Volatility Spillover from Soybean Oil Futures to Crude Palm Oil Spot & Futures: An Empirical Evidence

By

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ABSTRACT

This study examines volatility spillovers from soybean oil (SO) futures market to both crude palm oil (CPO) spot and futures markets by adopting the trivariate volatility spillover model for the period of 2nd January 2004 - 31st December 2013. Time series of data are collected for Malaysia CPO spot and futures prices, and Chicago Board of Trade (CBOT) listed SO futures prices. A number of important findings are found: (1) there is a presence of a long-run equilibrium relationship between SO futures and CPO futures markets, but not between SO futures and CPO spot, and between CPO futures and CPO spot prices, (2) there is a convergence between CPO futures and CPO spot prices and a bi-directional causality exists between their prices, (3) markets seem to respond strongly to bad new rather than to good news, (4) there is a persistence in volatility for SO futures prices, and a significant volatility spillover from SO futures prices to CPO spot and futures prices, (5) volatility of CPO spot market in the current period is found to be affected by volatility of CPO futures market in the previous period, and vice versa, (6) volatilities of CPO spot and futures spillover ratios are below 20% for the period before the 2008 financial crisis; however, they go up to around 45% during the crisis period, implying a close link between peaks in volatility of SO prices and CPO spot and futures spillover ratios during the post 2008 financial crisis period, and that CPO spot and futures price volatilities are strongly affected by SO futures price volatility. Findings of the study are believed to be beneficial to policy makers, and both investors and speculators to make their strategic investment decisions from time to time.

Keywords: soybean oil, crude palm oil, multivariate GARCH, volatility spillovers
JEL Classification C12- C13- G10 – G1

1. **Introduction**

The growing trend of information transmission between two commodity markets is well documented in past studies. Dynamic changes in price and volatility in a commodity market often cause a significant reaction in another commodity market (Wilkinson, 1976; Brandt, 1985; Mad and Fatimah, 1992; and Chan et al., 1991). Most part studies have focused on the link between the spot and futures prices of a commodity, and found that the price volatility of a commodity in a spot market can have a significant impact on its prices in a future market (Lee et al., 2007; and Liu and Wan, 2011). However, issue of volatility spillover between markets of two substitute goods such as soybean oil (SO) and crude palm oil (CPO) is found to be rarely discussed. The link between markets of two substitute commodities is believed to be important, and thus, often observed by food processors to make their product switching decisions in the presence of frequent edible oil price fluctuation. Moreover, according to Chicago Mercantile Exchange (CME) Group's report in 2013, SO and CPO had jointly accounted for about 56% and 68% of the world traded edible oil production, respectively. Thus, the price fluctuation of these two commodities is definitely in the great interest of various parties, i.e. investors, traders, consumers, and policy makers. Understanding the volatility transmission from SO futures to CPO markets is important for making investment and hedging decisions. In addition, being aware of volatility spillover will help traders and producers to formulate appropriate risk management decisions and pay greater attention on the use of time-varying hedging strategies.

To fill in the research gap, this study aims to examine the volatility spillover effect from SO market to CPO spot and futures markets. Using three time series of data, i.e. Malaysia CPO spot and futures prices, and Chicago Board of Trade (CBOT) listed SO futures prices, collected from the SIRCA - Thompson Reuters Database, a trivariate volatility spillover model is adopted and run for the period of 2nd January 2004 - 31st December 2013. A number of important findings are found: (1) there is a presence of a long-run equilibrium relationship between SO futures and CPO futures markets, but not between SO futures and CPO spot, and between CPO futures and CPO spot prices, (2) there is a convergence between CPO futures and CPO spot prices and a bi-directional causality exists between their prices, (3) markets seem to respond strongly to bad new rather than to good news, (4) the persistence in volatility for SO futures prices, and that there is a significant volatility spillover from SO futures prices to CPO spot and futures prices, (5) volatility of CPO spot market in the current period is found to be affected by volatility of CPO futures market in the previous period, and vice versa, (6) volatilities of CPO spot and futures spillover ratios are below 20% for the period before the 2008 financial crisis; however, they go up to around 45% during the crisis period, implying a close link between peaks in volatility of SO prices and CPO spot and futures spillover ratios during the post 2008 financial crisis period, and that CPO spot and futures price volatilities are strongly affected by SO futures price volatility. Findings of the study are believed to be beneficial to policy makers, and both investors and speculators to make their strategic investment decisions from time to time.

The rest of the paper is organized as follows: Section 2 provides a literature review related to the area of volatility spillover for agricultural commodities; Section 3 provides details of data and methodologies adopted in this study; Section 4 discusses empirical results; and Section 5 provides key conclusions.

2. Literature Review

There is a growing literature in volatility spillover and risk transmission between commodity markets. Many attempts have been made to empirically investigate volatility spillover in commodity markets.

Using weekly data of corn and ethanol prices, Trujillo-Barrera, Mallory, and Garcia (2012) examined the volatility spillover in the United States from crude oil market to corn and ethanol markets during the period of July 2006 - November 2011. The authors found that there is a volatility spillover from crude oil market to each of corn and ethanol markets, and there is also a volatility spillover from ethanol market to corn market. In another study by Wu, Guan, and Myers (2011), a strong positive correlation between volatilities of crude oil and corn prices is also found. However, the authors did not find any significant co-integration between crude oil and corn prices.

Du, Yu, and Hayes (2011) examined the volatility spillovers between the crude oil market and each of the two agricultural commodity markets: corn and wheat over two periods: (1) November 1998 - October 2006, and (2) November 2006 - January 2009. Results obtained for the first period (November 1998 - October 2006) showed no statistically significant evidence of volatility spillover between crude oil market and the two agricultural commodity markets.

However, correlations between price volatility of crude oil market and those of corn and wheat markets, are found to be statistically significant for the second study period (November 2006 - January 2009).

