

Simulating the Impacts of Global Palm Oil and Soybean Oil Market Dynamics on Economic and Social SDG Indicators in Major Producing Countries

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ABSTRACT

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Global vegetable-oil markets are increasingly interconnected, allowing productivity changes in major producing countries to propagate through prices, trade, production, and economic activity. This study examined how simulated productivity improvements in major palm-oil and soybean-oil producing countries affected economic and social Sustainable Development Goal (SDG) indicators through global market linkages. A validated simultaneous-equation model of the global palm-oil and soybean-oil markets was used to conduct historical and forecasting simulations. The scenarios imposed exogenous productivity increases in major producing countries, namely Indonesia and Malaysia for palm oil and Brazil, China, Argentina, and the United States for soybean oil. The simulated effects were traced across four SDG-related indicators: decent work and economic growth, poverty, inequality, and hunger. The simulations revealed substantial cross-country spillovers from productivity shocks, demonstrating that improvements in production efficiency generated effects beyond the country where the shock originated. Economic responses were most consistently reflected in decent work and economic growth, while responses in poverty, inequality, and hunger were more heterogeneous across countries. Productivity gains in major exporters also altered competitive conditions between palm oil and soybean oil through changes in international supply, prices, and trade flows. The results further indicated that economic gains were not automatically translated into broad-based social improvements. Productivity enhancement in globally integrated vegetable-oil markets can strengthen economic performance while simultaneously generating heterogeneous social outcomes across producing countries. The findings highlight the importance of combining productivity-oriented strategies with value addition, inclusive distribution mechanisms, and social protection to ensure that market-driven economic gains contribute more broadly to sustainable development.

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1. INTRODUCTION

1.1 Background and Significance

Global vegetable-oil markets have become increasingly interconnected through international trade, processing, consumption, and substitution among competing oils. Palm oil and soybean oil occupy particularly important positions within this system because they are widely traded, used across food and industrial applications, and produced in geographically concentrated regions. Global agricultural trade remains concentrated among a limited number of major producing and exporting countries, while vegetable-oil markets are influenced by changes in production, consumption, trade, energy prices, and international market conditions (1–3). Consequently, changes in the productive capacity of a major producing country may extend beyond domestic markets by affecting international supply, prices, trade flows, and the competitive position of other vegetable oils (4,5).

The economic importance of these market linkages extends beyond commodity-market performance. Agricultural productivity is an important mechanism through which technological and efficiency improvements can influence agricultural output, income generation, employment, and poverty reduction (6,7). However, the magnitude and distribution of these effects are not uniform across countries. Previous studies have shown that agricultural productivity growth can contribute to poverty reduction, but its effects depend on economic structure, market participation, sectoral linkages, and the extent to which productivity gains are transmitted to producers and consumers (8–10). Similarly, evidence from export-oriented agricultural economies indicates that expansion in agricultural production can generate income and employment while producing heterogeneous distributional outcomes across regions and population groups (11–13). Thus, increased productivity does not necessarily translate automatically into broad-based improvements in social welfare.

This issue is particularly important for palm oil and soybean oil because the two commodities are interconnected through substitution in several food and industrial uses. Although they differ in production systems, geographical concentration, and downstream applications, changes in the supply and relative price of one oil can influence demand and production incentives for the other. Empirical studies have documented significant price relationships and market integration between palm oil and soybean oil, indicating that these commodities should not be examined entirely as independent markets (14,15). A productivity improvement in one major producing country may therefore affect not only domestic production and exports but also international prices, competing vegetable-oil markets, and production conditions in other countries.

The implications of these market adjustments are directly relevant to the Sustainable Development Goals (SDGs). The 2030 Agenda recognizes the interdependence between economic growth, poverty reduction, food security, employment, and inequality (16,17). In particular, SDG 1 concerns poverty, SDG 2 addresses hunger and food security, SDG 8 focuses on inclusive economic growth and productive employment, and SDG 10 concerns inequality. Changes in agricultural productivity and international commodity markets can influence these dimensions through multiple transmission channels, including producer income, employment, export earnings, consumer prices, food availability, and distributional effects. The resulting outcomes, however, may differ substantially across countries because the transmission of market gains depends on production structures, trade exposure, downstream processing capacity, and the ability of domestic economies to capture and distribute economic benefits.

The significance of this issue is heightened by the concentration of palm-oil and soybean-oil production among a relatively small number of major producing countries. Indonesia and Malaysia are central to palm-oil production, while Brazil, the United States, Argentina, and China play important roles in soybean production and the associated vegetable-oil market. A productivity shock in any of these economies can therefore generate effects that extend beyond national boundaries through changes in production, trade, prices, and substitution between vegetable oils (18–22). Understanding these transmission mechanisms is important because policies designed to increase agricultural productivity are often evaluated primarily from the perspective of domestic production and income, whereas their broader international and social consequences may remain insufficiently considered.

1.2 Research Gap and Objectives

Although previous studies have generated substantial evidence on agricultural productivity, commodity-market integration, and socioeconomic outcomes, these strands of research have largely been examined separately. Studies of agricultural productivity have predominantly assessed its relationship with poverty, income, employment, or economic growth (4,9,12), whereas commodity-market studies have focused mainly on price transmission, market integration, and interdependence among vegetable oils. Other research has examined the socioeconomic consequences of palm-oil and soybean expansion within individual producing countries. These approaches provide important insights but provide limited evidence on how a productivity shock originating in one major producing country propagates simultaneously through interconnected commodity markets and subsequently affects multiple economic and social development indicators across countries.

