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PRICE INTEGRATION OF MAJOR VEGETABLE OILS: A VECM APPROACH

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ABSTRACT

Globally four main vegetable oils are soybean, rapeseed, sunflower, and palm oils. Although these oils compete, their prices typically trend in the same direction. This research aims to investigate the short-term and long-term pricing relationships among these four oils. After using the Vector Error Correction Model (VECM) for analysis, the study applies variance decomposition and impulse response approaches. Monthly data from January 2003 to December 2024 is included in the dataset. The results show that each vegetable oil's price is impacted by its historical price in the short run. On the other hand, the four oil prices show a long-term link over the long run, suggesting that they are cointegrated. It is evident from variance decomposition and impulse response function analysis that soybean oil's price significantly has a greater influence on the price of palm, sunflower, and rapeseed oils. The conclusion is that the price fluctuations of rapeseed oil, sunflower oil, and palm oil are largely driven by changes in soybean oil prices.

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INTRODUCTION

The world's largest producer of palm oil at the moment is Indonesia. Given the rising market share and consumption of palm oil, Indonesia sees significant opportunities through export activities (Khairunisa & Novianti, 2017). The most popular vegetable oil product on the world market right now is palm oil, with Indonesia leading the way as its export volumes reach 3.6 million tonnes by 2023, followed closely by Malaysia at 3.5 million tonnes. Other countries such as Guatemala and Thailand follow, with export volumes of 811,364 tonnes and 803,698 tonnes, respectively (TradeMap, 2024). The dominance of palm oil in the global market is driven by major producers such as Indonesia and Malaysia, which compete fiercely, especially in key markets like China and India (Rifin, 2013).

According to BPS data (2023), Indonesia produced 42.88 million tonnes of crude palm oil (CPO) in 2018 and 47.12 million tonnes in 2019, marking a significant rise. However, in 2020 and 2021, production declined to 45.74 million tonnes and 45.12 million tonnes, respectively, with the decline expected to be caused by the effects of the COVID-19 outbreak. In 2021, CPO production decreased by 1.36% compared to the previous year, to 45.12 million tonnes. However, in 2022, production increased again to 46.82 million tonnes, showing signs of recovery after the crisis period. As plantation land continues to expand, Indonesia's palm oil production volume also shows a significant positive effect on the sector's productivity (Nuryanto et al., 2023). This data can be seen visually in the following figure.

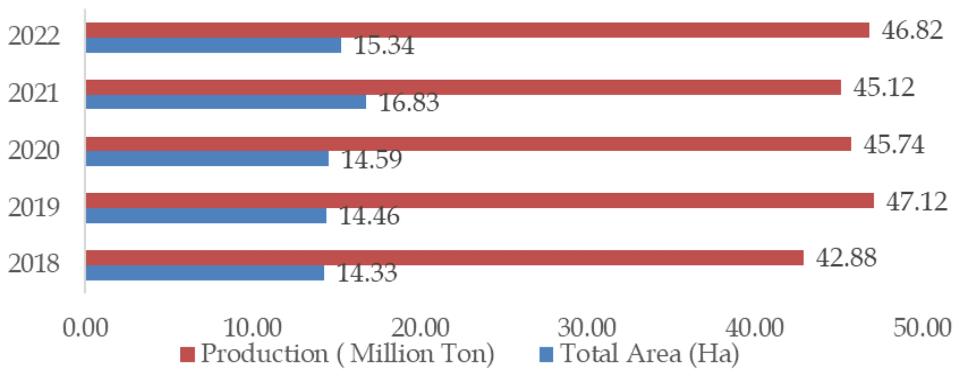

Figure 1.
Total Area and Production of Indonesian Oil Palm Plantations 2018-2023 (BPS, 2023)

Palm oil has surpassed soybean oil in production, capturing a market share of 40% in 2021, while soybean oil's share has decreased to 33% (Sipayung, 2024). Palm oil's productivity advantage, yielding 3.36 tonnes per hectare per year, makes it more efficient than other vegetable oils such as rapeseed and sunflower (PASPI, 2022).

