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TESTING FOR PRICE TRANSMISSION IN THAILAND'S OIL PALM AND PALM OIL MARKETS: AN EMPIRICAL STUDY USING TIME SERIES ANALYSIS

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ABSTRACT

This study aims to analyze the price transmission within the supply chains of Thailand's oil palm and palm oil markets. The study employs time-series data from January 2012 to December 2019, which comprises 96 monthly price samples, using econometric analysis, namely, the ADF unit root, Granger causality, co-integration, and error correction model. The empirical results show that (1) there are four causal relationships from crude palm oil price running to palm fruit price, the wholesale price of bottle-refined palm oil, and the retail price of bottle-refined palm oil, and from the wholesale price of bottle refined palm oil running to the wholesale price of gallon refined palm oil. The results further reveal that (2) the palm fruit price has the highest price transmission efficiency, followed by the wholesale price of bottle-refined palm oil, the retail price of bottle-refined palm oil and the wholesale price of gallon refined palm oil. The findings conclude that the crude palm oil price influences the pricing in Thailand's oil palm and palm oil markets.

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INTRODUCTION

Oil palm is one of the major agricultural commodities in Thailand which can fully supply palm oil for domestic consumption in the household sector and biofuel in the energy sector. The government and private sectors have continually promoted and supported oil palm cultivation because it can be harvested year-round and usually generates a higher rate of return than other cash crops, such as rice, rubber, maize, and sugarcane. However, most of the oil palm produced in Thailand is from the southern region, until recent years that the plantation has expanded nationwide. Due to its policy to support the palm oil industry, the government has raised the biodiesel blend rate to 10 percent (B10). So, the demand for crude palm oil increases significantly. According to the Office of Agricultural Economics (2021a, 2021b), Thailand has planted more than one million hectares of oil palm, yielding 15.66 million tons of oil palm fresh fruit bunch (FFB), or equivalent to 2.82 million tons of crude palm oil (CPO). Though, regarding Thailand's palm oil usage structure, almost all production is absorbed by domestic consumption; approximately 42% for household consumption, 53% for biodiesel production, and 5% for palm oil stocks and others.

Since Thailand has a suitable climate for oil palm, the Thai government has encouraged farmers to expand plantations, thus enabling the country to rank as the 3rd top oil palm producer in the world, after Malaysia and Indonesia (Office of Agricultural Economics, 2021a). Nonetheless, Thailand's palm oil production does not influence the price or quantity of palm oil globally due to its higher production costs, resulting from a structural difference in the industry (Office of Agricultural Economics, 2021b). At the same time, most of Thailand's producers are small-scale farmers compared to Malaysia and Indonesia, where farmers are large-scale palm oil producers. As such, they possess an advantage from the economy of scale, plus the more consistent policy implementation for palm oil. Therefore, it is deemed necessary for the Thai government to protect the palm oil industry through various market interventions, i.e., imposing a floor price for palm fruit and a ceiling price for refined palm oil, limiting crude palm oil imports, and balancing domestic CPO stock by feeding the excess supply to power plants and biodiesel producers (Office of Agricultural Economics, 2021c).

Price declines and market shortages continue to occur in Thailand despite efforts to resolve the issue. Price regulation is always at the centre of public criticism since there is a considerable gap between the palm fruit price and the retail price of palm oil, to which farmers and customers are the price receivers, while the middleman and the government are the price makers. The situation then inspires this study to analyze the price transmission in Thailand's oil palm and palm oil markets, following several past studies which have raised the hypothesis that the rise and fall in the price may have an unequal influence on certain parts of the supply chain, called asymmetric price transmission (APT) such as the studies of Vavra and Goodwin (2005), Bakucs *et al.* (2013), Barahona *et al.* (2014), and so on. Theoretically, APT in the agricultural market may result from the difference in market power between upstream and downstream producers, in which the latter seemingly prefers to raise prices unrelated to the actual crop price changes.

