Long-term relationship of crude palm oil commodity pricing under structural break

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Abstract

Purpose – The purpose of this paper is to examine the pricing efficiency of the Malaysian crude palm oil (CPO) market before and after the structural break. This study uses the daily closing price of CPO and CPO futures (CPO-F) for the period ranging from June 2009 to August 2016 while taking structural breaks into account.

Design/methodology/approach – In this study, symmetric and asymmetric long-run relationship model are employed, such as the Johansen cointegration, VECM, TAR and M-TAR models, to examine the impact of structural breaks on the pricing efficiency of the Malaysian CPO market.

Findings – This finding establish that Malaysian CPO price is efficient before and after the structural break. The consistent efficiency of the Malaysian CPO market supports the trading of the CPO-F in Globex and the use of Malaysian CPO pricing as the reference price. This study establishes that a structural break in the Malaysian CPO price series does not affect the pricing efficiency of the market.

Research limitations/implications – This study shows that using Malaysian CPO price as a reference price is sustainable even in the event of a structural break. Therefore, market participants in the Malaysian CPO market have less to worry about the CPO price as it supports the weak form of efficiency. Price deviation in the short run may not lead to arbitrage profit as transaction cost may not be covered.

Practical implications – This study implies that if there is distortion in the price due to shocks, both manufacturers and producers need to hedge their positions in the futures market (subject to their positions in the underlying market). By entering into the futures market, pricing is locked in advance; hence, price risk is eliminated. Such a distortion could also affect the efficiency of the CPO price, therefore this study also addresses the issue of efficiency of the local CPO market.

Originality/value – Previous studies on Malaysian CPO pricing efficiency did not take the effect of structural break into consideration, making it difficult for these studies to show consistency in the efficiency of the Malaysian CPO market.

Keywords Malaysian CPO and CPO-F, Symmetric and asymmetric models,
Pricing efficiency and structural break, VECM and TAR model

Paper type Research paper

1. Introduction

Even though the issue of long-run relationship between markets has been extensively examined, understanding the relationship between markets continues relevant because knowledge about commodity price is important in order to take a position in the commodity market. It is one of the reasons that empirical studies on the long-run relationship between markets continue to emerge until now (see e.g. Peri and Baldi, 2010; Sehgal *et al.*, 2015; Ghosh and Kanjilal, 2016; Nambiappan *et al.*, 2018). Since understanding the long-run relationship is the main concern regarding pricing efficiency, information about the speed of adjustment of short-run deviation is crucial. Once the long-run relationship between the two markets is established, market deviation in the short run becomes temporary.

Pricing efficiency reflects the healthiness of a market and the source of attraction for potential market participants. In Malaysian crude palm oil (CPO) market, plantations and industries that use CPO as a major input of their production commit a huge amount of their investment to take a position in the CPO market and simultaneously offset their position in the CPO futures (CPO-F) market. CPO-F plays a substantial role in quantifying CPO price and mitigates risk due to the unfavourable fluctuation in the underlying market price. The expectation of the underlying price in the future is determined by the underlying–futures differences. The difference in both prices could either be positive or negative. If the difference is negative, it implies that the underlying price will increase in the future time and this is known as contango. Nevertheless, if the difference is positive, the underlying price will reduce as backwardation (Figuerola-Ferretti and Gonzalo, 2010; Kolodziej et al., 2014). Therefore, a consistent efficiency of CPO pricing is important to attract huge numbers of foreign market participants. As in the case of Malaysia, the CPO market has been consistently active and contributing to the economic growth since the past three decades. Furthermore, Malaysia is among the first two global largest exporters of the CPO signifying the need to keep the price attractive and stable. This study aims to examine the long-run relationship between the underlying and futures prices of CPO.

Cointegrated prices are efficient prices that reflect newly announced information on the same day as the event; otherwise, the market is inefficient. This implies that the pricing of a commodity could either be efficient or inefficient. Pricing efficiency is examined using symmetric or asymmetric models (see e.g. Balke and Fomby, 1997; Peri and Baldi, 2010; Çağli and Mandaci, 2013; Wang and Wu, 2013; Beckmann et al., 2014; Gil-Alana and Yaya, 2014; Ghosh and Kanjilal, 2016). In this study, we employ symmetric and asymmetric models to quantify the efficiency of CPO price.

In most recent studies on long-run pricing efficiency, a linear relationship is assumed. With this assumption, the findings on the long-run relationship studies offer three possible results: the existence of a long-run relationship or short-run relationship or no relationship between markets. However, studies on asymmetric long-run relationship show that the long-run relationship may be asymmetric. The findings of this study established a symmetric long-run relationship between CPO and CPO-F prices. The finding of this study, hence, supports the efficient market hypothesis (EMH) theory which explains that the CPO price reflects all the available information in the market. Similarly, the trading of CPO-F in the Globex platform is justified by having an efficient price.

