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Effective Cross Hedging: Evidence from Physical Crude Palm Oil and Its Non-Interrelated Energy Futures Contracts

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ABSTRACT

Recent researchers found that Crude Palm Oil Futures contract (FCPO) in Bursa Malaysia Derivatives is no longer an effective hedging tool to mitigate the price risk in cash market due to the excessive speculation trading activities. This is very alarming to the hedgers hence possible hedge pair alternatives to crude palm oil physical must be identified to ensure that the hedging can be executed effectively. Therefore in this study, Ordinary Least Square, bivariate VAR and bivariate VECM were used to examine whether the non-interrelated energy futures contracts could serve as effective cross-hedging mechanisms for the CPO. Weekly data of agricultural and energy futures contracts from Intercontinental Exchange (ICE), New York Mercantile Exchange (NYMEX), and Tokyo Commodity Exchange (TOCOM) are employed to cross hedge the physical crude palm oil prices. The study starts from 2006 until 2016. Empirical results indicate that bivariate VECM gives more hedging variance reduction. Surprisingly, overall FCPO is still the best futures contract for hedging purposes while Japanese crude oil futures (TOCOM) represents the energy futures market as the best cross hedge alternatives for CPO.

1. Introduction

Hedging effectiveness of crude palm oil futures (FCPO) traded in Bursa Malaysia Derivatives has been under a bright spotlight in recent years. As the global benchmark for vegetable oil prices for more than 30 years, FCPO surprisingly has shown that the futures market has been significantly disturbed by speculators or noise traders (Go and Lau, 2018). This is worrisome as the speculative trading causes the short term price swings which does not really illustrate the true picture of overall current market trend. As

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a result, the speculation activity has turned the FCPO from its true purpose as the hedging mechanism due to the unpredictable volatility and turned the hedgers to have lack of confidence of FCPO.

Following to the unsatisfactory hedging performance, hedgers are keen to find hedging alternatives other than FCPO, especially to see whether CPO physical can be hedged by other non-interrelated commodity futures like energy derivatives. In these days the commodity spot-futures markets are not only related by their underlying-derivatives relationships, but the markets are also somehow related to the other substitutes and complimentary commodities across geographical borders (Murti, 2017). Logically, when two markets are correlated, it would lead the use of one of them for the prediction of the other (Granger, 1986).

The agricultural-energy cross markets interaction becomes stronger over the years following the extensive development efforts to produce biodiesel as replacement for fossil oil. This has created a new link between agricultural and energy commodity markets (Hochman, Rajagopal, and Zilberman, 2010; Kapusta and Lajdová, 2016).

Therefore, the empirical notes on cross markets interdependence have brought this paper to discover the possibility of cross hedging the Malaysian physical crude palm oil with the non-interrelated energy futures contracts in other exchanges. The research objectives are twofold. First, it is to determine the optimal hedge ratio of Malaysian CPO with the selected foreign non-interrelated commodity futures contracts of crude oil, gas oil, and natural gas in TOCOM, ICE and NYMEX; and second, it is to examine the cross hedging effectiveness for Malaysian CPO with the non-interrelated commodity futures contracts.

The objectives highlighted above intend to bring a new definition of price discovery function in cross markets spot-futures. This means the agricultural markets and energy markets possibly dictate each other to move therefore one of them could be leader and the other one is a laggard. When cross markets positive correlation is shown, it means that hedging with interrelated futures contracts other than the physical own futures contract is possible. In other words, cross hedging is deem viable in a positively correlated spot-futures markets.

2. Literature Review

2.1 Agricultural and Energy Spot-Futures Price Relationships

The agricultural and energy markets relationship has been long established in the United States. Among the earlier authors, Wei and Chen (2012) witnessed that the short run relationships between crude oil futures and agricultural grain commodities futures for soybeans, wheat and corn were detected whereby the change in each of agriculture grain commodities is significantly influenced by the change in the crude oil and other agriculture grain commodities. Other latest studies also indicate volatility in agricultural commodities price evidently influenced the volatility of crude oil price (Kumar, 2017).

Corpora studies have proven that futures contracts across the markets are the successful way to predict the future prices of a commodity. Ramakrishna and Jayasheela (2009), as well as Arora and Kumar (2014) are among the most recent scholars who proved that futures contracts are still relevant for price discovery. The price discovery function benefits the hedgers where to forecast for a long term for price risk, the series of spot and futures prices are found to be associated to one and the other, shows that there is a stable long-run equilibrium relationship in futures and spot market. The markets interdependence does not restrict to price but extendable to volatility linkages across the markets. Luo and Ji (2018) authored on high-frequency volatility connectedness between the US crude oil market and China's agricultural commodity markets thus discovered that obviously increased for negative volatility relative to positive volatility, implying that volatility transmission has a leverage effect across markets.

Therefore, in these days the commodity spot-futures markets are not only related by their underlying-derivatives relationships, but the markets are also somehow related to the other substitutes and complimentary commodities across geographical borders.

2.2 The Mechanics of Hedging

The primary objective of hedging the physical asset with the derivatives product is to offset the foreseeable losses in cash market. Mckenzie and Singh (2011) listed the two main functions of futures markets in agricultural commodity markets (1) a price discovery role, and (2) a price risk management role. The ultimate goal of hedging, as explained by Li and Vukina (1998), is to obtain the optimality of variance reduction. In a study of hedging effectiveness of yield futures contract, they explained that the hedgers can compare the reduction in the variance of revenue between various hedging strategies and the cash marketing strategy, or between two different hedging strategies. In other words, this study suggests that better return is gained in the variance of revenue generated by the dual hedging strategy compared to single price futures hedging strategy. That ideates the emergence of optimal investment portfolio structuring strategy.