The growth in global palm oil production and use is mainly because of more people wanting it, especially in big countries like China and India. In China, the amount of edible oil used went up from 13.9 million tonnes in 2001 to 36.81 million tonnes by 2019 (PASPI, 2019). India also saw a big increase, with vegetable oil use rising from 9 million tonnes in 2001 to 22 million tonnes in 2018. Palm oil became a popular choice there because it is cheaper (Zakaria et al., 2017).

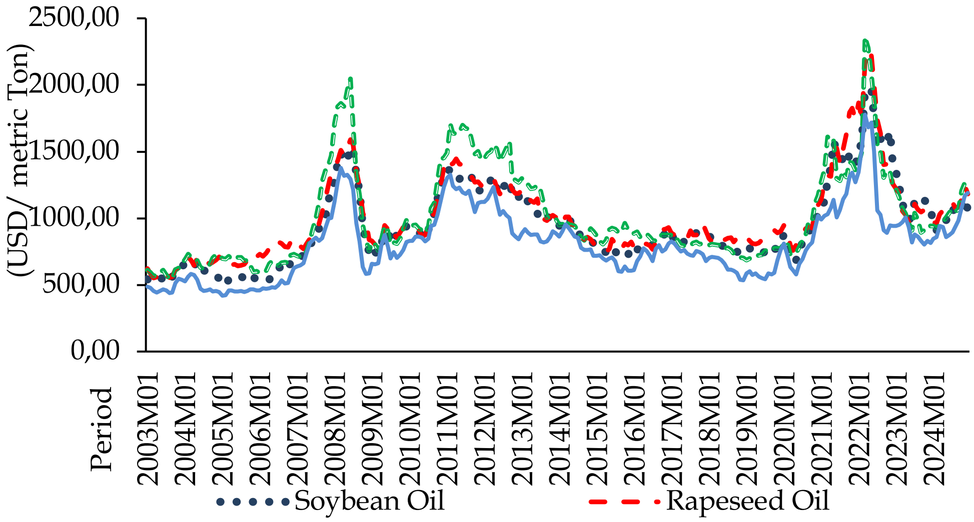

Figure 2.
The Price Developments of Palm Oil (CPO), Sunflower Oil, Soybean Oil, and Rapeseed Oil From January 2003 and June 2024 (World Bank, 2024)

Many external factors, such as weather variations, political issues, and the demand for biofuels, have an impact on palm oil prices. It can be challenging to forecast the amount of palm oil that will be produced due to weather patterns like El Niño and La Niña According to a study by Akmalia (Akmalia, 2022), El Niño can reduce Indonesia's oil palm harvests, which lowers supply and raises the price of palm oil globally. Additionally, political issues like the Russia-Ukraine conflict and the US-China trade war increase market uncertainty for palm oil. These nations purchase a lot of palm oil, and a study by Enh et al. (Enh et al., 2024) revealed that these disputes can affect vegetable oil prices globally. The price of palm oil is also linked to the price of other vegetable oils, such as rapeseed, sunflower, and soybean oils. When the price of one vegetable oil rises or falls, it frequently impacts the prices of other vegetable oils, such as palm oil, causing a substitution effect, according to research by Rifin and Nauly (Rifin & Nauly, 2021).

According to studies like the one by Oktiani (2019), the prices of soybean and sunflower oils have an impact on one another, confirming the notion that the world's vegetable oil market is interconnected.Using various economic tools for analysis, numerous studies have examined how prices move in these markets, particularly in relation to market integration (Helbawanti et al., 2022; Zaidi et al., 2022).