This study differs from other past studies that examine CPO price in Malaysia (see e.g. Murphy, 2014; Haron and Salami, 2015; Nambiappan et al., 2018) because they did not consider structural break in their studies. In other words, these studies ignore the abrupt change in time series at a point in time. As this study account for the effect of structural break, we are then able to examine whether distortion in price pattern due to shocks in price has any impact on the long-run cointegration between CPO and CPO-F prices. Distortion in price could either be upward or downward. If the price is distorted upward, there will be impact on manufacturers (buyers) as it could lead to the increase in the cost of production. If the price is distorted downward, CPO producers/the plantation companies (sellers) will be affected due to the reduction in revenue because of lower CPO price. This indicates that distortion in the price due to shocks could either affect manufacturers (buyers) or CPO producers (sellers). Therefore, both manufacturers and producers need to hedge their positions in the futures market. Hence, by incorporating structural break, this study provides insight on the price distortion of CPO price in Malaysia and the appropriate risk management strategies to be taken due to price uncertainty. Moreover, this study also addresses the efficiency of the Malaysian CPO markets. By looking at price distortion and its implication on risk management, and also examining pricing efficiency, this study, hence, stands out from other studies and fills the gap in the literature.

The rest of this paper is organised as follows: Section 2 discusses previous studies on asymmetric and symmetric long-run relationship, Section 3 explains the methodology employed, Section 4 is about data and result and Section 5 is the conclusion.

2. Theoretical framework and literature review

EMH focuses on the instantaneous reflection of all the available information on the price. Ever since EMH is introduced, researchers have tested the theory on several classes of assets as well as commodities (Arouri *et al.*, 2013). According to Tuyon and Ahmad (2016), EMH remains puzzled and therefore remains a debated issue in finance as many studies are testing the validity of the theory. The complexity of the behaviour of the commodity price is important in order to explain the deviation of the price from EMH (Alvarez-Ramirez *et al.*, 2015). In a similar manner, event that causes long memory in the price could lead to inefficiency in the market price (Wang and Wu, 2012). Ali *et al.* (2010) use EMH to explain the overreaction of investors towards newly available information in the Malaysian stock market. The validity of EMH is examined in their study.

Empirical studies on symmetric and asymmetric approach provide an understanding on pricing efficiency through the establishment of long-term relationship between CPO and CPO-F prices. Different underpinning assumptions on factors that guide the speed of adjustment towards long-term relationship have been established. The continuous adjustment assumption guides the symmetric long-term relationship, while discrete adjustment guides the asymmetric long-term relationship. With the introduction of asymmetric long-term relationship researchers have the opportunity to explain price changes in other different directions from the symmetric approach. The securities pricing theory assumes continuous trading opportunities, while empirical evidence concludes on discrete intervals (Camilleri and Green, 2014).

Radha and Balakrishnan (2017) studied the efficiency of Indian commodities prices and employed Johansen cointegration as well as the VECM approach. The finding of the study established cointegration between CPO and CPO-F for the four month contracts. The study concluded that hedgers benefit by offsetting their position in the futures market and described futures market as significant tools in reducing price risk.

Chetan and Nagaraj (2018) examine price discovery among the four underlying–futures markets, i.e. Chilly, Cumin, Coriander and Turmeric, using the VECM technique. Long-run relationship is established between the underlying and its futures price, and the study further concluded that price discovery originates from futures price. The study supports the pricing efficiency in the commodity market. Their finding is consistent with previous the finding by Pandey and Vipul (2017) on market efficiency and information content on the Indian commodity futures markets. Pandey and Vipul (2017) established long-run relationship between underlying and the futures prices of eight commodities and concluded that price efficiency originates from futures price, while information content in each commodity is different.

Dolatabadi *et al.* (2018) examine the long-run relationship between 17 commodities for the period from 1983 to 2012. The study establishes a long-run relationship among the commodities but do not examine the existence of structural break within the period of the study. This may provide inaccurate evidences as the presence of structural break in the price series could obstruct the findings and may result in misleading conclusion.

Fowowe (2016) investigated the effect of oil price on the agricultural commodity prices in South Africa and accounted for the existence of structural break. The study failed to establish long-run relationship between oil price and agricultural commodity prices in South Africa. The author concluded that shock in the price of global oil price has no effect on the agricultural commodity prices in South Africa.