Pennings and Meulenberg (1997) have illustrated how the hedge strategy is being executed; (1) the opposite and equivalent position in the futures market must be taken, (2) hedgers must act as a speculator as the futures positions will be marked-to-market by daily basis and the cash equity in futures trading account will be varied accordingly to the daily unrealized profit and loss. The latter example however, need the traders or the hedgers to be execellently conversant with the markets volatility and psychological dynamics in that particular futures market to avoid being doped by deceptive market directions.

In Malaysia, the establishment of crude palm oil futures contract in Bursa Malaysia Derivatives (BMD FCPO) is meant for the derivatives product for physical CPO. Ali (1998) had tested the price risk transfer ability of the BMD FCPO using the price from the period of January 1985 to August 1996 after the restructuring of the new set of rules and regulations to suppress illegal and improper trading practices. The study found that the BMD FCPO is an effective price discovery and reliable hedging mechanism with the condition where the physical traders must establish a counterbalancing positioning approach in trading the BMD FCPO. Hence, the refiners and growers would be able to compensate any loss in the cash market with a profit in the futures market.

2.3 The Emergence of Cross Hedging Strategy

There is a growing concern by the scholars that speculation activity in FCPO has become unfavorably uncontrollable. Ong, Tan and Teh (2012) as well as Go and Lau (2014) witnessed that it is already shown a low level of hedging effectiveness for CPO on super excessive speculation levels. The deterioration of FCPO ability to offset the price risk of CPO has become the utmost worrisome among the physical traders. Pertaining to this, the hedgers are keen to find the alternative futures contracts on which could provide the best hedging too because the excessive speculation activity could impede the hedging effectiveness of a futures contract. This has been highlighted by Bloomfield, O'Hara and Saar (2007) on how the market speculation or noise could misrepresent the genuine underlying market trend. The distorted function of FCPO raised several questions as to whether there are any other non-interrelated futures contracts such as energy futures market have that strong positive price association with Malaysian physical CPO? Which markets have the strongest correlation with Malaysian commodity market? Is there a possibility of cross hedging for Malaysian CPO with the commodity futures in energy futures markets? Even if it is possible, is the cross hedging really effective? If so, then which markets offer the best cross hedging return?

To devise the cross hedge strategy of CPO with energy futures contracts in NYMEX, ICE, and TOCOM is important, but to quantify the cross hedge effectiveness of these futures markets is extremely crucial. Nonetheless, due to the effects of backwardation and contango, the ancient 1-1 hedging strategy in classical derivatives literatures for academic finance has been discovered to be incompetent to neutralize the price risk suffered by the physical players in cash market thus the optimal cross hedge ratios must be determined. Therefore, the cross hedging effectiveness of Malaysian palm with the chosen alternative futures markets will be thoroughly investigated in this research and it is intended to fill the niche related to the cross hedging strategy which at this juncture is still relatively new for Malaysian CPO atmosphere.

3. Methodology

3.1 Reseearh Design

This is the correlational and hypothesis testing studies. Foremost, the correlation index, hedge ratio and effectiveness of FCPO to offset the price risk of CPO were quantified for the purpose of being a benchmark in comparative analysis of hedging performance with other non-interrelated energy futures contracts. Hence, the study started by examining the degree of correlation between the prices of Malaysian physical CPO with its own futures contract of FCPO followed by the to investigate correlation between the prices of Malaysian CPO with non-interrelated futures contracts. In brief, the strength of relationship between CPO with non-interrelated futures contracts will give a good initial idea as to whether a particular futures contract is suitable for a cross hedge pair for CPO or not.

The collection of data was from Bloomberg Terminal and Malaysian Palm Oil Board website (MPOB). The step of inferential statistics begins with stationarity test by using three types of Unit Root Test; ADF, PP and KPSS. In case the data is not stationary at level, the differencing is needed in order to avoid spurious data which will reflect the results wrongly thereafter. After the data is confirmed as stationary, specifically the Pearson's Product Moment will illustrate the ideas of relationship strength of CPO with the non-interrelated futures contracts. Next, estimation of optimal hedge ratio will be conducted starting with the OLS model, followed by VAR. Then the data is tested for cointegration vectors by using Johansen cointegration test. If the spot and futures are found cointegrated, then VECM is needed to capture the long run relationship. Otherwise, the flow will proceed to finding the optimal hedge ratio and finally cross hedging effectiveness.

The cross hedging effectiveness for all CPO pairs and models are computed by the variance reduction in the hedged portfolio compared to that unhedged position. Finally, the comparison of both will be tabulated for clearer analysis.

3.2 Data

This investigation will make use of the local delivered Malaysian weekly physical crude palm oil average prices starting from the 13th January 2006 to the last week of 25th November 2016 and it is retrieved from MPOB website. The futures prices consist of ICE Brent crude oil, NYMEX West Texas Intermediate Crude Oil, NYMEX Natural Gas, TOCOM Crude Oil and Gasoline will be taken from Bloomberg Terminal spanning the same period as well. All prices are transformed and expressed in the return form as suggested by the literature (Bohl, Diesteldorf, Siklos, 2016).