Market integration is another name for price integration. Market integration is possible if a product or service has a relationship with another product in a different market. According to Nurhidayati et al. (2015), marketing efficiency is reflected in the integration of markets, especially when considering price efficiency. The relationship between a market and other markets based on their price connections is known as price integration. There is a long-term relationship between the prices of vegetable oils, per earlier research by Rifin & Nauly (2021). The significant price swings in the global vegetable oil market over the last three years, which have been impacted by numerous world events, make this study especially important. Due to supply chain disruptions and decreased production and export volumes, the COVID-19 pandemic caused changes in palm oil prices (Zahraturrahmi & Demircan, 2023). Furthermore, a shortage of sunflower oil brought on by the Russia-Ukraine conflict, which started in 2022, increased market instability (Jagtap et al., 2022). Palm oil and other vegetable oils saw price increases as a result of these shortages. Indonesia's economic activity and income distribution have been affected by the increase in global CPO prices (Winardi et al., 2017).

The EU Deforestation Regulation (EUDR), which went into effect in 2023, has also begun to affect the market by tightening the requirements for deforestation in the production of palm oil. This could result in a reduction in the world's supply of crude palm oil (PASPI, 2024). Producing countries like Indonesia now face additional challenges as a result of global efforts to reduce deforestation and international regulations like the EUDR. The research of Mutia et al. (2024), Indonesian palm oil producers have been pressured to adopt more sustainable practices by the EUDR, which upholds strict environmental regulations within the EU. The relationship between the prices of vegetable oil around the world reveals a complex scenario that involves both international policies and market forces, all of which influence price fluctuations. The purpose of this article is to examine the short- and long-term relationships between the prices of the four major vegetable oils.

RESEARCH METHOD

Monthly data types covering the period from January 2003 to December 2024 are included in the secondary data in the form of time series of prices for four vegetable oils (soybean, rapeseed, sunflower, and palm oil prices) from the World Bank. An econometric technique is used to analyse the quantitative data, and EViews 12 software is used to analyse the long-term association among the four vegetable oils for the VECM model. Every variable in the Vector Error Correction Model (VECM) is treated as endogenous (Enders, 2004). The VECM equation to be estimated in this study is presented as follows:

$$\Delta ln\, SO_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{1i}\, \Delta ln\, SO_{t-i} + \sum_{i=1}^{m} \alpha_{2i}\, \Delta ln\, RO_{t-i} + \sum_{i=1}^{m} \alpha_{3i}\, \Delta ln\, SFO_{t-i} + \sum_{i=1}^{m} \alpha_{4i}\, \Delta ln\, PO_{t-i} + \alpha_5\, ECT_{t-1} + \mu_t$$

$$\Delta ln\, RO_t = \beta_0 + \sum_{i=1}^{m} \beta_{1i}\, \Delta ln\, SO_{t-i} + \sum_{i=1}^{m} \beta_{2i}\, \Delta ln\, RO_{t-i} + \sum_{i=1}^{m} \beta_{3i}\, \Delta ln\, SFO_{t-i} + \sum_{i=1}^{m} \beta_{4i}\, \Delta ln\, PO_{t-i} + \beta_5\, ECT_{t-1} + \varepsilon_t$$

$$\Delta ln\, SFO_t = \gamma_0 + \sum_{i=1}^{m} \gamma_{1i}\, \Delta ln\, SO_{t-i} + \sum_{i=1}^{m} \gamma_{2i}\, \Delta ln\, RO_{t-i} + \sum_{i=1}^{m} \gamma_{3i}\, \Delta ln\, SFO_{t-i} + \sum_{i=1}^{m} \gamma_{4i}\, \Delta ln\, PO_{t-i} + \gamma_5\, ECT_{t-1} + \mathrm{v}_t$$

$$\Delta ln\, PO_t = \delta_0 + \sum_{i=1}^{m} \delta_{1i}\, \Delta ln\, SO_{t-i} + \sum_{i=1}^{m} \delta_{2i}\, \Delta ln\, RO_{t-i} + \sum_{i=1}^{m} \delta_{3i}\, \Delta ln\, SFO_{t-i} + \sum_{i=1}^{m} \delta_{4i}\, \Delta ln\, PO_{t-i} + \delta_5\, ECT_{t-1} + \mathrm{y}_t$$

Description: SO= The price of soybean oil internationally (USD per tons); RO = The price of rapeseed oil internationally (USD per tons); SFO = The price of sunflower oil internationally (USD per tons); PO = The price of palm oil internationally (USD per tons) (A logarithmic conversion will be applied to all prices); $\mu_t, \varepsilon_t, v_t, \mathrm{y}_t$ = Error term at time t; ECT_{t-1} = Error Correction Term value at time t-1.