Using a similar approach, Harri and Hudson (2009) examined volatility spillovers from two commodity markets, i.e. crude oil and corn, to the exchange market over two sample periods: (1) April 2003 - March 2006, and (2) April 2006 - March 2009. For the first sample period, the authors found that only crude oil price volatility had a significant impact on the fluctuation of exchange rates; however, no similar result was found for corn price volatility. For the second study period, results showed that crude oil price volatility had significant impacts on prices of both corn and exchange markets.

Alom, Ward and Wu (2011) examined the mean and volatility spillover effects of world oil prices on food prices for eight selected countries in the Asia Pacific region: (1) India, (2) Taiwan, (3) Hong Kong, (4) Thailand, (5) Singapore, (6) Australia, (7) South Korea and (8) New Zealand. Their empirical findings showed that world oil prices has a positive impact on both mean and volatility of food prices in all of the selected countries; however, magnitudes of the effects were different from country to country, and also for different time periods. In addition, significant results were only found for the short run, but not for the long run. Results obtained for the second sub-sample period of 2002 - 2010 showed stronger mean and volatility spillover effect as compared to those obtained for the first sub-sample period of 1995 - 2001, implying that food prices in the Asia Pacific region are getting more dependent on world oil prices in recent years.

3. **Research Methodology**

3.1 Data Selection

In this study, three time series of data , i.e. Malaysia CPO spot prices; Malaysia CPO futures prices, and Chicago Board of Trade (CBOT) listed SO futures prices, are collected from the SIRCA - Thompson Reuters Database for a period of 2nd January, 2004 - 31st December, 2013. Using daily closing prices from the nearest contract month, the total observations in the sample is 2428.

Daily returns for both futures and spot contracts are computed as follows.

$$R_{i,t} = \ln\left(\frac{P_{i,t}}{P_{i,t-1}}\right) \times 100$$

(Equation 1)

Where: $P_{i,t}$ and $P_{i,t-1}$ are the closing prices for the i^{th} futures/ spot contract, at time *t and t-1*, respectively. $R_{i,t}$ is the i^{th} futures/spot contract' s daily return at time *t*.

3.2 Models to Measure Volatility Spillover Effects

In this study, to measure the volatility spillover effect between SO futures market and each of CPO spot and futures markets, the trivariate volatility spillover model used in Ng (2000) and Wu, Guan, and Myers (2011) will be adopted. Details of this model are as follows:

$$\Delta f_{o,t} = E[\Delta\left(f_{o,t}\middle|I_{t-1}\right) + e_{fo,t}$$

(*Equation 2)*

$$\begin{bmatrix} p_{c,t} \\ f_{c,t} \end{bmatrix} = \begin{bmatrix} E\left(p_{c,t}\middle|I_{t-1}\right) \\ E\left(f_{c,t}\middle|I_{t-1}\right) \end{bmatrix} + \begin{bmatrix} \varepsilon_{p,t} \\ \varepsilon_{f,t} \end{bmatrix}$$

(Equation 3)

$$\begin{bmatrix} \varepsilon_{p,t} \\ \varepsilon_{f,t} \end{bmatrix} = \begin{bmatrix} \varphi_t \\ \omega_t \end{bmatrix} e_{o,t} + \begin{bmatrix} e_{p,t} \\ e_{f,t} \end{bmatrix}$$

(Equation 4)

where Δ is the first-difference operator; $f_{o,t}$, $p_{c,t}$, and $f_{c,t}$ denote as SO futures price, CPO spot price, and CPO futures price, respectively; I_{t-1} is information available at time *t*-1; $e_{o,t}$, $\varepsilon_{p,t}$, and $\varepsilon_{f,t}$ are random shocks in the SO futures market, the CPO spot and futures market, respectively; φ_t and ω_t are possibly time-varying spillover parameters; $e_t = [e_{p,t}, e_{f,t}]$ is a vector of idiosyncratic shocks in CPO spot and futures markets, which could be mutually correlated; however, both are uncorrelated with $e_{o,t}$.

In Equation (4), the SO idiosyncratic shock ($e_{o,t}$) is assumed to be distributed with a conditional mean of 0, implying a zero expected return to futures trading conditional on information available at time *t-1*. The SO shocks are also assumed to follow a conditional normal distribution and its conditional variance (σ_t^2) is allowed to vary over time in response to changing market conditions. As it is generally found that negative shocks lead to higher subsequent volatility than positive shocks of an equal magnitude, a threshold GARCH process that accounts for asymmetric volatility effect is, therefore proposed as follows.

$e_{o,t} \big| I_{t-1} \sim \mathrm{N}\,(0, \sigma_t^2)$

(Equation 5)

$$\sigma_t^2 = \alpha_0 + \alpha_1 e_{o,t-1}^2 + \lambda_1 d_{t-1}\, e_{o,t-1}^2 + \alpha_2 \sigma_{t-1}^2 + \alpha_3 Q_{1t} + \alpha_4 Q_{2t} + \alpha_5 Q_{3t} + \alpha_6 z_t$$

(Equation 6)

Where d_{t-1} *is* a dummy variable that takes a value of 1 if $e_{0,t-1} \leq 0$ and 0 otherwise. Q_1, Q_2, and Q_3 are seasonal dummies (the fourth quarter dummy - Q_4 - is omitted to avoid the dummy variable trap); and z_t is the number of days to contract maturity to allow for time-to-maturity effects.

CPO spot and futures prices computed by using the formula given in Equation 1, are composed of a conditional expectation and a random shock. Shocks to the CPO spot and futures prices are allowed to be driven by an external shock from the SO futures market in addition to a purely idiosyncratic component. In Equation 5, volatility spillover effects from SO futures market to CPO spot and futures markets are introduced via the idiosyncratic SO shock $e_{o,t}$ while $e_t = [e_{p,t}, e_{f,t}]$ is assumed to be uncorrelated with $e_{o,t}$ and follow a conditional normal distribution with a mean of zero and a time-varying covariance matrix, H_t.

