements SPS measures that are relatively moderate in comparison. These include certification requirements for pathogen control and antibiotic residue limits but do not stipulate contamination thresholds as strictly as the U.S. or Japan. Chile is recognized for its trade facilitation and streamlined bureaucratic procedures, which ease the documentation and

inspection process for importers. Spain and Denmark, as part of the European Union, enforce uniform SPS and TBT regulations derived from EU directives. Both countries require imported seaweed to comply with contamination thresholds generally set below 0.1 mg/kg for heavy metals such as mercury and lead. Denmark is particularly strict regarding environmental aspects of imported goods, enforcing regulations on single-use plastics and requiring comprehensive labeling in Danish. Labelling must include the country of origin and can only be applied post-arrival under specific conditions. Spain imposes similar standards and mandates that all documents, such as commercial invoices and import permits, are filed according to EU and national foreign trade policies. Across all countries, while SPS policies primarily address safety and contamination risks, TBT regulations tend to focus on conformity assessment procedures, packaging, labelling, and environmental standards. These combined requirements reflect each country's trade policy priorities, which must be carefully observed by Indonesian seaweed exporters to ensure successful market access.

## **Other Factors Affecting the Demand for Indonesian Seaweed**

### **1. Import Price of Indonesian Seaweed**

There is a significant influence between the import price set by the destination country and the volume of seaweed imports from Indonesia. Every 1% increase in import prices is associated with a 0.344% decrease in import volume. This finding supports the hypothesis that import prices play a crucial role in determining the demand for Indonesian seaweed. Given this price elasticity, maintaining competitive pricing is essential. Therefore, government policy should focus on reducing production and logistics costs, providing infrastructure support, and ensuring efficient export facilitation to keep Indonesian seaweed attractive in the global market.

### **2. Population**

Population growth in the destination country has a positive impact on the increase in seaweed import volume. Every 1% increase in population contributes to a 0.546% rise in the volume of seaweed imports from Indonesia to the destination country. This relationship is positive and significant, indicating that an increase in population in export destination countries drives the demand for Indonesian seaweed. This result aligns with the study by Sundari, Ruslan, and Hidayat (2025), which states that population, Gross Regional Domestic Product (GRDP), and inflation significantly and positively influence imports. The implication of this finding is that Indonesian exporters should expand market penetration in countries with rapid population growth by identifying demand niches and customizing products to local preferences.

### **3. GDP Per Capita**

An increase in per capita income by 1% is associated with a 0.972% decrease in the volume of seaweed imports from Indonesia. This relationship is negative and significant at a 5% confidence level, indicating that higher per capita income in export destination countries tends to reduce the demand for Indonesian seaweed. This finding is consistent with the study by Hodijah and Angelina (2021), which suggests that this occurs due to changes in consumption patterns in these countries. Higher income levels may lead to a preference for seaweed products with higher added value or those sourced domestically or from other countries with higher safety and quality standards. In response,

Indonesia needs to transition from exporting raw seaweed to processed, value-added products, and enhance quality certification and branding to meet evolving consumer expectations.

#### **4. SPS Regulations in Destination Countries**

An increase of 1% in the number of Sanitary and Phytosanitary (SPS) policies is associated with a 0.342% decrease in the volume of seaweed imports from Indonesia during the 2012–2022 period. This negative and significant relationship indicates that SPS policies have a strong influence in restricting Indonesian seaweed trade to these countries. This finding is similar to the study conducted by Sinta et al. (2018), which highlights that SPS policies—covering food safety and health standards—often serve as strict non-tariff barriers, particularly for food and fishery products such as seaweed. The decline in import volume reflects the challenges faced by Indonesian exporters in meeting these standards. Policymakers must therefore provide access to internationally recognized laboratories, training for exporters on food safety protocols, and support for compliance infrastructure to ensure that Indonesian seaweed consistently meets the requirements of importing countries.