Analysis of impulse response and variance decomposition will be carried out after the VECM model has been estimated. The analysis of impulse response looks at how an endogenous variable reacts to an exogenous variable shock. On the other hand, variance decomposition seeks to assess the proportion of a variable's variance explained by its own price as well as the influence of other variables simultaneously.

RESULT AND DISCUSSION

Testing the stationarity of each variable is the first step in this analysis to make sure there isn't a unit root present, which could produce biased results. The data used in this study must be stationary, exhibit relatively consistent variation, and tend to revert to an average value (Gujarati, 2004). The research dataset is made up of 259 observations, spans the period from January 2003 to December 2024.

Table 1. Results of the Augmented Dickey-Fuller (ADF) Test for the Prices of Sunflower Oil, Soybean Oil, Rapeseed Oil, and CPO at level

Variable	ADF Value	Mckinnon Critical Value			Prob.	Description
		1%	5%	10%		
Ln Soybean Oil	-2.536182	-3.455193	-2.872370	-2.572615	0.0773	Not Stationary
Ln Rapeseed Oil	-2.489113	-3.455193	-2.872370	-2.572615	0.1221	Not Stationary
Ln Sunflower Oil	-2.652188	-3.455685	-2.872586	-2.572730	0.1229	Not Stationary
Ln Palm Oil	-2.568023	-3.455685	-2.872586	-2.572730	0.0844	Not Stationary

Using the Augmented Dickey-Fuller (ADF) test, the four variables are examined at a 5% significance level. The data is non-stationary if a unit root is present, as indicated by the null hypothesis (H_0: $\beta_1 = 0$), but the alternative hypothesis (H_1: $\beta_1 \neq 0$) implies that there is no unit root and the data is stationary. A p-value below the significance level (5%) indicates the rejection of the null hypothesis. The following table displays the findings of the unit root test conducted using the ADF test.

The Augmented Dickey-Fuller (ADF) test indicates that none of the variables are stationary at the initial level. Therefore, the next step is to take the first difference and convert all variables into a stationary series. The following table displays the outcomes of this transformation.

Table 2. Results of the Augmented Dicky Fuller (ADF) Test for the Prices of Sunflower Oil, Soybean Oil, Rapeseed Oil, and CPO at the First Difference Level

Variable	ADF Value	Mckinnon Critical Value			Prob.	Description
		1%	5%	10%		
Ln Soybean Oil	-10.53851	-3.455193	-2,872370	-2.572615	0.0000	Stationary
Ln Rapeseed Oil	-11.85179	-3.455193	-2.872370	-2.572615	0.0000	Stationary
Ln Sunflower Oil	-11.34924	-3.455193	-2.872370	-2.572615	0.0000	Stationary
Ln Palm Oil	-11.02314	-3.455193	-2.872370	-2.572615	0.0000	Stationary

The next step is to ascertain whether there is a long-term correlation or cointegration between the prices of the four vegetable oils. The Johansen Cointegration method is employed for this purpose. The results shown in Table 3 indicate that using the trace statistic rejects H0 (Prob below 0.05) which states that there is no cointegration or in other words there is a cointegrating equation.

Table 3. Results of Johansen's Cointegration Test for Cointegration

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.168453	82.25159	54.07904	0.0000
At most 1	0.052392	34.2902	35.19275	0.0623
At most 2 *	0.05102	20.29845	20.26184	0.0494
At most 3	0.025375	6.682763	9.164546	0.1442

The cointegration test outcome provides sufficient proof of a lengthy-term connection between the variables, indicating that cointegration exists in the model. This finding is in line with the results of Destiarni and Jamil (2021), which show that there is a long-term relationship between the prices of these vegetable oils. Therefore, the model will be estimated using the VECM method. Short-term and long-term correlations between the price variables of palm oil, soybean oil, rapeseed oil, and sunflower oil will be shown using the VECM estimation. The following are the Table 4 results of the long-run estimation of the VECM model.