The asymmetric version of the Baba-Engle-Kraft-Kroner (BEKK) model introduced in Kroner and Ng (1998) is adopted in this study to account for possibly asymmetric volatility effects due to the fact that negative shocks often have bigger impacts on future volatilities as compared to those produced by positive shocks with similar sizes. This part of the model is then specified as follows:

$e_t | I_{t-1} \sim \mathrm{N}\,(0, H_t)$

(Equation 7)

$$H_t = C'C + A' e_{t-1} e'_{t-1} A + B' H_{t-1} B,$$

(Equation 8)

Where H_t is the BEKK conditional volatility, **C** is an upper triangular matrix that corresponds to the constant, $e_{t-1}\, e'_{t-1}$ are the squared lagged errors, A is the matrix of ARCH parameters, H_{t-1} is the lagged conditional volatility, and B is the matrix of

GARCH parameters. The volatility of the errors $e_{p,t}$ and $e_{f,t}$ is specified using the Baba, Engle, Kraft and Kroner (BEKK) specification of a multivariate GARCH which two desirable characteristic. It is positive definite by construction and it allows the estimation of the volatility spillover between crude palm oil spot and future. Equation 8 defines the BEKK-GARCH model.

The above-mentioned bivariate BEKK-GARCH will be used to examine further on how volatilities of CPO spot and futures volatilities interact with one another, and also how SO futures price volatility influence the volatilities of the two CPO markets.

$$\begin{bmatrix} h_{pp,t} & h_{pf,t} \\ h_{fp,t} & h_{ff,t} \end{bmatrix} = \begin{bmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{bmatrix}' \begin{bmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' \begin{bmatrix} e^2_{p,t-1} & e_{p,t}e_{f,t-1} \\ e_{f,t-1 e_{p,t}} & e^2_{f,t-1} \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}' \begin{bmatrix} h_{pp,t-1} & h_{pf,t-1} \\ h_{fp,t-1} & h_{ff,t} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$$

$$h_{pp,t} = c^2_{11} + a^2_{11} e^2_{c,t-1} + 2_{a_{11}} a_{21} e_{p,t-1} e_{f,t-1} + a^2_{21} e^2_{f,t-1} + b^2_{11} h_{pp,t-1} + 2b_{12} b_{22} h_{pf,t-1} + b^2_{22} h_{ff,t} \text{ ,}$$

(*Equation 9*)

$$h_{ff,t} = c^2_{12} + a^2_{22} + a^2_{12} e^2_{p,t-1} + 2a_{12} a_{22} e_{p,t-1} e_{f,t-1} + a^2_{22} e^2_{f,t-1} + b^2_{11} h_{pp,t-1} + 2b_{12} b_{22} h_{pf,t-1} + b^2_{22} h_{ff,t-1}$$

(Equation 10)

Where $h_{pp,t}$ and $h_{ff,t}$ are conditional idiosyncratic volatility of CPO spot (p) and CPO futures (f) markets, $h_{pf,t}$ is the conditional variance, and $e_{ij,t}$ (i, j) = p, f are the lagged own squared and cross-market random shocks. Taking the square of Equation 10 and under assumption of no correlation between $e_{o,t}$ .and e_t the conditional variances of CPO spot and futures markets are given as follows:

$$E\ (\varepsilon^2_{p,t} \mid I_{t-1}) = h_{pp,t} + \emptyset^2 \sigma^2_t$$

(Equation 11)

$$E\ (\varepsilon^2_{f,t} \mid I_{t-1}) = h_{ff,t} + \omega \sigma^2_t$$

(Equation 12)

Where the significance of φ^2 and ω^2 determine whether there is a volatility spillovers from SO futures markets. Volatility spillover between CPO spot and futures are determined by the signs and significance of the terms in Equation 11 and Equation 12.

There are a large number of parameters that require to be estimated in the spillover model. In this study, the two-step procedure (Bakaert and Harvey, 1997; Ng, 2000; and Baele, 2005) will be used. In the first step, the vector error correction model (VECM) is estimated to obtain estimates of the shock vector ($\varepsilon_{p,t}$, $\varepsilon_{f,t}$) for CPO spot and futures prices. In the second step, estimates obtained in the first stage are then used as data in joint quasi- maximum likelihood estimation of the tri-variate volatility spillover model from the equation (10) and (12), assuming the purely idiosyncratic shock vector has a bi-variate conditional normal distribution with a mean of zero and a time-varying variance matrix.

3.3 Volatility Spillover Ratios

Under the assumption of no correlation between $e_{o,t}$ and $e_t = [e_{p,t}, e_{f,t}]'$, the conditional variances of CPO spot and futures prices are given by:

$$E\,(\varepsilon_{p,t}^2 \mid I_{t-1}) = H_t^{11} + \varphi_t^2\sigma_t^2 \qquad \textit{(Equation 13)}$$

$$E\,(\varepsilon_{f,t}^2 \mid I_{t-1}) = H_t^{22} + \omega_t^2\sigma_t^2 \qquad \textit{(Equation 14)}$$

Where H_t^{ij} is the element in the *i*th row and the *j*th column of H_t.The signs and significance of φ_t and ω_t determine whether volatility spillover effects from SO futures markets are present in CPO spot and futures markets. To measure the proportion of the variance of CPO spot and futures markets contributed by SO futures volatility spillover effects, we define spillover ratios for CPO cash and futures prices as follows:

$$SR_{p,t} = \frac{\varphi_t^2\sigma_t^2}{H_t^{11} + \varphi_t^2\sigma_t^2} \in [0,\ 1] \qquad (\textit{Equation 15})$$

$$SR_{f,t} = \frac{\omega_t^2\sigma_t^2}{H_t^{22} + \omega_t^2\sigma_t^2} \in [0,\ 1] \qquad (\textit{Equation 16})$$

These ratios summarize the relative importance of shocks in SO futures markets on volatilities of CPO spot and futures markets at different points in time.

