EcceS:
Economics, Social, and Development Studies

Volume 13 Number 1, Ed:June, 2026: page:22-47
p-ISSN: 2407-6635 e-ISSN: 2580-5570
journal homepage: https://journal.uin-alauddin.ac.id/index.php/ecc/index

Industry Economic Determinants of Indonesia's Crude Palm Oil Exports: Evidence from the Moment Quantile Regression Approach

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(Article history) Received: 2026-04-16, Revised: 2026-05-18, Accepted: 2026-05-30, Available online: 2026-06-12

DOI: 10.24252/ecc.v7i1.13382,

Abstract

The rising global demand for crude palm oil (CPO) has strengthened Indonesia's role as a major exporter, yet its export performance remains heterogeneous across importing countries. This study examines how economic, demographic, environmental, institutional, and spatial factors in partner countries influence Indonesia's CPO exports across different export levels. Using panel data from 40 importing countries in Asia, the Pacific, and Africa, this research applies a moment quantile regression approach to capture distributional heterogeneity. The results show that population size and Free Trade Agreements consistently have positive and significant effects across quantiles, while land use change and geographical distance negatively affect exports. Gross domestic product and CO_2 emissions exhibit conditional effects, becoming more influential at higher export levels. These findings confirm that export determinants vary across trade intensity levels rather than being uniform. The study highlights the importance of external demand conditions and institutional frameworks in shaping Indonesia's CPO export performance, implying the need for targeted trade policies, sustainable production practices, and improved logistics to enhance competitiveness in global markets.

Keywords: Crude Palm Oil; Indonesia's Export; Importing Countries; Moment Panel Quantile.

1. Introduction

The global demand for agricultural commodities has intensified over the past decades, driven by population growth, rising incomes, and structural transformation in both developed and developing economies. Among these commodities, crude palm oil (CPO) has emerged as one of the most strategic and versatile products, widely used in food processing, cosmetics, and biofuel production (Kacaribu et al., 2025; Juang Yeo et al., 2020). As a result, international trade in CPO has expanded significantly, positioning it as a critical component of global

commodity markets and a key driver of export revenues for producing countries (Alhaji et al., 2024). Indonesia, as the world's largest producer and exporter of crude palm oil, plays a pivotal role in shaping global supply dynamics. The country's dominance in the CPO market is supported by favorable agro-climatic conditions, extensive plantation areas, and relatively low production costs (Khatiwada et al., 2021; Nabila et al., 2023). Over time, CPO exports have become a cornerstone of Indonesia's trade balance, contributing substantially to foreign exchange earnings and rural economic development (Rabbani and Parianom, 2026; Pradina and Adhitya, 2023). However, this dependence also exposes the sector to external shocks originating from international markets. Despite Indonesia's strong position, the performance of its CPO exports is not solely determined by domestic production capacity (Syahza, 2019). Instead, it is increasingly influenced by demand-side factors originating from importing countries. Economic conditions, industrial activity, population dynamics, and environmental considerations in importing countries can significantly shape their demand for CPO (Rahman et al., 2025; Hariyanti et al., 2024). Consequently, understanding the external determinants of Indonesia's CPO exports is essential for capturing the complexity of global trade interactions.

In recent years, the structure of global demand for CPO has undergone notable changes. Emerging economies in Asia and Africa have become increasingly important markets, driven by rapid industrialization and urbanization (Przybek, 2025). At the same time, traditional markets have experienced shifts in consumption patterns due to sustainability concerns, regulatory frameworks, and substitution effects with alternative oils (Palomba and Tedeschi, 2025; Duan et al., 2023). These evolving dynamics highlight the importance of examining export determinants from a multi-country perspective. Furthermore, the heterogeneity across importing countries suggests that the determinants of CPO exports may not be uniform (Fitrady et al., 2026). Countries differ in terms of economic scale, energy needs, industrial structure, and environmental policies. For instance, countries with expanding manufacturing sectors may exhibit higher demand for palm oil-based inputs (de Barros & Chimeli, 2025), while others may impose restrictions due to environmental considerations (Ikefuji & Ono, 2024). Such variations imply that aggregate analyses may overlook important distributional differences in export behavior.

Another critical aspect relates to the role of global environmental discourse, particularly concerning deforestation and carbon emissions associated with palm oil production. Increasing pressure from international stakeholders has led to stricter sustainability standards and trade regulations in several importing countries (Amer, 2023; Bae et al., 2022). These developments have introduced new layers of complexity into the export landscape, potentially altering demand patterns and market access for Indonesian CPO. Moreover, fluctuations in macroeconomic indicators such as income levels, population growth, and energy consumption in importing countries can directly influence their import capacity and preferences. Higher income levels may increase demand for processed goods that utilize palm oil, while population growth can drive consumption of basic commodities (Ayompe et al., 2021; Krishna and Kubitza, 2021). Similarly, energy demand, particularly in countries adopting biofuel policies, can create additional channels through which CPO demand expands (Acobta et al., 2025).

Despite the growing literature on commodity exports, existing studies largely emphasize aggregate export relationships or single-country analyses, which often overlook heterogeneity among importing countries. In addition, previous studies rarely examine how export determinants vary across different levels of export distribution, potentially concealing asymmetric effects across markets. Addressing these gaps, this study contributes to the literature in several important ways.

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Economics, Social, and Development Studies
Volume 13 Number 1, Ed:June, 2026: page:22-47
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First, this study shifts the analytical perspective from a conventional supply-side approach toward a demand-side framework by focusing on the economic characteristics of importing countries. Second, this research employs a multi-country panel dataset covering 40 importing countries across Asia, the Pacific, and Africa, enabling a broader comparative analysis of heterogeneous export demand patterns. Third, the study integrates economic, demographic, and environmental indicators simultaneously, providing a more comprehensive explanation of Indonesia's crude palm oil (CPO) export performance. Fourth, this study highlights distributional heterogeneity in export behavior, allowing the analysis to capture asymmetric responses across different export market conditions.

The findings of this study are expected to provide several important implications. First, the results may assist policymakers in identifying priority export destinations based on specific economic and environmental characteristics of importing countries. Second, this study can support the formulation of more adaptive and targeted export strategies in response to heterogeneous market conditions. Third, the research contributes to the empirical development of demand-oriented commodity trade analysis, particularly for developing countries dependent on primary commodity exports. Finally, the study may serve as a reference for future research examining asymmetric trade relationships and cross-country heterogeneity in international commodity markets.

2. Literature Review

2.1. GDP and Indonesia's CPO Export

The relationship between economic size and international trade is fundamentally grounded in classical and neoclassical trade theories, particularly the concept of comparative advantage and the gravity model of trade. The gravity framework posits that larger economies tend to engage in higher trade volumes due to greater purchasing power and industrial capacity. In the context of crude palm oil (CPO), importing countries with higher GDP are expected to exhibit stronger demand, as economic growth increases both consumption and industrial usage of palm oil-based products. This argument is supported by Narayan and Nguyen (2016) and Freeman and Lewis (2021), who demonstrate that GDP plays a central role in determining bilateral trade flows.

However, the deterministic role of GDP has been challenged by alternative perspectives emphasizing structural and institutional constraints. Dadakas, Kor and Fargher, (2020) argue that economic size alone may not guarantee higher trade flows, particularly in countries with limited trade openness or regulatory barriers. Similarly, Lypko (2022) highlights that income effects may be offset by domestic substitution policies or changing consumption patterns. These findings suggest that the influence of GDP on trade is conditional rather than universal.

From a structuralist perspective, developing countries such as Indonesia are highly dependent on demand conditions in larger economies. Studies by Mirzaye and Mohiuddin, (2025) and Ado et al., (2025) emphasize that fluctuations in GDP among importing countries significantly affect export performance, reinforcing asymmetric trade relationships. At the same time, Wang and Wang (2025) argue that domestic policies and institutional quality can moderate the impact of external demand, creating further complexity in the GDP–trade relationship. Synthesizing these perspectives, GDP can be understood as a key but conditional determinant of CPO exports, whose influence varies depending on economic structure, institutional context, and market integration.

H1: GDP of the importing country has a positive effect on Indonesia's CPO exports.

