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ARTICLE

The Global Pepper Value Chain: A Geographic Scope Analysis of Indonesia's Pepper Exports under Comparative Advantage and Importer Non-Tariff Measures

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ABSTRACT

Developing economies often participate in global value chains primarily through low-value-added upstream activities, while downstream processing rents accrue disproportionately to higher-income hubs. Indonesia is a case study of a developing country that is the largest producer of pepper, but still operates in the upstream segment. This study tests the hypothesis that export performance is increasingly governed by non-price market-access mechanisms, particularly non-tariff measures (NTMs) imposed by importers, rather than by export prices. Using a gravity model and panel data for 2014–2022 across fourteen major importing countries, we map the geographic reach of Indonesia's pepper exports and identify their key determinants. The empirical results demonstrate high explanatory power, with the model achieving an R-squared value of 0.85, indicating that the selected variables ac-

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curately capture the determinants of trade flows. The estimates show that exporter and importer economic size, economic distance, real exchange rates, revealed comparative advantage, and importer NTMs significantly shape export flows. In contrast, export prices are not robust predictors of export performance. This study contributes to the GVC and trade literature by providing empirical evidence that regulatory barriers and compliance-based competitiveness function as gatekeeping forces that condition market access and constrain upgrading opportunities for primary producers. The policy implication is the need to strengthen the capacity of the post-harvest industry, establish consistent quality standards, and implement upgrading strategies that can shift the export orientation from quantity to quality, making it competitive in the global value chain.

Keywords: Global Value Chain; Pepper Exports; Gravity Model; Non-Tariff Measures; Revealed Comparative Advantage

1. Introduction

The global spice market shows prospective growth, projected to increase from 17.48 billion USD in 2025 to 26.22 billion USD in 2035, with a Compound Annual Growth Rate (CAGR) of 4.14%[1]. This upward trend indicates strong expansion opportunities within the spice industry. The growth of the global spice market is driven by the use of spices to enhance food flavor and aroma, the diversification of culinary practices, and the rising consumption of ethnic cuisines. The market continues to expand in line with increasing consumer preferences for incorporating spices into daily diets, particularly within the context of culinary globalization[2]. Moreover, the sensory attributes of spices, such as their distinctive aroma profiles, further stimulate global demand[2]. The growing international interest in authentic cuisines and the adoption of exotic flavors encourage producers to supply high-quality spice products that consistently comply with international standards.

Pepper (Piper nigrum), widely known as the "*King of Spices*", holds a distinctive position among spice commodities as the most traded spice globally[3] and one of the oldest export commodities in international trade[3–5]. Its historical role and continued economic relevance make pepper a strategic commodity with enduring influence in global market dynamics. Pepper remains an important export commodity for producing countries such as Indonesia, serving as a key contributor to international trade[6]. Trademap data[7] show that Indonesia ranks as the second-largest global exporter of pepper (300,730,000 USD in 2024), following Vietnam (996,077,000 USD in 2024). In the long run, Indonesia is projected to maintain a positive net export position for pepper[8]. Previous studies highlight the competitiveness of International markets, with Wardani and Sunyigono[9] reporting a strong Revealed Comparative Advantage (RCA) relative to India, and Mahdi and Suprehatin[10] further showing high price and expenditure sensitivity of demand. Consequently, pepper contributes significantly to Indonesia's foreign exchange earnings and export performance[11,12]. Pepper cultivation plays a crucial role in Indonesia, significantly contributing to foreign exchange revenues and supporting the livelihoods of rural populations, which largely consist of smallholder farmers. Most production originates from smallholder plantations (97%), while large private estates account for 3%[8]. Recent advances in cultivation and technology, including the use of nanoparticles and biochar-based fertilizers, nutrient recovery techniques, and digital tools for predicting crop prices or early detection of pest diseases, have the potential to increase crop yields, reduce production costs, and mitigate supply chain risks. Several studies report promising economic and technological outcomes in resource recovery, advanced material applications, and biowaste valorization[13–17]. In addition, recent literature emphasizes the role of circular economy principles, global value chain dynamics, and agricultural capacity building in supporting sustainable development[18–20].

The bargaining power of Indonesian pepper farmers tends to be weak due to ineffective governance structures, which create uncertainty in supply chains, limit

farmers' access to market information, and hinder their ability to negotiate better prices. Inefficient governance often results in unequal distribution of profits among actors in the supply chain. Farmers, who operate at the upstream level, frequently lack adequate information on market prices and consumer demand, forcing them to sell to intermediaries at lower prices, thereby diminishing their bargaining position [20,21]. Low pepper prices directly affect farmers' welfare and reduce their motivation to maintain pepper crops optimally [22,23].