This limitation is important because the effects of productivity shocks cannot be fully represented by a single-country or single-market perspective. An increase in productivity may initially increase domestic production and export capacity, but the resulting change in international supply can alter prices and competitive conditions in substitute vegetable-oil markets. These market adjustments may subsequently influence production incentives, trade revenues, employment, income, and social indicators in other

producing countries. The final effects may therefore differ from the initial domestic effect and may be heterogeneous across countries depending on their economic structure and position within the international vegetable-oil system.

A further gap concerns the limited integration of commodity-market transmission with multiple SDG dimensions within a single analytical framework. Existing evidence provides support for relationships between agricultural productivity and poverty reduction (17), as well as between agricultural commodity expansion and socioeconomic outcomes. However, less is known about whether productivity-driven economic gains in internationally integrated vegetable-oil markets are accompanied by comparable improvements in poverty, inequality, and hunger. In particular, the extent to which productivity shocks generate cross-country spillovers across these different SDG dimensions remains insufficiently established.

Addressing this gap requires an analytical framework capable of representing simultaneous interactions among production, prices, trade, and development outcomes. A validated simultaneous-equation model provides such a framework by allowing interconnected market variables to adjust jointly and enabling counterfactual simulations of productivity changes in major producing countries. This approach makes it possible to distinguish direct effects in the country experiencing a productivity shock from indirect effects transmitted through international market linkages and substitution between palm oil and soybean oil.

Accordingly, this study aimed to simulate the impacts of productivity changes in major palm-oil and soybean-oil producing countries on selected economic and social SDG indicators. Specifically, the study examined: (1) how productivity shocks in major producing countries propagate through interconnected palm-oil and soybean-oil markets; (2) how these market adjustments affect decent work and economic growth, poverty, inequality, and hunger in the country experiencing the shock; and (3) how these effects are transmitted to other major producing countries through international market linkages.

The study contributes to the literature by integrating commodity-market dynamics and multidimensional development outcomes within a single simulation framework. Rather than evaluating productivity gains solely through changes in production or economic performance, the analysis traces their transmission across interconnected markets and examines their implications for multiple SDG-related indicators. This approach provides a system-level perspective on the extent to which productivity improvements can generate economic gains, cross-country spillovers, and heterogeneous social outcomes within globally integrated vegetable-oil markets.

2. MATERIALS AND METHODS

2.1 Study Design and Analytical Approach

This study employed a quantitative simulation design based on a simultaneous-equation econometric model representing the interrelationships between global palm-oil and soybean-oil markets and selected economic and social Sustainable Development Goal (SDG) indicators. The simulation framework was derived from a structurally specified and empirically estimated system in which endogenous variables could simultaneously function as dependent variables in one equation and explanatory variables in other equations. This structure was used because the economic variables represented reciprocal relationships within interconnected commodity markets and socioeconomic systems.

The analytical framework consisted of four sequential stages: model specification, parameter estimation, model validation, and policy-oriented simulation. The structural model incorporated the major economic mechanisms linking production, prices, trade, macroeconomic conditions, and SDG-related outcomes. The estimated system was subsequently used as the baseline model for historical and forecasting simulations. The simulation analysis focused specifically on productivity shocks in major palm-oil and soybean-oil producing countries and traced their effects through the interconnected market system to selected SDG indicators.

The model covered the major producing economies represented in the underlying system, including Indonesia and Malaysia for palm oil and Brazil, China, Argentina, and the United States for soybean oil. The analysis evaluated four SDG-related outcome dimensions: decent work and economic growth (DWE), poverty (POV), inequality (IEQ), and hunger (HUN). The country-specific indicators were denoted by country suffixes, with I representing Indonesia, M representing Malaysia, B representing Brazil, C representing China, A representing Argentina, and U representing the United States.

2.2 Data and Model Structure

The analysis used annual secondary data covering the period 1994–2024. The dataset was constructed from internationally comparable information on commodity production, productivity, prices, exports, domestic economic conditions, and socioeconomic indicators used in the structural equations. The underlying model incorporated variables representing the production and trade dynamics of palm oil and soybean oil together with macroeconomic and SDG-related variables.

The structural specification was formulated as a system of simultaneous equations because several economic relationships were inherently interdependent. For example, commodity production affected market supply and prices, while prices and economic conditions simultaneously influenced production, trade, and socioeconomic outcomes. The use of an equation-by-equation ordinary least squares approach was therefore considered inappropriate for the endogenous components of the system because explanatory variables could be correlated with the disturbance terms. The simultaneous-equation framework was consequently estimated using

Nurachmat H. et al, Simulating the Impacts of Global Palm Oil and Soybean Oil Market Dynamics on Economic and Social SDG Indicators in Major Producing Countries

an instrumental-variable approach through Two-Stage Least Squares (2SLS). The underlying dissertation specified the equations as overidentified, providing the basis for the application of 2SLS(23).

The model contained separate equations for the major economic and SDG variables. The SDG component included equations for DWE, POV, IEQ, and HUN for the major producing countries. The economic component included equations representing production, prices, exports, and related market variables for palm oil and soybean oil. The estimated equations jointly represented the transmission mechanism through which changes in commodity productivity could propagate across national markets.