#### **5. TBT Regulations in Destination Countries**

An increase of 1% in the number of Technical Barriers to Trade (TBT) policies is associated with a 0.325% decrease in the volume of seaweed imports from Indonesia during the 2012–2022 period. This negative and significant relationship demonstrates that TBT policies have a substantial impact in restricting Indonesian seaweed trade. TBT policies, such as technical standards, labeling requirements, and certification, often act as non-tariff barriers that increase compliance costs for exporters. The decline in import volume indicates that the increasing number of TBT policies enforced in export destination countries creates additional challenges for Indonesian exporters to meet these standards. To address this, the government should assist exporters through labeling standardization training, regulatory harmonization efforts, and financial support for certification costs, thereby enabling Indonesian seaweed products to gain wider market access.

## **CONCLUSION AND SUGGESTION**

### **Conclusion**

Indonesia is an archipelagic country rich in seaweed resources, making this commodity highly potential for further development. Seaweed has several advantages, including being economically valuable, abundant, and in high demand globally. The quality and quantity of Indonesian seaweed make it attractive to various major importing countries, including Chile, China, Denmark, Japan, Spain, and the United States. In addition to raw seaweed, processed and dried seaweed products have also been widely exported. Given the strategic importance of seaweed to Indonesia's marine economy, the emergence and tightening of Non-Tariff Measures (NTMs), particularly SPS and TBT regulations, must be anticipated and addressed. NTMs represent structural barriers that could limit the growth potential of seaweed exports if not managed properly. Considering Indonesia's strong position as one of the largest seaweed producers globally, policy interventions are urgently needed to ensure that this commodity continues to contribute to national economic growth. Statistical tests confirm that the most suitable estimation method used in this study is the Random Effect Model (REM). The regression results indicate that Indonesia's seaweed trade with six major destination

countries is influenced by multiple factors, including import price, population size, GDP per capita, and the presence of NTMs in the form of SPS and TBT regulations. Panel data regression analysis shows that both SPS and TBT have a negative impact on import demand for Indonesian seaweed, with SPS policies exerting a statistically significant effect. This highlights the need for Indonesian exporters to ensure full compliance with food safety and quality assurance protocols required by importing countries. Certification, quality improvement, and adoption of technological innovations are key measures needed to overcome these regulatory challenges. Cases of seaweed export rejection typically stem from non-compliance with destination country standards. These include contamination with heavy metals (e.g., mercury and cadmium), presence of pathogenic bacteria, excessive histamine levels, poor cold chain management, degradation in product quality, and the use of prohibited or excessive food additives. Therefore, strengthening regulatory compliance and improving production standards across the entire supply chain are crucial for safeguarding Indonesia's position in the global seaweed market.

### **Suggestion**

To address the trade barriers posed by SPS and TBT regulations, the Indonesian government should prioritize the establishment of internationally accredited laboratories in major seaweed-producing regions, enabling exporters to comply with safety and quality standards. A national seaweed quality assurance system should also be developed, including standardized grading, post-harvest handling protocols, and exporter training programs to reduce rejection rates. In addition, policies should support the industrialization of seaweed through incentives for downstream processing industries, focusing on high-value products like carrageenan and agar. The creation of a compliance support unit under KKP or the Ministry of Trade would assist exporters by providing technical guidance and regulatory updates aligned with destination country requirements. Strategic market research is also essential, particularly in high-income countries where rising GDP per capita reduces raw seaweed demand. Exporters should be encouraged to shift toward value-added products that meet evolving consumer preferences. On the policy front, trade diplomacy should aim to harmonize standards and simplify compliance procedures through bilateral agreements. For future research, the use of more detailed data—such as firm-level exports or disaggregated seaweed categories—is recommended. Incorporating higher-frequency SPS/TBT policy data, certification timelines, and rejection statistics would improve analytical precision and provide deeper insights into the operational impacts of NTMs on seaweed exports.

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