The long-run relationship indicates that the prices of rapeseed oil (RO) and palm oil (PO) have a negative and notable impact, as evidenced by the high t-statistics values in parentheses. The constant (C) of 0.138527 reflects the fixed effect in the long-run price balance between variables within the model, which remains unchanged despite fluctuations in the prices of other vegetable oils.

Table 4. The long-run Relationship Between the Four Edible Oil Prices

	Long -run	
Variable	Coefficient	t- statistics
LNSO(-1)	1.000000	
LNRO(-1)	-0.365728*	-3.75852
LNSFO(-1)	0.081006	0.89187
LNPO(-1)	-0.750679*	-8.73892
C	0.138527	0.65615

Note: * significant at 5%

In the long run, the price of rapeseed oil (RO) exhibits a strong negative relationship with the price of soybean oil (SO). A 1% increase in the price of rapeseed oil (RO) leads to a 0.365728% decrease in the price of soybean oil (SO), with a significance level of 5% and a t-statistic of 3.76. This indicates that changes in rapeseed oil prices significantly influence soybean oil prices in the long term.

Meanwhile, the price of sunflower oil (SFO) has a positive relationship with the price of soybean oil (SO) in the long run. The price of soybean oil goes up by 0.081006% for each 1% increase in the price of sunflower oil. However, because the t-statistic is 0.89, beneath the critical value of 1.96, this relationship is not statistically significant at the 5% level. Therefore, the price of sunflower oil has no long-term impact on the price of soybean oil.

The price of palm oil (PO) and soybean oil (SO) have a substantial negative correlation over the long term. The price of soybean oil decreases by 0.75% for every 1% increase in palm oil prices. Given that the t-statistic is 8.74—which is significantly higher than 1.96—this association is extremely strong. This indicates that the price of palm oil has a significant long-term impact on the price of soybean oil. This demonstrates that soybean oil and palm oil are interchangeable on the international market and serve comparable functions (Simanjuntak et al., 2020).

The average impact of outside variables that are not part of the model is represented by the constant (C) in the long-run table. However, short-term changes in vegetable oil prices are mostly due to the lag of variables in the model rather than external factors indicated by the constant because the constant isn't significant in the models.The R-squared values for ΔLnSO, ΔLnRO, ΔLnSFO, and ΔLnPO are 0.24, 0.20, 0.18, and 0.19, respectively.

These figures imply that oil prices are influenced by additional variables not included in the model. This VECM analysis examines short-term interactions between the variables in addition to long-term relationships. Table 5 displays the short-run analysis's findings.

Table 5. The Short-Run Relationship Between the Prices of Four Vegetable Oils

Variable	Variable dependent							
	ΔLnSO	t-stat	ΔLnRO	t-stat	ΔLnSFO	t-stat	ΔLnPO	t-stat
ΔLnSO t-1	0.42*	4.05	0.25*	2,41	0.27*	2.03	0.17	1.28
ΔLnSO t-2	0.04	0.38	0.01	0.05	0.07	0.49	-0.18	-1.33
ΔLnSO t-3	-0.03	-0.27	-0.08	-0.72	-0.01	-0.04	-0.05	-0.40
ΔLnRO t-1	-0.14	-1.50	-0.08	-0.89	-0.27*	-2.25	-0.16	-1.34
ΔLnRO t-2	0.05	0.54	-0.12	-1.32	0.10	0.81	0.05	0.44
ΔLnRO t-3	-0.06	-0.71	0.01	0.12	-0.14	-1.21	-0.02	-0.14
ΔLnSFO t-1	0.07	1.02	0.15*	2.05	0.21*	2.22	-0.01	-0.10
ΔLnSFO t-2	0.13	1.78	0.10	1.30	-0.05	-0.53	0.26*	2.77
ΔLnSFO t-3	-0.30	-0.30	0.04	0.51	-0.04	-0.36	-0.11	-1.14
ΔLnPO t-1	-0.04	-0.60	-0.00	-0.03	0.11	1.21	0.43*	4.65
ΔLnPO t-2	-0.17*	-2.33	0.05	0.68	-0.08	-0.83	-0.18	-1.84
ΔLnPO t-3	0.03	0.37	-0.01	-0.17	0.13	1.36	0.18	1.88
ECT t-1	-0.19*	-3.64	-0.06	-1.16	-0.16*	-2.34	0.09	1.31
R-squared	0.24		0.20			0.18	0.19	

