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PALM OIL TRADE AND PRODUCTION TOWARD ACHIEVING SUSTAINABLE DEVELOPMENT GOALS: A GLOBAL PANEL REGRESSION ANALYSIS

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Abstract

Palm oil is considered the most consumed edible oil in the world. An estimated 75% of overall palm oil production is destined for export with the total export value amounting to USD 28.2 billion in 2016. Currently, more research is needed to understand the associations between palm oil trade and production, and its environmental, social, and economic development aspects in accordance with the UN's Sustainable Development Goals (SDGs). This research explores the possible associations between the key SDG indicators and palm oil trade and production. Statistical tools are employed in order to analyze the relationships between the key SDG indicators and palm oil trade and production. Random and fixed effects regression models were developed to identify the impacts of key SDG indicators on palm oil trade and production. The results showed that a reduction in the number of undernourished people significantly enhances the growth of palm oil imports, exports and production. An increase in agricultural employment significantly increases palm oil imports, exports, and production. Furthermore, it was found that temperature has a significant negative impact on palm oil trade and production. Recommendations for policy development toward sustainable palm oil trade in moving toward achievement of the SDGs are addressed to ensure a future for the sustainable growth of palm oil trade and production.

Keywords: Palm oil, international trade, agricultural production, random effects, panel data, SDG

1. INTRODUCTION

Oil crops are considered the second most important source of food calories for humans after starch-rich foods (Murphy, 2018). Oil palm in particular is a valuable oil crop used all over the world, especially in the biofuel, agri-food, and body care sectors (Mutsaers, 2019). Palm oil accounts for approximately 60% of global oilseed exports (Carter et al., 2007) with demand projected to rise substantially in the future (Vijay et al., 2016). The economic advantage of palm oil compared to other vegetable seed oils is the significantly

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higher production per unit area (Khatun et al., 2017), which contributes to the livelihoods of many communities and economies. Production of palm oil also contributes to the achievement of the sustainable development goals (SDGs), namely, Goal 1 (No Poverty), Goal 2 (Zero Hunger), and Goal 8 (Decent Work and Economic Growth) (Ayompe et al., 2021).

With the increasing global demand, there has also been a rapid increase in the amount of palm oil produced and the total area cultivated in regions where oil palms are grown (Sayer et al., 2012). The demand growth is being triggered by China, India (Wilcove & Koh, 2010), and European Union countries (Kremen et al., 2012; Villela et al., 2014). By 2050, demand is forecast to be 240 million tonnes per year, nearly twice what it was in 2009 (Corley, 2009). However, traditional ways of oil palm plantation and expansion can be detrimental to environments, especially to tropical forests, as they cause deforestation (Lord & Clay, 2006; Brown & Jacobson, 2005), forest fragmentation (Reza, 2014), habitat loss (Brown & Jacobson, 2005), biodiversity loss (Freudmann et al., 2014), food chain disruption, soil property changes (Hamilton et al., 2016; Hartemink, 2005), water and air pollution (Lord & Clay, 2006; Comte et al., 2015), conversion of peatlands (Miettinen, 2012) and arable lands (Koh & Wilcove, 2009), increased carbon dioxide (CO_2) emissions (Inubushi et al., 2003; Hooijer et al., 2006), and increased forest fires (Hooijer et al., 2006), as well as increased subsidence and flood risk.

Mardiharini et al. (2021) reported that palm oil contributes to 15 goals/sub-goals of the SDGs with emphasis on its contribution to gender equality and the social inclusion of women by providing job opportunities for women as farmers, agronomic workers, and employees in palm plantations. On the other hand, Jamaludin et al. (2017) claimed that the palm oil industry receives criticism from various parties for the issue of sustainability. It is imperative to identify potential socioeconomic factors in promoting palm oil production and trading without compromising environments, as this sector increases in its contribution to several industries. Addressing the demand for palm oil and other palm oil-based products would mean utilizing more land to expand the operations or yield intensification. This requires analysis of factors associated with the volume and value of production, imports, and exports of these products. The ultimate goal of sustainable development would be achieved only if palm oil production technology does not bring harmful effects to ecosystems and the balance of global trade while improving the economic status of local farmers and processors.