Participation in global value chains (GVCs) has important implications for poverty reduction in rural areas of developing countries, as it has the potential to increase incomes and create employment opportunities [23]. However, most smallholders in developing countries encounter various constraints that limit their ability to engage competitively in GVCs, raising concerns that these producers remain excluded from key growth opportunities. Common constraints faced by farmers in competing within national and international markets include limited market access, lack of training, weak coordination and collaboration, and insufficient access to finance [24].

A global value chain structure refers to an internationally distributed network of production activities where various stages of a product's production are carried out in different countries to capitalize on the cost advantages and expertise of each location. This structure encompasses several key components, including raw material suppliers, manufacturing processes, assembly, distribution, and marketing, each of which can be located in different countries depending on its strategic factors. Value chain analysis describes the full set of activities undertaken by firms and workers to bring a product from conception to final consumption and beyond. It examines labor inputs, technology, standards, regulations, products, processes, and markets within specific industries and locations, thereby offering a holistic perspective of an industry from both top-down and bottom-up approaches [25]. This underscores the importance of analyzing the pepper value chain, as pepper is an export commodity that requires a holistic analytical approach. The involvement of pepper in global production and trade networks positions it as a connector between producing countries in tropical regions and consumer markets worldwide. From a geographical perspective, the pepper trade exhibits distinct patterns of exchange between production areas in developing countries and demand centers in high-income economies. These spatial patterns shape value chain governance, influencing the distribution of economic benefits, relationships among actors, and competitive dynamics in international markets [26,27].

Mahutga [28] emphasizes that the geographic scope dimension must be considered in GVC analysis, as it explains the extent to which production processes and inter-firm relationships extend beyond national borders. Through the concept of the spatialization of global value chains, various studies [28–30] illustrate the degree of global interconnectedness within value chains. This geographical dispersion is shaped not only by governance structures among actors but also by the spatial distribution of economic activities within the international production system. Kano et al. [31] add that contemporary global business activities tend to be organizationally fragmented and geographically dispersed, reflecting increasingly interconnected global production.

The intrinsic relationship between geographic coverage and value chain upgrading in global value chains is that geographic coverage involves spatial proximity and strong innovation networks, potentially supporting increased production capacity and value position in GVCs. However, coverage that is too broad and geographically fragmented can limit the potential for local value enhancement and create dependency on distant partners. Furthermore, ecological and social factors also shape the dynamics of upgrading in the context of geographic coverage [20,31–35].

The GVC analytical framework proposed by Gereffi and Fernandez-Stark [29] and Hernández and Pedersen [30] positions geographic scope as a dimension that explains the spatial distribution of economic activities at local, regional, and global levels. Value chain mapping identifies stages of production from design to final consumption and the countries that perform these functions, thus revealing that the extent to which production, trade, and innovation are dispersed across countries. Previous research has shown that the degree of global-

ization varies across industries; high-tech sectors, such as electronics, tend to have strong global chains, while the agriculture and food sectors are more regional [35,36]. These differences reflect global economic integration and determine a country's position within the international production system.

The growing global industry, supported by advances in transportation and communication, allows production activities to be dispersed based on regional comparative advantages. Countries that focus on raw material exports generally achieve lower value-added than countries engaged in high-value processing, design, or distribution [25]. Developing countries typically focus on primary production, while developed countries tend to dominate functions that generate higher economic value. Spatial value chain analysis is often conducted by identifying the locations of key firms and assessing each country's contribution through data on exports and industrial activity. Agustina et al. [37] highlighted that Indonesia's participation in GVCs lags due to low domestic value added.

Not all value chains are global; many develop regional patterns as interregional economic cooperation increases [25]. Therefore, geographic scope is important for understanding the distribution of economic activity, regional and global integration, and their impact on export performance and a country's position. In the context of pepper, this understanding explains the spatial reach of its value chain, Indonesia's position in the international market, and strategies for increasing export competitiveness, in line with Sustainable Development Goals (SDG), particularly Goal 17, which emphasizes increasing exports from developing countries.

The involvement of Indonesian pepper exports to various destination countries is analyzed using a gravity model, focusing on competitiveness and non-tariff barriers in the global value chain. Conceptually, the volume or value of Indonesian pepper exports to destination countries is expected to increase along with the growing economic size of importing countries, as reflected in the GDP of destination countries, and the strengthening of Indonesia's supply capacity, as proxied by Indonesia's GDP. Trade fractions, reflected by economic distance, can hinder pepper exports because they represent transportation costs, information costs, and cross-border transaction risks. The real exchange rate is also a factor, where the depreciation of the Rupiah against trading partner currencies is generally expected to increase export price competitiveness, thereby boosting pepper export performance. From a price perspective, Indonesian pepper export prices are seen as influencing demand in destination countries. This study uses the Revealed Comparative Advantage (RCA) variable as a key indicator of competitiveness, so a higher RCA is expected to correlate with increased exports. The intensity of the application of Non-Tariff Measures (NTMs) in importing countries is an important indicator that has a hindering effect because it increases compliance costs and technical requirements that must be met by exporters. Thus, the relationship between these variables forms the basis of the hypothesis that Indonesian pepper exports are driven by market size and competitiveness, but have the potential to be held back by the implementation of NTMs in destination countries.