Table 1. Summary of Commodities and Exchanges

Futures Contract	Code	Exchange
West Texas Intermediate Crude Oil	WTI	New York Mercantile Exchange
Brent Crude Oil	BRENT	Intercontinental Exchange
Natural Gas	NGAS	New York Mercantile Exchange
Dubai Crude Oil	TCRUDE	Tokyo Commodity Exchange
Gas Oil	TGAS	Tokyo Commodity Exchange

3.3 Correlation Test

Pearson's product moment correlation will be used as the preliminary assessment in this study. The parameterization is expected to purposely illustrate the basic idea of briefed linear dependence between CPO and the inter-related and non- inter-related futures contracts. The model is as follows:

$$\rho_{x,y}=\frac{\sum(x_i-\bar{x})(y_i-\bar{y})}{(N-1)\sigma_x\sigma_y}=\frac{\sigma_{x,y}}{\sigma_x\sigma_y} \quad (1)$$

Where x = CPO, y = energy futures contracts, $\boldsymbol{\sigma_x}$= standard deviations of CPO, $\boldsymbol{\sigma_y}$= standard deviations the energy futures contracts. According to the above equations, the results of the correlations is bounded to lie on the (–1,1) interval. A correlation of 1 (–1) indicates a perfect positive (negative) association between the series while correlation zero (0) indicates no relationship at all (Brooks, 2014).

3.4 Ordinary Least Square

Ordinary Least Square method is one of the simplest methods in linear regression model. It is meant to minimize the sum of the squares of the differences of the values which are being tested. The optimal hedge ratio can be derived by applying the ordinary least square (OLS) regression as given below:

$$r_{st} = \alpha + \beta r_{ft} + \varepsilon_t \quad (2)$$

Where r_{st} is the CPO return at time *t*, r_{ft} is the futures return at time *t*, α *and* β are coefficients of the regression and ε_t is the error term. β in this equation is also used to represent the optimal hedge ratio between the CPO and the energy futures contract.

3.5 Vector Autoregressive (VAR)

Despite OLS model is undoubtedly being the easiest applicable regression model, this model is suffering by the fact that the problems of serial correlations in OLS residuals could affect the minimum variance hedge ratio (Casillo, 2004). To tackle this problem, the most popular method is Vector Autoregressive Model introduced by Sim (1980).

$$r_{st} = \alpha_s + \sum_{i=1}^{m} \beta_{si} r_{st-i} + \sum_{j=1}^{n} \gamma_{si}\, r_{ft-i} + \varepsilon_{st}$$
$$r_{ft} = \alpha_f + \sum_{i=1}^{m} \beta_{fi} r_{st-i} + \sum_{j=1}^{n} \gamma_{fi}\, r_{ft-i} + \varepsilon_{ft} \quad (3)$$

Where r_{st} and r_{ft} stands for the CPO and energy futures return at time *t*; α, β are the coefficients to be estimated, *n* number of lag length as proposed by SIC, *i* denotes stationary order while ε_{st} and ε_{ft} is the residual series of spot and futures and time *t*. It is to be noted here that residual error ε_t for both spot and futures are independently identically distributed error terms.

3.6 Johansen Cointegration Test

The correlational study and VAR model is not sufficed to explain the long run relationship of variables. Hence, the cointegration of CPO with inter-related and non-related futures contract is tested with Johansen cointegration test. One of the earliest approach to VAR is the well-known procedure to measure the long run variables multicollinearity used likelihood ratio (Johansen and Juselius, 1990). The statistical ways to calculate the co-integration is as followed (Quitino, David and Vian, 2017; Tas and Tokmakçioğlu, 2010):

$$\lambda_{trace}(r) = -T + \sum_{i=r+1}^{n} 1n(1 - \lambda_i) \quad (4)$$

Where H_0 : Rank Π_y = *r* null hypothesis, H_1 : Rank Π_y= *n* alternate hypothesis. Hence the maximum eigenvalue statistics:

$$\lambda_{max}\,(r, r+1) = -T\; 1n(1 - \lambda_{r+1}) \quad (5)$$

Where H_0 : Rank Π_y = *r* null hypothesis is tested against H_1 : Rank Π_y= *r*+1 alternate hypothesis

Following above, $\hat{\lambda}_i$ are estimated values of eigenvalues obtained from matrix Π, and *T* is the number of observations. Null hypothesis here is that there is a maximum of number of cointegrating vectors, or *r*. However in most cointegration studies looked at the trace test result (Abu Hassan Asari, Baharuddin, Jusoh, Mohamad, Shamsudin and Jusoff, 2011) however max-eigenvalue results are crucial to support the inference of cointegrating vectors.