Studies have shown that imposing certain policies can have negative impacts on a country's trade flows (Srisawasdi et. al., 2023). During commodity price spikes, countries usually implement export bans on agricultural products in order to protect domestic consumers from volatile prices (Deuss, 2017). Recently, Indonesia has begun a ban on palm oil exports (Reuters, 2022). Such action could threaten global food prices and put tremendous pressure on the increasing cooking oil prices worldwide. The ban from Indonesia is believed to be due to the domestic cooking oil shortages in Indonesia, which led to high domestic cooking oil prices triggering recent protests in the country (Reuters, 2022). Currently, Indonesia is by far the world's largest supplier of palm oil (OEC, 2022). Thus, depriving the global markets of the most widely consumed edible oil in the world will have a profound impact on the cost of food prices as palm oil is essential for cooking process in many countries.

Currently, Indonesia is by far the largest exporter of palm oil in the world, followed by Malaysia. In 2017, Indonesia exported around 29 million tons of palm oil with a total value of approximately USD 23 billion (UN Comtrade, 2018). As of 2021, the top five palm oil exporters in the world were Indonesia ($27.3.9B), Malaysia ($15B), Netherlands ($1.18B), Guatemala (715M), and Papua New Guinea ($706M). Figure 1 illustrates the percentage breakdown of top palm oil exporters in the world in terms of export value (in USD).

In terms of total palm oil production, Indonesia, Malaysia, and Thailand, are the top three palm oil producers in the world. The total palm oil production of these three countries is 44,500,000, 18,700,000 and 3,120,000 metric tons, respectively. The total production output of palm oil of these three producers accounts for over 90% of total palm oil production in the world. Palm oil production from the world's major producers is also expected to grow substantially in the projected future. Figure 2 illustrates the global palm oil production in comparison to Indonesia and Malaysia from 1995 to 2020, as well as the projected palm oil production in 2025.

Given this background, the present study

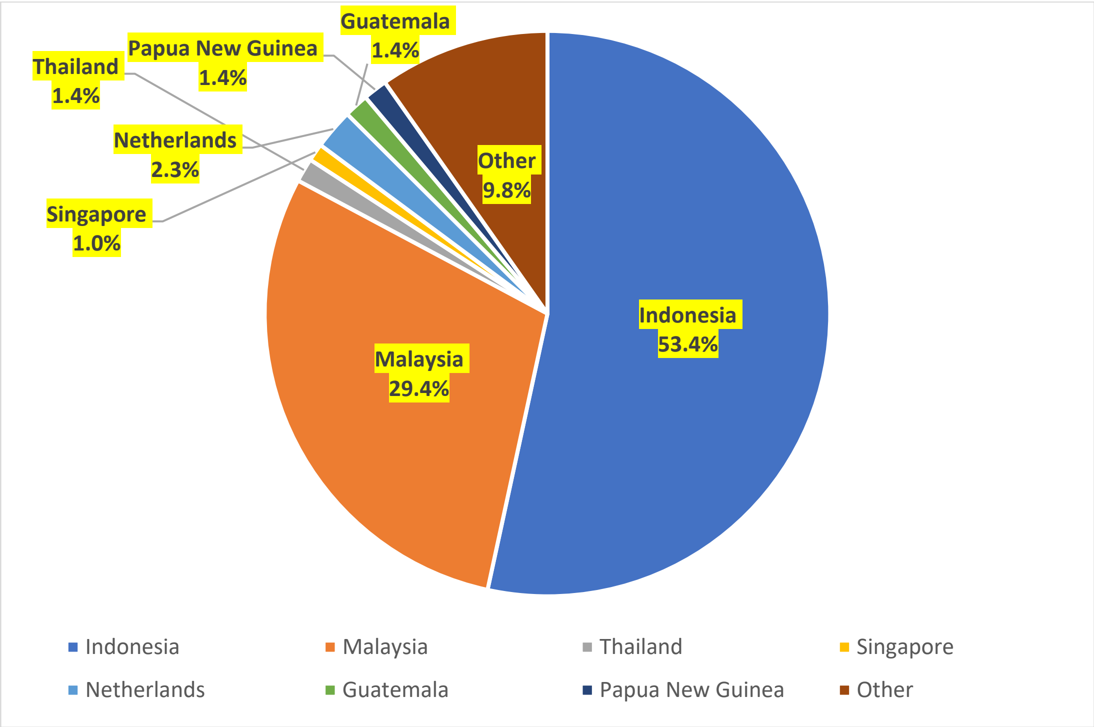

Figure 1 Percentage Breakdown of Palm Oil Exporters in 2021. (Source: OEC, 2022)