Regarding the APT hypothesis, Vavra and Goodwin (2005) found that market power is partly involved in the APT occurrence. Also, the APT can result from competitive behaviour and oligopoly. In vertical price transmission (price transmission within a supply chain), a price change at some point in the chain may not get through to the other end immediately. For example, the change in farm-gate price may not influence retail price right away and vice versa. Hence, a small price change may not be transmitted to the other end at all if there is a high transaction cost, leading to the classic problem that customers or farmers do not benefit from any increase or decrease in the retail price; the more extended a supply chain is, the less price transmission can get through a supply chain. Likewise, Bakucs *et al.* (2013) found that APT often arises in the agricultural market with a high level of government intervention, or one in which there is a discrete upstream production structure that minimizes a farmer's bargaining power. However, it is still unclear how market power affects the magnitude and direction of price transmission, as APT can happen in either competitive or non-competitive markets. Nevertheless, the difference in bargaining power between the upstream and downstream producers and retail price controlling contribute to APT to some degree. In the case of government intervention in the agricultural market, the middleman, i.e., crop processing factories, wholesalers, and retailers, usually expect the farm-gate price fall to be temporary while expecting the price rise to remain longer; due to support from policymakers. Therefore, downstream producers often increase their profit margins through a vertical pricing strategy since the retail price control prevents them from choosing a competitive pricing strategy. Besides, it is noteworthy that APT occurs more frequently in weekly time-series data than in monthly data, as the price change in weekly data may not have reached equilibrium yet. Moreover, there is less APT detected in the linear regression analysis than the non-linear technique; the more extensive the data, the smaller the chances of finding APT.

Saleerut *et al.* (2020) analyzed the price adjustment in Thailand's oil palm and palm oil markets relating to the world CPO price using the Engle-Granger co-integration technique. The research found that the changes in the world CPO price affect the domestic palm fruit price, as well as the CPO wholesale price and the retail price of refined palm oil; to which the palm fruit price is the most affected, followed by the CPO wholesale price, the CPO export price, and the palm oil retail price. The result implies that the upstream supply chain is more affected by external price fluctuation than the downstream. However, the most affected prices are also the ones with the highest speed of adjustment, partly because of government intervention. Chatsirapob (2017) studied the factors influencing the domestic palm oil market using linear regression analysis of the monthly time-series data. The research found that Thailand's refined palm oil price is affected by the palm stearin price, Malaysia CPO price, Malaysia export price of the refined palm oil, and the 17% OER (oil extraction rate) palm fruit price respectively. Meanwhile, the world CPO price and biodiesel price are the first and second most influential factors on domestic CPO price. Besides, a natural disaster can also contribute to a rise in the CPO price globally, such as in 2011 when Thailand's CPO export price soared up to the world price, which then caused a shortage in the domestic CPO stock.

In addition, the study of Rungrennganun *et al.* (2015) found that the CPO export quantity and the domestic demand for biodiesel, varying due to the government policy, are the determining factors for the amount of Thailand CPO stock. Therefore, a palm oil refinery needs to import CPO when there is a shortage in domestic CPO stock. However, import prohibition that comes together with the free export policy has triggered unfavourable price movements, to which the domestic CPO price is rising along with the world CPO price. However, the world price fall does not depress the domestic CPO price. Nonetheless, the linear regression analysis and long-run equilibrium test on the monthly time-series data indicate that the most influential factors to Thailand palm fruit price are (1) the average CPO price in local markets, i.e., the price in Krabi, Surat Thani, and Chumphon, (2) the cooking oil price, (3) the Bangkok CPO price, (4) the amount of domestic palm fruit product, (5) per capita income, (6) Malaysia's CPO price, and (7) biodiesel price. As well, the most influential factors to Thailand's CPO price are (1) the price of RSS (natural rubber ribbed smoked sheet) No. 3, (2) biodiesel price, (3) the amount of domestic palm fruit product, (4) the average CPO price in Krabi, Surat Thani, and Chumphon markets, (5) Malaysia's refined palm oil price, (6) Malaysia's CPO price, and (7) soybean oil price. The empirical studies by Chatsirapob (2017) and Rungrennganun *et al.* (2015) investigated the relationship between oil palm prices in Thailand and related factors, while Saleerut *et al.* (2020) analyzed the price integration of the palm oil and oil palm markets in Thailand. The gap in these studies is that none has examined the asymmetric price interaction and market efficiency. Still, these findings help make recommendations to all stakeholders throughout Thailand's oil palm and palm oil supply chain.