2. Materials and Methods

2.1. Data and Variable

The data used in this study consist of secondary data for the period 2014–2022, collected from various sources (**Table 1**). The type of pepper examined is whole peppercorns, as Trademap data [7] indicates that whole pepper (97%) is exported in significantly larger quantities than processed pepper. Specifically, the study employs the 6-digit Harmonized System (HS) code HS 090411 (Pepper of the Piper genus, crushed or ground). This research analyzes pepper as an aggregate commodity, as international trade data do not differentiate between white and black pepper. Fourteen export destination countries are included in the analysis: Vietnam, the United States, Singapore, India, Germany, China, the Netherlands, Japan, France, Malaysia, South Korea, Italy, Hong Kong, and the United Arab Emirates. These countries represent Indonesia's major pepper importers and re-exporters to global markets.

Table 1. Type of data and data source.

Type of Data	Data Source
Volume of Indonesia's pepper exports to importing countries	Trademap: https://www.trademap.org/Index.aspx
Gross domestic product (GDP) of Indonesia's export destination countries in year	World Bank: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD
Indonesia's GDP in year	World Bank: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD
Economic distance between Indonesia and importing country *j* in year	Centre for Prospective Studies and International Information (CEPII): https://www.cepii.fr/cepii/en/bdd_modele/bdd_modele_item.asp?id=6
Real exchange rate between Indonesia (*i*) and importing country (*j*) in year	World Bank: https://data.worldbank.org/indicator/PA.NUS.FCRF
Coverage ratio of Non-Tariff Measures (NTMs) on pepper products in year	World Trade Organization : World Trade Organization—Integrated Trade Intelligence Portal—Home page
Indonesia's pepper export price to destination countries in year	Trademap: https://www.trademap.org/Index.aspx
Revealed Comparative Advantage (RCA)	Trademap: https://www.trademap.org/Index.aspx

2.2. Data Analysis

The geographical analysis is based on an examination of global supply and demand conditions, conducted by assessing trade flows at each stage of the value chain. One of the key contributions of Global Value Chain (GVC) analysis is its ability to map shifts in the geographic scope of global industries [37,38]. The analysis of trade flows in this study employs the gravity model. This model is used to examine international trade patterns, identify the factors influencing trade flows, and formulate trade-related policy recommendations. The gravity model was first introduced by Leibenstein and Tinbergen [39] to explain international trade flows between countries. It has since been widely applied in empirical trade studies due to its simplicity and strong explanatory power. Frankel (1997) highlights three main reasons for its widespread use: robust empirical performance, improved theoretical foundations, and renewed interest among economists in the geography of trade, which has strengthened the model's relevance in trade analysis.

The basic structure of the gravity model is as follows:

$$T_{ij} = Y_i * Y_j / D_{ij} \quad (1)$$

Description:

T_{ij}—Bilateral trade flow between country *i* and country *j*;

Y_i and Y_j —National income of countries *i* and *j*, respectively, measured in terms of GDP;

D_{ij} —Distance between the capital cities of country *i* and country *j* (in kilometers).

The analysis of trade flows is conducted using the gravity model, which is specified by the following equation:

$$\begin{aligned} X_{ijt} =& \beta_1 \ln(GDPNT_{ijt}) + \beta_2 \ln(GDPIN_{ijt}) + \beta_3 \ln(DIST_{ijt}) + \beta_4 \ln(ER_{ijt}) \\ &+ \beta_5 \sqrt{CR\ NTM_{ijt}} + \beta_6 \ln(PEX_{ijt}) + \beta_7 \sqrt{RCA_{ijt}} + c_{ijt} + \varepsilon_{ijt} \end{aligned} \quad (2)$$

Description:

X_{ijt} = Indonesia's pepper exports from country *i* to importing country *j* in year *t*. Reflects Indonesia's export performance in the Global Pepper Value Chain across various geographic markets.

$GDPNT_{ijt}$ = GDP of the export destination country in year *t*. Proxy for market size and demand in importing countries, which is estimated to have a positive effect on exports.

$GDPIN_{ijt}$ = GDP of Indonesia in year *t*. Represents Indonesia's pepper production capacity and supply in the upstream value chain.

$DIST_{ijt}$ = Economic distance between Indonesia (*i*) and importing country *j* in year *t*. Depicts trade costs and geographic barriers, which

are expected to negatively impact exports.

ER_{ijt} = Real exchange rate bbetween Indonesia (*i*) and importing country *j* in year *t*. Measuring the price competitiveness of Indonesian pepper in the international market.