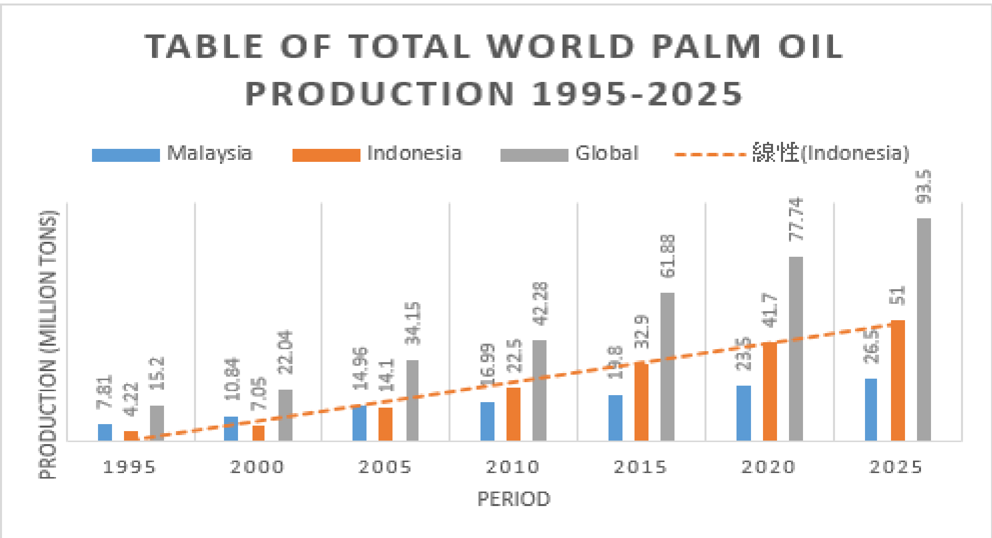

Figure 2 Total Palm Oil Production of Indonesia, Malaysia, and the World, from 1995 to 2025. (Source: Mielke, 2015)

aims to identify the key factors associated with palm oil trade flows and production. In particular, this research aims to investigate the impact of key SDG indicators on palm oil production and trade at the country level over the recent decade. Annual data of over 200 countries were collected from FAO, FAOSTAT, and World Bank. Panel regression methods, random and fixed effects, were employed to quantify the impacts of the key SDG indicators and socioeconomic variables on the production and trade of palm oil globally.

2. LITERATURE REVIEW

Due to rapid globalization, international trade has become a crucial factor in driving the economy of many countries around the globe, including Thailand (Dankaew and Silpcharu, 2020). The importance of the palm oil trade and production toward achieving multiple dimensions of the SDGs has been established in many studies (GAPKI, 2021). Empirical studies have found that the palm oil industry has contributed to the realization of 16 out of the total 17 goals of the SDGs. Regarding the economic dimension, the palm oil industry has helped to eradicate poverty (SDG 1), erase hunger and malnutrition, and develop inclusive food resilience (SDG 2), develop sustainable energy sources (SDG 7), promote economic growth and job opportunities (SDG 8), foster infrastructure, industrialization and innovation (SDG 9), reduce inequality (SDG 10) and promote sustainable consumption and production (SDG 12). Regarding social impacts, the palm oil industry has led to improved health and welfare of the people (SDG 3), improved quality of education (SDG 4), a reduced gap in gender inequality (SDG 5), promotion of clean water and sanitation (SDG 6), development of inclusive, safe, and sustainable, cities and communities (SDG 11) and promotion of peace and justice (SDG 16). Regarding the environment, the palm oil industry has helped to tackle climate change impacts (SDG 13), foster conservation and sustainable use of water (SDG 14), and protect biodiversity, land, and forest ecosystems (SDG 15) (GAPKI, 2021).

Several recent studies also identified the associations between palm oil production and trade flows on the SDGs. Mardiharini et al. (2021) reviewed the GESI framework performance in the palm oil sector using qualitative methods by collecting secondary data and conducting key informant interviews. They found that the palm oil industry can have a positive effect on gender equality and inclusivity for creating economically, socially, and environmentally sustainable palm oil supply chains and sectors. Mohd Hanafiah et al. (2021) reviewed articles related to palm oil and SDGs in the Malaysian palm oil context. They concluded that the health impact of palm oil is still unclear, as the benefits of the phytonutrients in palm oil seem to be offset by the high level of saturated fat (SDG 2 & 3). Regarding the economic impact, palm oil contributes to economic growth by alleviating poverty, ensuring food security, creating an alternative energy source and employment opportunities; however, these benefits come at the expense of human rights violations and inequities from palm oil production (SDG 1, 2, 8, 9, 10 and 12). Palm oil production causes an environmental impact by increasing greenhouse gas emissions, leading to a multitude of problems such as forest fires, annual trans-boundary haze, changes in microclimate, and loss of biodiversity (SDG 6, 13, 14 and 15).