3.7 Vector Error Correction Model

VECM includes the error correction terms which is capable to capture both short-run and long-run effects that would determine the actual value of how the dependent variable evolves over time (Yusupov and Duan, 2010). Otherwise if the cointegration is not taken into account, the empirical evidence may appear significantly bias towards detecting linear and nonlinear causality between the predictor variables.

$$r_{st} = \alpha_s + \sum_{i=1}^{m} \beta_{si} r_{st-i} + \sum_{j=1}^{n} \gamma_{si}\, r_{ft-i} + \lambda_s Z_{t-1} + \varepsilon_{st}$$
$$r_{ft} = \alpha_f + \sum_{i=1}^{m} \beta_{si} r_{st-i} + \sum_{j=1}^{n} \gamma_{fi}\, r_{ft-i} + \lambda_f Z_{t-1} + \varepsilon_{ft} \quad (6)$$

Based on the above, the VECM has the additional regression line which is the error correction term, $\lambda_s Z_{t-1}$ and $\lambda_f Z_{t-1}$. When $Z_{t-1} = S_{t-1} - \delta Ft - 1$ is error correction term with $1 - \delta$ as the co-integration vector and λ_s, λ_f will function as the adjustment speed parameters.

3.8 Optimal Hedge Ratio for VAR and VECM

The residual series or error term in VAR and VECM model for both spot and futures are to be used as the yields to calculate the optimal hedge ratio. From the residuals, covariance between spot and futures and variance of futures are taken in order to obtain the minimum variance hedge ratio. Hence, variance for spot return, $\varepsilon_{st} = \sigma_{\Delta s}$, variance for futures return, $\varepsilon_{ft} = \sigma^2{}_{\Delta f}$ and covariance ε_{st} , $\varepsilon_{ft} = \sigma_{\Delta s \Delta f}$; therefore where h_f^* represents the futures contract of hedge pair for CPO, the minimum variance hedge ratio can be expressed as followed:

$$h_f^* = \frac{\sigma_{\Delta s \Delta f}}{\sigma^2 \Delta_f} \tag{7}$$

3.9 Hedging Effectiveness Measures

For OLS model, Ong et al. (2012) explained that the classical way of measuring hedging effectiveness lies at the R^2 of the estimated regression as it represents the hedging effectiveness between the two products. It means that larger R^2 shows better minimum variance of hedging effectiveness. However the authors added that the MVHR approach is more accurate and supersedes the R^2 in OLS model estimation results since it accounted for the variance of hedged and unhedged ratio.

The hedging effectiveness is computed by the variance reduction in the hedged portfolio compared to that unhedged position, which is using the Minimum Variance Hedge Ratio (MVHR). Johnson (1960) and Ederington (1979) developed the procedure to measure hedging effectiveness (HE) as follows:

$$HE = \frac{Variance_{Unhedged} - Variance_{Hedged}}{Variance_{Unhedged}} \tag{8}$$

Above all, the correlation, optimal hedge ratio and hedging effectiveness of FCPO for CPO will be taken as a benchmark in order to compare the superiority of energy futures hedging effectiveness analysis.

3.10 Hypotheses

Hypotheses statements are developed to answer the research questions:

H_1: There is a positive hedge ratio of Malaysian CPO and non-interrelated energy futures contracts in NYMEX, ICE, and TOCOM.

H_2: The hedge ratio of non-interrelated futures contracts in NYMEX, ICE, and TOCOM is more effective in minimizing the hedging variance of CPO than the hedge ratio of FCPO.

4. Results and Discussions

4.1 Correlation Coefficient

Pearson product moment results show that CPO has the strongest correlation with FCPO, which is 0.7. This means that there is a 70 percent chance that the CPO and FCPO are moving in the same direction. It is safe enough to say that any attempt for cross hedging strategies, the correlation between CPO and prospect hedge pair must be as closest as this value or bigger than this value therefore it could be the best alternative of hedging other FCPO.

In energy futures market, the Crude Oil Futures in Tokyo has the strongest correlation of 0.26 with CPO among the energy futures markets in Europe and the US. The correlation strength is accordingly weaker for BRENT, TGAS, and WTI, which recorded at 0.23, 0.23, and WTI. The weakest correlation 0.05 represented by the NGAS in Chicago. Generally, all futures commodities markets dataset in sample showed a justified relationship strength with 1 percent significance level except Dalian soybean derivatives product.

Table 2. Summary of Pearson Product Moment

Exchange	Futures Contract	CPO	Nature of Relationship
BMD	FCPO	0.7070 0.0000***	Strong positive
NYMEX	WTI	0.2109 0.0000***	Weak positive
ICE	BRENT	0.2319 0.0000***	Weak positive
NYMEX	NGAS	0.0565 0.1904***	Weak positive
TOCOM	TCRUDE	0.2623 0.0000***	Mildly weak positive
TOCOM	TGAS	0.2311 0.0000***	Weak positive

Note: Figures in parentheses indicate the probability value (p-value).
*** Significant at 1% level

These results show that TOCOM crude oil has the highest value of correlation with CPO which is 0.26 while NYMEX Natural Gas has the weakest correlation with CPO at 0.05. Overall TOCOM crude oil surpassed other energy futures contracts and placed itself at second rank after FCPO. This result gives clue that TOCOM crude oil might have the most optimal hedge ratios and hedging effectiveness compared to the rest.

4.2 Ordinary Least Square

One unit or contract of FCPO contract size is known equals to 25 metric tonne per contract based on specification set by Bursa Malaysia Derivatives. The hedge ratio from OLS model is the output of beta coefficient, $\boldsymbol{\beta}$ while beta FCPO to CPO is 0.72; means that the hedger no longer need to use 1-1 naïve hedge pair strategy or 25 metric tonne physical to one contract of FCPO. Instead, OLS model recommends only 18 metric tonne of CPO physical is advisable to be hedged with one contract of FCPO.

