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Simulating Indonesia's Sugar Supply Policy Using a Simultaneous Equation Model

Nur Amin[1*)], Jusniaty[2)], Fitriani[3)]
[1,2,3]Universitas Muhammadiyah Sinjai, Indonesia
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Correspondent:
aminbpd34@gmail.com

ABSTRACT

Purpose: *This study aims to analyze and simulate the effects of sugarcane production, sugar recovery rate, and domestic sugar consumption on national sugar supply, as well as to evaluate the policy implications of an integrated sugar supply management framework in Indonesia to maintain a balance between production enhancement and consumption control.*

Design/Methodology/Approach: *This study employs a quantitative approach with an econometric analysis design. Equations were estimated using the two-stage least squares (2SLS) method. The data used in this study consists of secondary data in the form of a 30 year time series covering the period 1992 to 2021. The analysis is conducted using a simultaneous equation model to capture the interrelationships among variables. The validated model is subsequently used to perform policy simulations under several scenarios.*

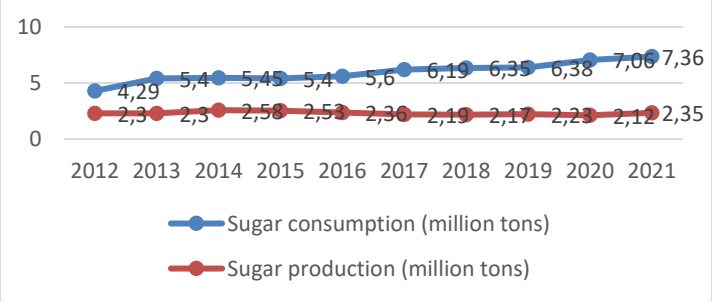
Findings: *The simulation results indicate that domestic sugar consumption has the most significant impact on national sugar supply compared to increases in sugarcane production and sugar recovery rates. A combined scenario involving increased production and recovery rates accompanied by a reduction in domestic sugar consumption yields the most optimal outcome in reducing import dependency and maintaining domestic supply balance.*

Research Implications: *An integrated policy framework encompassing the production, trade, and consumption sectors is required to strengthen the resilience of Indonesia's sugar supply system amid global market fluctuations.*

INTRODUCTION

Sugar is one of the strategic commodities that plays an important role in the Indonesian economy, both as a staple food and industrial raw material (Amin et al., 2024). Sugar, along with rice, corn, and soybeans, has been designated as a special commodity at the World Trade Organization (WTO) negotiation forum (Rambe & Aslam, 2022). Indonesia is a country with high sugar consumption, but national sugar production has not been able to meet domestic demand (Sembiring & Widyastutik, 2023; Silalahi, 2024). The increasing demand for sugar, which has not been accompanied by sufficient increases in domestic production, has triggered excess demand (Sutanto & Muljaningsih, 2022) (Figure 1).

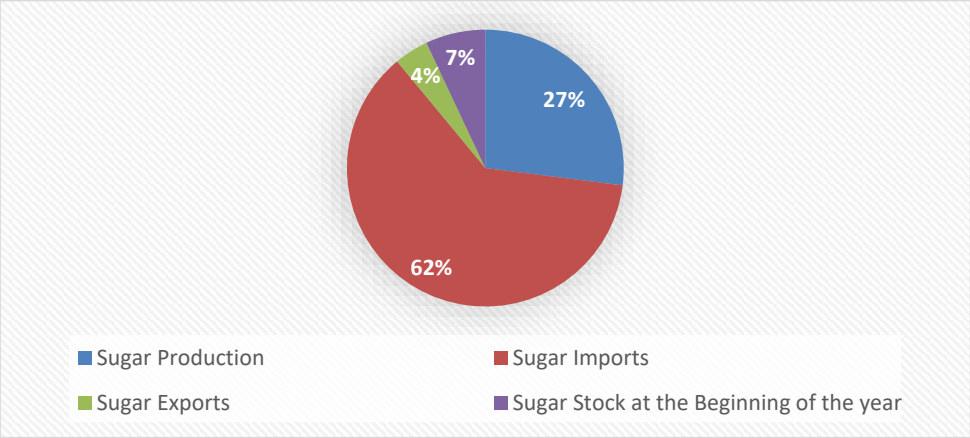
Figure 1. Indonesian Sugar Consumption and Production 2012-2021



Source: Modified from Statista (2022); BPS (2022)

Limited domestic production means that sugar supply needs are met through imports. In 2021, imports contributed 62 percent of the total national sugar supply, while domestic sugar production contributed only 27 percent of Indonesia's total sugar supply (Figure 2).