Ayompe et al. (2021) conducted a thorough literature review on the direct and indirect impacts of palm oil trade. They found that most of the case studies were conducted in Indonesia and Malaysia which account for the majority of global palm oil production. The results show both negative and positive direct impacts on humans. Indirect impacts through ecosystem services were predominantly negative, as were the direct impacts. The most frequently studied negative impacts were conflicts, including housing conditions and land grabbing, while the most frequently studied positive impacts were income generation and employment. Saswattecha et al. (2017) examined the environmental sustainability of palm oil production in Thailand through four scenarios; (1) business-as-usual, (2) current-policy, (3) strong-growth and (4) green-development. The business-as-usual scenario indicates that negative environmental impacts may double. The current-policy scenario shows that current policy would lead to a considerable increase in the negative environmental impacts. The strong-growth scenario, is also not enough to avoid an increase in negative environmental impacts. However, the green-development scenario would considerably reduce negative environmental impacts. Meijaard et al. (2020) conducted an extensive review on the environmental impacts of palm oil in the context of achieving the SDGs, concluding that there has been little research into the impacts and trade-offs of other alternative vegetable oil crops and that greater research attention needs to be given to investigate the impacts of palm oil production compared to other alternative vegetable oil crops for a trade-off comparison at the global scale. There are a total of 17 SDGs according to the United Nations (Smerchuar et. al., 2020). Table 1 summarizes the 17 SDGs and their descriptions.

Following the review of the related literature, it is clear that there is a distinct connection between palm oil production and trade and the SDG indicators. However, there has been little research emphasizing the quantification of the effects of key SDG indicators on palm oil production and trade. Therefore, the main objective of this study aims to fill the current literature gap by analyzing the quantitative impacts of the key

Table 1 Details of the UN's 17 SDGs and Their Descriptions (source: UNDP).

No.	SDG	Description
1	No poverty	Eradicate all forms of poverty.
2	Zero hunger	Eradicate hunger, promote food security and sustainable agriculture.
3	Good health and well-being	Promote healthy well-being for all.
4	Quality education	Ensure quality education and lifelong learning for all.
5	Gender equality	End discrimination against all females.
6	Clean water and sanitation	Sustainable clean water management and promote sanitation for all.
7	Affordable and clean energy	Promote reliable, affordable and sustainable energy for all.
8	Decent work and economic growth	Promote sustainable economic growth and a productive and decent working environment for all.
9	Industry, innovation, and infrastructure	Ensure sustainable and inclusive infrastructure, industrialization and innovation.
10	Reduced inequalities	Ensure equalities within and between countries.
11	Sustainable cities and communities	Ensure sustainable, resilient and safe cities and human settlements.
12	Responsible consumption and production	Promote sustainable production and consumption for all countries.
13	Climate action	Combat climate change and mitigate its impacts.
14	Life below water	Ensure the sustainable use of oceans and marine resources.
15	Life on land	Protect and promote sustainable management of land ecosystems and forests, and combat desertification.
16	Peace, justice and strong institutions	Promote peaceful and sustainable societies and ensure justice for all.
17	Partnership for the goals	Strengthen and revitalize partnerships among countries for sustainable development.

SDG indicators on palm oil production and trade toward the achievement of sustainable palm oil trade and production on a global scale.

3. MATERIALS AND METHODS

3.1 Data Collection

Country-level annual panel data were collected from 200 countries. The data were recorded on a monthly basis covering January 2000 to December 2020. The collected data were classified into four major categories, namely trade, production, SDG indicators, and socioeconomic data. The trade and production values for the palm oil, SDG indicators, environmental, and economic indicators, were obtained from FAOSTAT database (FAOSTAT, 2022). Meanwhile, temperature data were obtained from the World Bank (World Bank, 2022).