$CR\,NTM_{ijt}$ = Coverage ratio of Non-Tariff Measures (NTMs) applied to pepper products in year *t*. Indicates the level of non-tariff barriers in importing countries that could potentially limit Indonesian pepper exports.

PEX_{ijt} = Indonesia's pepper export price to destination country *j* in year *t* (US$/kg). This variable is used as a control variable to accommodate variations in nominal prices across countries and time.

RCA = Revealed Comparative Advantage. Measuring Indonesia's comparative advantage and competitive position in the global pepper trade.

$_{ijt}$ = Individual effect or fixed effect for entity *i.*

ε_{ijt} = Error term.

Coverage ratio analysis of Non-Tariff Measures (NTMs) using the following formula:

$$C_{ijt} = \cdots \left[\frac{\sum (D_{kt}\, V_{kt})}{\Sigma V_{kt}} \right] \times 100 \qquad (3)$$

D_{kt} = Dummy variable indicating the presence or absence of one or more non-tariff measures applied to product *k* in year *t.*

C_{ijt} = Coverage ratio of exporter *i* to importer *j* in year *t* (%).

V_{kt} = Value of product *k* accumulated over the total quantity imported in year *t.*

The performance of the proposed model is evaluated using the coefficient of determination (R^2). R^2 measures the proportion of variance in the dependent variable that can be explained by the independent variables in the model.

Mathematically, R^2 is defined as:

$$R^2 = 1 - \left[\sum (y_i - \hat{y}_i)^2 / \sum (y_i - \bar{y})^2 \right] \qquad (4)$$

where:

y_i: observed (actual) value;

$\hat{y}_i$: predicted value generated by the model;

$\bar{y}$: mean of the observed values;

n: number of observations.

The numerator $\Sigma(y_i - \hat{y}_i)^2$ represents the Sum of Squared Errors (SSE), while the denominator $\Sigma(y_i - \bar{y})^2$ represents the Total Sum of Squares (SST). The value of R^2 ranges between 0 and 1. A value closer to 1 indicates that the model has a higher explanatory power and better performance in explaining the variability of the dependent variable.

3. Results and Discussion

3.1. Geographical Distribution of Value-Creation Activities in the Global Pepper Chain

The geographic scope of the Global Value Chain (GVC) for pepper illustrates how production, processing, distribution, and consumption activities are dispersed across countries and regions. Pepper is one of the most strategic spice commodities, supported by an extensive global trade network and high demand from the food, pharmaceutical, and cosmetics industries.

The GVC analytical framework proposed by Gereffi and Fernandez-Stark[38,40] includes the upstream stage, which encompasses primary production activities that form the basis for value creation along the commodity chain. For pepper, these activities are concentrated in tropical countries with optimal agroclimatic conditions, such as temperature, humidity, and soil quality that support pepper cultivation. Globally, pepper production is relatively concentrated in developing countries in Asia, Africa, and Latin America (see **Figure 1**).

According to FAO[41], Vietnam is the world's largest producer, with a production volume of 257,427.1 t, almost double that of Brazil. This second-largest producer has a production volume of 126,548.0 t. Other producers include Burkina Faso (73,836.2 t), Indonesia (70,169.0 t), India (65,739.6 t), Iraq (48,584.6 t), Sri Lanka (45,166.0 t), Malaysia (40,675.3 t), China (34,131.2 t), Tajikistan (23,273.4 t), and Zimbabwe (23,123.5 t). This data indicates a concentration of primary production in countries with favorable climatic and soil conditions.

At the midstream stage, or advanced processing

and high-value-added activities, occur primarily in developed countries. Countries such as the United States, Germany, the Netherlands, and several Western European countries have sophisticated spice processing industries, including sterilization, high-quality milling, oleoresin extraction, and modern packaging. This geographic pattern indicates a shift in value creation from producing countries to developed countries with technological advantages, capital, and access to the global market.