3.4 Johansen's Cointegration Tests

If there is strong evidence of cointegration between SO futures and CPO spot and futures markets, a vector error correction model (VECM) will be estimated as shown in Equation 17 and 18. Model selection criterion (AIC) is used to determine lags. Details of the VECM are as follows:

$$\Delta p_{c,t} = \pi\, ECT_{t-1} + \sum_{i=1}^{4} \beta_i \Delta p_{c,t-i} + \sum_{i=1}^{4} \gamma_i\, \Delta f_{c,t-i} + \varepsilon p_{c,t}$$

(Equation 17)

$$\Delta f_{c,t} = \pi\, ECT_{t-1} + \sum_{i=1}^{4} \delta_i \Delta p_{c,t-i} + \sum_{i=1}^{4} \emptyset_i \Delta f_{c,t-i} + \varepsilon f_{c,t}$$

(Equation 18)

Where ECT_{t-1} denotes the error correction term to capture the cointegration relationship.

Equation 17 and 18 generates residuals that are the estimates of the shock vector ($\varepsilon_{p,t}$, $\varepsilon_{t,t}$) for CPO spot and futures prices presented in Equation 3. These are used to jointly estimate Equation 3 and 5 using a quasi-maximum likelihood procedure

4. Empirical Findings

4.1 Results of Descriptive Statistics.

Descriptive statistics of log price and returns for SO futures, CPO spot and futures contracts are given in Table 1 below.

Table 1: Summary Statistics and Correlation Analysis

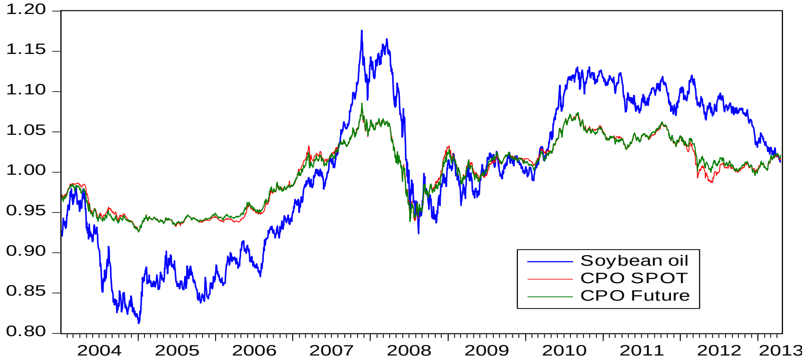
This table presents descriptive statistics of log price and returns. Correlations between contracts are also given at the bottom of the table.

	Log price			Returns		
Statistics	**SO Futures**	**CPO Spot**	**CPO Futures**	SO Futures	CPO Spot	CPO Futures
Minimum	1.2755	3.1047	3.0997	-3.3736	-3.4722	-4.7317
Maximum	1.8476	3.6236	3.6365	3.2592	3.4740	4.1262
Mean	1.5710	3.3497	3.3487	0.0058	0.0064	0.0073
Median	1.5812	3.3728	3.3777	-0.0123	0.0283	0.0000
Std.Dev.	0.1453	0.1365	0.1359	0.7155	0.6229	0.7542
Skewness	-0.2463	-0.1807	-0.1725	0.0415	-0.5571	-0.3293
Kurtosis	1.8478	1.8023	1.8001	5.2011	8.9014	6.8724
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total Observation	2428	2428	2428	2428	2428	2428
	Correlations			**Returns**		
	SO Futures	**CPO Spot**	**CPO Futures**	**SO Futures**	**CPO Spot**	**CPO Futures**
SO F	1.0000	0.9318***	0.9492		0.3145***	0.4000***
CPO Spot	0.9318***	1.0000	0.9948	0.3145***		0.6415***
CPO Futures	0.9492***	0.9948***	1.0000	0.4000***	0.6415***	

Notes: SO futures, CPO spot, and futures prices are converted to logs; and their respective returns are multiplied by 100. Triple asterisks (***) represent significance at the 1% level.

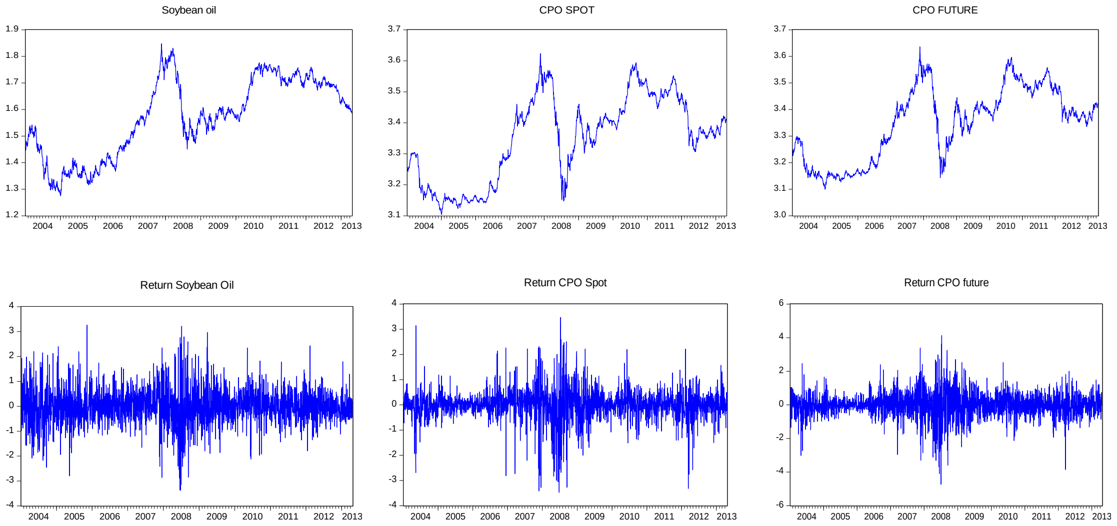
Table 1 shows that the means of returns for SO futures, CPO spot, and futures contracts are all positive and close to zero, suggesting similar positive growth rates are present for the three contracts' prices. Large differences between the minimum and maximum returns of the three above-mentioned contracts indicate the high variability in their prices. It is also noticeable that the maximum return (4.126) of CPO futures contract is higher than that (3.259) of the SO futures contract. In addition, the highest price volatility (0.7542) is found for CPO futures contract as compared to those (0.6229 and 0.7155) of CPO spot and SO futures contracts, respectively. As shown in Table 1, strong positive correlations are also found for returns of the three contracts at the 1% level of significance, of which stronger correlations (0.642 and 0.400) are found between the returns of CPO futures and the returns of other two contracts, i.e. CPO spot and SO futures contracts, respectively.