Note: * significant at 5%

The long-term dynamic response can be observed in this step of the Impulse Response Function test, which helps interpret the VECM model by looking at how each variable responds to external shocks (Paramita et al., 2015). A one-unit shift in a variable's standard deviation is referred to as a shock. By displaying the pattern of a variable's reaction to a shock and the amount of time required to return to equilibrium, the IRF shows how the system's variables react to shocks over time.

Changes in the price of soybean oil (LnSO) have a greater impact to own price than changes in the prices of rapeseed, sunflower, and palm oils. In the beginning, the price of rapeseed oil (LnRO) is primarily determined by its own price; however, over time, changes in the price of soybean oil have a significant effect on the price of rapeseed oil. This is consistent with the short-term model, which indicates that the price of soybean oil has a significant impact on the price of rapeseed oil. Compared to changes in the prices of soybean, rapeseed, and palm oils, changes in the price of sunflower oil (LnSFO) have the largest impact during the first period. Interpreting the VECM model is made simpler by this step of the Impulse Response Function test, which explains how variables respond over time to changes in other variables. A one-unit shift in a variable's standard deviation is referred to as a shock.

According to the impulse response analysis, even after the initial period, changes in the price of soybean oil (LnSO) have an impact on the prices of rapeseed oil (LnRO), sunflower oil (LnSFO), and palm oil (LnPO). The prices of the other oils will therefore probably be impacted by changes in the price of soybean oil. This lends credence to the notion that changes in palm oil prices can be explained by changes in soybean oil prices (Hassan & Balu, 2016; Ismail et al., 2019; Manik et al., 2018; Zakaria et al., 2017).