2.3 Parameter Estimation Using SAS

The simultaneous-equation system was estimated using the SAS System, specifically the SYSLIN procedure, with the Two-Stage Least Squares (2SLS) estimation method. The 2SLS procedure was applied to address simultaneity and endogeneity among the endogenous variables in the structural system.

In the first stage, endogenous explanatory variables were projected on the set of exogenous and predetermined variables included in the system to obtain their fitted components. In the second stage, these fitted components were used in the structural equations to estimate the structural parameters. This procedure provided consistent parameter estimates under the identification and instrument conditions required by the simultaneous-equation framework.

The estimation output included parameter estimates, standard errors, t-statistics, significance probabilities, coefficient of determination (R^2), adjusted R^2 , root mean square error (Root MSE), and the Durbin–Watson statistic. The dissertation estimation results confirmed the implementation of 2SLS through the SAS SYSLIN procedure and reported 24 observations for the estimated equations.

The estimated structural coefficients were retained as the parameters of the simulation model. No re-estimation was performed between individual simulation scenarios. Consequently, differences between the baseline and simulated outcomes represented the model-implied responses to the imposed exogenous shocks under an otherwise unchanged structural system.

2.4 Model Validation and Baseline Construction

Before the simulation experiments were conducted, the estimated model was evaluated to ensure that it adequately represented the historical relationships among the variables included in the system. Model evaluation considered statistical, economic, and econometric criteria, consistent with the model-building procedure used in the underlying research (24).

The estimated equations demonstrated substantial explanatory capacity across the economic and SDG components of the system. The model included separate equations for DWE, POV, IEQ, and HUN as well as production, price, and trade variables. The estimation results reported high explanatory power for many equations, including the SDG equations, while the Durbin–Watson statistic and first-order autocorrelation were examined as part of the econometric assessment.

Following validation, the model was solved under the baseline condition, representing the model-generated path without an imposed productivity shock. The baseline solution provided the reference values against which each counterfactual simulation was compared. This procedure allowed the effect of an individual shock to be isolated from the model's endogenous evolution.

2.5 Simulation Design

The simulation analysis consisted of two forms of simulation: historical simulation (ex post) and forecasting simulation (ex ante). Historical simulation was used to evaluate the model's ability to reproduce historical conditions and to assess the structural response of the system to a specified productivity shock. Forecasting simulation was subsequently used to examine the prospective effects of the same type of productivity intervention under the model's forward-looking structure.

The principal simulation experiment imposed an exogenous increase in productivity in one major producing country while holding other exogenous conditions at their baseline values. The resulting system was solved simultaneously, allowing endogenous production, prices, trade, and SDG indicators to adjust according to the estimated structural relationships.

For palm oil, the productivity shocks were applied to Indonesia and Malaysia. For soybean oil, the shocks were applied to Brazil, China, Argentina, and the United States. The dissertation included country-specific productivity scenarios, including a 1% increase in Indonesian palm-oil productivity, a 10% increase in Malaysian palm-oil productivity, a 1% increase in Brazilian soybean productivity, a 10% increase in Chinese soybean productivity, a 2% increase in Argentine soybean productivity, and a 1% increase in United States soybean productivity. These scenario magnitudes were retained from the original simulation design rather than standardized across countries.

For each scenario, the model was solved twice: first under the baseline condition and subsequently under the imposed productivity shock. The simulated impact was obtained from the difference between the shocked solution and the corresponding baseline solution. The simulation outcomes were evaluated for the four SDG-related indicators DWE, POV, IEQ, and HUN in each country represented in the system. This procedure allowed both direct effects in the country receiving the productivity shock and indirect spillover effects transmitted through international commodity-market linkages to be identified.

2.6 Transmission of Productivity Shocks

The transmission mechanism was interpreted through the endogenous interactions embedded in the simultaneous-equation system. An increase in productivity first altered the productive capacity of the shocked commodity. Changes in production subsequently affected supply conditions, international prices, trade flows, and the relative competitiveness of palm oil and soybean oil. Because the two commodities were represented within an interconnected vegetable-oil market system, changes originating in one commodity could affect the other through substitution and market adjustment mechanisms.

The resulting changes in commodity-market variables were then transmitted to the economic and social equations. Changes in economic activity were reflected through DWE, while changes in poverty, inequality, and hunger were captured through POV, IEQ, and HUN, respectively. The model therefore allowed the simulation to capture heterogeneous responses across countries rather than imposing a common direction or magnitude of effect.

This structure was particularly important for distinguishing domestic productivity effects from international spillovers. For example, the underlying simulations showed that a productivity increase in Indonesia affected not only Indonesian SDG indicators but also indicators in other major producing countries through changes in the global vegetable-oil market. Similar cross-country effects were observed for productivity shocks originating in Brazil, China, Argentina, and the United States.

2.7 Data Analysis and Interpretation of Simulation Results

The simulation results were analyzed by comparing the baseline and shocked solutions for each country and SDG indicator. The analysis emphasized the direction and magnitude of changes in DWE, POV, IEQ, and HUN and identified whether the simulated effects occurred domestically or through cross-country transmission.