3.2 Panel Data Modelling

The panel regression method is applicable when data are repeatedly observed on the same set of observation units over two or more time periods (Arellano, 2003). Panel regression models are useful in controlling for unobservable time-invariant heterogeneity that would otherwise cause severe estimation biases such as the endogeneity bias in estimated coefficients. This heterogeneity can be eliminated through differencing the variables over time, which is a major advantage of obtaining and analyzing panel data (Woodridge, 2010). There are two commonly used panel regression methods: the fixed effect (FE) model and the random effect (RE) model (Tsusaka and Otsuka, 2013ab). The FE model refers to models in which the individual means are fixed (non-random) as opposed to the RE model in which the individual means are not fixed over time (Ramsey and Schafer, 2002). However, the RE model is the more efficient model (i.e., the model with greater statistical power) than the FE model (Green, 2008). The RE model is a special case of the FE model, where the former can be adopted when the unobservable time-invariant individual-specific effects are uncorrelated with the independent variables (Greene, 2011). Another advantage of the RE model is that time-invariant independent variables can be included in the model; these are absorbed by the intercept in the case of FE models (Anitha et al., 2020).

To examine the impacts of key SDG indicators on palm oil trade flows, statistical analytical tools were used. First, a descriptive statistics analysis was carried out. The descriptive statistics analyses included the central tendency (arithmetic mean), measures of dispersion (standard deviation), and correlation analysis. A standard unit root test was then conducted, followed by the random effects and fixed effects regression. A unit root test is used to determine whether time series data is non-stationary and possesses unit root. If the time series data contains a unit root, then the data must first be differenced to render the data stationary. Lastly, the Variance Inflation Factor (VIF) was calculated to examine the potential multicollinearity between the independent variables. Variables with a VIF greater than 10 were removed from the model specification in order to eliminate any potential multicollinearity issue. Any observation unit with missing data for the dependent variables (palm oil import, export, and production value) was removed from the model. The statistical program used in this study was STATA/SE 16.1. Prior to running panel regression models, it is important to test the presence of unit roots. There are many methods for testing the presence of unit roots. In this study, the Augmented Dickey-Fuller (ADF) test (1981) was employed for testing the presence of unit roots. The ADF test has a null hypothesis stating that the panels contain unit roots. Therefore, rejecting the null hypothesis implies that there is no presence of unit roots in the panels.

In the current study, the random effects model was as expressed in Equation 1.

$$Y_{it} = \alpha + \beta X_{it} + U_i + \varepsilon_{it} \qquad \text{Eq. (1)}$$

where Y_{it} represents palm oil trade and production value for country i and year t, α represents the intercept, X_{it} represents the vector of the observed independent variables, β represents the vector of the coefficients for the independent variables, U_i represents the unobservable time-invariant country-specific effects, and ε_{it} represents the random error term.

The fixed effects (FE) regression method for panel data is typically applied in models with observation unit-specific fixed effects. It provides several advantages over the random effects method (Allison, 2009). The fixed effects method accounts for certain characteristics of an observation unit (a country in this case) that remain constant or unchanged over time. Generally, the fixed effects regression model can be expressed as shown in the following equation;

$$Y_{it} = \beta_1 X_{1,it} + \cdots + \beta_k X_{k.it} + \alpha_i + U_{it}$$

where i = 1, …, n and t = 1, …, T. α_i represents entity-specific intercepts that capture heterogeneities across entities, and U_i represents the unobservable country-specific effects.

3.3 Variables

This research aimed to investigate the impact of key SDG indicators on global palm oil trade flows. The variables included in the regression analyses were the key SDG

Table 2 Variables Used for Analyzing the Impact of Key SDG Indicators on Global Palm Oil Trade and Production

Variable	Definition	Source
Trade		
Palm oil imports	Total palm oil import value per country in thousands of US dollars	UN Comtrade, 2022
Palm oil exports	Total palm oil export value per country in thousands of US dollars	UN Comtrade, 2022
Land use		
Agricultural land use	Total land use for agricultural purposes (Hectares)	FAOSTAT, 2022
Employment		
Agricultural employment (Total)	Total employment in agriculture, forestry, and fishing, by status of employment (thousands of people)	FAOSTAT, 2022
SDG indicators		
Undernourished people	Number of undernourished people (millions)	FAOSTAT, 2022
Severe food insecurity	Population in severe food insecurity (thousands of people)	FAOSTAT, 2022
Agricultural productivity	Productivity of large-scale food producers (agricultural output per unit labor, PPP) (constant 2011 international $)	FAOSTAT, 2022
Plant genetic accessions stored	Plant genetic resource accessions stored ex situ (number)	FAOSTAT, 2022
Agricultural value added	Agricultural value added share of GDP (%)	FAOSTAT, 2022
Temperature		
Temperature	Average annual temperature in degrees Celsius	World Bank, 2022
GDP indicators		
GDP (US$)	Total value of country's GDP in US$	World Bank, 2022
GDP per capita (US$)	Value of country's GDP per capita in millions US$	World Bank, 2022