2.2. Population and Indonesia's CPO Exports

Population is widely recognized as a fundamental determinant of trade within the gravity model framework, representing market size and aggregate consumption potential. Larger populations imply higher demand for goods and services, including commodities such as CPO. Yu and Gu (2025) and Osuma and Nzimande (2024) emphasize that population expansion directly contributes to increased trade flows by enlarging domestic markets. Supporting this view, Lugo-Arias et al., (2024) argue that demographic growth is closely linked to rising consumption of processed food, cosmetics, and biofuels, all of which rely on palm oil as a key input. This aligns with demand-driven trade theories, which highlight the importance of consumption-side factors in shaping global commodity markets . However, opposing arguments suggest that population alone may not be sufficient to drive trade. Niri et al., (2024) note that institutional barriers, trade restrictions, and domestic production capacity can limit the translation of population size into import demand. Similarly, structural constraints in developing economies may weaken the expected positive relationship. Despite these limitations, most empirical studies consistently find a positive association between population and trade flows, indicating that demographic size remains a robust determinant of export demand.

H2: Population size has a positive effect on Indonesia's CPO exports.

2.3. CO2 Emissions and Indonesia's CPO Export

The role of environmental factors in international trade is increasingly explained through environmental economics and the Environmental Kuznets Curve (EKC) hypothesis. The EKC suggests that environmental degradation initially increases with economic growth before declining as countries adopt stricter environmental policies. In the context of CPO trade, CO_2 emissions can serve as a proxy for industrial activity, which is expected to increase demand for palm oil-based inputs. Wang et al., (2024) and Shahbaz (2019) provide empirical support for this relationship. From a demand-driven perspective, higher emissions often reflect greater industrialization, which in turn increases demand for raw materials such as CPO. This suggests a positive relationship between CO_2 emissions and trade flows.

Conversely, critics of the EKC hypothesis argue that environmental concerns may lead to stricter regulations and reduced demand for environmentally sensitive commodities. Ulucak and Bilgili (2018) and Destek et al., (2018) highlight that environmental awareness can alter consumption patterns or impose non-tariff barriers. Ye and Xue (2026) further emphasize that environmental regulations may reshape trade flows rather than reduce them. Synthesizing these competing views, CO_2 emissions are expected to have a conditional effect on CPO exports, reflecting the balance between industrial demand and environmental constraints.

H3: CO_2 emissions have a conditional effect on Indonesia's CPO exports.

2.4. Land Use Change and Indonesia's CPO Exports

Land use change represents a critical environmental factor in global commodity trade, particularly for palm oil, which is closely associated with deforestation and ecological degradation. Environmental economics literature suggests that increased land use change may trigger regulatory responses and reduce demand for environmentally sensitive commodities. Judijanto (2025) and Wu et al., (2025) emphasize the growing importance of sustainability standards in shaping trade patterns. Supporting this view, Wang (2024) and Brandi et al., (2020) argue that environmental regulations often act as non-tariff barriers, restricting imports

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from countries associated with unsustainable practices. This suggests a negative relationship between land use change and CPO exports. However, alternative perspectives argue that environmental pressures do not necessarily reduce trade but instead lead to adjustments in production and certification practices. Barati et al., (2023) highlight that sustainability standards may reshape trade flows without significantly reducing demand.

Despite this debate, the prevailing evidence suggests that environmental constraints associated with land use change tend to reduce trade intensity, particularly in environmentally sensitive markets.

H4: Land use change has a negative effect on Indonesia's CPO exports.

2.5. Free Trade Agreements (FTA) and Indonesia's CPO Exports

The role of Free Trade Agreements (FTA) in international trade is well established within institutional and gravity-based trade theories. FTAs reduce tariffs, improve market access, and facilitate trade flows by lowering transaction costs. Huang (2026) and Akram et al., (2024) highlight the importance of institutional arrangements in enhancing bilateral trade. From a demand-oriented perspective, FTAs create a more predictable and efficient trade environment, encouraging importing countries to increase their reliance on foreign commodities. Xiang and Zhao (2025) further argue that trade facilitation mechanisms are essential for sustaining large-scale trade relationships. However, some studies suggest that the effectiveness of FTAs depends on implementation and complementary policies. Baier et al., (2019) note that non-tariff barriers and regulatory differences may limit the benefits of trade agreements. The literature strongly supports the positive role of FTAs in promoting trade flows, particularly for commodities such as CPO.

H5: The existence of an FTA has a positive effect on Indonesia's CPO exports.

2.6. Geographical Distance and Indonesia's CPO Exports

Geographical distance is a central component of the gravity model, representing trade costs such as transportation, time delays, and information barriers. A greater distance is generally associated with lower trade volumes, as emphasized by Reviane et al., (2025) and Tiits et al., (2024). This negative relationship is further supported by demand-side trade theories, which highlight the importance of accessibility and connectivity in shaping trade flows. William and Pham 2020) argue that logistical efficiency is a key determinant of trade intensity, particularly in global commodity markets. Nevertheless, advancements in transportation and trade facilitation may reduce the impact of distance. Choi et al., (2019) suggest that technological progress and institutional arrangements can partially offset spatial barriers. Despite these developments, empirical evidence consistently shows that distance remains a significant constraint in international trade, particularly for bulk commodities such as palm oil.

H6: Geographical distance has a negative effect on Indonesia's CPO exports.

Figure 1 illustrates the research framework that links importing-country characteristics to Indonesia's CPO export performance. The framework emphasizes that export outcomes are shaped by a combination of economic capacity, demographic dynamics, environmental pressures, and trade-related factors. By structuring these relationships into a unified model, the study provides a clear basis for empirically testing how each determinant contributes to variations in export performance, thereby paving the way for the formulation of testable hypotheses.

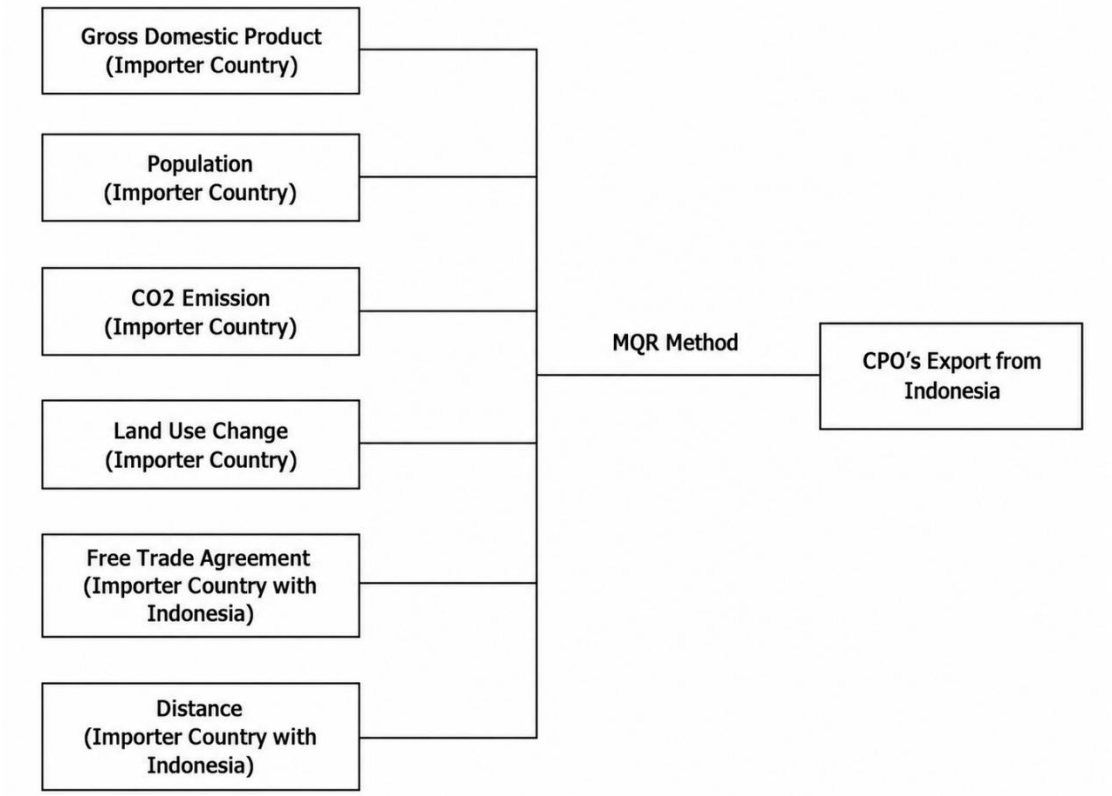

Figure 1: Research Framework

3. Data and Methodology

3.1 Data description

This study utilizes a bilateral panel dataset covering palm oil trade flows from Indonesia's CPO exports to 40 importing countries across Asia, Oceania, and Africa over the period 1995–2023. The unit of observation is Indonesia as exporter–importer year triplet, allowing for a comprehensive analysis of trade patterns in the palm oil industry over time and across regions, resulting in a total 1160 country-year observations. The dependent variable is the nominal value of bilateral exports of crude palm oil (CPO), which captures the intensity of trade relationships between Indonesia and country pairs. Zero trade flows are retained in the dataset to reflect the true structure of international trade and to avoid sample selection bias, which is particularly important in disaggregated commodity trade such as palm oil. The explanatory variables include standard gravity-type covariates as well as environmental indicators relevant to the palm oil industry.