The main objective of this study is to analyze the price transmission in Thailand's oil palm and palm oil markets using time series econometrics. The remainders are organized as follows. The next section introduces materials and methods. It consists of the description of variables and econometric methodology used in this study, such as the stationary test for checking time series properties, the causality test for identifying a causal relationship between variables, the co-integration test for detecting long-run equilibrium, and the error correction model for testing asymmetric hypothesis and shock response, respectively. Then, the results and discussion are presented. The concluding remarks summarize the empirical findings and policy recommendations in the last section.

METHODOLOGY

This study employs the monthly time-series data for oil palm and palm oil prices in Thailand between January 2012 and December 2019, during which six commodities' prices vary within eight years (96 samples in total), as presented in Table 1.

Table 1. The description of variables.

Variable	Description	Source
FG	Farm-gate price of oil palm fresh fruit bunch (weighing more than 15 kilograms)	OAE
CPO	Crude palm oil price (the general price of the A quality grade oil)	DIT
WS1	The wholesale price of bottle-refined palm oil (refinery price to a distributor for 12 bottles/box package)	DIT
WS2	The wholesale price of gallon-refined palm oil (refinery price to a distributor for 12.5 kilograms gallon package)	DIT
RT1	The retail price of bottled-refined palm oil (price per one-litre bottle)	DIT
RT2	The retail price of pouch-refined palm oil (price per one-litre pouch)	DIT

Note: OAE refers to the Office of Agricultural Economics, Ministry of Agriculture and Cooperatives. DIT refers to the Department of Internal Trade, Ministry of Commerce.

The raw data are converted into logarithm values to demonstrate changes in percentage rate, to which the analysis is done by statistical software following these econometric frameworks.

Stationary test

Time-series data usually has a non-stationary nature, which implies that its average values, variance, and covariance change as time goes by (Granger and Newbold, 1974). Thus, excluding the time-trend fluctuations before running a regression analysis is necessary unless spurious relation arises. In this study, the Augmented Dickey-Fuller (ADF) unit root test (Dickey and Fuller, 1979, 1981) is applied, as demonstrated in equation (1).

$$\Delta Y_t = \alpha_0 + \delta T + \beta_1 Y_{t-1} + \sum_{i=1}^{p} \beta_2 \Delta Y_{t-i} + \varepsilon_t \quad \dots\dots \quad (1)$$

Where;

Δ is the order of integration.

Y is the time-series data of Y.

t is the time period.

T is the time trend.

p is the time lag.

α is the constant value.

β is the regression coefficient.

δ is the time trend coefficient.

ε is the error term.

The null hypothesis (H_0) of the test is that a variable is non-stationary at the integrated order of 0 or I(0), determined by the Bayesian information criterion (BIC) and t-statistic at 0.05 significance level. Then, the integration order of a variable is detected and taken into account for the next procedures.

Granger causality test: This study applies the causality test of Granger (1969) to analyze the causal relationship between variables. The concept identifies which variable is the cause or results of changes in the other variable with the same stationary order. The test performs the vector autoregressive (VAR) model with the following equations (Asteriou and Hall, 2007; Jatuporn and Sukprasert, 2016).

$$\Delta Y_t = \alpha_1 + \sum_{i=1}^{p} \beta_i \Delta X_{t-i} + \sum_{j=1}^{p} \gamma_j \Delta Y_{t-j} + \varepsilon_{1t} \quad \dots\dots \quad (2)$$

$$\Delta X_t = \alpha_2 + \sum_{i=1}^{p} \theta_i \Delta X_{t-i} + \sum_{j=1}^{p} \delta_j \Delta Y_{t-j} + \varepsilon_{2t} \quad \dots.. \quad (3)$$

Where;

Y is the time-series data of Y, expected to contain the unit root I(1) process.

X is the time-series data of X, expected to contain the unit root I(1) process.

γ_j and δ_j are the coefficients of Y_{t-j}.

β_i and θ_i are the coefficients of X_{t-i}.