The simulation results were not interpreted as unconditional causal effects observed in the real economy. Rather, they represented counterfactual responses generated by the estimated structural model under specified productivity shocks. Accordingly, the results were interpreted conditional on the estimated parameters, model structure, baseline assumptions, and scenario specifications.

The historical simulations were used to examine the response of the established system under observed historical conditions, whereas the forecasting simulations were used to evaluate the prospective consequences of productivity changes. The forecasting simulations included productivity scenarios for Indonesia, Malaysia, Brazil, China, Argentina, and the United States. The resulting changes in the SDG indicators were then compared across countries to identify heterogeneous responses and international spillover patterns.

2.8 Software and Computational Procedure

All econometric estimation and simulation procedures were implemented using SAS. The SYSLIN procedure was used for estimation of the simultaneous-equation system using 2SLS. The estimated structural parameters were subsequently used to generate the baseline and counterfactual simulation solutions.

The computational procedure followed a consistent sequence: (1) preparation and organization of the annual dataset; (2) estimation of the structural equations using 2SLS; (3) evaluation of model adequacy; (4) generation of the baseline solution; (5) introduction of the specified productivity shock; (6) simultaneous solution of the model under the shocked condition; and (7) calculation and comparison of simulated changes in the SDG indicators.

2.9 Ethical Considerations

The study used secondary, aggregate-level data obtained from publicly available international and national statistical sources and did not involve human participants, personal identifiers, or experimental intervention. Consequently, informed consent and institutional review board approval were not applicable to the simulation analysis.

3. RESULTS

3.1 Model Validation

The estimated simultaneous-equation model demonstrated adequate statistical performance for subsequent simulation analysis. The model was evaluated using the mean percentage error (MPE), root mean square percentage error (RMSPE), and Theil's inequality coefficient (U-Theil), together with the explanatory and autocorrelation statistics obtained from the structural estimation.

The validation results showed that the model generally reproduced the historical behavior of the endogenous variables with relatively small prediction errors. The U-Theil coefficients were generally close to zero, while the MPE and RMSPE values indicated acceptable deviations between the simulated and historical values. The validation results therefore supported the use of the estimated system for counterfactual simulation of productivity shocks. Table I summarizes selected validation statistics for the major SDG and commodity-market variables.

Table I. Selected model validation statistics for major endogenous variables.

Variable	MPE	RMSPE	U-Theil	Interpretation
DWE Indonesia (DWEI)	0.57	0.27	0.16	Low prediction error
DWE Malaysia (DWEM)	01.00	0.00	0.00	Very close historical replication
POV Malaysia (POVM)	0,06875	0.01	0.00	Very close historical replication
IEQ Malaysia (IEQM)	0,05902778	0.00	0.14	Low systematic error
HUN Malaysia (HUNM)	0,05347222	0.01	0.22	Acceptable predictive performance
DWE Brazil (DWEB)	0,06875	0.00	0.00	Very close historical replication
POV Brazil (POVB)	0,06875	0.00	0.00	Very close historical replication
IEQ Brazil (IEQB)	0,06875	0.00	0.00	Very close historical replication
HUN Brazil (HUNB)	0,06875	0.00	0.01	Very close historical replication
DWE China (DWEC)	0,04791667	0.21	0.10	Low prediction error
POV China (POVC)	0,06597222	0.00	0.04	Low systematic error
IEQ China (IEQC)	0,05763889	0.00	0.17	Low systematic error
HUN China (HUNC)	0,06875	0.01	0.00	Very close historical replication
DWE Argentina (DWEA)	0,05972222	0.14	0.01	Low prediction error
POV Argentina (POVA)	0,05972222	0.14	0.00	Low prediction error
IEQ Argentina (IEQA)	0,06111111	0.12	0.00	Low prediction error
HUN Argentina (HUNA)	0,05972222	0.14	0.00	Low prediction error
DWE United States (DWEU)	0,06875	0.00	0.00	Very close historical replication
POV United States (POVU)	0,06875	0.00	0.01	Very close historical replication
IEQ United States (IEQU)	0,06875	0.00	0.01	Very close historical replication
HUN United States (HUNU)	—	—	0.01	Limited variation

Source: Author's simulation using SAS SYSLIN (2SLS).

Note: MPE = mean percentage error; RMSPE = root mean square percentage error; U-Theil = Theil's inequality coefficient. Values were reported from the model-validation output. A dash indicates that the corresponding statistic was not reported in the extracted validation output.

The validation results established the baseline reliability required for the simulation experiments. The model subsequently generated historical and forecasting solutions under alternative productivity scenarios.

3.2 Productivity Simulation Scenarios

Six productivity scenarios were evaluated across the major palm-oil and soybean-oil producing countries. The scenarios consisted of a 1% increase in palm-oil productivity in Indonesia, a 10% increase in palm-oil productivity in Malaysia, a 1% increase in soybean productivity in Brazil, a 10% increase in soybean productivity in China, a 2% increase in soybean productivity in Argentina, and a 1% increase in soybean productivity in the United States. Table II presents the simulation design used to evaluate the effects of productivity shocks.

Table II. Productivity shock scenarios applied in the simulation model.