Economic size is proxied by gross domestic product (GDP), while market size and labor availability are captured by total population for both exporting and importing countries. Environmental factors are represented by carbon dioxide (CO_2) emissions and land-use change indicators, which reflect environmental pressures associated with agricultural expansion and industrial activity; these variables are allowed to take zero or negative values to account for net land restoration or emission reductions in certain countries and periods. Bilateral trade costs are approximated by geographical distance, measured as the great-circle distance between the capital cities of exporter and importer countries. In addition, institutional trade integration is captured through a free trade agreement (FTA) dummy variable, which equals one if an FTA is in force between a country pair in a given year and zero otherwise. To explore heterogeneity

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in trade patterns, importing countries are further classified by income level and geographical region, and these classifications are incorporated directly into the dataset for subsample analysis without altering the underlying data structure. All macroeconomic and demographic data are obtained from internationally recognized sources to ensure consistency and comparability across countries and over time. Table 1 summarizes the variables used.

Table 1. Variable Used

Variables	Symbol	Measurement	Data Source
Exports of Palm Oil	CPO	The nominal value of bilateral exports of palm oil	WITS (World Integrated Trade Solution)
Gross Domestic Product	GDP	Gross domestic product (constant prices)	World Development Indicators (World Bank)
Population	POP	Total population	World Development Indicators (World Bank)
CO_2 Emissions	CO2	Carbon dioxide emissions (MT CO_2)	Global Carbon Budget
Land Use Changes	LUCE	Land-use change indicator (Ha)	Global Carbon Budget
Distance	DIST	Distance between capital cities of exporting and importing countries (kilometers)	CEPII
Free Trade Agreement	FTA	Dummy variable: 1 if an FTA is in force between two countries, 0 otherwise	World Trade Organization (WTO)

3.2 Methods

Before estimating the panel quantile regression model, several pre-estimation procedures are conducted to ensure the robustness and validity of the empirical results. First, cross-sectional dependence (CSD) tests are employed to examine whether shocks or disturbances in one country may affect other countries within the Asia-Pacific-Africa region, which is particularly relevant given the strong variables among countries in the sample. To detect the presence of CSD, this study applies three complementary approaches, namely the Pesaran CD test, the scaled Lagrange Multiplier (LM) test, and the Breusch–Pagan LM test, as specified in Equations (1) and (2) by Polcyn et al., (2023)

$$\mathrm{CSD} = \mathrm{T}\sum_{\mathrm{i}=1}^{\mathrm{N}-1}\sum_{\mathrm{j}=\mathrm{i}+1}^{\mathrm{N}.3}\rho_{\mathrm{ij}} \quad (1)$$

$$\mathrm{CSD} = \sqrt{\frac{3\mathrm{T}}{\mathrm{N}(\mathrm{N}-1)}}\sum_{\mathrm{i}=1}^{\mathrm{N}-1}\sum_{\mathrm{j}=\mathrm{i}+1}^{\mathrm{N}}\rho_{\mathrm{ij}} \quad (2)$$

The use of multiple CSD tests helps strengthen the reliability of the diagnostic process and reduces the possibility of biased estimations arising from cross-country dependence. Following the CSD examination, panel unit root testing is conducted using the Cross-sectionally Augmented IPS (CIPS) test based on the Cross-sectional Augmented Dickey–Fuller (CADF) framework, as presented in Equation (3), to verify the stationarity properties of the variables while accounting for cross-sectional dependence according to Paddu et al., (2024).

$$\mathrm{CIPS} = \mathrm{N}^{-1} \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{CADF} \quad (3)$$

Subsequently, the study performs model specification testing to determine the most appropriate panel structure with the fixed effect model. Based on the specification results and the nature of cross-country heterogeneity variables, the fixed effect model is selected as the preferred baseline specification before proceeding to the panel quantile regression estimation

In this study, the Panel Quantile Regression (PQR) approach is employed to examine the heterogeneous effects of variables. Unlike the conventional Ordinary Least Squares (OLS) estimator, which captures only the average effect of explanatory variables on the dependent variable, panel quantile regression enables the estimation of covariate effects across different points of the conditional distribution of the dependent variable. This approach has strong correlations because the effects of variables may vary across countries with low, medium, and high levels of Indonesia's CPO export. Therefore, PQR provides a more comprehensive understanding of the heterogeneous distributional dynamics across the panel of all countries.

$$\mathrm{y_{it}} = \mathrm{x_{it}}\beta + \alpha_{\mathrm{i}} + \mathrm{u_{it}}, \mathrm{i} = 1,2,\ldots,\mathrm{N}; \mathrm{t} = 1,2,\ldots,\mathrm{T} \quad (4)$$

where, i denotes the cross-sectional units (countries), t denotes the time dimension, $\mathrm{X_{it}}$ represents the vector of explanatory variables, β is the vector of slope coefficients and α_{i} captures the unobserved country-specific fixed effects and $\varepsilon_{\mathrm{it}}$ is the error term. The conditional quantile specification of the panel model is then formulated as:

$$\mathrm{Q_{yit}}(\tau_{\mathrm{j}}|\mathrm{x_{it}}, \alpha_{\mathrm{i}}) = \mathrm{x'_{it}}\beta(\tau_{\mathrm{j}}) + \alpha_{\mathrm{i}}, \mathrm{i} = 1,2,\ldots,\mathrm{N}; \mathrm{t} = 1,2,\ldots,\mathrm{T} \quad (5)$$

The quantile equation above assumes that the individual effects are fixed. For this equation, Koenker (2004) pointed out that when the number of individuals N is large and the number of observations contained by each individual is relatively small, appropriate contraction control of the individual effect can effectively reduce the variance α_{i} due to estimation. For the linear quantile loss function $\rho_{\mathrm{T}}(\mu)$, in order to maintain the linear characteristics of the objective function, 1_{i} linear penalty term can be considered, that is.

$$\mathrm{P}(\alpha) = \sum_{\mathrm{i}=1}^{\mathrm{n}} |\alpha_{\mathrm{i}}| \quad (6)$$

Based on the variables employed in this study, the empirical PQR model for CPO export is specified as

$$\mathrm{Q}_{\tau}(\mathrm{LnCPO})_{\mathrm{it}}|\mathrm{X_{it}}) = \beta_0(\tau) + \beta_1(\tau)\mathrm{LnGDP_{it}} + \beta_2(\tau)\mathrm{LnPOP_{it}} + \beta_3(\tau)\mathrm{LnCO2_{it}} + \beta_4(\tau)\mathrm{LUCE_{it}} + \beta_5(\tau)\mathrm{DIST_{it}} + \beta_6(\tau)\mathrm{FTA_{it}} + \varepsilon_{\mathrm{it}}(\tau) \quad (7)$$

Equations (7) represent the main analytical framework of this study, allowing the examination of how all variables influence the distribution of Indonesia's CPO export across different quantiles.

4. Results

4.1. Descriptive Statistics

Table 2 indicates substantial variation in Indonesia's CPO exports across importing countries, reflecting heterogeneous global demand. The distribution is highly dispersed and asymmetric, suggesting that a small number of countries dominate export volumes while others

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import relatively small amounts. Economic and demographic variables, such as income and population, also show considerable variation, indicating diverse demand conditions across countries. Environmental indicators exhibit noticeable heterogeneity, reflecting differences in environmental pressures and regulatory contexts among importing nations. In contrast, institutional and geographical variables are relatively more stable. Free Trade Agreements follow a binary pattern, while geographical distance captures consistent spatial differences across countries. These statistics highlight the diversity of the sample and support the need for a distribution-sensitive empirical approach.