Applying the aforementioned, based on Table 3, TCRUDE has the highest beta value among the rest of the futures contracts, which is 0.24. It means that in practical, the hedger should only hedge his physical crude palm by 24 percent to the respective TOCOM crude oil futures contract size. For quick instance, a one contract of TOCOM crude oil set by Tokyo Commodity Exchange equals to 50 kilo litre. Given the conversion of a kilo litre and metric tonne is equal to 2.41 metric ton per kilo litre, hence when the CPO hedgers are advisable to hedge their physical plants by 24 percent of the contract size, that equals to 28.92 metric tonne of CPO physical to hedge with one contract (50 kilo litre) of TOCOM crude oil futures. The next best alternative is TOCOM gasoline, 22 percent. The worst hedge ratio is NGAS whereby the beta coefficient of 0.0628 constitutes that CPO has almost no relationship to NGAS.

The energy futures have interesting story where the R^2 readings shows that at least 5 percent of CPO price swings can be explained by ICE crude oil (BRENT), TOCOM crude oil (TCRUDE) and TOCOM gasoline (TGAS). The New York WTI however has the least value over CPO for energy futures contract whereby only 4 percent of variation in CPO can be explained by WTI. For OLS regression model, the R^2 results estimations give indications that the hedge efficiency is deteriorate as the R^2 value become lower.

Table 3. Optimal Hedge Ratio Results

	FCPO	WTI	BRENT	NGAS	TCRUDE	TGAS
α	0.0006 (0.0312)	0.0018 (0.0014)	0.0018 (0.0014)	0.0020 (0.0014)	0.0018 (0.0013)	0.0018 (0.0014)
β	0.7226*** (0.0010)	0.1748*** (0.0350)	0.2145*** (0.0388)	0.0628*** (0.0479)	0.2403*** (0.0382)	0.2223*** (0.0404)
h^*	0.7226	0.1748	0.2145	0.0628	0.2403	0.2223
R^2	0.4998	0.0445	0.0538	0.0032	0.0688	0.0534
HE	49.98%	4.45%	5.38%	0.32%	6.88%	5.34%

Note: *** Significant at 1% level

Therefore, the best alternative for FCPO in energy derivatives would be Tokyo crude oil futures. The β or optimal hedge ratio is 0.2403 and 6 percent of movement in CPO market can be explained by TCRUDE in Japan according to the R^2 result. In short, the β for non-related futures contracts are in a range of 0.0628 to 0.24. Equally noticeable that; (1) the optimal hedge ratios become proportionately smaller as the correlation coefficient matrix between spot and futures become less correlated; and (2) the $R2$ results can explain the dynamics of return in spot market by futures market, however the $R2$ is not a superior measure to estimate hedging effectiveness as it does not illustrate clearly the return variance that has been minimized by the OLS regression model.

4.3 Vector Autoregression (VAR) Results

This model is expected to give better results than the OLS model since there are two variables in a regression model, whereby a current value of dependent variable is depend on the previous values of both variables. Earlier studies (Kim, 2010; Armstrong and Kutner, 2012) tend to choose Schwarz information criterion (Schwarz, 1978) with a maximum of eight lag lengths. For this study, SIC proposed two lag lengths for FCPO while one lag length to pair the CPO with WTI, BRENT, NGAS, TCRUDE, and TGAS.

Table 4. Optimal Hedge Ratio from the Bivariate VAR Model

	$Cov\ (\varepsilon_s\ \varepsilon_f)$	$Var\ (\varepsilon_f)$	h^*

FCPO	0.000616	0.00086	0.7163
WTI	0.000213	0.001395	0.1527
BRENT	0.000189	0.001081	0.1748
NGAS	0.000031	0.000801	0.0382
TCRUDE	0.000239	0.001096	0.2181
TGAS	0.000178	0.000996	0.1787

The difference of hedge ratios across the non-interrelated futures contracts have the same application with beta ratio, where to hedge 100 percent of the whole physical asset is not advisable as the spot and futures prices are not moving completely in tandem with each other due to both are traded in the different markets.

Based on Table 4, VAR model suggests the optimal hedge ratio of CPO with FCPO by 0.71, a slight decrease compared to OLS model recommendation of 0.72. The TCRUDE is ranked highest by its optimal hedge ratio of 0.21, followed by TGAS, WTI and NGAS. It is noticeable that the optimal hedge ratios were lessen when two variables were put in a model and lag lengths were accounted in, hence it produces more reliable results as OLS is simply a linear regression model.

The relevancy of using VAR to capture more accurate relationships between variables is because the previous OLS model could not be able to address the autocorrelation problem and no omission for residual series issue. Hence, the VAR regression model is expected to produce more accurate results.

Vector Autregression model brings the idea that the current price of dependent variable factorized by the previous value of its own and the previous value of independent variable at one time. With reference to Table 5, the negative signs in the result estimates $r_{s,t-i}$ and $r_{f,t-i}$ indicates that if the difference between spot and futures return is positive in one period, therefore the spot price will fall during the next period to restore the equilibrium.