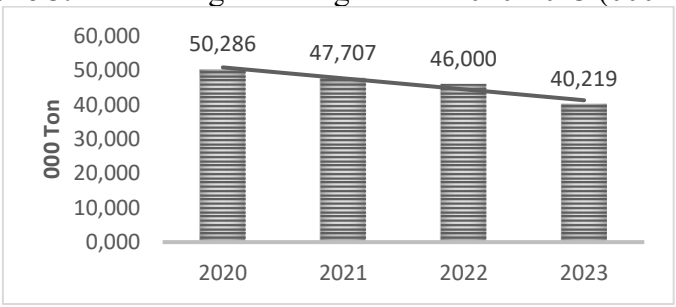
Figure 2. Percentage of Indonesia's Sugar Supply in 2021



Source: Compiled from FAO (2021); BPS (2022)

In addition to domestic factors, the problem of domestic sugar supply is also caused by disruptions in the global sugar supply. Sugar production in India, China, and Pakistan fell by up to 33 percent, causing global sugar stocks to decline. Figure 3 shows the decline in global sugar stocks from 2020 to 2023. This decline in stocks has changed the direction of international trade and triggered a global increase in sugar prices. Although Brazil was able to increase sugar exports when prices were high, global supply could not keep up with demand due to declining harvests (Wijayati et al., 2022).

Figure 3. Global Sugar Ending Stocks 2020-2023 (000 tons)



Source: Modified from USDA (2024)

The decline in sugar stocks has caused several major sugar importing countries to impose export restrictions, including India and Guatemala, which have reduced sugar exports following a decline in production due to El Niño and rising domestic demand. Export restrictions imposed by exporting countries, which have led to price increases, have had an impact on Indonesia as a net importer. Indonesia's position as a net importer in the global sugar trade will be greatly influenced by the global sugar trade situation. Sugar consumption in Indonesia in 2023 reached 7.5 million tons. With national sugar production at only around 2.3 million tons, 5.2 million tons of sugar must be imported to compensate for the domestic supply shortage for both household consumption and industrial needs ([USDA] United States Departement of Agriculture, 2024). The high global demand for sugar has caused subtle volatility in global sugar prices (Laili et al., 2014). This situation in the global sugar market will have an impact on sugar-importing countries, including Indonesia.

If sugar imports cannot be reduced and exports cannot compensate, this could lead to an even greater trade deficit (Pudjiastuti, 2014). In addition, the high percentage of imports in the total domestic sugar supply makes Indonesia vulnerable to fluctuations in global sugar prices. A sharp increase in sugar prices has the potential to trigger inflation, given that sugar is a commodity that contributes significantly to inflation, along with rice and cayenne pepper

([BPS] Badan Pusat Statistik, 2023). In addition, high sugar prices also affect household spending on food. Based on the above description, this study aims to simulate and analyze Indonesia's sugar supply policy in response to global supply dynamics using a quantitative approach.

Numerous studies have been conducted on sugar supply in Indonesia; however, there remains a research gap in conceptual, methodological, and empirical aspects. Sadiyah et al. (2014) found that sugar supply is influenced by fertilizer prices, wages, interest rates, domestic sugar prices, sugarcane production, and imports from the previous period. Meanwhile, (Apriyanto, 2009) stated that sugar supply is influenced only by the area under sugarcane cultivation, (Abdul et al., 2017) showed that sugar supply is a function of production and imports. These research findings reveal inconsistent results. Furthermore, most studies focus solely on white crystal sugar and measure supply based on production and imports, without incorporating stock and export variables as part of a comprehensive supply system. Based on this, this study aims to analyze and simulate the effects of sugarcane production, sugar yield, and domestic sugar consumption on national sugar supply. The novelty of this study lies in the use of a simultaneous equation model approach capable of capturing the interrelationships among variables, as well as the integration of production, consumption, and related variables into a more comprehensive simulation analysis of sugar supply policy compared to previous studies.