Table 2. Summary statistic

Variables	Mean	Median	Minimum	Maximum	Std. Dev	Skewness	Obs
CPO	52325.93506	0	0	446500.14	334769.63	8.5773004	1160
GDP	$5.19974e^{11}$	72815642072	1953664804	$1.84881e^{13}$	$1.70415e^{12}$	6.5463135	1160
POP	100173809	23748176	298276	1450935791	276866078.7	4.0269034	1160
CO2	93.70644575	8.592971236	0.1231161	3322.054865	352.776045	6.5508661	1160
LUCE	5.97859131	0.319315	-99.1628	160.3614	18.2825968	1.47391225	1160
FTA	0.6	1	0	1	0.49010924	-0.4087771	1160
Dist	6712.4456	6977.118	886.1407	12569.47	2973.72165	-0.0255121	1160

To complement the descriptive statistics, Table 3 presents the correlation matrix among the variables. The results indicate that Indonesia's CPO exports are positively associated with key demand-side factors such as economic size, population, and environmental indicators, suggesting that countries with larger economies and higher consumption capacity tend to import more CPO. The correlations among independent variables show moderate relationships, particularly between macroeconomic and environmental factors, reflecting the linkage between economic growth, population, and emissions. In contrast, geographical distance exhibits a negative association with trade, highlighting the role of transport costs, while Free Trade Agreements show mixed relationships. The correlation matrix suggests diverse relationships among variables and supports the need for a distribution-sensitive empirical approach.

Table 3. Matrix Correlation

	LnCPO	LnGDP	LnPOP	LnCO2	LUCE	FTA	Dist
LnCPO	1.0000						
LnGDP	0.3801	1.0000					
LnPOP	0.4641	-0.4201	1.0000				
LnCO2	0.3386	0.5438	0.5260	1.0000			
LUCE	0.0302	0.0359	0.2021	-0.0338	1.0000		
FTA	0.3523	0.3983	0.3688	-0.3299	0.1383	1.0000	
Dist	-0.1399	-0.1311	-0.0305	-0.1041	-0.1652	-0.2938	1.0000

4.2. Pre-Estimation Diagnostic Test

The next step involves conducting a series of pre-estimation diagnostic tests to ensure the reliability and appropriateness of the empirical estimation strategy. These procedures are essential for validating the underlying assumptions of panel data analysis, particularly given the heterogeneous characteristics of importing countries and the potential interdependence across cross-sectional units.

As an initial diagnostic procedure, this study examines the presence of cross-sectional dependence (CSD) across the panel units. This step is crucial in the context of international trade, where economic linkages, regional integration, and global market dynamics may generate

correlated shocks among importing countries. Table 4 reports the results of the cross-sectional dependence tests using three complementary approaches: the Breusch–Pagan LM test, the Pesaran scaled LM test, and the Pesaran CD test. The results indicate that all variables exhibit strong and statistically significant cross-sectional dependence across all testing procedures. This finding suggests that shocks affecting one importing country—such as changes in economic activity, environmental conditions, or trade policies—are systematically correlated with those in other countries within the sample. Such interdependence is consistent with the integrated nature of global commodity markets, particularly for crude palm oil, where demand dynamics are influenced by shared economic trends and policy spillovers across regions, including Asia, the Pacific, and Africa.

From a methodological perspective, the presence of cross-sectional dependence has important implications for model selection and inference. Specifically, it indicates that first-generation panel techniques assuming cross-sectional independence may lead to biased and inconsistent estimates. Therefore, the evidence reported in Table 4 provides strong justification for employing second-generation panel unit root tests that explicitly account for cross-sectional correlations. This also supports the use of an estimation framework capable of accommodating heterogeneity and interdependence across countries.

Table 4. Cross-Sectional Dependency Test

Variables	Breusch-Pagan LM	Pesaran Scaled LM	Pesaran CD
LnCPO	21743.00***	550.7221***	148.9381***
LnGDP	20950.19***	510.6785***	144.1191***
LnPOP	20962.94***	511.0015***	137.9510***
LnCO2	16249.01***	391.6519***	115.7607***
LUCE	20347.00**	518.8429***	126.8303***

Notes: *** p < 0.01, **p < 0.05, *p < 0.1

Following the detection of cross-sectional dependence, the next diagnostic step is to examine the stationarity properties of the variables using a second-generation panel unit root approach. Given that cross-sectional dependence may invalidate conventional unit root tests, this study employs the Cross-sectionally Augmented IPS (CIPS) test, which is specifically designed to address cross-sectional correlations in panel data.

Table 5 presents the results of the CIPS unit root tests under three alternative specifications: no trend, constant, and constant with trend. The findings indicate that several variables are not stationary under the most restrictive specification but achieve stationarity when deterministic components are included. In particular, stationarity is more consistently observed under the constant and constant-with-trend specifications, suggesting that the variables exhibit heterogeneous stochastic processes and may be influenced by deterministic trends across countries. The results confirm that the variables satisfy the required stationarity conditions after accounting for cross-sectional dependence and deterministic components. This ensures that the dataset is suitable for subsequent panel estimation and reduces the risk of spurious regression results. Taken together, Tables 4 and 5 provide a coherent diagnostic framework: while Table 4 establishes the presence of interdependence among cross-sectional units, Table 5 verifies the time-series properties of the variables within that interdependent structure.

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Table 5. CIPS Unit Root Tests Results

Variables	No Trend	Constant	Constant and Trend
LnCPO	-2.96550*	-2.99551**	-3.18703***
LnGDP	-0.57820	-1.97351	-3.44472***
LnPOP	-1.12667	-2.21268**	-2.97462***
LnCO2	-0.46963	-2.42541**	-2.58826**
LUCE	-2.13827**	-2.94487***	-3.24853***

Notes: *** p < 0.01, **p < 0.05, *p < 0.1

As an additional pre-estimation step, this study employs the fixed effect model as a baseline panel specification prior to the main estimation. The fixed effect approach is particularly appropriate in this context as it controls for unobserved, time-invariant country-specific heterogeneity, such as structural differences in economic development, institutional settings, and trade infrastructure across importing countries.

Table 6 reports the fixed effect regression results across several model specifications. The findings reveal that key demand-side variables—including economic size, population, environmental indicators, and trade-related factors—exhibit varying degrees of statistical significance and directional consistency. Population and Free Trade Agreements consistently show positive and significant associations with Indonesia's CPO exports, indicating their robust role in shaping export demand. In contrast, land use change tends to exhibit a negative and significant relationship, reflecting the potential influence of environmental constraints on trade patterns. Other variables, such as GDP, CO_2 emissions, and geographical distance, display more heterogeneous effects across model specifications. This variation suggests that the relationships between these determinants and CPO exports may not be uniform across all observations, thereby indicating the presence of underlying heterogeneity in the data. Such findings reinforce the limitations of mean-based estimation approaches in capturing complex trade dynamics.

Table 6. Regression Results Fixed Effect Model

Variables	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	Support for Hypotheses
LnGDP	-0.1292		0.8874***	0.1825**	-0.0068	0.1322	-0.0361	Yes
	(0.2127)		(0.2036)	(0.0818)	(0.2128)	(0.236)	(0.2135)	
LnPOP	0.9588***	0.9105***		0.8999***	0.8594***	1.003***	0.8852***	Yes
	(0.0828)	(0.0766)		(0.0823)	(0.0823)	(0.084)	(0.0837)	
LnCO2	0.2883*	0.1653**	-0.1722		0.1931	0.1284	0.2052	No
	(0.1637)	(0.0633)	(0.1697)		(0.1661)	(0.1675)	(0.1661)	
LUCE	-0.0304***	-0.0201**	-0.0041	-0.0198**		-0.018**	-0.0173***	Yes
	(0.0062)	(0.0061)	(0.0063)	(0.0061)		(0.0062)	(0.0061)	
FTA	1.5331***	1.5496***	1.9851***	1.5319***	1.5193***		1.7782***	Yes
	(0.2519)	(0.2521)	(0.2661)	(0.2548)	(0.2568)		(0.2482)	
LnDist	-0.0131***	-0.0120**	-0.0539**	-0.0118**	0.01013**	-0.0183***		Yes
	(0.00381)	(0.0387)	(0.0403)	(0.0388)	(0.03855)			
Constant	10.8156**	13.127***	20.175***	17.16099**	12.388**	16.5752***	12.8355***	
	(4.5758)	(1.1945)	(4.4727)	(1.6782)	(4.59312)	(4.5731)	(4.5633)	
R-squared	0.3175	0.2706	0.1946	0.2695	0.2638	0.2471	0.2646	
Adjusted-R squared	0.2959	0.2674	0.1911	0.2663	0.2606	0.2437	0.2614	
F-statistic	87.7423	85.6459	55.7745	85.1562	82.7315	75.7196	83.0631	
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Obs	1160	1160	1160	1160	1160	1160	1160	

Notes: *** p < 0.01, **p < 0.05, *p < 0.1

From a model performance perspective, the fixed effect estimates demonstrate consistent goodness-of-fit across specifications, as indicated by the reported explanatory measures and statistically significant F-statistics. These results confirm the joint relevance of the included

regressors in explaining variations in Indonesia's CPO exports across importing countries. Consequently, the fixed effect model serves as a robust baseline for identifying average relationships before proceeding to a more distribution-sensitive estimation framework. The pre-estimation diagnostics provide strong empirical support for the chosen methodological approach. The presence of cross-sectional dependence, combined with heterogeneous stationarity properties and varying coefficient estimates, underscores the importance of employing an estimation technique capable of capturing distributional heterogeneity. These findings justify the subsequent use of a quantile-based regression framework to obtain a more comprehensive understanding of the determinants of Indonesia's CPO exports.