indicators related to the global production and trade of palm oil, which are critical to the development of the palm oil industry. The country-level imports, exports, and total production values were assigned as dependent variables. The independent variables were the key SDG indicators, which included the number of undernourished individuals in the population (SDG 1, SDG 2, SDG 3, SDG 6, SDG 10, SDG 12), population in severe food insecurity (SDG 1, SDG 2, SDG 3, SDG 12), agricultural productivity (SDG 1, SDG 8, SDG 12), agricultural value added (SDG 8, SDG 9, SDG 12), agricultural land use (SDG 8, SDG 9, SDG 11, SDG 13, SDG 15) and total agricultural employment (SDG 1, SDG 2, SDG 3, SDG 8, SDG 10, SDG 12). Additionally, the average annual temperature was added as the key control variable in the regression model, as temperature is a critical variable for palm oil production. Table 2 summarizes the details of the variables included in the study.

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics Analyses

Table 3 summarizes the descriptive statistics of the key variables related to the development of palm oil trade and production toward achieving SDGs.

According to Table 3, the arithmetic mean for palm oil imports, exports, and production were 171,922.86, 266,344.75, and 1,012,654.8 thousand USD, respectively. The maximum values for palm oil imports, exports and production were 9,711,038, 25,400,164 and 22,133,210 thousand USD, respectively. The standard deviation for palm oil imports, exports and production were 564,400.64, 1.774.772.9, and 3,575,313.1 thousand USD, respectively. For the key SDG indicators, the arithmetic average for the number of undernourished people, people with severe food insecurity, plant accessions stored, and agricultural value added were 4.98, 85.44, 28,463.42, and 12.13, respectively, while the standard deviations were 20.95, 291.57, 57,060.09 and 12.48, respectively. For the agricultural and key economic indicators, the arithmetic average for agricultural land use, temperature, GDP, and GDP per capita were 26,175.58 Hectares, 20.08 Celsius, 349,221.54 Million USD, and 12,259.16 USD, respectively. The maximum values for agricultural land use, temperature, GDP, and GDP per capita were 528.217.63, 29.38, 21,433,226 and 119,210, respectively, while the standard deviations were 670,080.35, 7.79, 1,424,943.8 and 17,772.38, respectively.

Table 3 Descriptive Statistics Results Containing the Arithmetic Mean, Standard Deviation, Minimum and Maximum Values of Key Variables.

Variable	Unit of measurement	Mean	Std. Dev.	Min	Max
Palm oil imports	Thousand USD	171,992.86	564,400.64	1	9,711,038
Palm oil exports	Thousand USD	266,344.75	1,774,772.9	0	25,400,164
Palm oil production	Thousand USD	1,012,654.8	3,575,313.1	167	22,133,210
Undernourished people	Per million	4.98	20.95	0	249.6
Severe food insecurity	Per thousand	85.44	291.57	0	4,299.9
Agricultural value added	% share of GDP	12.13	12.48	0	79.69
Agricultural land use	Hectares	26,175.58	67,080.35	0.4	528,217.63
Temperature	Degrees Celsius	20.08	7.79	-16.23	29.38
GDP	Million USD	349,221.54	1,424,943.8	13.279	21,433,226
GDP per capita (USD)	USD	12,259.16	17,772.38	86.187	119,210

Based on the descriptive statistics results, it can be interpreted that, on average, the palm oil export value is greater than the import value. Additionally, the standard deviation of palm oil exports is much greater than for imports. This means that the palm oil exports have greater dispersion than the imports. In terms of the key SDG indicators, on average, the number of undernourished people is shown to be significantly lower than the number of people with severe food insecurity (4.98 per million of the population vs 85.44 per thousand of the population). Thus, it is very important for developing countries to emphasize the maintenance of food security. In terms of key agricultural indicators, it is important to note that the average percentage share of agricultural value added is only 12.13% compared to the maximum of 79.69%. This means that many countries can increase the percentage share of agricultural value added, which can effectively boost the economy, especially for the agriculturally based economies.