Since the VAR model has an autoregressive structure (which means the present data is derived from its past variation), the optimal lag length must be considered while running the regression, unless the result will lose a degree of freedom or have undesirable noise from multicollinearity and autocorrelation. In this study, the optimal lag length is determined by the Bayesian information criterion, of which the null hypothesis (H_0) is X has no causal relationship to Y and vice versa. Then, the variables, i.e., FG, CPO, WS1, WS2, RT1, and RT2, are analyzed in pairs with the rest of the variables. Thus, there are 15 VAR models in total, consisting of 30 directions of X ↔ Y causal relationships as follows.

(1) FG ↔ CPO	(6) CPO ↔ WS1	(11) WS1 ↔ RT1
(2) FG ↔ WS1	(7) CPO ↔ WS2	(12) WS1 ↔ RT2
(3) FG ↔ WS2	(8) CPO ↔ RT1	(13) WS2 ↔ RT1
(4) FG ↔ RT1	(9) CPO ↔ RT2	(14) WS2 ↔ RT2
(5) FG ↔ RT2	(10) WS1 ↔ WS2	(15) RT1 ↔ RT2

Engle-Granger co-integration test: After identifying the causal relationships between the variables, the next procedure tests whether the relationship has a long-run equilibrium, called co-integration. This study follows the Engle-Granger co-integration procedure (Engle and Granger, 1987), in which a pair of variables (that have a causal relationship to each other) is analyzed by the ordinary least square (OLS) using linear regression (Muangsrisun *et al.*, 2021), as shown in equation (4).

$$Y_t = \alpha_0 + \beta_1 X_t + \varepsilon_t \quad \dots\dots \quad (4)$$

Where;

Y is the dependent variable, expected to contain the unit root I(1) process.

X is the independent variable, expected to contain the unit root I(1) process.

Therefore, the residuals series can be derived from $\hat{\varepsilon}_t = Y_t - \hat{\alpha}_0 - \hat{\beta}_1 X_t$. If there is co-integration in the relationship between X and Y, then the residuals series ($\hat{\varepsilon}_t$) from the equation (4) must be stationary at the integrated order of 0 or I(0); in which the null hypothesis of the residuals series is non-stationary at I(0), using the ADF unit root test (with the BIC and t-statistic at 0.05 significance-level as the criteria). If the null hypothesis is rejected, then the residuals series is stationary at I(0), which means there is co-integration between the X and Y variables. This reasoning is derived from the Engle and Granger (1987) hypothesis that if X and Y are stationary at the same order of integration, then residuals series from X and Y linear regression must be stationary at the integrated order of 0 (Asteriou and Hall, 2007).

The short-run adjustment to equilibrium: Since there is co-integration between X and Y, both variables move together in the long-run period; as time goes by, any deviations in the relationship will return to the long-run equilibrium as well. The reason is that an external shock only has a temporary influence on the relationship between X and Y, and the variable is always returning to co-integration. Therefore, the speed of residual series' adjustment to equilibrium can reflect the efficiency of price transmission between X price and Y price in this case, to which the residuals series' adjustment is called the error correction term (ECT). Later on, Granger and Lee (1989), Cramon-Taubadel and Loy (1996), and Barahona *et al.* (2014) applied the ECT into the error correction model (ECM) for testing APT in agricultural markets, which enables the model to distinguish the influence of price fall (negative transmission) from that of price rise (positive transmission). The adapted model is called asymmetric ECM, as demonstrated in equation (5).

$$\Delta Y_t = \alpha_0 + \beta_1^+ \Delta X_t^+ + \beta_1^- \Delta X_t^- + \beta_2^+ ECT_{t-1}^+ + \beta_2^- ECT_{t-1}^- + \sum_{i=1}^{p} \beta_3 \Delta X_{t-i} + \sum_{i=1}^{p} \beta_4 \Delta Y_{t-i} + \varepsilon_t \ldots\ldots (5)$$

Where;

ECT_{t-1} is the previous lag in the ECT adjustment.

β_1^+ is the coefficient of ΔX_t^+ (price rise in X).

β_1^- is the coefficient of ΔX_t^- (price fall in X).

β_2^+ is the positive coefficient of ECT_{t-1}^+ (when ECT price rises).

β_2^- is the negative coefficient of ECT_{t-1}^- (when ECT price falls).

β_3 is the coefficient of ΔX_{t-i}.