Scenario	Commodity	Country	Productivity shock	Simulation type	SDG outcomes evaluated
S1	Palm oil	Indonesia	1%	Historical and forecasting	DWE, POV, IEQ, HUN
S2	Palm oil	Malaysia	10%	Historical and forecasting	DWE, POV, IEQ, HUN
S3	Soybean oil	Brazil	1%	Historical and forecasting	DWE, POV, IEQ, HUN
S4	Soybean oil	China	10%	Historical and forecasting	DWE, POV, IEQ, HUN

Scenario	Commodity	Country	Productivity shock	Simulation type	SDG outcomes evaluated
S5	Soybean oil	Argentina	2%	Historical forecasting and	DWE, POV, IEQ, HUN
S6	Soybean oil	United States	1%	Historical forecasting and	DWE, POV, IEQ, HUN

Source: Author's simulation using SAS SYSLIN (2SLS).

The simulation results showed that each productivity shock generated effects beyond the country in which the shock was imposed. The magnitude and direction of the responses differed across countries and SDG indicators.

3.3 Historical Simulation of Palm-Oil Productivity

3.3.1 Indonesia

A 1% increase in Indonesian palm-oil productivity generated the most pronounced response in the decent work and economic growth indicator. The response was observed in Indonesia and was also transmitted to other major producing countries. The spillover response was particularly evident in Brazil, Malaysia, and the United States.

The responses of poverty, inequality, and hunger were comparatively smaller than the response of DWE. The simulation therefore produced a differentiated pattern across SDG dimensions rather than a uniform improvement in all indicators. Figure 1 presents the simulated responses to a 1% increase in Indonesian palm-oil productivity.

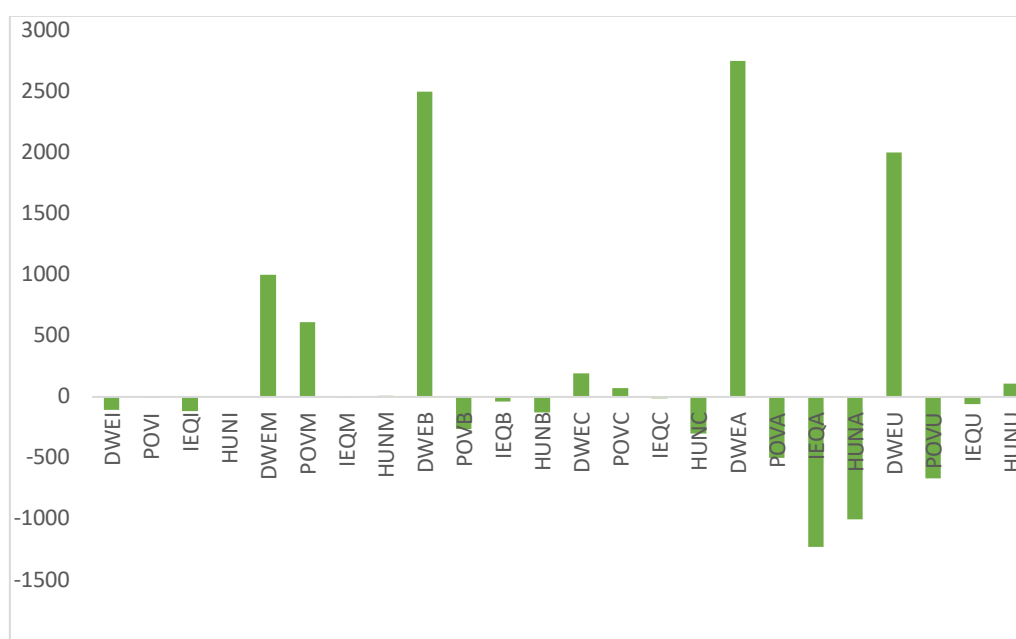


Figure 1. Simulated effects of a 1% increase in Indonesian palm-oil productivity on DWE, POV, IEQ, and HUN across major producing countries.

The figure shows the distribution of simulated changes across the four SDG indicators and the six countries represented in the model. The results indicate that the strongest responses were concentrated in the DWE indicators, while the social indicators displayed smaller and more heterogeneous changes.

3.3.2 Malaysia

A 10% increase in Malaysian palm-oil productivity generated its strongest response in Malaysia's DWE indicator. Positive spillover responses were also identified in Brazil, Argentina, and the United States.

The responses in POV, IEQ, and HUN were smaller and more heterogeneous than the DWE response. The pattern indicated that the productivity shock was transmitted more strongly through economic activity and international market linkages than through the social indicators. Figure 2 presents the simulated effects of the Malaysian productivity shock.