The Pearson Correlation Coefficient (PPC) test was carried out in order to measure the linear correlation between the key variables. The PPC results (Table A1) showed that the correlation coefficients between the key dependent and independent variables were statistically significant. Palm oil imports, exports and production exhibited a significant correlation with the number of undernourished people, people with severe food insecurity, agricultural value added, employment in agriculture, agricultural land use, and temperature.

4.2. Panel Regression Analyses

The Augmented Dickey-Fuller (1981) unit root test was employed for testing the presence of unit roots prior to running the random and fixed effects regression models. The ADF results (Table A2) implied that no panels contained unit roots and were stationary at their base levels. Thus, there was no need to take the first difference for any variables in the panels.

A random effects panel regression technique was used to analyze the effects of the key SDG indicators on palm oil trade and production. The results of the random effects regression models are summarized in Table 4.

According to the random effects regression results shown in Table 4, the key SDG indicators that had statistically significant effects on imports, exports and the total

Table 4 Results of the Random Effects Regression Model

Variables	Model 1 Imports (SE)	Model 2 Exports (SE)	Model 3 Production (SE)
Number of undernourished (per one million people)	**-35,495.87***** (5,255.76)	**-9,605.11*** (5,313.8)	**-195,377.4***** (71,628.47)
Severe food insecurity (per one thousand people)	-57.92 (127.68)	27.73 (163.31)	53.72 (698.24)
Agricultural value added (% share of GDP)	2,479.43 (4,787.57)	-8,018.47 (18,282)	-24,681.2 (39,018.8)
Employment in agriculture (per one thousand people)	**66.82***** (6.01)	**15.94***** (6.05)	**503.78***** (52.79)
Agricultural land use (Hectare)	**2.94*** (1.68)	8.34 (7.01)	1.29 (13.81)
Temperature (Celsius)	-1,947.69 (5,282.96)	**-54,547.49***** (7,673)	**-100,652***** (17,542.89)
Constant	-14,935.17 (144,501.9)	143,611 (393,578.7)	1,924,374 (796,222)

Note: '***' = p-value < 0.01, '**' = p-value < 0.05, '*' = p-value < 0.1

production value of palm oil (one thousand USD) were the number of undernourished people (per million), employment in agriculture (per thousand), and agricultural land use (hectares). The coefficients for the number of undernourished people were negative across all three models. The units for the dependent variables were thousand USD, thus it can be interpreted that on average, an increase in the number of undernourished people has a significant negative effect on the imports, exports and production value of palm oil. More specifically, a unit increase in the number of undernourished people (per million) leads to a decrease in the values of total palm oil imports, exports, and production by 35,495.87, 9,605.11 and 195,377.4 thousand USD, respectively. Furthermore, it can be observed that the coefficients for the employment in agriculture variable showed significant positive effects across all three models. This can be interpreted as, on average, one unit increase in employment in agriculture (per thousand people) leads to an increase in the values of palm oil's imports, exports and production by 66.82, 15.94, and 503.78 thousand USD, respectively. Agricultural land use only shows a significant positive effect on palm oil's import value. It can be interpreted that a one hectare increase in agricultural land use increases palm oil's import value by 2.94 thousand USD. For the temperature variable, it can be observed that the coefficients for temperature showed significant negative effects on palm oil's export and production values. On average, an increase of 1 degree Celsius in the annual mean temperature leads to a decline in a country's palm oil export and production values by 54,547.49 and 100,652 thousand USD, respectively. Since temperature shows negative effects on palm oil production and exports, it can be interpreted that an increase is temperature is not ideal for fostering the growth of palm oil.

The fixed effects regression results are summarized in Table 5. The results show that the number of undernourished people has a significant negative marginal effect on palm oil imports (-90,536.46). Palm oil is highly associated with a reduced rate of undernourished people (Mohd Hanafiah, 2021). Therefore, it is likely that an increase in the rate of undernourished people can lead to a reduction in the demand to import palm oil. Employment in the agricultural workforce showed a significant positive marginal effect on palm oil imports and exports. Increasing