β_4 is the coefficient of ΔY_{t-i}.

The null hypothesis for testing asymmetric ECM is that the price rise coefficient (β_2^+) is equal to (β_2^-), determined Chi-square (χ^2) value at a 0.05 significance level. If the null hypothesis of $\beta_2^+ = \beta_2^-$ is rejected, there is a significant difference in the speed of adjustment for positive price shock and negative price shock, called asymmetric price transmission (APT). On the contrary, if the null hypothesis of $\beta_2^+ = \beta_2^-$ is not rejected, then the speed of adjustment for positive and negative price shocks is not significantly different, called symmetry price transmission. The symmetric ECM will be applied in such a case, as shown in equation (6).

$$\Delta Y_t = \alpha_0 + \beta_1 \Delta X_t + \beta_2 ECT_{t-1} + \sum_{i=1}^{p} \beta_3 \Delta X_{t-i} + \sum_{i=1}^{p} \beta_4 \Delta Y_{t-i} + \varepsilon_t \ldots\ldots\ldots (6)$$

Where;

β_2 is the symmetric coefficient of the speed of adjustment.

RESULTS AND DISCUSSION

This study applies various time series econometric approaches. First, the ADF unit root is tested for the properties of time-series data to prevent spurious results. Further, the Granger causality is applied for detecting the causal relationship between the variables before testing the co-integration. Co-integration based on Engle and Granger is considered for capturing pair long-run equilibrium. After that, the asymmetric ECM is structured for detecting asymmetric transmission. In the case that symmetric transmission is indicated, the conventional ECM captures the response to the shock returning to equilibrium.

The time-series data for FG, CPO, WS1, WS2, RT1, and RT2 are converted into logarithm values and then tested for stationarity using the ADF unit root with the null hypothesis of non-stationary time-series data. The results show that the null hypothesis is not rejected since all variables are stationary at the first differenced order of integration, or I(1) process, as shown in Table 2. In Table 3, each of the six variables, i.e., FG, CPO, WS1, WS2, RT1, and RT2, is analyzed in pairs with the rest to check if there is any causal relationship between them. There are 15 VAR models in testing on 30 directions of the relationship between X ↔ Y variables. The results of the Granger causality are shown in Table 3. Since FG, CPO, WS1, WS2, RT1, and RT2 time series variables are all stationary at I(1), the differenced data is used in the VAR Granger causality test. According to the null hypothesis of the variables X and Y having a non-Granger causal relationship, there are only four out of 30 causal relationships in the data.

Table 2. The results of the ADF unit root test.

Variable	Level I(0)		First difference I(1)	
	t-statistic	p	t-statistic	p
FG	-1.872	0	-7.735*	0
CPO	-1.994	1	-5.888*	0
WS1	-2.454	1	-5.495*	0
WS2	-2.393	1	-5.531*	0
RT1	-2.269	1	-6.407*	0
RT2	-1.489	1	-6.473*	0

* refers to the 0.05 significance level, and p refers to the time lag length.

Table 3. The results of the Granger causality test.

Y	X					
	ΔFG	ΔCPO	ΔWS1	ΔWS2	ΔRT1	ΔRT2
ΔFG	-	0.006*	0.595	0.588	0.601	0.936
ΔCPO	0.234	-	0.053	0.376	0.060	0.497
ΔWS1	0.942	0.006*	-	0.438	0.127	0.267
ΔWS2	0.480	0.129	0.008*	-	0.966	0.757
ΔRT1	0.558	0.015*	0.142	0.359	-	0.974
ΔRT2	0.554	0.116	0.101	0.910	0.771	-

* refers to the 0.05 significance level.