Beckmann *et al.* (2014) studied a long-run relationship within the US commodities index. The study focused on commodity products with special attention on crude oil, heating oil,

natural gas and unleaded gasoline. They examined the daily closing series from January 2, 1991 to October 29, 2011 using the Johansen cointegration model. The result showed that the underlying and futures commodities indexes are cointegrated.

Peri and Baldi (2010) studied a linear long-run cointegration relationship between three agricultural commodities and one non-agricultural commodity within the European Union. Agricultural commodities comprise of RapOil (rapeseed oil), SoyOil (soybean oil), SunOil (sunflower seed oil), and the non-agricultural commodity comprises GasOil (fossil diesel). Weekly prices were estimated using the VECM for the study period from January 2005 to November 2007. The findings indicated that RapOil and GasOil are linearly cointegrated in the long run, while SunOil–GasOil and SoyOil–GasOil are not cointegrated in the long run.

However, prior to the seminal paper of Balke and Fomby (1997), the asymmetric long-run relationship was discussed but not extensively studied. Balke and Fomby's (1997) paper is highly significant in opening up awareness that the long-run relationship is not necessarily linear, and the awareness of non-linearity in the long-run relationship opened up a new area of research. In their paper, Balke and Fomby (1997) proposed that some pricing mechanisms exhibit the asymmetric long-run relationship which attracts discrete policy intervention. Discrete adjustment is required only in the situation in which the price increases above the ceiling price (Peri and Baldi, 2010; Subervie, 2011). Similarly, Gil-Alana and Yaya (2014) supported the view that the asymmetric model is non-restrictive, but the symmetric model is very restrictive.

Wang and Wu (2013) examined the asymmetric cointegration relationship between the underlying and futures prices of crude oil in the US market from January 1986 to February 2011. The study shows the unidirectional relationship of futures price driving underlying price towards the equilibrium level. The study applies the threshold VECM (TVECM) method and finds a cointegration relationship between the underlying and futures crude oil price only when the price differential is greater than the threshold value. Wang and Wu (2013) explained further that the non-linearity of the underlying and futures prices of crude oil might be due to structural break, basis (backwardation and contagion), risk premium and transaction cost. Rittler (2012) found that the futures price lead the underlying market to equilibrium, meaning that price discovery originates from the futures market. Similarly, Honarvar (2009) found the asymmetric long-run cointegration relationship between gasoline and crude oil in the US market. Although the study of Wang and Wu (2013) focuses only on the underlying and futures prices of crude oil, Honarvar (2009) focuses on two related underlying markets – gasoline and crude oil – in the same market and their results are similar.

Liu, Chen and Wan (2013) found an asymmetric long-run relationship between the China market and international oil prices such as those of the USA, the UK, Dubai and Saudi Arabia. The study uses weekly prices and applies threshold TVECM for the period between January 2001 and December 2011. They divided series into two parts, following the structural break test, and found asymmetric long-run relationship only in the first break but not in the second. They concluded that the integration of the China market and the international oil prices is not supported. Similarly, Peri and Baldi (2010) used weekly price series and applied TVECM to establish an asymmetric long-run relationship between RapOil and GasOil for the period from January 2005 to December 2007.

Liu, Hammoudeh and Thompson (2013) examined an asymmetric long-run cointegration relationship between BRICS stocks index (Brazil, Russia, India, China and South Africa) and country risk ratings. Economic, financial and political are the three country risk ratings considered in this study and modelled using M-TAR for the study period from September 1995 to April 2011. The result shows the presence of asymmetric long-run cointegration between the BRICS stock index and country risk rating. They found that asymmetric adjustment towards the long-run equilibrium is faster. The speed of adjustment towards deviation in the long-run equilibrium is negative for Russia, while the remaining markets have a positive adjustment to the long-run equilibrium. Liu, Chen and Wan (2013)

and Liu, Hammoudeh and Thompson (2013) concluded that such asymmetric adjustment enables investors to trap different profit opportunities. This finding supports the finding of Liu, Chen and Wan (2013) and Liu, Hammoudeh and Thompson (2013) in establishing an asymmetric long-run relationship between China and international oil markets, which comprise of China, the USA, the UK, Dubai and Saudi Arabia by using the threshold model.

Valadkhani (2013) applied TAR, M-TAR and OLS models. The optimality of the long-run relationship is determined by the Schwarz Bayesian Criterion and a general-to-specific approach is used in determining the asymmetric speed of adjustment. The result shows asymmetric adjustment in the rises and falls of Australian petrol prices; that is the price rises faster than it falls. The finding is consistent with the recent findings of Bumpass *et al.* (2015) that the retail price of gasoline rises faster than it falls in the US study.