Ash shown in Figure 1 and 2, prices of SO futures, CPO futures and spot contracts all move in the same direction, from which an upward trend is observed between the beginning of 2005 and mid-2007, followed by a steep downward trend till the end of 2008. The sharp declines in prices by the end of 2008 for the three contracts shown in Figure 1 and 2 could be explained by the low demand for oil caused by the 2008 global financial crisis. However, the three contracts' prices rebounded to their 2007-price levels by mid-2010, since when prices of the three contracts have exhibited considerable price volatilities. .



In this figure, price to mean ratios are graphed for all the three contracts, i.e. SO futures, CPO futures, and CPO spot.

Figure: 1 Prices Divided by Own Mean



In this figure,indvidual prices and returns are plotted for each of the three contracts, i.e. SO futures, CPO futures, and CPO spot.

Figure 2: Log Price and Returns

4.2 Results of Unit Root Tests

Results of two unit root tests, i.e. Augmented Dickey Fuller (ADF) and Phillips-Perron (PP), are summarized in Table 2.

Results obtained from ADF and PP tests all suggest that time series for prices of the three contracts are stationary at the 1st difference, but not at level, implying that time series for returns of the three contracts are stationary.

Table 2: Results Obtained from Augmented Dickey Fuller (ADF) and Phillips- Perron (PP) Tests

Results obtained from two unit root tests, i.e. ADF and PP, are presented in this table. Lags for ADF test were chosen by AIC model selection criterion, and the ACFs and PACFs also were examined to ensure the residuals were white noise.

Variable Model

		t-value	
Prices Series	**Lags**	**Level**	**First Difference of Prices:**
SO Futures	1	-1.6434	-22.29198**
CPO cash	2	-1.6804	-42.7220**
CPO Futures	1	-1.8878	-32.9233**

Phillips- Perron Test

Variable Model	**Lags**	**t Statistic**	**P-value**
SO Long Lags	20	-1.7011	0.7508
SO Short Lags	5	-48.5930***	0.0001
Crude palm oil cash Long Lags	20	-1.9375	0.6343
Crude palm oil cash short Lags	5	-42.8357***	0.0000
Crude palm oil future Long Lags	20	-2.0212	0.5888
Crude Palm oil future Short Lags	5	-50.5781***	0.0001

*Notes: Double and triple asterisks (** and ***) represent significance at the 5% and 1% levels, respectively.*

Table 3: Results of Johansen's Cointegration Tests

In this table, results obtained from two Johansen's cointegration tests: (1) the trace test and (2) the Lambda-Max test, are presented for three bi-variate relationships in three panels: (1) CPO spot and futures prices (Panel A), (2) SO futures and CP sport prices (Panel B), and (3) SO futures and CPP futures prices (Panel C).

	Panel A: CPO Sport and Futures Prices				**Lag : 4**
			Critical value		**Critical value**
Cointegration Rank	**Eigenvalue**	**Trace statistics**	**95%**	**Max Statistics**	**95%**
None	0.27	18.29**	15.49	16.35**	14.26
At most 1	0.15	1.93	3.84	1.93	3.84

	Panel B: SO Futures and CPO Sport Prices				**Lag: 2**
			Critical value		**Critical value**
Cointegration Rank	**Eigenvalue**	**Trace statistics**	**95%**	**Max Statistics**	**95%**
None	0.01	18.62**	15.49	15.67**	14.26
At most 1	0.00	2.95	3.84	2.95	3.84

	Panel C: SO Futures and CPO Futures Prices				**Lag: 2**
			Critical value		**Critical value**
Cointegration Rank	**Eigenvalue**	**Trace statistics**	**95%**	**Max Statistics**	**95%**
None	0.01	24.36**	15.49	21.09**	14.26
At most 1	0.00	3.27	3.84	3.27	3.84

Notes: Double asterisks (**) represent significance at the 5% level.

Table 3 shows results obtained from Johansen's cointegration tests, i.e. the trace test and the Lambda-max test, for the three bivariate relationships: (1) CPO spot and futures, (2) SO futures and CPO cash, and (3) SO futures and CPO futures. As shown in Panel C of Table 3, both Trace statistics and Max statistics suggest that the null hypothesis of no cointegration between SO futures and CPO futures prices should be rejected at the 5% level, suggesting the presence of a long-run equilibrium relationship between SO futures and CPO futures markets. The null hypothesis of no cointegration at the 10%

level is rejected for the other two bi-variate relationships: SO futures and CPO spot, and CPO futures and CPO spot prices.

4.3 Results of Vector Error Correction Model (VECM) and Granger Causality Tests

Results obtained from VECM and the Granger Causality tests are showed in Table 4 and 5, respectively. As shown in Table 4, the value of ECT is found to be positive, i.e. 1.2462, and significant at the 5% level, implying the convergence between CPO Futures and CPO Spot Prices. In terms of the direction of information flow and the lead- lag relationship between Spot and Futures Prices, the significant p-values found for both F-statistics obtained from Granger causality test at the 1% level as shown in Table 5, suggest that a bi-directional Granger causality exists between CPO Futures and CPO Spot markets.