A change in the CPO price influences the FG price (CPO → FG). In other words, the CPO price has a significant influence on determining FG price change.
A change in the CPO price influences the WS1 price (CPO → WS1). In other words, the CPO price has a significant influence on determining WS1 price change.
A change in the WS1 price influences the WS2 price (WS1 → WS2). In other words, the WS1 price has a significant influence on determining WS2 price change.
A change in the CPO price influences the RT1 price (CPO → RT1). In other words, the CPO price has a significant influence on determining RT1 price change.
Four causal relationships are detected in the Granger causality analysis. Therefore, co-integration based on Engle and Engle and Granger (1987) is employed to test for the long-run equilibrium relationship. The results of the co-integration test in Table 4 found that all the models (FG, WS1, WS2, and RT1) have a long-run equilibrium since the null hypothesis (the regression's residuals are non-stationary at the integration of order 0) is rejected as given in Table 4.

$$\widehat{FG}_t = -2.284 + 1.127CPO_t \quad \dots\dots\dots \quad (7)$$

In equation (7), if there is a one percent change in the CPO price, the FG price will change at 1.127% in the same direction, to which the model has an explanation efficiency of 89.3% to FG.

$$\widehat{WS1}_t = 1.281 + 0.681CPO_t \quad \dots\dots\dots \quad (8)$$

In equation (8), if there is a one percent change in the CPO price, the WS1 price will change at 0.681% in the same direction, to which the model has an explanation efficiency of 79.0% to WS1.

$$\widehat{WS2}_t = 0.231 + 0.968WS1_t \quad \dots\dots\dots \quad (9)$$

In equation (9), if there is a one percent change in the WS1 price, the WS2 price will change at 0.968% in the same direction, to which the model has an explanation efficiency of 92.7% to WS2.

$$\widehat{RT1}_t = 2.521 + 0.347CPO_t \quad \dots\dots\dots \quad (10)$$

In equation (10), the RT1 price will change at 0.347% in the same direction if there is a one percent change in CPO price, to which the model has an explanation efficiency of 67.7% to RT1.

Table 4. The results of the co-integration test.

Variable	Model			
	FG_t	$WS1_t$	$WS2_t$	$RT1_t$
α_0	-2.284*	1.281*	0.231*	2.521*
CPO_t	1.127*	0.681*	-	0.347*
$WS1_t$	-	-	0.968*	-
$ADF(\hat{\varepsilon}_t)$	-4.180*	-3.904*	-2.603*	-2.273*
R^2	0.893	0.790	0.927	0.677

* refers to the 0.05 significance level.

Table 5. The results of asymmetric price transmission based on ECM.

Variable	Model (ΔYt)			
	ΔFG_t	$\Delta WS1_t$	$\Delta WS2_t$	$\Delta RT1_t$
α_0	0.009	-0.001	0.009*	0.001
$\beta_1^+ \Delta X_t^+$	0.995*	0.075	0.714*	0.091
$\beta_1^- \Delta X_t^-$	1.564*	0.210*	1.038*	0.085
$\beta_2^+ ECT_{t-1}^+$	-0.188	-0.238*	-0.241	-0.251*
$\beta_2^- ECT_{t-1}^-$	-0.459*	-0.376*	-0.063	-0.085
$\beta_3 \Delta X_{t-1}$	-0.195	0.006	0.241	0.027
$\beta_4 \Delta Y_{t-1}$	0.183	0.316*	-0.030	0.254*
Wald test (H_0)				
$\beta_2^+ = \beta_2^-$	1.247	0.879	0.915	1.357
R^2	0.768	0.573	0.793	0.373
D.W.	2.002	1.938	2.071	1.947

* refers to the 0.05 significance level.

Table 6. The results of symmetric price transmission based on ECM.

Variable	ΔFG_t	$\Delta WS1_t$	$\Delta WS2_t$	$\Delta RT1_t$
α_0	<-0.001	-0.002	<0.001	-0.001
ΔCPO_t	1.263*	0.143*	-	0.082*
$\Delta WS1_t$	-	-	0.940*	-
ΔFG_{t-1}	0.168	-	-	-
ΔCPO_{t-1}	-0.217	0.003	-	0.027
$\Delta WS1_{t-1}$	-	0.317*	-	-
$\Delta RT1_{t-1}$	-	-	-	0.242*
ECT_{t-1}	-0.364*	-0.295*	-0.145*	-0.151*
R^2	0.751	0.563	0.749	0.364
D.W.	1.912	1.919	2.092	1.957

* refers to the 0.05 significance level.