Table 5. Bivariate VAR Model Estimates

	α	β_1	β_2	γ_1	γ_2
$r_{CPO,t}$	0.0015* (1.1580)	-0.0994*** (-1.6664)	-0.1579*** (-2.7466)	0.4962*** (8.4519)	0.2013*** (3.3084)
$r_{FCPO,t}$	0.0015 (1.1545)	0.3374*** (5.5721)	0.1298 (2.2251)	0.0601** (1.0084)	-0.2200*** (-3.5624)
$r_{CPO,t}$	0.0015 (1.1237)	0.2710*** (6.4077)	-	0.0630 (1.7948)	-
$r_{WTI,t}$	0.0002 (0.1452)	0.0200 (0.3888)	-	0.2664*** (6.2407)	-
$r_{CPO,t}$	0.0015 (1.1352)	0.2607*** (6.1570)	-	0.1060*** (2.6978)	-
$r_{BRENT,t}$	0.0002 (0.1217)	0.0315 (0.6932)	-	0.3160*** (7.4900)	-
$r_{CPO,t}$	0.0016 (1.2203)	0.2832*** (6.8336)	-	0.0774* (1.6752)	-
$r_{NGAS,t}$	-0.0013 (-1.0457)	0.0187 (0.4902)	-	0.2163*** (5.0866)	-
$r_{CPO,t}$	0.0015 (1.1247)	0.2706*** (6.3051)	-	0.0572*** (1.4516)	-

$r_{TCRUDE,t}$	0.0001 (0.0705)	0.0341 (0.7380)	-	0.3254 (7.6725)	-
$r_{CPO,t}$	0.0015 (1.1193)	0.2614*** (6.1749)	-	0.1079** (2.6357)	-
$r_{TGAS,t}$	0.0003 (0.2176)	0.0435 (0.9959)	-	0.3210*** (7.6019)	-

Note: * Significant at 10% level
** Significant at 5% level
*** Significant at 1% level

4.4 Johansen Cointegration Test Result

The Johansen co-integration test is basically the approach to VAR. In this co-integration test, the answer of whether two variables are co-integrated or not lied on the value of the trace test and the critical value. The critical value of 95 percent is referred and the rule of thumb for Johansen co-integration test is the trace and maximum eigenvalue test must exceed the critical value in order to reject the hypothesis.

Table 6 below shows the tested null and alternative hypothesis for the tested bivariate. Overall the null and alternative hypothesis or H0 : r = 0 are rejected for the hypothesis of no cointegration between the bivariate of CPO and its pair of FCPO, WTI, BRENT, NGAS, TCRUDE, and TGAS.

Table 6. Johansen Cointegration Analysis Results

	Hypothesis	**Eigenvalue**	λ_{trace}	λ_{max}	**95% Critical Value**
CPO & FCPO	H_0: r = 0*	0.3244	289.4753	289.4753	15.4947
	H_1: r ≤ 0*	0.1536	86.3775	86.3775	3.8415
CPO & WTI	H_0: r = 0*	0.1749	167.9648	100.7569	15.4947
	H_1: r ≤ 0*	0.1204	67.2080	67.2080	3.8415
CPO & BRENT	H_0: r = 0*	0.1689	162.5879	96.9584	15.4947
	H_1: r ≤ 0*	0.1177	65.6295	65.6295	3.8415
CPO & NGAS	H_0: r = 0*	0.1938	194.2633	112.8618	15.4947
	H_1: r ≤ 0*	0.1439	81.4015	81.4015	3.8415
CPO & TCRUDE	H_0: r = 0*	0.1585	153.5047	90.4014	15.4947
	H_1: r ≤ 0*	0.1135	63.1034	63.1034	3.8415
CPO & TGAS	H_0: r = 0*	0.1639	167.6117	93.7970	15.4947
	H_1: r ≤ 0*	0.1314	73.8147	73.8147	3.8415

Note: Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level

The trace test and maximum eigenvalue of all CPO pairs are found exceeded its respective critical values and it concludes that the alternative hypothesis or $H_0 : r < 1$ of CPO and its' bivariate pair of FCPO, WTI, BRENT, NGAS, TCRUDE, and TGAS to be co-integrated at most 1 co-integrating vectors also rejected. Therefore, CPO and its pairs are having at least two co-integrating vectors and all the cointegration tests are significance at 5 percent significant level.

4.5 Vector Error Correction Model (VECM) Result

The existence of co-integration vector between spot and futures means that error correction term must be modelled in VAR equation otherwise the hedge ratio is downwardly biased (Ghosh, 1993). The estimates for VECM, with two lag lengths when pairing CPO with FCPO, while one lag length for energy futures contracts according to Schwarz (1978).

The result shows that the speed of adjustment parameter λ_f is significant only in the futures equation with a positive value, which means that the futures prices are tracking the cash prices and not the other way round.

Table 7. Optimal Hedge Ratio from the Bivariate VECM

	$\boldsymbol{\varepsilon_S\,\varepsilon_f}$	$\boldsymbol{\varepsilon_f}$	$\boldsymbol{h^*}$
WTI	0.000390	0.001510	0.2597
BRENT	0.000359	0.001197	0.2999
NGAS	0.000008	0.000774	0.0102
TCRUDE	0.000435	0.001305	0.3333
TGAS	0.000347	0.001171	0.2963

According to Table 6, surprisingly BRENT capability to hedge the CPO improve significantly higher to nearly 0.30 compared to the previous VAR estimates (optimal hedge ratio of 0.17) when error correction terms were added in VAR model. TOCOM crude oil as expected provides the highest hedge ratio, which is 0.33, followed by BRENT, TGAS and WTI with 0.2999, 0.2963 and 0.2597 respectively. However hedgers should avoid NGAS as it only capable to allocate 0.01 hedge ratio for CPO.