LITERATURE REVIEW

Sugar Cane Production, Yield, and Sugar Supply

International studies suggest that the relationship between sugarcane production, yield, and sugar supply is complex and shaped by multiple factors. (Mehdi et al., 2024) show that environmental conditions such as water availability, temperature, pests, and abiotic stress directly affect sucrose accumulation and sugar output. (Ntakirutimana et al., 2025) highlight that despite increasing sugarcane production, technical efficiency (around 80%) remains a key constraint, while the gap between domestic production and demand continues to drive imports. In addition, (Silva et al., 2024) emphasize that yield is determined by the interaction of technology, agroclimatic conditions, and production management.

In this context, domestic sugar supply is essentially determined by national sugar production capacity, which is derived from sugarcane production and yield levels. Sugarcane production reflects the upstream sector's ability to supply raw materials, which is greatly influenced by the size of the planted area, land productivity, and the application of cultivation technology. Increased sugarcane production directly contributes to increased national sugar production, although the impact is highly dependent on the efficiency of the processing at sugar factories (Amin et al., 2024). Therefore, sugar supply is not solely driven by production increases but also yield quality, and technological and environmental factors affecting the conversion process.

H1: Sugarcane production has a positive effect on Indonesia's sugar production

In addition to sugarcane production, yield is a technical factor that determines the conversion of sugarcane into crystal sugar (Apriawan et al., 2015). Low yields indicate production process inefficiencies, either due to suboptimal raw material quality or inadequate processing technology. Increasing yield has the potential to increase sugar output without the need for extensive expansion of planting areas, so it is often seen as a more efficient strategy in the medium and long term. Therefore, yield plays a strategic role in strengthening domestic sugar supply and reducing dependence on imports.

H2: Sugarcane yield has a positive effect on Indonesia's sugar production

Domestic Sugar Consumption and Supply Balance

On the other hand, the national sugar supply is also greatly influenced by the level of domestic sugar consumption. High sugar consumption, both for household and industrial needs, puts pressure on the national sugar market balance. An imbalance between production and consumption will encourage an increase in sugar imports as a market adjustment mechanism. This shows that sugar consumption is one of the main factors that significantly affects the volume of Indonesia's sugar imports.

Sugar consumption patterns in Indonesia tend to increase in line with population growth, rising incomes, and the development of the food and beverage industry. This situation has made consumption control one of the relevant policy instruments in managing the national sugar supply. Thus, sugar consumption not only plays a role as a demand variable, but also as a factor determining supply dynamics through import and stock mechanisms.

H3: Domestic sugar consumption has a positive effect on Indonesia's sugar imports

International Trade and Global Supply Dynamics

As a net sugar importer, Indonesia is highly vulnerable to global sugar supply and price dynamics. Production disruptions in major producing countries, export restriction policies, and global sugar price volatility can directly affect domestic sugar availability and prices. The study (Laili et al., 2014) confirms that global sugar price volatility is strongly correlated with domestic sugar price fluctuations, particularly in importing countries.

High dependence on imports also has implications for the stability of the trade balance and domestic inflation. (Pudjiastuti, 2014) states that an increase in sugar imports that is not offset by exports can widen the trade deficit, while increasing the economy's vulnerability to external shocks. Therefore, sugar supply policies need to be designed taking into account global market conditions and Indonesia's position in international sugar trade.

Simultaneous Equation Model in Sugar Policy Analysis

The relationship between sugar production, consumption, imports, exports, and stocks forms an interrelated and simultaneous system. The simultaneous equation model approach is relevant because it captures the reciprocal interactions between economic variables that cannot be explained partially. The simultaneous equation model is particularly suitable for analyzing agricultural sector policies involving interrelationships between markets and economic actors (Sitepu & Sinaga, 2018).

In the context of this study, the use of simultaneous equation models allows for a more comprehensive analysis of the impact of sugar supply policies, whether through increased production, improved yields, or consumption control. In addition, this model can be used to simulate policies in order to evaluate various scenarios in response to global sugar supply dynamics.