Table 4: Results Obtained from VECM Test for CPO Spot and Future Prices

This table presents results obtained from VECM tests for crude palm oil spot (Panel A) and futures (Panel B) prices. The following VECM models are used for testing:

$$\Delta p_{c,t} = \pi\, ECT_{t-1} + \sum_{i=1}^{4} \beta_i \Delta p_{c,t-i} + \sum_{i=1}^{4} \gamma_i \Delta f_{c,t-i} + \varepsilon p_{c,t}$$

$$\Delta f_{c,t} = \pi\, ECT_{t-1} + \sum_{i=1}^{4} \delta_i \Delta p_{c,t-i} + \sum_{i=1}^{4} \emptyset_i \Delta f_{c,t-i} + \varepsilon f_{c,t}$$

Panel A:

	Dependent Variable: $\Delta p_{c,t}$	
Variables	**coefficients**	**t-statistic**
ΔCPO Spot$_{t-1}$	-0.3587	-4.5311**
ΔCPO Spot$_{t-2}$	-0.4253	-6.7594**
ΔCPO Spot$_{t-3}$	-0.3300	-7.4585**
ΔCPO Spot$_{t-4}$	-0.1722	-6.9637**
ΔCPO Future$_{t-1}$	-0.3780	-4.4416**
ΔCPO Future$_{t-2}$	-0.0647	-0.9484
ΔCPO Future$_{t-3}$	0.0058	0.1190
ΔCPO Future$_{t-4}$	0.3997	1.5281
ECT$_{t-1}$	-0.9280	-10.0518**

Panel B:		
	Dependent Variable: $\Delta f_{c,t}$	
Variables	**coefficients**	**t-statistic**
ΔCPO Spot$_{t-1}$	-1.0548	-9.8585**
ΔCPO Spot$_{t-2}$	-0.7952	-7.35089**
ΔCPO Spot$_{t-3}$	-0.4707	-7.8764**
ΔCPO Spot$_{t-4}$	-0.2317	-6.9334**
ΔCPO Future$_{t-1}$	0.3110	2.7822**
ΔCPO Future$_{t-2}$	0.3389	3.6744**
ΔCPO Future$_{t-3}$	0.1827	2.7699**
ΔCPO Future$_{t-4}$	0.0839	2.3745**
ECT$_{t-1}$	1.2462	9.9879**

Notes: Double asterisk (**) represents significance at the 5% level.

Table 5: Results Obtained from Granger Causality Test

This table shows results obtained from Granger causality test for CPO spot and futures prices.

	F-statistics	**p-values**
H_0 : CPO spot prices do not Granger-cause changes in CPO futures prices	4.9729	0.0005***
H_0 : CPO futures prices do not Granger-cause changes in CPO spot prices	7.8075	0.0000***

Notes: Triple asterisk (***) represents significance at the 1% level.

4.4 Results Obtained from GJR-GARCH Test for Price Volatility Spillover

Using GJR-GARCH to estimate the conditional volatility of SO futures prices, the obtained results are shown in Table 6. The significant positive value found for λ_1 suggests that negative unexpected shocks generate stronger impacts on price volatility of SO futures as compared to those generated by positive shocks. As shown in Table 6, although the value (0.1936) of λ_1 is statistically significant at the 5% level, and larger than the value (0.0083) of α1, the value of α_1 is not statistically significant. Thus, it may indicate that markets seem to respond strongly to bad new rather than to good news.

In addition, coefficient of the GARCH term - α_2 - has a significant value of 0.9465 at the 5% level as shown in Table 6, suggesting that about 95% of variation in SO futures prices in the previous period remains in the following day. This finding has confirmed the presence of volatility clustering in daily returns, and also the long lasting effect generated by price volatility in SO futures markets.

Table 6: Results Obtained from GJR-GARCH Test for SO Futures Prices

This table presents results obtained from the following GJR-GARCH model:

$$\sigma_t^2 = \alpha_0 + \alpha_1 e_{o,t-1}^2 + \lambda_1 d_{t-1} e_{o,t-1}^2 + \alpha_2 \sigma_{t-1}^2 + \alpha_3 Q_{1t} + \alpha_4 Q_{2t} + \alpha_5 Q_{3t} + \alpha_6 z_t$$

Where d_{t-1} *is a dummy variable that takes a value of 1 if* $e_{0,t-1} \leq 0$ *and 0 otherwise.* Q_1, Q_2, *and* Q_3 *are seasonal dummies (the fourth quarter is the default and is omitted); and* z_t *is the number of days to contract maturity to allow for time-to-maturity effects.*

Variable	Coefficient	t-statistic
α_0	0.0041	2.2019
α_1	0.0083	0.2345
λ_1	0.1936	3.1266**
α_2	0.9465	20.7645**

Note: Double asterisks (**) represent significance at the 5% level

4.5 Results Obtained from the Constant Volatility Spillover Model - Bivariate BEKK GARCH

Using bivariate BEKK GARCH model, all spillover parameters are constrained to be constant over time. The obtained results are presented in Table 7. As shown in Table 7, obtained results show that the estimated BEKK model captures all dynamics in both mean and variance of soybean futures prices.

As shown in Table 7, for both ARCH and GARCH parameter matrices -*A* and *B* respectively -, the estimated coefficients are large and statistically significant at the 5% level, implying the persistence in volatility for SO futures prices. Furthermore, significant positive values for both φ and ω are also found at the 1% level, which suggests that there is a significant volatility spillover from SO futures prices to CPO prices, which then caused an increase in CPO price volatility as a result.