It is initially presumed that the OLS model is unable to allocate the omission of the error correction term plus VAR is insufficient to capture the long run relationships that affects the CPO. As displayed in Table 8, the negative signs in the result estimates $\boldsymbol{r_{s,t-i}}$ and $\boldsymbol{r_{f,t-i}}$ indicates that if the difference between spot and futures return is positive in one period, therefore the spot price will fall during the next period to restore the equilibrium.

It is worth to be noted that VECM is modelled with error correction term on which it is lacked in OLS model and VAR model. Hence, based on Table 8, all the estimated $Z_{f,t-1}$ are found to be greater than $Z_{s,t-1}$. This means that the futures return series have a superior speed of adjustment to the previous period's deviation from long-run equilibrium than the spot return series. This results are consistent with the derivatives market theory that futures price will eventually adjust and converge itself to the prevailing spot price upon maturity.

Table 8. Bivariate VEC Model Estimates

	α	β_1	β_2	γ_1	γ_2	Z_{t-1}
$r_{CPO,t}$	0.0003 (0.2001)	-0.0680 (-0.6580)	-0.1969*** (-3.1944)	-0.3979*** (-3.5120)	-0.1758** (-2.5181)	-0.9579*** (-6.7992)
$r_{FCPO,t}$	0.0003 (0.2120)	-0.5357*** (-5.1038)	-0.3097*** (-4.9495)	0.2216* (1.9270)	-0.0277 (-0.3909)	0.9970*** (6.9718)
$r_{CPO,t}$	0.0002 (0.1469)	-0.3039*** (-7.1447)		-0.0947** (-2.3427)		-0.1812*** (-5.3867)
$r_{WTI,t}$	0.0002 (0.1174)	-0.2988*** (-6.2568)		0.0358 (0.7880)		0.4803*** (12.7202)
$r_{CPO,t}$	0.0002 (0.1391)	-0.2840*** (-6.6595)		-0.0990** (-2.1745)		-0.2310*** (-6.2477)
$r_{BRENT,t}$	0.0002 (0.1325)	-0.2415*** (-5.6073)		0.0376 (0.8190)		0.4388*** (11.7528)
$r_{CPO,t}$	0.0002 (0.1371)	-0.3818*** (-9.5106)		0.0541 (0.9872)		0.0000*** (-0.0889)
$r_{NGAS,t}$	0.0001 (0.1155)	0.0565* (1.7980)		0.1776*** (4.1371)		0.0067 (17.1647)
$r_{CPO,t}$	0.0002 (0.1386)	-0.2097*** (-4.6177)		-0.1206*** (-2.8192)		-0.3693*** (-7.7621)
$r_{TCRUDE,t}$	0.0001 (0.0551)	-0.2242*** (-4.6016)		-0.1357*** (-2.9555)		0.4167*** (8.1618)
$r_{CPO,t}$	0.0002 (0.1277)	-0.2023*** (-4.6332)		-0.1446*** (-3.2414)		-0.3896*** (-8.6146)
$r_{TGAS,t}$	0.0002 (0.1659)	-0.2029*** (-4.5153)		-0.1115** (-2.4285)		0.4016*** (8.6311)

Note: T-statistics are in the parenthesis.
* Significant at 10% level
** Significant at 5% level
*** Significant at 1% level

4.6 Measuring Hedging Effectiveness

The hedging effectiveness of a futures contract is tested when variance of a hedged position is divided by the variance of unhedged position. Hence the analysis will focus on comparative analysis of hedging effectiveness of futures contracts in this study relative to reducing the price risk of the underlying asset. The following notes discuss the best futures contract as the pair of Malaysian physical palm oil.

According to Table 9, FCPO is ranked among the top of the futures contracts which yields the highest hedging effectiveness when it is tested with three regression models of OLS, VAR and VECM. The VECM produced at least 58 percent hedging effectiveness to the physical palm when it is hedged with FCPO which it means that more than a half of price risk of a 25 metric tonne physical palm oil is mitigated or 42 percent of price risk. The hedging effectiveness of FCPO decreased when OLS and bivariate VAR are used, where the 48 to 50 percent price risk from market volatility is prevailing to the hedgers.

While for energy futures contracts in NYMEX and TOCOM tell a different story. VECM yields quite a tremendous results of cross hedging with energy futures, where 12 percent of hedging effectiveness recorded. Based on its underlying commodity which is the Dubai crude oil, the nearly-double hedging effectiveness compared to the other energy futures contracts in NYMEX and TOCOM might be due to the change by the TOCOM to make the contract specification better aligned the contract with the practices of the Japanese petroleum trading community, where Dubai crude oil prices are more widely accepted as the benchmark.