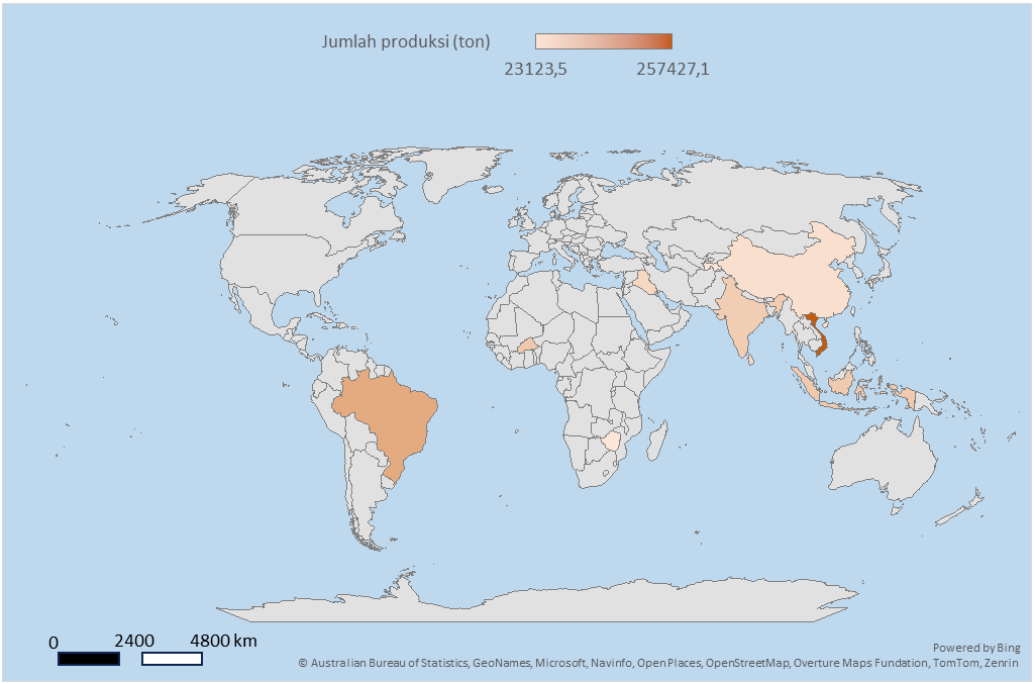

Figure 1. Global Pepper Producers.

Source: Authors' analysis based on Trade Map (2024).

In the downstream segment, global pepper consumption is concentrated in countries with high per-capita demand and advanced processed food industries. The United States, the United Kingdom, Japan, Canada, the Netherlands, France, Germany, Saudi Arabia, and Australia are the primary markets that absorb the world's pepper[7]. North America, Europe, and parts of East Asia—particularly Japan— are centers of global demand, where pepper is not only a household spice but also a key ingredient in the food, beverage, pharmaceutical, and cosmetics industries. The presence of multinational companies in these sectors further strengthens the dominance of developed countries in controlling distribution networks, marketing channels, and branding management.

This geographical distribution of activities highlights a spatial inequality in the creation and distribution of value added. Producing countries, including Indonesia, largely operate within low–value-added segments such as cultivation and raw material supply, while importing and processing countries dominate high–value activities, including advanced processing, product development, international marketing, and brand management. This pattern aligns with the smile curve in Global Value Chains (GVCs), where the highest value creation occurs in pre-production (e.g., design and technology) and post-production stages (e.g., branding and global distribution), while primary production generates relatively low value.

3.2. Geographical Distribution and Value Capture of Indonesian Pepper in the Global Value Chain

Indonesia remains one of the world's largest pepper producers, with major production centers in Bangka Belitung, Lampung, West Kalimantan, and Sulawesi[41,42]. Pepper production is primarily carried out by smallholder farmers who rely on traditional, inher-

ited methods, resulting in relatively low productivity and inconsistent commodity quality. This weakens Indonesia's bargaining position in the global market due to its limited ability to meet international quality standards. This phenomenon aligns with Global Value Chain (GVC) literature, which shows that developing countries are often trapped in primary commodity production without the capacity for functional or technological upgrading. The map of Indonesia's geographic participation in the peer GVC, as shown in **Figure 2**, shows key production locations and global trade routes from upstream farmers to industrial players in consuming countries, providing the physical and economic context of Indonesia's role in the upstream value chain.

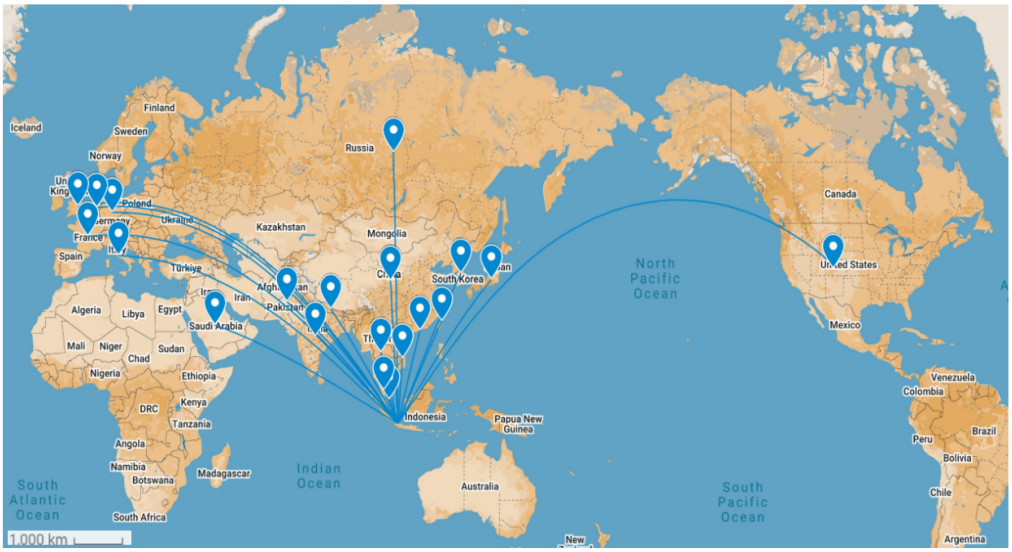

Figure 2. Geographical Scope of Indonesia's Pepper in the Global Value Chain.