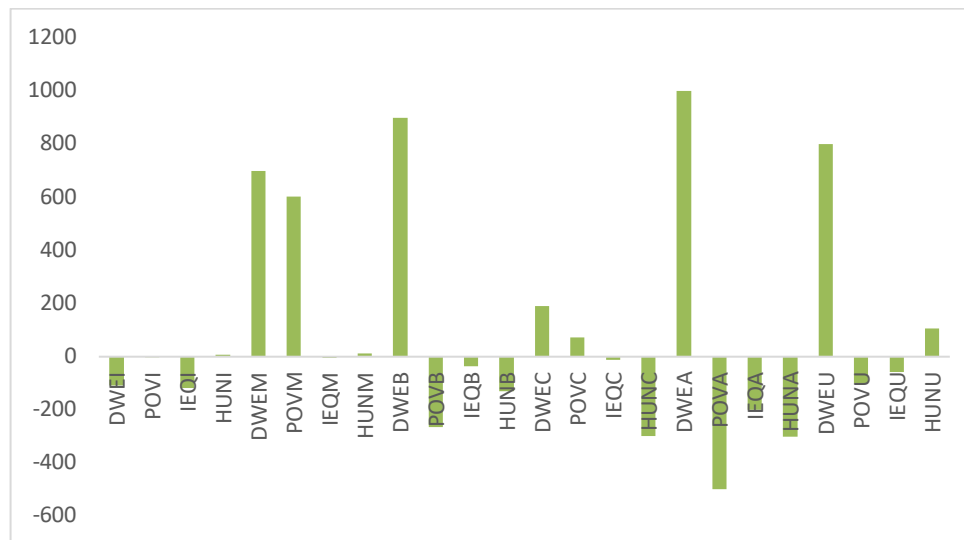


Figure 2. Simulated effects of a 10% increase in Malaysian palm-oil productivity on DWE, POV, IEQ, and HUN across major producing countries.

3.4 Historical Simulation of Soybean Productivity

3.4.1 Brazil

A 1% increase in Brazilian soybean productivity generated its strongest response in Brazilian DWE. Positive spillover responses were also observed in Malaysia, Argentina, the United States, and China.

The simulation further showed heterogeneous responses in POV, IEQ, and HUN. The effects varied according to the position of each country within the international soybean and palm-oil markets. Changes in soybean supply altered competitive conditions between soybean oil and palm oil and generated adjustments among competing producing countries. The simulated effects of a 1% increase in Brazilian soybean productivity across the major producing countries are presented in Figure 3.

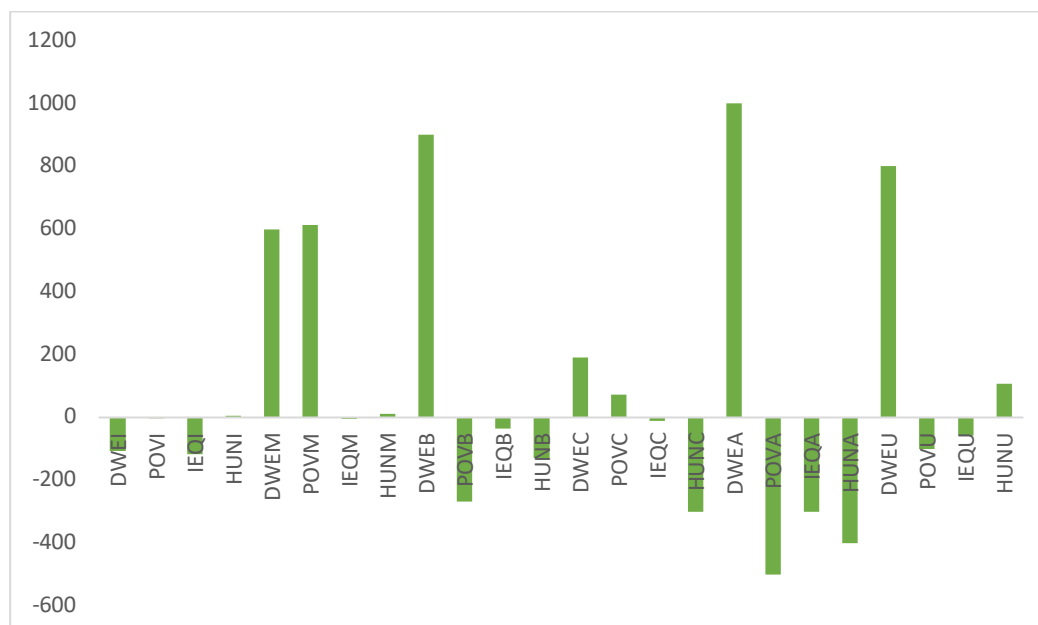


Figure 3. Simulated effects of a 1% increase in Brazilian soybean productivity on economic and social SDG indicators

3.4.2 China

A 10% increase in Chinese soybean productivity generated a pronounced response in DWE in China and produced spillover effects in Malaysia, Brazil, Argentina, and the United States.

The responses of POV, IEQ, and HUN differed across countries. The results showed that the same productivity shock could generate different social responses depending on the country's position in the international commodity system. Figure 4 presents the simulated effects of the Chinese productivity shock.

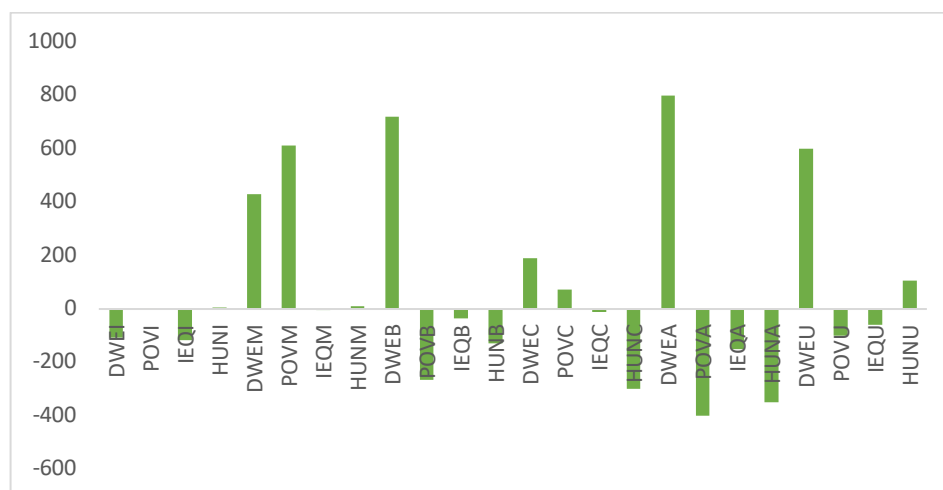


Figure 6. Simulated effects of a 1% increase in United States soybean productivity on economic and social SDG indicators