METHODS

The type of data used in this study is secondary data in the form of time series for the period 1992-2021. The data used is annual data collected from various sources, including FAOSTAT, the World Bank, Bank Indonesia, BPS, Statista, the Indonesian Sugar Association (AGI), United States Department of Agriculture (USDA), Trade Map, and the Ministry of Agriculture. Data estimation in this study was performed using Microsoft Excel 2010 and SAS 9.4. The analysis method used was a quantitative method employing a simultaneous equation model approach. Each equation in this study was estimated using the two-stage least squares (2SLS) method. By the order condition, an equation can be identified if it includes at least as many variables as the number of endogenous variables minus one. The structural model identification formula (Koutsoyiannis, 2001) is (K-M) > (G-1), where K = Total number of

variables in the model (endogenous and predetermined variables); M = Number of endogenous and exogenous variables in a single equation; G = Total number of equations in the model (number of endogenous variables). If (K-M) > (G-1), the equation is over-identified. If (K - M) = (G-1), it is exactly identified. If (K-M) < (G-1), it is underidentified. The identification results for each structural equation must be exactly identified or overidentified in order to estimate the parameters. The model identification results are presented in Table 1.

Table 1. Model Identification Results For Each Equation

Variable	K	M	G	K-M	G-1	Description
PGIt	17	6	5	11	4	Over Identified
IGIt	17	8	5	9	4	Over Identified
EGIt	17	7	5	10	4	Over Identified
SGATt	17	3	5	14	4	Over Identified
SGIt	17	5	5	12	4	Over Identified

Model validation is necessary to determine whether the model is valid enough to be used for policy simulation, so that it can represent actual conditions. The validation of the econometric model estimation values used are Mean Square Error (MSE), Theil's Inequality Coefficient (U Theil) and variance portion (US) (Sitepu & Sinaga, 2018). The importance of stationarity tests in time series data analysis is to eliminate autocorrelation, which can result in non-stationary data. Time series data is considered stationary if its mean and variance remain constant over time, and changes in the covariance between two time series depend solely on the time difference between them. Based on the mean and variance, data is said to be stationary in its mean if its fluctuations are centered around a constant mean over time. Meanwhile, data is said to be stationary in its variance if its fluctuations have a constant variance over time. Non-stationarity in the mean of the data is addressed by applying a differentiation process to the original data series. Meanwhile, non-stationarity in variance is addressed by transforming the original data into the Ln (natural logarithm) form. Data that is not yet stationary in terms of its mean or variance can be addressed by applying differentiation and transformation using the square root or Ln . There are three methods that can be used to evaluate stationarity: examining the data trend on a graph, using autocorrelation and a correlogram, and conducting a unit roots test. Subsequently, the unit roots test was selected for application in this study. Based on the results of the stationarity test, it was found that some variables were already stationary at the level, while others became stationary only after the first differentiation. Therefore, data handling was performed according to the integration order of each variable before further analysis was conducted. Simulation was conducted to determine the policy strategies that can be implemented to control Indonesia's sugar supply in response to global supply dynamics. The simulation will examine the impact of changes in response variables on explanatory variables in the model. The policy simulation conducted in this study consists of a single scenario and a combination scenario. The simulation scenarios in this study are as follows: Scenario 1 (S1), a single scenario increases sugarcane production by 10% Scenario 2 (S2), a single scenario that increases yield by 10% Scenario 3 (S3), a single scenario that reduces sugar consumption by 10% Scenario 4 (S4), a combined scenario that increases sugarcane production and yield by 10% and reduces sugar consumption by 10%.

RESULT AND DISCUSSION

Model Validation Results

Model validation in simultaneous equations is necessary to determine whether the model is valid enough to be used for policy simulation, so that it can represent actual conditions. This validation process is important because simultaneous models usually consist of several interrelated equations that influence each other, requiring testing of the accuracy and consistency of the model as a whole. The main objective is to ensure that the parameter estimation results are reliable and unbiased. Through the validation process, it can be

determined whether the model has a small forecasting error, does not show systematic patterns (random errors), and can be used for accurate policy decision-making or economic policy simulation. Thus, model validation serves as a final step to ensure that simultaneous equation models are not only theoretically valid but also empirically reliable.

Table 2. Model Validation Test Results

Variable	Unit	MSE	U-Theil	US
PGIt	Ton	2.019	0.0323	0.10
IGIt	Ton	2.134	0.0835	0.03
EGIt	Ton	3.675	0.1452	0.02
SGATt-1	Ton	2.047	0.8210	0.01
SGIt	Ton	2.074	0.4166	0.05

Based on the results of model validation, it is known that the predicted values are close to the actual values with a relatively small total mean square error (MSE). The U-Theil and variance portion (US) values are relatively small and close to zero (Table 1), meaning that the values obtained from the simulation results will be close to the actual values. Based on the measures used in the validation test, the simultaneous equation model used in this study is generally valid and relatively safe to use for simulation.