4.3. Estimation Result of Moment Quantile

This section presents the core empirical findings derived from the moment quantile regression framework. Unlike conventional mean-based estimations, this approach allows the analysis to capture how the effects of explanatory variables vary across different points of the conditional distribution of Indonesia's CPO exports. As such, the results provide a more comprehensive depiction of heterogeneous relationships across low-, medium-, and high-export regimes. Table 7 reports the estimated coefficients across multiple quantiles, offering insights into the distributional dynamics of export determinants.

The results reveal that the impact of economic size, proxied by GDP, is not uniform across the distribution of exports. At lower quantiles, the effect appears negligible, indicating that economic capacity in importing countries does not play a significant role in markets characterized by relatively low export volumes. However, as the analysis moves toward higher quantiles, the influence of GDP becomes more pronounced, suggesting that larger economies are more relevant in driving high-volume export relationships. This pattern highlights the increasing importance of economic scale in shaping export intensity at the upper tail of the distribution. Population consistently demonstrates a positive and statistically significant effect across most quantiles. This indicates that demographic size serves as a stable and robust determinant of CPO demand, regardless of the level of exports. The effect becomes more pronounced at higher quantiles, suggesting that countries with larger populations are not only more likely to import CPO but also tend to account for higher volumes of trade. This finding aligns with the role of population as a proxy for consumption demand in international trade.

The influence of CO_2 emissions exhibits a conditional and evolving pattern across quantiles. At lower levels of exports, the relationship appears weaker and less consistent, reflecting the limited role of environmental pressure in smaller markets. However, at higher quantiles, the effect becomes positive and statistically significant, indicating that countries with higher emissions—often associated with industrial activity tend to import larger volumes of CPO. This suggests that environmental indicators may indirectly capture industrial demand for palm oil-based inputs. Land use change consistently shows a negative effect across most quantiles, particularly in the middle and upper segments of the distribution. This implies that higher levels of land use change in importing countries are associated with reduced imports of Indonesian CPO. The negative relationship may reflect environmental constraints, regulatory pressures, or shifts toward alternative inputs, especially in countries with heightened awareness of sustainability issues. The consistency of this pattern across quantiles underscores the relevance of environmental considerations in shaping trade outcomes.

The role of Free Trade Agreements (FTA) is strongly positive and becomes increasingly significant at higher quantiles. While the effect is relatively modest in lower export regimes, it intensifies substantially as export volumes increase. This indicates that formal trade agreements are particularly effective in facilitating large-scale trade relationships, reducing barriers, and enhancing market access. The strengthening effect across quantiles highlights the importance

EcceS: Economics, Social, and Development Studies
Volume 13 Number 1, Ed:June, 2026: page:22-47
p-ISSN: 2407-6635 e-ISSN: 2580-5570
journal homepage: https://journal.uin-alauddin.ac.id/index.php/ecc/index

of institutional arrangements in sustaining high-volume export flows. Geographical distance exhibits a predominantly negative effect, consistent with theoretical expectations regarding trade costs. The negative association is more evident in higher quantiles, suggesting that distance becomes a more critical constraint for larger trade volumes. This pattern reflects the increasing importance of transportation costs and logistical efficiency in sustaining high levels of exports. In lower quantiles, the effect is weaker, indicating that distance may be less binding for smaller trade flows.

The results demonstrate substantial heterogeneity in the effects of key determinants across the distribution of CPO exports. Variables such as population and FTA exhibit relatively stable and consistently positive effects, while others, including GDP, CO_2 emissions, and distance, display varying influences depending on the export level. This heterogeneity confirms that the determinants of CPO exports cannot be fully understood through average effects alone and require a distribution-sensitive analytical approach. Furthermore, the transition from lower to higher quantiles reveals a structural shift in the drivers of export performance. In lower export regimes, the influence of explanatory variables is generally weaker and less consistent, suggesting that smaller markets may be influenced by factors not fully captured in the model. In contrast, higher quantiles exhibit stronger and more systematic relationships, indicating that large-scale export markets are more responsive to economic, environmental, and institutional determinants.

Table 7. Estimating Results From Moment Quantile Regression Framework

	LnGDP	LnPOP	LnCO2	LUCE	FTA	LnDist
0.1QR	0.0000 (0.0597)	0.0000 (0.0285)	0.0000 (0.0468)	0.0000 (0.0035)	0.0000 (0.0629)	0.0000 (0.00195)
0.2QR	0.0000 (0.0815)	0.0000 (0.0389)	0.0000 (0.0641)	0.0000 (0.0048)	0.0000 (0.0859)	0.0000 (0.00163)
0.3QR	0.0000 (0.10039)	0.0000 (0.04793)	0.0000 (0.07886)	0.0000 (0.00596)	0.0000 (0.10593)	0.0000 (0.00201)
0.4QR	0.0000 (0.1149)	0.0000 (0.05489)	0.0000 (0.09031)	0.0000 (0.00682)	0.0000 (0.21119)	0.0000 (0.00235)
0.5QR	0.0000 (0.12075)	0.0000 (0.05766)	0.0000 (0.09487)	0.0000 (0.00717)	0.0000 (0.12732)	0.0000 (0.00241)
0.6QR	-0.7166** (0.25956)	0.8571*** (0.12802)	0.86293*** (0.19042)	-0.02969** (0.01184)	2.94448*** (0.48942)	0.000206** (0.008181)
0.7QR	-0.9283** (0.30227)	0.9844*** (0.12979)	0.98281*** (0.22665)	- 0.03458*** (0.003836)	4.42343*** (0.61396)	0.00175** (0.00775)
0.8QR	-0.751596** (0.50835)	0.94618*** (0.174335)	0.74917** (0.33564)	-0.0228*** (0.00473)	5.68513*** (0.64909)	-0.00382** (0.00739)
0.9QR	1.9987*** (0.5483)	0.80924*** (0.22534)	1.14843** (0.50382)	0.00219** (0.00478)	3.80434** (1.323553)	- 0.00202*** (0.005195)

Notes: *** p < 0.01, **p < 0.05, *p < 0.1

It is important to note that all estimated coefficients at the lower quantiles (0.1–0.5) are reported as 0.0000. This outcome does not necessarily indicate the absence of relationships between the explanatory variables and CPO exports. Rather, it may reflect the characteristics of the data distribution and the estimation approach employed. In particular, the use of Koenker's penalized quantile regression can produce zero coefficients at lower quantiles when the

dependent variable exhibits a high concentration of zero or near-zero values. This phenomenon is common in datasets with limited variation in the lower tail, where the optimization process shrinks coefficients toward zero. Therefore, the results at higher quantiles (0.6–0.9) provide more informative insights into the determinants of Indonesia's CPO exports under varying market conditions.

These findings reinforce the importance of adopting a quantile-based framework to capture the complexity of international trade dynamics. The variation in coefficient magnitude and significance across quantiles provides clear evidence of non-linearity and heterogeneous effects, which would be obscured under traditional mean-based estimation techniques. Consequently, the results offer a more nuanced understanding of how different factors shape Indonesia's CPO exports across diverse market conditions.

The graphical representation in Figure 2 further complements the results presented in Table 7 by illustrating the evolution of coefficient estimates across quantiles. The figure visually confirms the presence of heterogeneous effects, as reflected in the varying slopes and confidence intervals of each explanatory variable. In particular, the upward trend observed for variables such as GDP, population, and FTA at higher quantiles highlights their increasing importance in high-export regimes, while the downward trend for land use change reinforces its negative influence. Moreover, the graphical patterns reveal smoother transitions and potential non-linearities that are less apparent in tabular form. The widening confidence bands at certain quantiles indicate varying levels of estimation uncertainty, particularly at the extremes of the distribution. Taken together, the visual and numerical results provide consistent evidence of distributional heterogeneity, strengthening the robustness of the empirical findings and offering a comprehensive interpretation of the determinants of Indonesia's CPO exports.