3.5 Cross-Country and Cross-Commodity Spillovers

The six productivity scenarios consistently generated cross-country effects. The transmission did not remain confined to the country receiving the productivity shock. Palm-oil productivity shocks affected soybean-producing countries, while soybean productivity shocks affected palm-oil-producing countries. Table III summarizes the principal direction and relative prominence of the simulated responses reported across the scenarios.

Table III. Direction and relative prominence of simulated SDG responses by productivity scenario.

Productivity shock	Direct country response	Most prominent SDG response	Cross-country spillover	Overall pattern
Indonesia palm oil +1%	Positive	DWE	Pronounced in Brazil, Malaysia, and United States	Economic response stronger than social response
Malaysia palm oil +10%	Positive	DWE	Pronounced in Brazil, Argentina, and United States	Strong economic transmission
Brazil soybean +1%	Positive	DWE	Malaysia, Argentina, United States, China	Strong cross-commodity transmission
China soybean +10%	Positive	DWE	Malaysia, Brazil, Argentina, United States	Broad international transmission
Argentina soybean +2%	Positive	DWE	Other major producers	Economic and social responses both evident
United States soybean +1%	Positive	DWE	Other major producers	Asymmetric cross-country effects

Source: Author's simulation using SAS SYSLIN (2SLS).

Note: "Most prominent" refers to the relative prominence reported in the simulation results and does not represent a statistical ranking of countries or scenarios.

Across the scenarios, DWE was the most consistently responsive indicator. By contrast, POV, IEQ, and HUN displayed greater heterogeneity in both direction and magnitude. The results therefore demonstrated that productivity shocks propagated through the market system with different consequences for economic and social outcomes.

3.6 Forecasting Simulation

The forecasting simulations generated patterns broadly consistent with the historical simulations. Productivity increases in the major producing countries affected both the domestic economy and the international vegetable-oil market.

The forecasting experiments confirmed that productivity improvements in Indonesia, Malaysia, Brazil, China, Argentina, and the United States could generate effects beyond the originating country. In particular, the forecasting scenarios for Brazil, China, Argentina, and the United States demonstrated that changes in soybean productivity affected the competitive balance between soybean oil and palm oil.

Nurachmat H. et al, Simulating the Impacts of Global Palm Oil and Soybean Oil Market Dynamics on Economic and Social SDG Indicators in Major Producing Countries

The forecasting results also showed that economic effects were more systematically reflected in DWE, whereas POV, IEQ, and HUN exhibited heterogeneous responses across countries. The results were therefore consistent with the presence of asymmetric transmission within the international vegetable-oil system.

4. DISCUSSION

4.1 Key Findings

The simulation results demonstrated that productivity shocks in major palm-oil and soybean-producing countries generated both domestic effects and international spillovers. Across the six scenarios, the most consistent response occurred in decent work and economic growth, whereas poverty, inequality, and hunger displayed more heterogeneous responses. The findings indicate that the economic transmission of productivity improvements was broader and more systematic than their social transmission(25).

A second central finding was the presence of cross-commodity transmission. Productivity changes in palm oil affected soybean-producing countries, while soybean productivity changes affected palm-oil-producing countries. This pattern is consistent with the interconnected structure of international vegetable-oil markets represented in the simultaneous-equation model.

4.2 Comparison with Existing Knowledge

The stronger response of DWE to productivity shocks is consistent with the established relationship between agricultural productivity and economic activity. Productivity improvements increase productive capacity and can raise output, trade, investment, and employment when the additional supply can be absorbed by domestic and international markets. The simulation results therefore support the broader empirical literature linking agricultural productivity growth with income and poverty reduction, while simultaneously demonstrating that the economic response can occur more rapidly and systematically than corresponding social improvements.

The heterogeneous responses of POV and IEQ are also consistent with evidence showing that aggregate agricultural growth does not necessarily translate proportionally into poverty reduction or improved income distribution. Previous research has demonstrated that the poverty-reducing effect of agricultural productivity depends on the structure of agricultural production, factor ownership, market access, and the distribution of productivity gains. The simulation results extend this perspective by showing that these distributional differences can also emerge through international commodity-market transmission.

The cross-commodity effects observed in the simulations are consistent with empirical evidence on the integration of vegetable-oil markets. Previous studies have documented price relationships between palm oil and soybean oil, indicating that changes in the supply and price conditions of one commodity can affect the other. The present simulation results extend this market-integration perspective by linking commodity-market transmission to economic and social indicators rather than restricting the analysis to price movements (26).