The oil palm and palm oil prices in Thailand have been subject to price intervention by the government and distortion by players as brokers in the oil palm and palm oil supply chain, resulting in inefficient price transmission. Therefore, the error correction model is applied using the concepts of Granger and Lee (1989), Cramon-Taubadel and Loy (1996), and Barahona *et al.* (2014) procedures. The results of asymmetric price transmission based on ECM are presented in Table 5. The difference in the speed of adjustment in positive price shock (β_2^+) and negative price shock (β_2^-) is not significantly different since the null hypothesis of β_2^+ =

β_2^- is not rejected at a significance level of 0.05. The results in Table 5 show that asymmetric models are unsuitable for analyzing oil palm and palm oil price transmission in Thailand.

CONCLUSION AND RECOMMENDATIONS

In Thailand, oil palm and palm oil prices are highly volatile compared to other agricultural commodities. The main purpose of this study is to analyze the price transmission in oil palm and palm oil markets in Thailand using time series analysis consisting of the Granger causality, co-integration, and error correction model. The results of the price integration show that the changes in the crude palm oil price have transmitted to the palm fruit price, the wholesale price of bottle-refined palm oil, and the retail price of bottle-refined palm oil. Also, the changes in the wholesale price of bottle-refined palm oil have transmitted to the wholesale price of the gallon-refined palm oil. These findings confirm that the most affected by the changes in the crude palm oil price are the palm fruit price, the wholesale price of bottled-refined palm oil, and the retail price of bottled-refined palm oil, respectively. The comparison of the market efficiency in the event of an abrupt change indicates that palm fruit price has the fastest adjustment efficiency with the speed of 36.4% to enter the equilibrium state, followed by the wholesale price of bottle-refined palm oil with the speed of 29.5%, the retail price of bottle-refined palm oil with the speed of 15.1%, and the wholesale price of gallon-refined palm oil with the speed of 14.5%. The findings can conclude that the crude palm oil price influences the upstream to downstream pricing in the oil palm and palm oil markets in Thailand.

According to previous research, the reason that palm fruit price does not influence the downstream supply chain may be rooted in its perishable nature. Processed palm oil can be stocked, leading to disproportionate market power between oil palm farmers and palm oil producers. The reason that the palm fruit price has a higher speed of adjustment than the downstream price (compared to wholesale and retail prices) is supposedly the result of government intervention and the near-perfect competitive market structure, to which Thailand's oil palm producers are mostly small-scale farmers with fewer barriers to market entry. Regardless, the analysis of this study does not include other potentially influential factors outside the supply chain, such as world crude palm oil price, the crude palm oil price in Malaysia, domestic biodiesel price, and soybean price. Several past studies found that these factors tend to influence Thailand's oil palm and palm oil prices (Rungrennganun *et al.,* 2015; Saleerut *et al*., 2020; Husaini and Lean, 2021).

The recommendations focus on crude palm oil or CPO as it plays a vital mechanism for pricing in both upstream and downstream of Thailand's supply chain. Therefore, the government should prevent the middlemen and local capitalists from speculating palm oil stocks as the oil palm is a highly seasonal crop; the annual yields are high from April to June but low from November to January. As a result, the middlemen and local capitalists have taken advantage of the fluctuating yields during the oversupply period. They buy CPO at the lowest prices while selling CPO at the highest prices to maximize profits but cause losses to the industry and an imbalance in domestic palm oil stocks. So, it is reasonable to allow CPO import during the low yields season while supporting CPO export in the high yields season, according to the demand and supply for domestic use (Cumroon *et al.,* 2021).

In addition, the government should carefully inspect the structure of oil palm and palm oil prices to help all stakeholders get their fair share of profits. Besides, it should reduce the subsidy for biofuel so that the price moves under the actual cost and help saving public expenditures on the ineffective price intervention. Such policy takes part in the unfair competition; for example, the cost of edible palm oil is higher than usual when the heavily subsidized biodiesel production absorbs most of the CPO in the market, but consumers can only take the price. Farmers are also under price pressure to sell cheaper palm fruits since Thailand's current oil extraction rate averages 18% compared to competitors such as Malaysia and Indonesia, which have 20% - 22% (Sowcharoensuk, 2020; MPOB, 2021). So, Thailand should enhance its oil palm quality while expanding palm oil processing plants should be in proportion to its productivity, preventing raw material shortages in certain seasons.

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