Source: Authors' analysis based on Trade Map (2024).

Most of the global pepper value added is generated at the midstream and downstream stages, which are dominated by multinational companies and developed countries. Activities such as sterilization, high-quality milling, oleoresin extraction, spice formulation, branded packaging, and global distribution are carried out outside Indonesia. Vietnam serves as a strategic example, as the majority of Indonesian pepper is exported to Vietnam, further processed, and then resold to Europe and the United States at significantly higher prices. This trade flow pattern, detailed in **Figure 3**, illustrates the stages of sorting, grading, and value-added processing, illuminating how midstream and downstream processes influence Indonesia's ability to capture economic value.

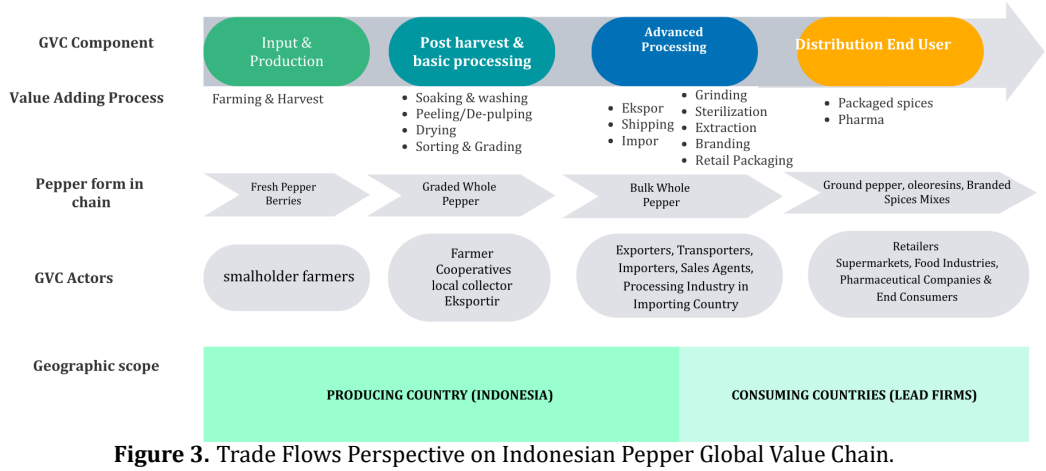

Figure 3. Trade Flows Perspective on Indonesian Pepper Global Value Chain.

Source: Author's analysis.

The mapping of the global value chain (GVC) in **Figure 3** provides a conceptual foundation for the trade flow analysis using the gravity model. The geographic scope illustrated in the chain represents the physical and economic distance that pepper travels from upstream smallholder farmers in Indonesia to downstream lead firms in consuming countries. Furthermore, the value-adding processes, such as sorting and grading, are critical for meeting the Non-Tariff Measures (NTM) imposed by importing nations. By examining trade flows at each stage from whole pepper to advanced derivatives like oleoresins. This study utilizes the gravity model to identify the determinants that allow Indonesia to expand its presence across the global industry scope.

At the global distribution stage, Indonesia's position as a price taker becomes increasingly apparent. Flexibility to influence international prices is limited, while high-value-added products, such as branded pepper powder, oleoresin extracts for the pharmaceutical industry, and functional spices, are still produced domestically in small quantities. Indonesia's pepper trade pattern exhibits a combination of South-South and North-South trends, with the majority of exports directed to developing countries such as Vietnam, India, and China, which not only act as consumers but also serve as processing and re-export hubs. Final consumption remains dominated by developed markets, such as the United States and EU Member States, underscoring Indonesia's strong strategic position in terms of production quantity but weaknesses in technology, innovation, and branding.

In the context of GVC upgrading, Indonesia's participation is limited primarily to process upgrading and has not yet achieved significant functional upgrading. Domestic initiatives, such as the development of ground pepper and small-scale branded products, are emerging, but their contribution to national export performance remains marginal. To increase its role and add value in the global supply chain, Indonesia needs to strengthen its capacity in sterilization, milling, and oleoresin extraction technologies, as well as the development of high-value processed products in functional foods and pharmaceuticals. Furthermore, strengthening quality certification systems (ISO, HACCP, organic), protecting geographical indications, and developing national pepper brands can enhance competitiveness and expand control over high-value segments of the global value chain.