Policy Simulation

The simulation aims to observe the impact of changes in response variables on explanatory variables in the model. The simulation results in Table 2 show that a 10% increase in sugarcane production (Scenario 1) increases domestic sugar production (PGIt) and sugar exports (EGIt) by 1.37% and 3.77%, respectively, and reduces sugar imports (IGIt) by 1.41% or the equivalent of 32,721 tons. Although sugar production increased, total sugar supply (SGIt) decreased slightly because the decline in imports was greater than the increase in production. Although sugar production increased, the total sugar supply (SGIt) slightly decreased because the decline in imports was greater than the increase in production. Rationally, this condition can be explained by the fact that an increase in domestic production encourages substitution for imported sugar, thereby significantly reducing dependence on imports. However, since imports contribute a relatively large share to the total supply, the sharp decline in imports cannot be fully offset by the increase in domestic production, resulting in an overall decrease in total sugar supply.

Meanwhile, a 10% increase in sugarcane yield (Scenario 2) drives a higher increase in sugar production (PGIt) and exports (EGIt) compared to scenario 1. However, it also causes a greater decline in sugar imports (IGIt), resulting in a greater decline in total sugar supply (SGIt) compared to scenario 1. This finding is in line with research conducted by (Nurmalina et al., 2011) which shows a positive relationship between yield and sugar production.

Table 3. Simulation Results of Policies on Indonesia's Sugar Supply

Simulation	Endogenous	Base Value	Simulation Value	Unit Change	Percentage (%)
Scenario 1: 10% Increase in Sugar Cane Production	PGIt	2185750	2215699	29949	1,37
	IGIt	2321911	2289160	-32751	-1,41
	EGIt	14765,5	15322	556,5	3,77
	SGATt-1	-1253018	-1253018	0	0
	SGIt	3239877	3236518	-3359	-0,1
Scenario 2: 10% Yield Increase	PGIt	2185750	2272257	86507	3,96
	IGIt	2321911	2227311	-94600	-4,07
	EGIt	14765,5	16373	1607,5	10,89
	SGATt-1	-1253018	-1253018	0	0

	SGIt	3239877	3230177	-9700	-0,30
Scenario 3: 10% decrease in sugar consumption	PGIt	2185750	2185750	0	0
	IGIt	2321911	1920279	-401632	-17,30
	EGIt	14765,5	14765,5	0	0
	SGATt-1	-1253018	-1253018	0	0
	SGIt	3239877	2838245	-401632	-12,40
Scenario 4: Sugarcane Production and Yield Increase by 10% + domestic consumption decrease by 10%	PGIt	2185750	2302206	116456	5,33
	IGIt	2321911	1792928	-528983	-22,78
	EGIt	14765,5	16929,5	2164	14,66
	SGATt-1	-1253018	-1253018	0	0
	SGIt	3239877	2825186	-414691	-12,80

A 10% reduction in sugar consumption (Scenario 3) significantly reduces imports by 17.30% or the equivalent of 401,632 tons without affecting production and exports, so that the total sugar supply falls by the amount of the reduction in imports. This finding is in line with research conducted by (Aushaf et al., 2018; Rusdi et al., 2021) which shows a positive relationship between sugar consumption and imports. These results indicate that domestic sugar consumption has a significant effect on domestic sugar supply. Therefore, clear regulations and re-education are needed to raise public awareness about the health impacts of excessive sugar consumption. The combination of a 10% increase in production and yield and a 10% decrease in consumption (Scenario 4) increases sugar production and exports by 5.33% and 14.66%, respectively, and reduces imports by 22.78%, equivalent to 528,983 tons. The decrease in imports and increase in exports cause the total domestic sugar supply to fall by 414,691 tons (12.8%).