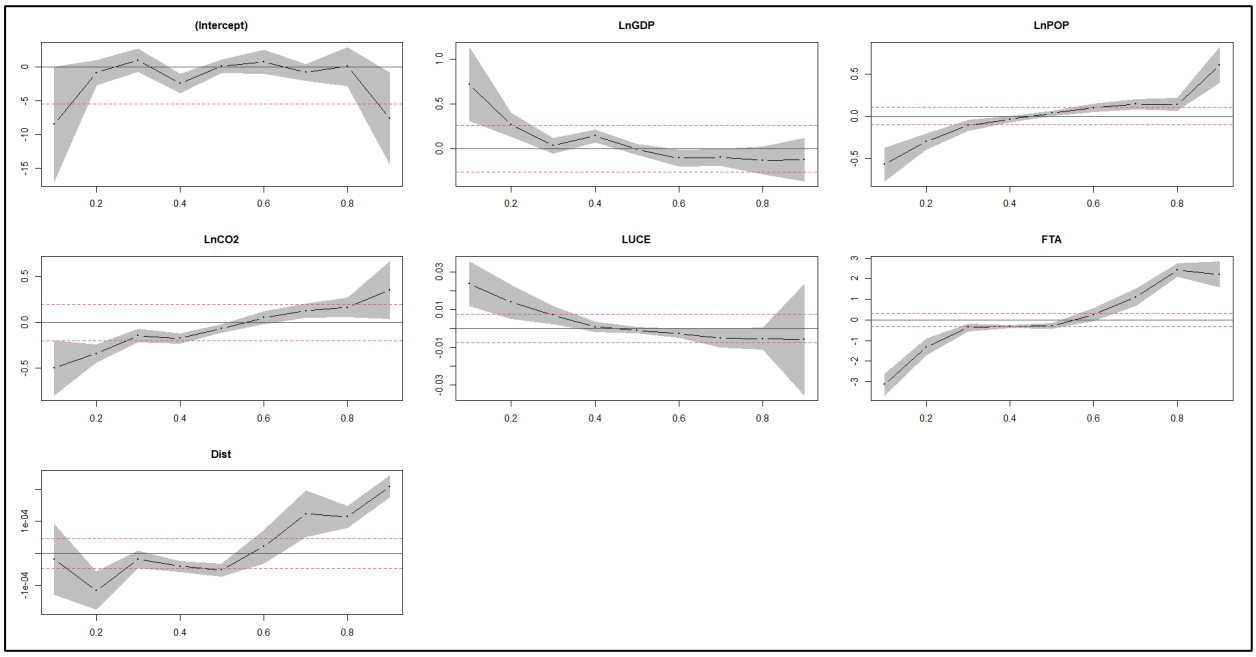

Figure 2: Moment Quantile Regression Framework for Model

5. Discussion

5.1. GDP and Indonesia's CPO Export

The empirical findings reveal that the effect of GDP on Indonesia's CPO exports is heterogeneous across quantiles, indicating that economic size does not exert a uniform

EcceS:
Economics, Social, and Development Studies
Volume 13 Number 1, Ed:June, 2026: page:22-47
p-ISSN: 2407-6635 e-ISSN: 2580-5570
journal homepage: https://journal.uin-alauddin.ac.id/index.php/ecc/index

influence across different export regimes. This result challenges the conventional assumption of a stable and linear relationship between economic capacity and trade flows, as typically suggested in classical and neoclassical trade theories. Instead, the findings suggest that the role of GDP becomes more relevant as export intensity increases, highlighting the importance of distribution-sensitive analysis in capturing such dynamics. From a theoretical perspective, the positive association between GDP and exports at higher quantiles is consistent with the gravity model of trade, which emphasizes economic size as a key determinant of bilateral trade flows. Larger economies tend to have greater purchasing power and more developed industrial sectors, which in turn increase demand for intermediate inputs such as crude palm oil. This aligns with the argument put forward by Narayan and Nguyen (2016) and Freeman and Lewis 2021), who emphasize that economic scale significantly enhances trade volume through increased consumption and production linkages.

However, the weak or insignificant relationship observed at lower quantiles suggests that economic size alone is insufficient to drive export demand in smaller markets. This finding supports the critique of traditional trade theories that overly rely on supply-side or aggregate demand explanations. As noted by Dadakas, Kor and Fargher (2020), trade relationships are often shaped by additional structural and institutional factors that may limit the role of income in less developed or smaller economies. In this context, GDP may not fully capture the complexity of demand behavior in lower-volume export destinations. Furthermore, the results resonate with structuralist and dependency perspectives, which argue that developing exporting countries are highly dependent on the economic conditions of major importing economies. The increasing significance of GDP at higher quantiles suggests that Indonesia's CPO exports are particularly influenced by large and economically advanced countries. This supports the argument of Mirzaye and Mohiuddin (2025) and Ado et al., (2025), who highlight the asymmetric nature of global trade relationships, where demand from dominant economies disproportionately shapes export performance.

On the other hand, the findings also provide partial support for the opposing view that domestic and institutional factors may moderate the impact of external demand. The absence of a strong GDP effect in lower quantiles indicates that factors such as trade policies, market access, and logistical constraints may play a more prominent role in smaller export markets. This is in line with Lypko (2022), who argue that institutional quality and policy frameworks can significantly influence trade outcomes beyond pure economic size. The heterogeneity observed across quantiles further suggests the presence of non-linear relationships between GDP and export performance. In particular, the transition from insignificant to significant effects across the distribution implies that the influence of economic size is conditional upon the scale of trade engagement. This finding reinforces the argument presented by Wang and Wang (2025), who emphasize that trade determinants may operate differently across varying levels of market integration and export intensity. The results support the hypothesis that GDP has a positive effect on Indonesia's CPO exports, but only under certain conditions, particularly in higher export regimes. This leads to a nuanced conclusion: while the gravity model provides a useful baseline, it does not fully capture the complexity of export dynamics across heterogeneous markets. The synthesis of these findings suggests that economic size is a critical but conditional determinant, whose influence becomes more pronounced in structurally integrated and high-demand markets.

5.2. Population and Indonesia's CPO Exports

The estimation results indicate that population exerts a consistently positive and statistically significant effect on Indonesia's CPO exports across nearly all quantiles. Unlike GDP, whose influence varies depending on the export regime, population demonstrates a more stable

and pervasive role in shaping export demand. This finding suggests that demographic size constitutes a fundamental driver of palm oil consumption, reflecting the essential and widespread use of CPO in both food and non-food industries across importing countries.

From a theoretical standpoint, this result strongly aligns with the gravity model of trade, which identifies population as a proxy for market size and consumption potential. Larger populations imply greater aggregate demand for basic commodities, including palm oil, which is widely utilized in household consumption and industrial processing. This is consistent with the arguments of Yu and Gu (2025) and Osuma and Nzimande (2024), who emphasize that demographic factors play a central role in determining trade flows by expanding consumption capacity and market scale. Moreover, the robustness of the population effect across quantiles supports demand-oriented trade theories that prioritize consumption-side dynamics over purely production-based explanations. As highlighted in the literature, importing countries' characteristics, particularly demographic pressures, are crucial in explaining variations in commodity trade. In the context of CPO, population growth increases demand for processed foods, cosmetics, and biofuel-related products, thereby reinforcing the structural linkage between demographic expansion and import demand.

The strengthening effect of population at higher quantiles further indicates that large-population countries tend to dominate high-volume export markets. This pattern reflects the cumulative impact of demographic size and industrial demand, where populous countries not only consume more but also support larger processing industries that rely on palm oil as an input. This observation is consistent with Lugo-Arias et al., (2024), who argue that the scale of domestic demand significantly influences the intensity of trade relationships in global commodity markets. However, alternative perspectives suggest that population alone may not fully determine trade outcomes, particularly when institutional and policy constraints are present. For instance, Niri et al., (2024) argue that regulatory frameworks, trade barriers, and domestic substitution policies can moderate the effect of demographic size on import demand. Despite these potential constraints, the empirical findings of this study indicate that the positive influence of population remains robust, suggesting that consumption-driven demand for CPO is relatively inelastic to such moderating factors.