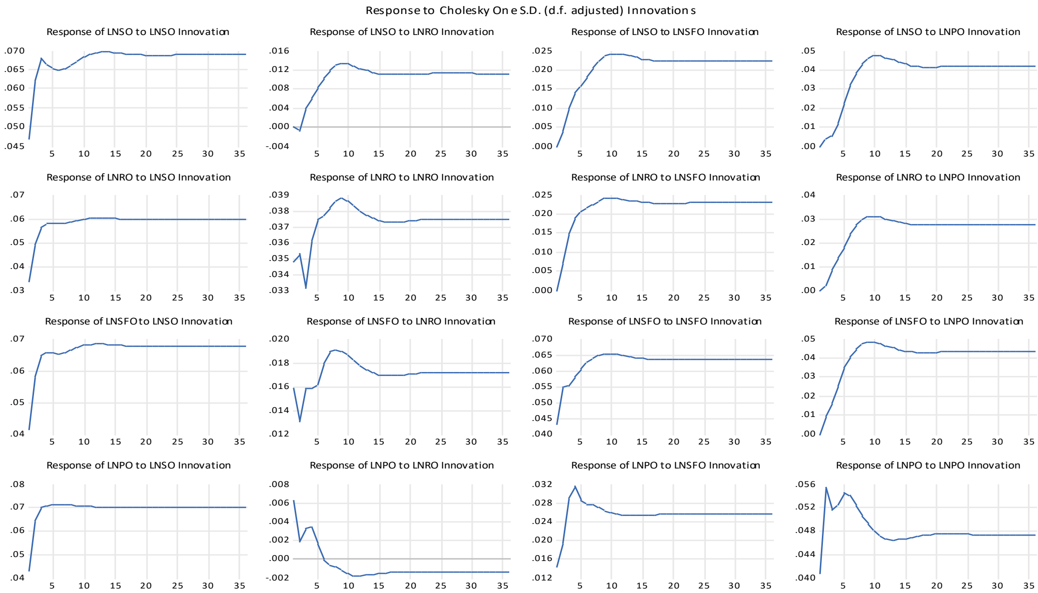

Figure 3.
IRF of Four Vegetable Oil Prices

Lastly, variance decomposition is employed, which examines how a variable's variation over time is impacted or molded by its own price and other variables. The relative significance of each variable in the system as a result of shocks is highlighted in this analysis. In order to determine which prices contribute to or cause price fluctuations, variance decomposition seeks to isolate the effect of each variable on the system's response. In this study, the focus is on determining which vegetable oil prices contribute to or drive price fluctuations.

Other vegetable oil prices have a relatively small contribution to the variation in soybean oil prices (LnSO) is relatively minor (Figure 4a). In the first period, the variance is entirely driven by its own price. After 24 months, the contributions of rapeseed oil and sunflower oil prices remain relatively minor, each under 20%, while palm oil contributes about 20%.

For rapeseed oil price variance (LnRO), in addition to its own price, the price of soybean oil plays a notable role (Figure 4b). The contributions of sunflower oil and palm oil to the variance of rapeseed oil price are relatively small. Similarly, the variance of sunflower oil prices (LnSFO) is influenced by soybean oil prices, along with its own price. Contributions from rapeseed oil and palm oil prices are relatively small (Figure 4c).

The variance in palm oil prices (LnPO) is predominantly driven by the price of soybean oil, which accounts for 61.13% of the variance by month 24. The contribution of palm oil prices reached 30.33% in month 24, showing a significant impact although not as large as that of soybean oil prices. The contribution from sunflower oil price is minimal, less than 10%, and the impact of rapeseed oil price is so small that it can be largely ignored (Figure 4d).

Based on the variance decomposition results, it is evident that fluctuations in soybean oil prices are primarily driven by its own price. Conversely, the price fluctuations of rapeseed oil, sunflower oil, and palm oil are mainly influenced by soybean oil prices. These results are in agreement with the findings reported by Azam et al. (2020), who found that compared to the prices of other vegetable oils, the price of soybean oil had a greater influence on the prices of rapeseed, sunflower, and palm oils.