Overall, the simulation results show that the dynamics of sugar supply in Indonesia are influenced not only by production capacity, but also by consumption patterns. Therefore, supply management policies must consider the balance between increasing production and controlling consumption in order to maintain domestic market stability. The policy simulation results support the research hypothesis that sugar production, yield, and consumption affect Indonesia's sugar supply. Increased production and yield have been shown to increase domestic sugar production, while domestic sugar consumption has the most dominant effect on imports and national sugar supply. Thus, the research hypothesis can be accepted, and the results of this study reinforce the theoretical framework regarding the importance of an integrated sugar supply policy approach. The simulation results indicate that, at the macro level, increases in sugarcane production and yield encourage higher domestic sugar production and exports, while reducing imports through an import substitution effect, thereby contributing positively to the trade balance. However, a larger decline in imports compared to the increase in production leads to a decrease in total sugar supply, which may create pressure on domestic price stability. On the other hand, improvements in yield are proven to be more effective than increases in sugarcane production, highlighting the importance of technical efficiency in enhancing the competitiveness of the sugar industry. A reduction in consumption has the most significant impact on lowering imports, while also providing additional public health benefits. Overall, these findings indicate the existence of a trade-off between self-sufficiency and supply adequacy, implying that sugar policies should be designed in an integrated manner by combining production enhancement, consumption control, as well as strengthening stock and distribution policies to maintain market stability.

Hypothesis Testing

The econometric model in this study is constructed as a simultaneous equation system and has undergone several stages of model re-specification. The model consists of structural equations and identity equations. The economic validity of Indonesia's sugar supply model is indicated by the conformity of the signs of the estimated coefficients of each explanatory variable with the hypotheses developed based on economic theory.

Table 4. Estimation Results of Indonesia's Sugar Production Equation

Variable	Coefficient	Prob.	Elasticity		Description
			SR	LR	
C	-18239,91	0,1642			Intercept
PTIR	0,5551***	0,0027	0,6519	1,0477	Sugarcane production (ton)
LAGLTIR	0,3081	0,1136			Sugarcane land area (ha)
RGIR	0,2848*	0,0719	0,0388	0,0623	Yield (%)
HGIR	0,0059	0,7327			Domestic sugar price (ton/ha)
LAGPGI	0,3163**	0,0428			Lag of sugar production (ton)
R-sq	0.7398				
F-stat	13.082				
DW	1.5074				

In the sugar production equation, the R^2 value of 0.7398 indicates that 73.98% of the variation in sugar production can be explained by the variables in the model. Sugarcane production has a positive and significant effect at the 1% level, with elasticities of 0.6519 (short run) and 1.0477 (long run). This indicates that increasing sugarcane production will increase sugar production, especially in the long run. Sugar yield also has a positive effect at the 10% level, although with relatively small elasticity, indicating that processing efficiency remains a constraint.

Table 5. Estimation Results of Indonesia's Sugar Import Equation

Variable	Coefficient	Prob.	Elasticity		Description
			SR	LR	
C	96552,45	0,1045			Intercept
KURS	-1,0085*	0,0599	-0,6313	-0,8697	Exchange rate (Rp/US$)
INIR	-0,0128	0,9369			Inflation (%)
KGIR	2,3182***	0,0015	2,4175	3,3303	Domestic sugar consumption(ton)
PGI	-2,2364**	0,0343	-2,2753	-3,1345	Sugar production (ton)
HGIR	0,3731	0,4737			Domestic sugar price (Rp/ton)
HGWR	-0,6949	0,1345			World sugar price (Rp/ton)
LAGIGI	0,2421	0,2848			Lag of sugar imports (ton)
R-sq	0,8667				
F-stat	19.8301				
DW	1.8727				

In the sugar import equation, the R^2 value of 0.8667 indicates very strong explanatory power. The exchange rate has a negative effect, meaning depreciation reduces imports. Domestic consumption has a positive and elastic effect, significantly increasing imports. Meanwhile, domestic production negatively affects imports, indicating reduced dependency on imports.

Table 6. Estimation Results of Indonesia's Sugar Import Equation

Variable	Coefficient	Prob.	Elasticity		Description
			SR	LR	
C	-117373,2	0,5433			Intercept
KURS	0,0511	0,9705			Exchange rate (Rp/US$)
LAGPGI	1,435410	0,6622			Sugar production (ton)
GDPIR	2,4683*	0,0555	13,2917	38,9653	GDP (Triliun Rp)
HGIR	-3,2931*	0,0911	-7,6928	-22,5517	Domestic sugar price (Rp/ton)
LAGEGI	0,6712**	0,0328			Lag of exports (ton)
R-sq	0,6860				
F-stat	7.9656				

DW	1.9377

In the sugar export equation, the R^2 value of 0.6860 indicates that 68.60% of export variation is explained by the model. GDP has a positive effect, indicating economic growth increases exports. Meanwhile, domestic sugar prices negatively affect exports, meaning higher prices reduce international competitiveness.