Table 9. Hedging Effectiveness across Models

	FCPO	WTI	BRENT	NGAS	TCRUDE	TGAS
			OLS			
σ_H^2	0.00052	0.000985	0.00098	0.00103	0.00096	0.00098
σ_U^2	0.00103	0.001031	0.00103	0.00103	0.00103	0.00103
HE	**49.96%**	**4.43%**	**5.37%**	**0.32%**	**6.87%**	**5.63%**
			Bivariate VAR			
σ_H^2	0.0004	0.000914	0.00091	0.00095	0.0009	0.00091
σ_U^2	0.00084	0.000947	0.00094	0.00095	0.00095	0.00094
h^*	**52.78%**	**3.43%**	**3.52%**	**0.12%**	**5.49%**	**3.38%**
			Bivariate VECM			
σ_H^2	0.0004	0.0011	0.00107	0.00111	0.00099	0.00101
σ_U^2	0.00095	0.0012	0.00118	0.00111	0.00114	0.00111
h^*	**58.17%**	**8.49%**	**9.15%**	**0.01%**	**12.74%**	**9.26%**

Based on VECM, cross hedging with TOCOM crude oil (TCRUDE) and ICE crude oil (BRENT) produced the same results, which the hedging effectiveness is around 9 percent. OLS and VAR on the other hand did not manage to produce hedging effectiveness more than 6 percent in general.

For energy futures market, TOCOM derivatives products of crude oil and gasoline produce best cross hedging effectiveness above the other energy futures, which is 12 and 9 percent respectively, followed by BRENT at 9 percent. WTI however placed last as it has the most of hedging variance which is nearly 92 percent unlikely to be handled.

5. Discussions and Conclusions

In order to answer the research objective number one (1), OLS, VAR and VEC models were used to find the optimal hedge ratio for energy futures contracts. As there is a limited number of research tries to investigate the relationship and hedging effectiveness of energy commodities futures contracts to CPO, this study has found that on average, energy commodities futures contracts in NYMEX, ICE and TOCOM have acceptable degree of relationships and optimal hedge ratios. This is not phenomenal as in recent study has proved that there was an increase and more variable correlation between oil and most agricultural commodities futures returns (Silvennoinen and Thorp, 2016).

Table 10. Summary of Optimal Hedge Ratio (Non-interrelated Futures Contracts)

	OLS	VAR	VECM
WTI	0.1748	0.1527	0.2597
BRENT	0.2145	0.1748	0.2999
NGAS	0.0628	0.0382	0.0102
TCRUDE	0.2403	0.2181	0.3333
TGAS	0.2223	0.1787	0.2963

Based on Table 10, the optimal hedge ratio by bivariate VECM is recommended for cross hedging and TOCOM energy derivatives is the most preferred.

The cross hedging effectiveness for energy futures paired with CPO for the purpose of research objective number two (2) can be illustrated as followed:

Table 11. Summary of Hedging Effectiveness

	OLS	BVAR	BVECM
WTI	4.43%	3.43%	8.49%
BRENT	5.37%	3.52%	9.15%
NGAS	0.32%	0.12%	0.01%
TCRUDE	6.87%	5.49%	12.74%
TGAS	5.63%	3.38%	9.26%

Japanese crude oil futures (TCRUDE) is the only non-interrelated futures contracts in this study which could yield more than 10 percent cross hedging effectiveness, taking the bivariate VECM as the parameter. The worst performer is NYMEX Henry Hub Natural Gas (NGAS) which provides almost no risk reduction for the cross hedging. The next best alternative for FCPO in energy futures market is TOCOM gasoline (TGAS), which could mitigate and yield almost 10 percent of price risk in CPO physical market.

Based on the results mentioned, the summary of acceptance and/or rejection of hypotheses built earlier can be shown as appended below:

Table 12. Summary of Results (Hedging Variance Reduction)

Hypothesis Statements	**Results**
H_1: There is a positive hedge ratio Malaysian CPO and non-interrelated energy futures contract in NYMEX, ICE, and TOCOM.	Accepted
H_2: The hedge ratio of non-interrelated futures contract in NYMEX, ICE, and TOCOM is more effective in minimizing the hedging variance of CPO than the hedge ratio of FCPO.	Rejected

The study output discussed in this study is none other than to be implemented in practical use. Other than the novel contribution to the body of knowledge, this study provides two biblical guide to the industry practioners; hedgers and non-hedgers. The optimal hedge ratios derived from this study are very applicable to the hedgers whose are physical buyers and sellers of physical crude palm oil and the cross hedging effectiveness produced from the cross hedge pairs are illustrated in this paper as well. For non-hedgers, they are market participants whose eyeing for gains from the volatility in futures markets (Go and Lau, 2017). The output from this paper could be their reference on cross markets interdependence thus practically will enhance their investment portfolio allocation strategy to not to be too vulnerable from foreign markets contagion impacts. The non-hedgers can even benefit the research findings when trading the futures contracts across time zones as it is empirically proven to yield positive returns to their trading portfolios (Du, 2018).

In an additional note, in case the Malaysian Financial Reporting Standards (MFRS) make it mandatory for the companies to evaluate the effectiveness of hedges, thus the methods to obtain the optimal hedge ratios and hedging effectiveness measurement applied in this study can be exemplified by the companies for the purpose of financial reporting (Kharbanda and Singh, 2018).

In conclusion, the alternative to cross hedge is available for the traders to reduce their price risk against the market agility. TOCOM crude oil is the best alternative as the cross hedging pair for CPO yielding 12 percent of hedging effectiveness while the NYMEX natural gas appears to be the worst pair for CPO cross hedge. Overall, TOCOM has the best performance of cross hedging provided by its' crude oil and gasoline followed by the BRENT in Intercontinental Exchange (ICE). Above all, this paper agrees with Salami and Haron (2018) that FCPO still manages to provide the best hedging mechanism for the Malaysian palm oil compared to other non-interrelated energy commodity derivatives tested in this study.

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