4.3 Mechanisms of Productivity Shock Transmission

The simulation results can be explained through three interconnected transmission mechanisms. First, productivity improvement increased the productive capacity of the shocked commodity. Higher productive capacity affected supply conditions and strengthened the ability of the originating country to participate in international trade.

Second, changes in supply altered the relative price and competitive position of palm oil and soybean oil. Because the two commodities function as substitutes in several applications, changes in the availability of one commodity generated adjustments in the demand and production conditions of the other. This mechanism explains why productivity shocks produced measurable effects in countries that were not directly exposed to the initial productivity change.

Third, changes in commodity-market conditions were transmitted to the broader economic system through production, trade, and economic activity. These changes affected DWE and subsequently interacted with the equations representing POV, IEQ, and HUN. The different responses across these indicators demonstrate that economic expansion and social improvement operated through different transmission channels (27).

The particularly strong DWE response observed across scenarios is therefore consistent with the direct connection between productivity, output, trade, and economic activity. In contrast, poverty, inequality, and hunger were affected through additional distributional and welfare mechanisms, producing more heterogeneous outcomes.

4.4 Heterogeneity Across Producing Countries

The simulations demonstrated that the effects of a common type of productivity intervention differed according to the position of each country within the international commodity system. Countries with strong production, processing, and trade linkages could transmit productivity gains through several economic channels, whereas countries more exposed to international commodity competition could experience adjustment pressures following productivity improvements elsewhere.

The Argentine soybean scenario provides a particularly clear illustration. The productivity increase generated a strong domestic DWE response together with changes in the social indicators, while other countries responded through changes in international trade

Nurachmat H. et al, Simulating the Impacts of Global Palm Oil and Soybean Oil Market Dynamics on Economic and Social SDG Indicators in Major Producing Countries

and commodity-market competition. Similarly, the Chinese soybean productivity scenario generated effects across both soybean- and palm-oil-producing economies, illustrating the importance of the country's position within the international vegetable-oil system.

These results indicate that the consequences of productivity policies cannot be evaluated solely from the perspective of the country implementing the intervention. International market position, commodity substitution, and trade relationships influence the distribution of resulting gains and adjustments.

4.5 Implications

The results have implications for the design of productivity-oriented development policies in major vegetable-oil-producing economies. Productivity improvement can strengthen economic activity and international competitiveness, but the simulation results indicate that economic gains do not necessarily produce proportional improvements in poverty, inequality, and hunger.

Consequently, productivity policies should be considered together with mechanisms that determine how additional economic value is distributed. Value addition, downstream processing, labor-market integration, producer participation, and social protection can influence whether productivity-driven economic gains extend beyond the primary production sector.

The international spillovers also indicate that national productivity policies may generate consequences for trading partners and competing commodities. Coordination of trade, agricultural productivity, and food-security policies may therefore be relevant where major producing countries are strongly interconnected through international vegetable-oil markets.

4.6 Limitations

Several limitations should be considered when interpreting the simulation results. First, the results were conditional on the structure and parameter estimates of the simultaneous-equation model. A simulated response therefore represented a model-based counterfactual rather than an unconditional forecast of the real economy.

Second, the productivity scenarios were imposed at predetermined magnitudes that differed across countries. The scenarios were designed to represent specific counterfactual productivity improvements rather than to estimate a common marginal effect for all countries.

Third, the model focused on selected major producing countries and four SDG-related indicators. Other countries, socioeconomic dimensions, environmental outcomes, and institutional mechanisms were not explicitly incorporated into the simulation outcomes reported in this study.

Finally, the simulation did not imply that productivity improvement alone determined SDG outcomes. The heterogeneous responses across POV, IEQ, and HUN indicated that distributional mechanisms, domestic institutions, and broader socioeconomic conditions remained important components of the transmission process.

4.7 Future Research

Future research could extend the framework by incorporating additional countries, environmental indicators, climate-related productivity shocks, and alternative trade-policy scenarios. Further work could also examine heterogeneous productivity shocks across farm sizes and production systems and explicitly model the distribution of productivity gains between producers, workers, processors, traders, and consumers.

An additional extension would be to combine the simultaneous-equation framework with scenario analysis for climate change, trade restrictions, biofuel policies, and changes in international food demand. Such extensions would provide a broader basis for evaluating how productivity, international commodity-market integration, and multidimensional sustainable development interact under alternative global economic conditions.

5. CONCLUSION

The simulation results demonstrate that productivity improvements in major palm oil and soybean oil producing countries can generate economic effects that extend beyond the country in which the productivity shock occurs. Across the simulated scenarios, impacts on decent work and economic growth (SDG 8) were more consistently pronounced than those on poverty, inequality, and hunger, while social outcomes varied across countries. The findings further show that the interconnectedness and substitutability of palm oil and soybean oil contribute to cross-country and cross-commodity transmission of productivity shocks through international market linkages. The study contributes a simulation-based perspective on how commodity-market dynamics interact with economic and social development indicators. Future research should incorporate more detailed trade, value-chain, and distributional mechanisms to further assess how productivity gains can be translated into broader and more inclusive sustainable development outcomes.

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7. CONFLICTS OF INTEREST

The authors declare no competing financial interests or conflicts of interest relevant to this work.

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Nurachmat H. et al, Simulating the Impacts of Global Palm Oil and Soybean Oil Market Dynamics on Economic and Social SDG Indicators in Major Producing Countries

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