Participation in GVCs does not automatically improve the welfare of producing countries without a comprehensive upgrading strategy. Therefore, Indonesia's primary challenge is not simply to expand its involvement in the global value chain, but to transform its role from a mere supplier of raw materials to a producer and owner of value-added products. This transformation is crucial to reducing dependence on volatile raw commodity markets. The structure of Indonesia's pepper GVC is primarily characterized by a South-South trade pattern, with primary exports to developing countries. However, North-South elements remain present, as final consumption occurs in developed markets, as reflected in **Figures 2** and **3**.

3.3. Factors Determining Indonesia's Pepper Trade Flows

Analyzing these factors within the GVC framework enables an assessment of how international trade policies, particularly non-tariff measures such as quality standards, SPS/TBT requirements, and traceability systems, shape the flow of Indonesia's pepper trade. Indonesia is an example of a developing country and a producer of raw materials. The results of the model selection test show a *p*-value of 0.000 for the Chow Test, 0.040 for the Hausman Test, and 0.002 for the LM Test. These results indicate that the Fixed Effect model is more appropriate than the Common Effect and Random Effect models. The Breusch-Pagan test analysis to determine the effects in the Fixed Effect model shows a *p*-value of 0.002 for the individual effect and 0.515 for the time effect. This indicates that correlations between countries have a significant influence on the dependent variable, while variations between years are significant. Thus, the Fixed Effect model with individual effects was selected as the final model. This indicates that differences in fixed characteristics between countries are the main factor influencing the analysis results. The estimation results are presented in **Table 2**.

The panel regression demonstrates strong overall performance, as evidenced by the goodness-of-fit indicators. The model yields a statistically significant F-

statistic probability and an R-squared value of 0.853. The results further indicate that, out of the seven independent variables included in the model, all are statistically significant at the 1%, 5%, or 10% levels, except for the export price variable. This suggests that price fluctuations did not directly influence Indonesia's pepper export volume during the study period.

With the c_i values presented in **Table 3**.

Table 2. Estimation of Indonesia's Pepper Export Flow Model to Major Destination Countries.

Variable	Coefficient	*t*-Stat	Prob.
GDP of destination country	1.5199×10^{7}**	2.285	0.033
Indonesia's GDP	-1.5211×10^{7}**	−2.286	0.033
Economic distance	$1.5212E \times 10^{7}$**	2.285	0.033
Exchane rate	$-2.9620E \times 10^{4}$*	−2.076	0.050
Non-Tariff Measure Coverage Ratio (CR NTM)	-3.5710×10^{3}***	−5.620	0.000
Export Price	2.2374×10^{3}	1.412	0.173
Revealed Comparative Advantage (RCA)	1.2306×10^{3}***	8.756	0.000
Weighted Statistics			
R-squared	0.853		
Adjusted R-squared	0.714		
F-statistic (*p*-value)	17.476*** (0.000)		

Source: Authors developed.
Note: ***) significant at the 1% level; **) significant at the 5% level.

Table 3. c_i Values.

Country	c_i	Country	c_i
Netherlands	−141,712,187.1	Germany	−141,519,759.3
China	−129,852,362.9	Korea	−129,881,216
France	−141,994,636.5	Malaysia	−107,168,175.1
Hong Kong	−133,434,746.7	Singapore	−102,915,218.5
India	−129,112,415.6	United arab emirate	−138,637,226.7
Italy	−135,048,294	USA	−146,957,267.6
Japan	−131,331,407.9	Vietnam	−121,476,913

Source: Author's computation.

Within the Global Pepper Value Chain (GVC) framework, empirical results indicate that the GDP of destination countries has a positive and significant effect at the 5% level on Indonesian pepper exports. This finding suggests that economic growth in importing countries strengthens final demand in the global value chain, both through increased household consumption and demand for the food processing industry. Consistent with Yarasevika et al. [43] and Tresliyana Suryana et al. [44], increased purchasing power in destination countries expands opportunities for Indonesia's integration into the pepper GVC, particularly in markets with more established demand and higher added value.

Conversely, Indonesia's GDP has a negative and significant effect at the 5% level, reflecting the pressure of domestic demand on export supply. From a GVC perspective, this finding suggests that domestic economic growth has not been fully accompanied by sufficient expansion of production capacity to simultaneously support domestic consumption and exports. As a result, some pepper supply is absorbed by the domestic market, limiting Indonesia's involvement in the global pepper value chain. This finding is consistent with Yarasevika et al. [43].

The geographical dimension of the GVC is reflected in the positive and significant effect of economic distance at the 5% level. These results indicate that geographically more distant markets actually offer greater export opportunities for Indonesian pepper. In the context of the global value chain, this suggests that these countries have a high dependence on imports, limited domestic substitution, or specific preferences for Indonesian pepper. This finding supports Xing et al.'s (2023) argument that geographical distance is not always a barrier when a product has characteristics that match the needs of the target market.