In addition, the results provide indirect support for structuralist and dependency theories, which emphasize the reliance of exporting countries on external demand conditions. The consistent significance of population across quantiles suggests that Indonesia's CPO exports are closely tied to demographic dynamics in importing countries, reinforcing the notion of demand dependency in global commodity trade. The findings strongly support the hypothesis that population has a positive effect on Indonesia's CPO exports. The consistency of this relationship across the entire distribution of exports underscores the fundamental role of demographic factors as a stable and reliable determinant of trade demand. The synthesis of theoretical and empirical insights suggests that population not only captures market size but also reflects broader consumption dynamics that are central to understanding the global palm oil trade.

5.3. CO2 Emissions and Indonesia's CPO Export

The empirical results indicate that the effect of CO_2 emissions on Indonesia's CPO exports is conditional and varies across quantiles. This finding suggests that environmental pressure, as proxied by emissions, does not exert a uniform influence on export performance but instead depends on the level of trade intensity. Such a pattern reflects the dual role of CO_2 emissions as both an indicator of industrial activity and a proxy for environmental constraints, thereby introducing complexity into its relationship with commodity trade.

EcceS: Economics, Social, and Development Studies
Volume 13 Number 1, Ed:June, 2026: page:22-47
p-ISSN: 2407-6635 e-ISSN: 2580-5570
journal homepage: https://journal.uin-alauddin.ac.id/index.php/ecc/index

From a theoretical perspective, the positive association observed at higher quantiles is consistent with the argument that CO_2 emissions reflect the scale of industrialization and energy consumption in importing countries. Higher emissions are typically associated with more intensive manufacturing activities, which increase the demand for raw materials and intermediate inputs, including crude palm oil. This aligns with the demand-driven trade framework highlighted in the literature , where industrial expansion in importing countries plays a crucial role in shaping commodity imports. However, this positive relationship is not uniformly observed across all quantiles, which lends support to the environmental economics perspective, particularly the Environmental Kuznets Curve (EKC) hypothesis. According to this framework, the relationship between economic development and environmental degradation is non-linear, with higher-income countries potentially reducing their reliance on environmentally sensitive commodities over time. As discussed by Wang et al., (2024) and Shahbaz, (2019), this implies that environmental concerns may begin to offset demand for products such as palm oil, especially in more advanced economies.

Conversely, an alternative strand of literature challenges the notion that environmental pressures necessarily reduce demand for resource-intensive commodities. Studies such as Ulucak and Bilgili, (2018) and Destek, Ulucak and Dogan (2018) argue that environmental awareness may lead to adjustments in production processes rather than a decline in consumption. In this context, countries with high emissions may continue to import CPO but under stricter sustainability standards or through certified supply chains. This perspective helps explain why the positive effect of CO_2 emissions becomes more pronounced in higher export quantiles. The heterogeneous pattern observed in the results also reflects the interplay between environmental regulation and industrial demand. In lower quantiles, where export volumes are relatively small, environmental considerations may play a more dominant role, potentially limiting imports. In contrast, in higher quantiles, the scale of industrial demand may outweigh environmental constraints, leading to a stronger positive relationship. This finding highlights the importance of considering both regulatory and economic dimensions when analyzing the role of environmental variables in trade.

Furthermore, the results are consistent with structuralist arguments emphasizing the dependence of exporting countries on the industrial dynamics of importing nations. Countries with higher emissions often represent major industrial hubs, and their demand for inputs such as palm oil can significantly influence export performance. As noted by Ye and Xue (2026), such asymmetries reinforce the dependence of commodity exporters on the production structures of importing economies. The findings support the hypothesis that CO_2 emissions have a conditional effect on Indonesia's CPO exports. The relationship is neither strictly positive nor negative but varies across different segments of the export distribution. The synthesis of competing theoretical perspectives suggests that CO_2 emissions capture a complex interaction between industrial activity and environmental constraints, both of which are critical in shaping global palm oil trade dynamics.

5.4. Land Use Change and Indonesia's CPO Exports

The empirical results demonstrate that land use change exerts a predominantly negative effect on Indonesia's CPO exports across most quantiles, particularly in the middle and upper segments of the distribution. This indicates that environmental transformation in importing countries captured through land use dynamics plays a restrictive role in shaping palm oil demand. The consistency of this negative relationship across quantiles suggests that land use change is a structurally important determinant rather than a context-specific factor.

From a theoretical standpoint, this finding aligns with environmental economics literature,

which emphasizes the growing importance of sustainability concerns in global commodity trade. Land use change is often associated with deforestation, biodiversity loss, and ecological degradation, all of which have become central issues in international environmental discourse. As highlighted in the literature, increasing environmental awareness and regulatory pressure in importing countries can significantly influence trade patterns, particularly for commodities such as palm oil that are closely linked to land-intensive production processes. The negative association also provides empirical support for the Environmental Kuznets Curve (EKC) framework, which suggests that as countries reach higher levels of development, they tend to adopt stricter environmental standards. In this context, countries experiencing significant land use change may implement policies aimed at reducing environmental degradation, including restrictions on imports of commodities perceived as environmentally harmful. This is consistent with the arguments of Judijanto (2025) and Wu et al., (2025), who emphasize the role of environmental regulation in reshaping trade flows.

However, an alternative perspective suggests that environmental constraints do not necessarily reduce trade volumes but instead alter the structure of trade. As argued by Wang (2024) and Brandi et al., (2020), countries may continue to import resource-intensive commodities while imposing stricter sustainability requirements. In this regard, land use change may act as a proxy for regulatory tightening rather than a direct deterrent to imports. The persistent negative effect observed in this study suggests that, in the case of CPO, such regulatory pressures may indeed translate into reduced trade intensity. The stronger negative effect observed in higher quantiles further indicates that environmental considerations become more binding in large-scale trade relationships. High-volume importing countries are more likely to face international scrutiny and domestic pressure to adopt sustainable sourcing practices. This is supported by Barati et al., (2023), who argue that environmental regulations often function as non-tariff barriers that disproportionately affect large-scale trade flows.

In addition, the findings reflect the broader structural dynamics emphasized in dependency theory, where export performance is shaped by external constraints imposed by importing countries. The negative impact of land use change suggests that Indonesia's CPO exports are sensitive to environmental conditions and policy responses in destination markets. This reinforces the notion that commodity exporters must adapt to evolving global standards to maintain competitiveness. The results support the hypothesis that land use change has a negative effect on Indonesia's CPO exports. The consistency and magnitude of this relationship across quantiles highlight the increasing importance of environmental factors in international trade. The synthesis of theoretical perspectives suggests that land use change operates both as an environmental constraint and as a signal of regulatory intensity, thereby exerting a significant influence on the global palm oil market.

5.5. Free Trade Agreements (FTA) and Indonesia's CPO Exports

The empirical findings indicate that Free Trade Agreements (FTA) exert a positive and increasingly significant effect on Indonesia's CPO exports across quantiles. The magnitude of this effect becomes stronger at higher quantiles, suggesting that FTAs play a particularly important role in facilitating large-scale trade relationships. This pattern highlights the institutional dimension of international trade, where formal agreements reduce barriers and enhance market access, especially in high-volume export markets.

From a theoretical perspective, the positive impact of FTAs is consistent with both classical and modern trade theories, particularly the gravity model, which incorporates institutional variables as key determinants of bilateral trade flows. FTAs reduce tariffs, streamline customs procedures, and improve regulatory alignment, thereby lowering transaction costs and

EcceS:
Economics, Social, and Development Studies
Volume 13 Number 1, Ed:June, 2026: page:22-47
p-ISSN: 2407-6635 e-ISSN: 2580-5570
journal homepage: https://journal.uin-alauddin.ac.id/index.php/ecc/index

increasing trade efficiency. This aligns with the arguments of Huang (2026) and Akram et al., (2024), who emphasize that trade agreements significantly enhance trade volumes by reducing frictions between trading partners. Furthermore, the results support demand-driven trade frameworks that highlight the importance of institutional arrangements in shaping market access. As discussed in the literature, export performance is not only determined by economic size and consumption capacity but also by the presence of trade facilitation mechanisms. FTAs create a more predictable and stable trade environment, encouraging importing countries to increase their reliance on Indonesian CPO, particularly in established trade corridors.