Table 5 Results of the Fixed Effects Regression Model

Variables	Model 1 Imports (SE)	Model 2 Exports (SE)	Model 3 Production (SE)
Number of undernourished (per one million people)	**-90,536.46***** (3,923.14)	-4,248.93 (4,519.28)	-11,980.69 (63,804.81)
Severe food insecurity (per one thousand people)	10.74 (122.07)	51.02 (140.11)	349.37 (540.92)
Agricultural value added (% share of GDP)	16,083.26 (12,694.6)	-12,720.11 (23,886.12)	-33,265.78 (41,939.51)
Employment in agriculture (per one thousand people)	**57.22***** (4.4)	**14.46***** (5.19)	-121.03 (102.89)
Agricultural land use (Hectare)	-14.15 (11.66)	28.16 (14.99)	**128.03***** (29.6)
Temperature (Celsius)	5,191.66 (4,546.99)	**-56,094.32***** (6,702.49)	**-144,658.5***** (14,312.16)
Constant	516,305 (317,961.4)	1,068,831 (500,572.6)	2,317,962 (1,104,435)

Note: '***' = p-value < 0.01, '**' = p-value < 0.05, '*' = p-value < 0.1

employment in agriculture can directly improve overall productivity in the agricultural sector (Zhao, 2022), thus boosting the trade flows of palm oil in the process. The agricultural land use variable showed a significant positive marginal effect on palm oil production (128.08). From this, it can be inferred that increasing agricultural land use (hectares) can lead to an increase in palm oil productivity. Lastly, the temperature coefficient showed a significant negative marginal effect on palm oil imports (-56,094.32) and palm oil production (-144,658.5). Therefore, countries that heavily rely on palm oil consumption should be aware that an increase in temperature may lead to a decrease in palm oil productivity.

5. CONCLUSION

This study focused on analyzing and quantifying the impacts of key SDG indicators on global palm oil trade flows and production. Random effects and fixed effects regressions were employed in this study. The results indicated that the number of undernourished people had statistically significant negative associations on palm oil imports, exports and production values. This means that palm oil trade and production can be boosted by reducing the of number of undernourished people, which is directly linked to the achievement of SDG 1, SDG 2, SDG 3, SDG 6, SDG 10 and SDG 12. Furthermore, an increase in agricultural employment, which is related to SDG 1, SDG 2, SDG 3, SDG 8, SDG 10 and SDG 12, showed significant positive associations on palm oil imports, exports and production. Therefore, it is recommended that policymakers should focus on increasing the level of employment in agriculture and reducing the number of undernourished people in the country. When there are more jobs in the agricultural sector, people can provide sufficient food for their families, thereby reducing the number of undernourished individuals in the process. This will lead to positive growth for palm oil production and trade as more people can work effectively in the industry. Furthermore, the findings from the random effects and fixed effects regression models suggest that temperature has a negative effect on palm oil trade and production. Therefore, an increase in temperature can negatively affect the growth of a country's palm oil trade and production values. When these recommended actions will be taken seriously by policymakers, the UN's SDGs will be effectively achieved along with ensuring sustainable growth of palm oil trade flows and production values.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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APPENDIX

Table A1 The Pearson Correlation Coefficient Test Results

	Import	Export	Pro-duction	Under nouris-hed	Severe food security	Agri value added	Employment agriculture	Agri-cultural land use	Temperature
Import				0.053*	0.087*		0.647*	0.45*	-0.09*
Export			0.925*	0.063*	0.044*		0.317*		-0.11*
Production		0.925*		0.136*	0.062*	-0.074*	0.735*		-0.29*
Undernourished	0.053*	0.063*	0.136*				0.98*	0.48*	-0.17*
Severe food security	0.087*	0.044*	0.062*			-0.15*		0.11*	
Agri. Value added			-0.074*		-0.15*			-0.04*	0.16*
Employment in agri.	0.647*	0.317*	0.735*	0.98*					0.16*
Agri. Land use	0.450*			0.48*	0.11*	-0.04*			-0.17*
Temperature	-0.095*	-0.108*	-0.29*	-0.17*		0.16*	0.16*	-0.17*	

Note: '*' signifies 0.05 level of significance. Only significant correlation coefficients are shown.

Table A2 The Augmented Dickey-Fuller Unit Root Test Results

Variables	Levels	First-differences
Palm oil import	-24.37***	-43.26***
Palm oil export	-18.52***	-29.93***
Palm oil production	-6.66***	-13.45***
Undernourished	-11.28***	-16.48***
Severe food insecurity	-1.67**	-4.85***
Agricultural value added	-21.94***	-32.78***
Employment in agriculture	-9.64***	-17.50***
Agricultural Land use	-22.29***	-32.37***
Temperature	-20.67***	-35.23***