Furthermore, the real exchange rate (IDR/USD) in 2022 showed a negative and significant effect at the 10% level, confirming that exchange rate appreciation weakens the competitiveness of Indonesian pepper in the

GVC. Relative price increases in international markets reduce Indonesia's ability to compete with other exporting countries. Exchange rate stability is crucial for maintaining Indonesia's continued participation in the global pepper value chain, in line with Yarasevika et al. [43], Azzahra et al. [45], and Rosi et al. [46].

The CR NTM variable, as a proxy for non-tariff measures from importing countries, showed a negative and highly significant effect at the 1% level. This indicates that non-tariff measures act as a primary filtering mechanism in the pepper GVC, limiting market access for exporting countries. Technical regulations, quality standards, and sanitary and phytosanitary requirements significantly reduce the geographic reach of Indonesian pepper exports. These barriers also provide opportunities to improve sustainability and circularity in the production process. By adapting pepper production and processing practices to environmental standards, utilizing waste into valuable products, and implementing resource efficiency, Indonesian producers can not only meet NTM requirements but also increase the added value of their products in the global market, in line with the principles of a circular economy in biowaste management [18] and technical economic optimization [18]. This finding aligns with Nasution [47] and Tresliyana Suryana et al. [44], who stated that non-tariff barriers (NTMs) are a major structural constraint in global agricultural commodity trade.

Revealed Comparative Advantage (RCA) has a positive and significant effect at the 1% level, indicating that comparative advantage is the main foundation of Indonesia's competitiveness in the global pepper GVC. The high RCA reflects Indonesia's production efficiency and specialization in pepper, which directly strengthens the country's ability to maintain and expand market share across geographic regions. These findings are supported by the findings of Rustiadini and Novianti [48] and Tresliyana Suryana et al. [44], who emphasize the central role of comparative advantage in deepening export integration into global value chains.

4. Conclusions

This study confirms that Indonesia's position in the global pepper value chain (GVC) has not shifted from its role as a raw material supplier. Based on the previous discussion, all of the study's main hypotheses are confirmed. The hypothesis regarding the positive influence of trading partner economic strength and comparative advantage is empirically proven. Non-tariff measures and currency appreciation are proven to be valid factors inhibiting exports in the gravity model used. However, price does not have a significant impact, indicating that the global pepper market has shifted from price competition to standards and quality-based competition. Indonesia's inability to move up to high-value-added activities is not simply a capital issue, but rather a result of a disconnect between local farmers' quality standards and increasingly stringent international regulatory expectations. Large export volumes without integrated processing technology actually strengthen Indonesia's dependence on middlemen countries that dominate the standardization process. Without a structural transformation that transforms pepper into an industrial product, Indonesia will remain in a low-margin position despite its natural comparative advantage. Strengthening advanced standardization infrastructure at the local level is necessary to overcome non-tariff measures, and conducting more aggressive trade diplomacy to ensure the harmonization of international standards is also crucial. As a developing country, synergy is necessary to enhance technical processing capacity and secure political support in trade negotiations, ensuring it is not merely a supplier of cheap raw materials in the global value chain. Further research is recommended to map the shift in pepper processing centers in Southeast Asia, identifying opportunities for regional (intra-ASEAN) collaboration to address technological dominance from developed countries. Despite its comprehensive approach, this study is limited by the use of aggregate pepper export data due to the lack of long-term disaggregated time series at the national level. Although white and black pepper occupy distinct niches within the global value chain (GVC), data constraints necessitated a unified analysis to maintain the statistical robustness of the gravity model. Consequently, the findings reflect general trade patterns rather than variety-specific dynamics. Future research using more granular data is recommended to explore the unique competitive advantages of each vari-

ety individually.

Author Contributions

Conceptualization, A.T.D., R.N., T.N. and S.; methodology and formal analysis, A.T.D., R.N., T.N. and S.; data collection, A.T.D.; writing—original draft preparation, A.T.D.; writing—review and editing, A.T.D., R.N., T.N. and S.; visualization, R.N., T.N. and S.; supervision, R.N., T.N. and S. All authors have read and approved the manuscript.

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Data Availability Statement

The data in this study were obtained from the following sources: https://trademap.org, https://data.worldbank.org, https://www.cepii.fr/CEPII/fr/welcome.asp, and https://www.wto.org.

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Conflicts of Interest

The authors declare no conflict of interest.

AI Use Statement

The authors used Gemini and Grammarly solely for grammar checking, sentence structure refinement, and improving the readability of the English text in this manuscript. The authors take full responsibility for all academic content, including all ideas, data, analyses, and conclusions presented herein. The use of AI was thoroughly reviewed and supervised by the authors.

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