Furthermore, both coefficients of A (p,f) and A(f,p) are statistically significant at the 5% level, suggesting bi-directional spillovers between two markets, i.e CPO futures and spot. This may be interpreted as volatility of CPO spot market in the current period is affected by volatility of CPO futures market in the previous period, and vice versa.

Table 7: Results Obtained from Bivariate BEKK GARCH for SO Futures Prices

This table presents results obtained from bivariate BEKK GARCH model stated below:

$$e_t|I_{t-1} \sim \mathrm{N}(0, H_t)$$

$$(H_t = C'C + A' e_{t-1} e'_{t-1} A + B' H_{t-1} B,$$

Variable	coefficient	Standard Error	z-statistic	p-value
φ	0.2618	0.0163	16.0371	0.0000**
ω	0.4200	0.0217	19.3252	0.0000**
C (p,p)	0.0023	0.0042	2.4567	0.0012**
C (f,p)	0.0174	0.0015	0.1331	0.5125
C (f,f)	0.0067	0.0010	6.9863	0.0000**
A (p,p)	0.8802	0.0080	114.9192	0.0000**
A (p,f)	0.0944	0.0065	14.5558	0.0000**
A (f,p)	-0.0096	0.0015	6.4993	0.0000**
A(f,f)	0.9099	0.0071	127.4700	0.0000**
B (p,p)	0.0694	0.0061	11.3285	0.0000**
B (p,f)	-0.0074	0.0011	6.8014	0.0000**
B (f,p)	0.8946	0.0075	118.8828	0.0000**
B (f,f)	0.0710	0.0059	12.0917	0.0000**

Note: Double asterisks (**) represent significance at the 5% level

To ensure the robustness of the above findings, Wald tests are carried out to test two null hypotheses: (1) 'there is no spillover effects from SO futures prices to CPO cash and futures prices', which is formulated as ‘H0: φ = ω = 0’; and (2) 'there is a similar impact on both CPO cash and futures prices caused by SO futures prices', which is formulated as ‘H0: φ = ω'.

Results obtained from Wald tests are presented in Table 8 below. As shown in Table 8, the value of p-value (0.0000) for the first t-statistics (1857.2720) suggests that the hypothesis of 'there is no spillover effects from SO futures prices to CPO cash and futures prices' should be rejected at the 1% level. In addition, p-value (0.6415) for the second t-statistics (30.0231) shown in Table 8 suggests that the null hypothesis of 'there is a similar impact on both CPO cash and futures prices caused by SO futures prices' should not be rejected at the 1% level.

Table 8: Results Obtained from Wald Test

In this table, results obtained from Wald test are shown. Two hypotheses are tested: (1) there is no spillover effects from soybean futures prices to CPO prices, or H0: $\varphi = \omega = 0$; (2) soybean futures prices affect both CPO cash and futures prices equally, or H_0: $\varphi = \omega$

	t-statistics	**p-values**
$\phi = \omega = 0$	1857.2720	0.0000***
$\phi = \omega$	30.0231	0.6415

Note: The triple asterisk (***) represents significance at the 1% level.

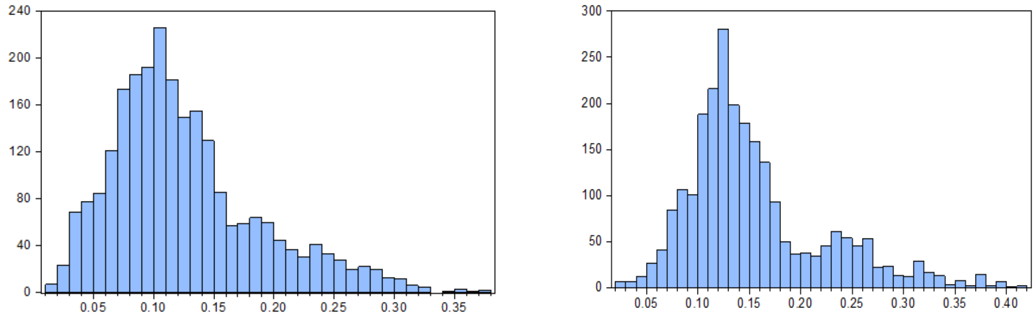
4.6 Results of SO and CPO Spot and Futures Volatility Spillover Ratios

To measure the strength of volatility transmission from SO futures prices to CPO spot and futures prices, spillover ratios are computed. Summary statistics of these spillover ratios are given in Table 9. These volatility spillover ratios are also used to measure the share of SO futures markets shocks on the overall volatility in CPO spot and futures markets at different points in time during the sample period (2nd January 2004 - 31st December 2013) as given in Figure 3.

Table 9: Summary Statistics of SO and CPO Spot and Futures Volatility Spillover Ratios

In this table, summary statistics of SO and CPO spot and futures spillover ratios are presented. The total number of observation is 2426

	SO and CPO Spot Volatility Spillover Ratio	**SO and CPO Futures Volatility Spillover Ratio**
Minimum	0.0138	0.0255
Maximum	0.3774	0.4152
1st Quartile	0.0826	0.1119
3rd quartile	0.1547	0.1775
Mean	0.1260	0.1548
Median	0.1126	0.1372
Standard Deviation	0.0624	0.6693
Skewness	0.9804	1.1681
Excess kurtosis	3.7805	4.2271



Volatility Spillover Ratios between SO and CPO Spot Markets

Volatility Spillover Ratios between SO and CPO Futures Markets

Figure 3: Histograms of SO and CPO Spot and Futures Spillover Ratios for the Period of 2nd January 2004 - 31st December 2013

As shown in Table 9, average volatility spillover ratios from SO market to CPO spot and futures markets are 12.60% and 15.48%, respectively. In addition, values of the maximum CPO spot and futures ratios suggest that SO volatility spillover effect makes up to 37.74% and 41.52% of the conditional variance of the CPO spot and futures prices, respectively (Table 9). The fluctuation in prices of the two substitute commodities like SO and CPO can be driven by factors such as nutritional awareness which causes a shift in demand of these two products, or weather condition which affects directly on the production of the two products, and therefore, the availability of theirs supply.