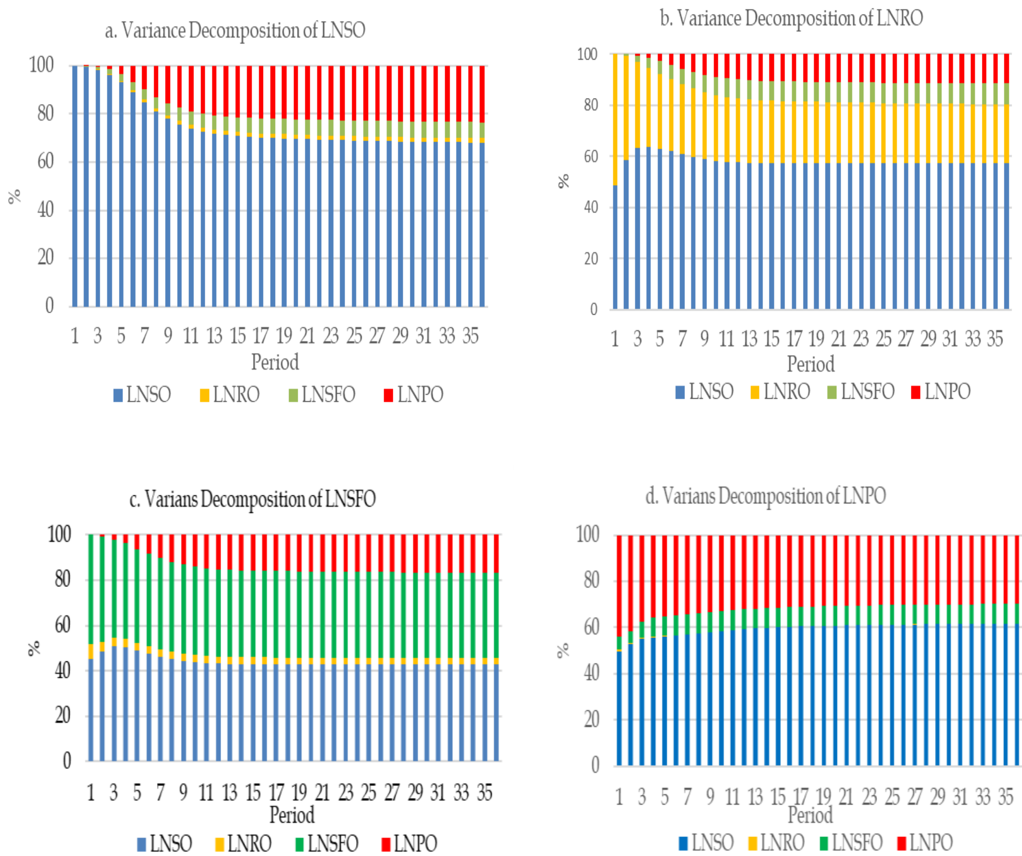

Figure 4.
Variance Decomposition of Four Vegetable Oil Prices

CONCLUSION

Four vegetable oils move together over an extended period of time, but not in the short term, according to the study. The study demonstrated that soybean oil prices have the largest impact using instruments known as the Impulse Response Function (IRF) and Variance Decomposition (VD). The price of other vegetable oils may fluctuate if the price of soybean oil changes abruptly. According to the study, nations that produce rapeseed, palm, and sunflower oils ought to keep a careful eye on the price of soybean oil. With effects beginning in the first month and continuing for months, changes in the price of soybean oil can have a rapid impact on the prices of other oils, such as palm, sunflower, and rapeseed.

The study recommends the Indonesian government to closely monitor changes in soybean oil prices, particularly in important export markets like China and India, as they have a greater impact on palm oil prices. The price of palm oil may be directly impacted through the price of soybean oil. The Indonesian government may think about taking steps like increasing national reserves or establishing domestic price caps to help maintain economic stability. By taking these precautions, local palm oil producers can be shielded from unanticipated fluctuations in the price of other vegetable oils, such as soybean or sunflower.

In addition, in order to lessen reliance on particular markets and increase export shares to nations that are not yet significant palm oil consumers, the government and CPO companies can create a market diversification strategy. Efforts ought to be focused on extending the reach of CPO exports to newly emerging markets or to nations that have not historically been established or traditional markets for palm oil. This can be achieved by entering into bilateral trade agreements or forming strategic partnerships with new countries to open market access for CPO products. Additionally, optimizing economic diplomacy policies with European and Asian countries, including renegotiating regulations that are considered restrictive on palm oil products, such as the EUDR, can be a strategic move. This would not only help expand the CPO market but also protect the interests of the national palm oil industry from competition with other vegetable oils.

AUTHOR CONTRIBUTION STATEMENT

[Author 1]: research designed, data collection, the initial manuscript draft, addressed reviewer's comments; [Author 2]: research supervision, analytical guidance, edited the manuscript; [Author 3]: research conceptualization, data analysis. All authors reviewed and approved the final version of the article.

DECLARATION OF COMPETING INTEREST

The authors have no competing financial interests or personal relationships that could have influenced the results of the research reported in this research.

ETHIC STATEMENT

The ethical review and approval process was waived for this study, as it did not involve any intervention and posed minimal risk to the participants. The present study employs a country-specific approach, leveraging readily available and accessible secondary data to mitigate risk.

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