DISCUSSION

The findings of this study provide important insights into the dynamics of Indonesia's sugar supply system, particularly in terms of the interaction between production, consumption, and trade variables. The results confirm that sugar supply is not solely determined by production capacity but is also significantly influenced by demand-side factors, especially domestic consumption. This finding is consistent with the study by (Sadiyah et al., 2014), which shows that sugar supply is influenced by multiple economic variables, including consumption and imports, indicating the multidimensional nature of supply formation.

First, the simulation results demonstrate that increases in sugarcane production and yield have a positive impact on domestic sugar production and exports, while reducing imports through an import substitution mechanism. This finding is in line with (Abdul et al., 2017), who state that sugar supply is closely related to domestic production and imports. However, this study extends previous findings by showing that an increase in production does not automatically increase total supply due to the dominant role of imports in Indonesia's sugar supply structure. This result also complements the findings of (Apriyanto, 2009), who emphasized the role of production factors but did not explicitly account for the interaction with import dynamics.

Second, the results reveal that yield improvement has a greater impact on sugar production compared to increasing sugarcane production. This supports the findings of (Apriawan et al., 2015; Nurmalina et al., 2011), which highlight the importance of technical efficiency and productivity in the sugar industry. Moreover, this finding is consistent with international studies such as (Mehdi et al., 2024) and (Silva et al., 2024), which emphasize that yield is strongly influenced by technological, environmental, and management factors. Thus, this study reinforces the argument that intensification strategies are more effective than extensification in increasing agricultural output.

Third, domestic sugar consumption is found to be the most influential variable affecting national sugar supply, particularly through its impact on imports. A reduction in consumption significantly decreases imports without affecting production levels. This finding is consistent with (Aushaf et al., 2018) and (Rusdi et al., 2021), who found a strong positive relationship between sugar consumption and imports in Indonesia. However, this study contributes further by demonstrating the magnitude of this effect through simulation analysis, showing that consumption control can be a key policy instrument in reducing import dependency.

Furthermore, the combined policy simulation (increasing production and yield while reducing consumption) produces the most optimal outcome in terms of reducing import dependency and strengthening domestic supply resilience. This finding supports the argument by (Sitepu & Sinaga, 2018) that simultaneous equation models are effective in capturing complex interrelationships among economic variables and are suitable for evaluating integrated policy scenarios. Compared to previous studies that analyze variables partially, this study provides a more comprehensive framework by integrating production, consumption, trade, and stock variables into a single analytical model.

Another important aspect highlighted in this study is the trade-off between self-sufficiency and supply adequacy. While reducing imports improves the trade balance, it may also reduce total supply if not accompanied by sufficient increases in domestic production. This finding is consistent with (Pudjiastuti, 2014), who noted that import reduction policies

can have implications for trade balance and domestic market stability. Additionally, the study by (Laili et al., 2014) supports the notion that global price volatility can affect domestic supply conditions, particularly in import-dependent countries like Indonesia.

Compared to previous literature, this study offers a novel contribution by explicitly quantifying the relative impact of production, yield, and consumption on sugar supply through a simulation-based simultaneous equation model. While earlier studies tend to focus on individual determinants, this research highlights the importance of policy integration across sectors. The results clearly show that relying solely on production increases is insufficient to stabilize supply without considering consumption control and trade dynamics.

Overall, the findings emphasize that an integrated policy approach combining production enhancement, efficiency improvement, consumption control, and adaptive trade policies is essential for maintaining the stability and sustainability of Indonesia's sugar supply system. Without such integration, policy interventions may lead to unintended consequences, such as supply shortages or increased price volatility.

CONCLUSION

The simulation results show that changes in sugarcane production, yield, and domestic sugar consumption have a direct impact on the national sugar supply. Among these three variables, domestic sugar consumption has the most significant effect on changes in supply. These findings confirm that the dynamics of sugar supply in Indonesia are determined not only by production capacity, but also by consumer behavior. The analysis confirms that the dynamics of sugar supply in Indonesia are not only influenced by production capacity, but also by consumption patterns. Therefore, sugar supply management policies need to be designed in an integrated manner, taking into account the balance between increasing production and controlling consumption.

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