In Figure 4, the volatilities of conditional standard errors of SO and CPO spot and futures spillover ratios are ploted. It is observed from Figure 4 that the volatilities of CPO spot and futures spillover ratios are below 20% for the period before the 2008 financial crisis; however, they go up to around 45% during the crisis period. Thus, there seems to be a close link between peaks in volatility of SO prices and CPO spot and futures spillover ratios during the post 2008 financial crisis period as shown in Figure 4. This may also imply that CPO spot and futures price volatilities are strongly affected by SO futures price volatility. In addition, it is also observed that, CPO futures volatility spillover ratios are higher than SO and CPO spot volatility spillover ratios during most of the sample period.

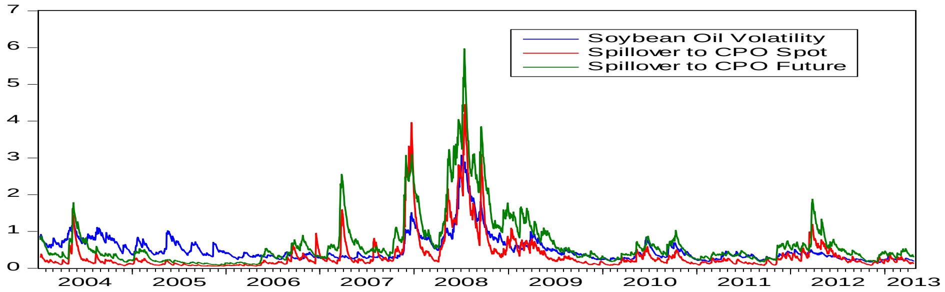


Figure 4: Conditional Standard Errors of SO and CPO Spot and Futures Spillover Ratios

To investigate further the interaction between CPO spot and futures prices, conditional correlations were then computed from BEKK- GARCH model, and plotted in Figure 5. Figure 5 shows a persistently strong correlation between CPO spot and futures markets before mid-year 2006 and after 2007, which is consistent with what is found for SO and CPO markets. This may explain why the three markets, i.e. SO and CPO spot and futures, are closely related in recent years.

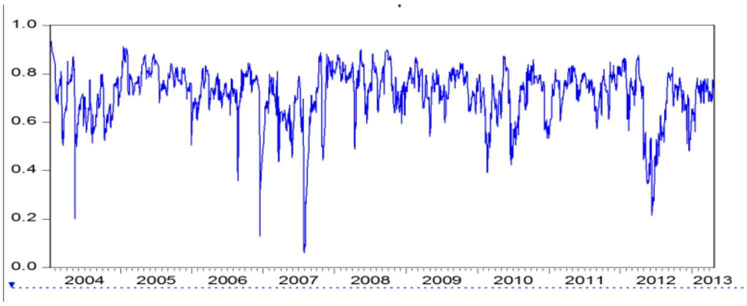


Figure 5: BEKK- GARCH Conditional Correlations between CPO Spot and Futures Prices

5. Conclusions

This study examines volatility spillovers from SO futures market to both CPO spot and futures markets by adopting the trivariate volatility spillover model for the period of 2nd January 2004 - 31st December 2013. Time series of data are collected for Malaysia CPO spot and futures prices, and Chicago Board of Trade (CBOT) listed SO futures prices. It is confirmed by ADF and PP tests that time series for returns of SO futures, CPO spot and futures prices are stationary. Results obtained from Johansen's cointegration tests suggest the presence of a long-run equilibrium relationship between SO futures and CPO futures markets, but not between SO futures and CPO spot, and between CPO futures and CPO spot prices. Results obtained from VECM suggests that there is a convergence between CPO futures and CPO spot prices. In terms of the direction of information flow and the lead- lag relationship between spot and futures prices, the significant p-values found for both F-statistics obtained from Granger causality test at the 1% level suggest that a bi-directional Granger causality exists between CPO futures and CPO spot prices.

Using GJR-GARCH to estimate the conditional volatility of SO futures prices, results obtained suggest that negative unexpected shocks generate stronger impacts on price volatility of SO futures as compared to those generated by positive shocks. This may imply that markets seem to respond strongly to bad new rather than to good news.

Results obtained from bi-variate BEKK GARCH model suggest the persistence in volatility for SO futures prices, and that there is a significant volatility spillover from SO futures prices to CPO spot and futures prices. In addition, volatility of CPO spot market in the current period is found to be affected by volatility of CPO futures market in the previous period, and vice versa. Results obtained from Wald tests confirm that there are spillover effects from SO futures prices to CPO cash and futures prices, and that the effects are similar in magnitude. In terms of the strength of volatility, results show that the volatilities of CPO spot and futures spillover ratios are below 20% for the period before the 2008 financial crisis; however, they go up to around 45% during the crisis period, implying a close link between peaks in volatility of SO prices and CPO spot and futures spillover ratios during the post 2008 financial crisis period and that CPO spot and futures price volatilities are strongly affected by SO futures price volatility. In addition, it is also observed that, CPO futures volatility spillover ratios are higher than SO and CPO spot volatility spillover ratios during most of the sample period. Using BEKK- GARCH model, conditional correlations are computed, and results show a persistently strong correlation between CPO spot and futures markets before mid-year 2006 and after 2007, confirming why the three markets, i.e. SO and CPO spot and futures, are closely related in recent years.

The above findings suggest that SO futures and CPO futures could be highly effective cross hedging tools for traders and producers when hedging CPO spot prices. Moreover, understanding the behaviour of volatility in SO futures and CPO markets is not only important for hedging decisions and derivative valuation, but is also important to policy makers to ensure the stability of financial market and high income generated from the export of CPO.

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