The strengthening effect of FTAs at higher quantiles suggests that institutional factors become more critical as trade intensity increases. Large-volume export relationships require more efficient logistics, reduced uncertainty, and stronger policy coordination, all of which are facilitated by formal trade agreements. This finding is consistent with Xiang and Zhao (2025), who argue that institutional quality and trade facilitation are key drivers of sustained trade expansion in global commodity markets. However, an alternative strand of literature suggests that FTAs may not uniformly enhance trade flows, particularly when non-tariff barriers or domestic policies remain restrictive. Baier, Yotov and Zylkin (2019) argue that the effectiveness of trade agreements depends on their implementation and the broader institutional environment. In some cases, regulatory complexities or sustainability standards may limit the expected benefits of FTAs. Despite these concerns, the results of this study indicate that FTAs maintain a consistently positive influence, suggesting that their net effect remains strongly trade-enhancing in the context of CPO exports.

In addition, the findings can be interpreted within the framework of structuralist and dependency theories, which emphasize the role of external institutional arrangements in shaping export performance. The positive and robust effect of FTAs indicates that Indonesia's CPO exports are closely linked to formal trade relationships with importing countries. This reinforces the argument that access to international markets is mediated not only by economic factors but also by institutional connectivity and policy alignment. The results provide strong support for the hypothesis that the existence of an FTA positively affects Indonesia's CPO exports. The increasing magnitude of the effect across quantiles underscores the importance of trade agreements in sustaining high-volume export relationships. The synthesis of theoretical and empirical insights suggests that FTAs function as a critical enabler of trade, reducing barriers and enhancing integration within the global palm oil market.

5.6. Geographical Distance and Indonesia's CPO Exports

The empirical results indicate that geographical distance exerts a predominantly negative effect on Indonesia's CPO exports, with the magnitude of the effect becoming more pronounced at higher quantiles. This finding suggests that spatial separation and associated trade costs remain a critical constraint in international trade, particularly for large-volume export relationships. The increasing strength of this negative relationship across quantiles highlights the growing importance of logistical efficiency and transportation costs as export intensity rises.

From a theoretical standpoint, this result is strongly consistent with the gravity model of trade, which posits that distance serves as a proxy for trade resistance, including transportation costs, time delays, and information frictions. Greater geographical distance increases the cost of moving goods across borders, thereby reducing trade flows. This aligns with the findings of Reviane et al., (2025) and (Tiits et al., (2024), who emphasize that distance remains one of the most robust and persistent determinants of bilateral trade. Moreover, the negative effect of distance supports the demand-oriented framework discussed in the literature, where trade flows are shaped not only by economic size and consumption capacity but also by

accessibility and connectivity between trading partners. Even when importing countries exhibit strong demand for CPO, greater physical distance can limit trade intensity due to higher shipping costs and logistical challenges. This reinforces the importance of spatial factors in determining trade patterns.

The stronger negative effect observed at higher quantiles suggests that distance becomes increasingly binding in large-scale export markets. High-volume trade requires efficient supply chains, reliable transportation networks, and cost-effective logistics, all of which are more difficult to maintain over long distances. This finding is consistent with William and Pham (2020), who argue that logistical efficiency plays a crucial role in sustaining high-intensity trade relationships, particularly in global commodity markets. However, alternative perspectives suggest that the impact of distance may be mitigated by technological advancements and institutional arrangements. Improvements in transportation infrastructure, digitalization, and trade facilitation mechanisms can reduce the effective cost of distance. Additionally, the presence of FTAs and regional trade agreements may offset some of the barriers associated with spatial separation. As noted by Choi, Chung and Young (2019) institutional and technological factors can partially weaken the traditional negative effect of distance on trade.

Despite these mitigating factors, the empirical findings of this study indicate that distance continues to exert a significant and negative influence on Indonesia's CPO exports. This suggests that, while globalization and technological progress have reduced some trade frictions, physical distance remains a relevant constraint, particularly in the context of bulk commodities such as palm oil, which rely heavily on maritime transportation and large-scale logistics. The results support the hypothesis that geographical distance negatively affects Indonesia's CPO exports. The consistency of this relationship across quantiles, along with its increasing magnitude in higher export regimes, underscores the enduring importance of spatial factors in international trade. The synthesis of theoretical perspectives suggests that distance operates as a fundamental constraint that interacts with economic and institutional variables, shaping the structure and intensity of global palm oil trade.

6. Conclusion

This study examines the demand-side determinants of Indonesia's crude palm oil (CPO) exports by incorporating economic, demographic, environmental, institutional, and spatial factors across importing countries. The results reveal that the effects of these determinants are heterogeneous across the distribution of exports, indicating that export performance is not governed by uniform relationships. Population and Free Trade Agreements consistently exhibit positive and robust effects, while land use change and geographical distance show predominantly negative influences. Meanwhile, GDP and CO_2 emissions display conditional effects, becoming more relevant in higher export regimes. These findings confirm that Indonesia's CPO exports are shaped by a complex interplay of external demand conditions that vary across market segments.

Furthermore, the analysis highlights that high-volume export markets are more sensitive to economic scale, institutional arrangements, and logistical constraints, whereas lower-volume markets exhibit weaker and less consistent relationships. This suggests that the drivers of export performance differ significantly depending on the intensity of trade engagement. Overall, the study provides strong empirical evidence that demand-side characteristics of importing countries play a crucial and differentiated role in shaping Indonesia's CPO export dynamics.

7. Implication of research

The findings of this study carry important policy implications for enhancing Indonesia's

EcceS:
Economics, Social, and Development Studies
Volume 13 Number 1, Ed:June, 2026: page:22-47
p-ISSN: 2407-6635 e-ISSN: 2580-5570
journal homepage: https://journal.uin-alauddin.ac.id/index.php/ecc/index

position in the global CPO market. Given the strong and consistent role of population, policymakers should prioritize export strategies that target countries with large and growing populations. Expanding market access in densely populated regions, particularly in emerging economies across Asia and Africa, can help sustain long-term demand for Indonesian CPO. This strategy should be complemented by efforts to strengthen supply chain efficiency to meet increasing consumption needs. The positive impact of Free Trade Agreements underscores the importance of deepening and expanding trade cooperation with importing countries. The government should actively pursue new trade agreements and optimize existing ones to reduce tariffs, streamline export procedures, and enhance market certainty. Strengthening institutional ties through bilateral and regional agreements can significantly improve Indonesia's competitiveness, particularly in high-volume export markets.

The negative influence of land use change highlights the growing importance of environmental considerations in international trade. To address this challenge, Indonesia should reinforce its commitment to sustainable palm oil production by adopting stricter environmental standards, improving certification systems, and promoting transparency in supply chains. Enhancing sustainability credentials will not only mitigate trade restrictions but also improve acceptance in environmentally sensitive markets. The persistent negative effect of geographical distance suggests the need to improve trade logistics and connectivity. Investments in port infrastructure, shipping efficiency, and transportation networks are essential to reduce trade costs and overcome spatial barriers. In addition, strengthening partnerships with logistics providers and optimizing distribution channels can help expand Indonesia's reach to more distant markets.

8. Limitation of study and future research

Despite providing comprehensive insights, this study has several limitations. The analysis focuses primarily on demand-side factors from importing countries, without explicitly incorporating detailed supply-side dynamics or domestic policy variations within Indonesia. In addition, the measurement of environmental variables may not fully capture the complexity of sustainability regulations and their enforcement across countries. These limitations may restrict the scope of interpretation and suggest the need for further refinement in future research.

Future studies could extend this analysis by integrating both demand-side and supply-side factors within a unified framework to provide a more holistic understanding of CPO export dynamics. Incorporating more detailed measures of trade policy, sustainability standards, and institutional quality may also enhance the explanatory power of the model. Furthermore, exploring sector-specific demand channels, such as the biofuel and food industries, could provide deeper insights into the structural drivers of palm oil trade. Expanding the analysis to include dynamic modelling approaches and broader country coverage would further enrich the empirical literature on global commodity trade.

Authors' contributions and responsibilities

F.D. conceived and designed the study, conducted the investigation, supervised the project, and secured funding. F.D., M.S.R., and S.D. developed the methodology. S.D., and A.M. contributed to software development. F.D. and M.S.R. performed validation, while S.D. and A.M conducted the formal analysis. M.S.R. and S.D. curated the data. F.D., M.S.R., A.M., and S.D. prepared the original draft. F.D., M.S.R., S.D., and A.M. reviewed and edited the manuscript. F.D., A.M., and S.D. contributed to data visualization. All authors have read and approved the final version of the manuscript.

Acknowledgement

This research received no external funding

Competing interests

There are no potential conflicts of interest reported by the authors.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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