Peri and Baldi (2010) carried out a test for an asymmetric long-run relationship between GasOil and RapOil of the European Union by using the Threshold model. The weekly prices of RapOil (rapeseed oil) and GasOil (fossil diesel) were used for the study from January 2005 to November 2007. The findings show asymmetric cointegration between the variables with the GasOil price predominantly leading the RapOil to the equilibrium level. The study shows the slower speed of adjustment for the RapOil relative to the GasOil. In the study by Peri and Baldi (2010), it is observed that long-run relationship among the prices is not necessarily linear but rather asymmetric in some markets.

With mixed results on long-run equilibrium relationship (linear and non-linear), this study proposes examining linear long-run relationship before proceeding with examining the asymmetric long-run relationship of the Malaysian CPO and derivatives market.

3. Research methodology
With a view to examine the pricing efficiency of CPO, both symmetric and asymmetric long-run relationships are examined in this study. In doing so, Johansen cointegration, VECM and TAR models are employed. Johansen cointegration and VECM techniques are employed for the symmetric model, while TAR model is used to examine the asymmetric long-run relationship of Malaysian CPO pricing. The use of TAR and VECM models to quantify the asymmetric and symmetric long-run relationship has been established in past studies (see e.g. Haughton and Iglesias, 2012; Valadkhani, 2013; Zhu *et al.*, 2011).

In this asymmetric cointegration, the threshold adjustment technique (TAR model) is used to identify the presence of asymmetric cointegration in the variables of the study.

3.1 VECM specification
Long-run relationship between the underlying and futures prices (CPO and CPO-F) using VECM is expressed as follows (Bohl *et al.*, 2011):

$$\Delta LnCPO_t = \alpha_{(LnCPO,0)} + \eta_{LnCPO}ECT_{t-1} + \sum_{i=1}^{P} \alpha_{LnCPO\ LnCPO,i}\Delta LnCPO_{t-i}$$

$$+ \sum_{j=1}^{q} \alpha_{LnCPO\ LnCPO-F,j}\Delta LnCPO - F_{t-j} + \mu_t, \tag{1}$$

$$\Delta LnCPO - F_t = \alpha_{LnCPO-F,0} + \eta_{LnCPO-F}ECT_{t-1} + \sum_{i=1}^{p} \alpha_{LnCPO-F\ LnCPO,i}\Delta LnCPO_{t-i}$$

$$+ \sum_{j=1}^{q} \alpha_{LnCPO-F\ LnCPO-F,j}\Delta LnCPO - F_t + \mu_t. \tag{2}$$

Then, this study proceeds with the TAR model to examine the asymmetric long-run relationship between CPO and CPO-F.

3.2 TAR model

$$\Delta\mu_t = I_t\rho_1\hat{\mu}_{t-i} + (1-I_t)\rho_2\hat{\mu}_{t-i} + \sum_{i=1}^{p} \lambda_i\Delta\hat{\mu}_{t-i} + \varepsilon_t, \tag{3}$$

where Δ represents the first difference, I_t represents the Heaviside indicator, I_t measures the difference between TAR and M-TAR specification (Koto, 2015), ρ represents a not serially correlated error term (ε_t) and λ_t is the variable indicator of threshold.

The coefficient of ρ_1 and ρ_2 is expected to be negative (Chang *et al.*, 2012) as it measures adjustment towards long-run equilibrium. Absolute value of ρs indicates the speed of adjustment. $\rho_1 > \rho_2$ in absolute value implies the faster speed of adjustment (Chang *et al.*, 2012). In this study, Equation (3) is the residual for the long-run equation, which further classifies into negative and positive residuals using TAR factor as in the following equation:

$$\text{TAR} = I_t = \begin{cases} 1 & \text{if } \mu_{t-i} \geqslant 0 \\ 0 & \text{if } \mu_{t-i} < 0 \end{cases}. \tag{4}$$

Noticeable in the use of I_t is that the TAR model uses the level value of the threshold indicator variable. From Equation (3), the changes in μ_t are expected subject to the positive or the negative shock.

4. Data and empirical results

Daily closing prices of CPO, CPO-F and basis are used in this study. CPO and CPO-F prices are obtained from the Bloomberg, while basis is the estimated value of CPO and CPO-F differential. The period of study ranges from 1 June 2009 to 16 August 2016. Price is converted into logarithm value and descriptive statistics is presented in Table I.

In Table I, it is shown that the mean of all the variables is positive and greater than 7. This statistical report of mean and standard deviation provides crucial information on the distribution pattern of series. The report shows that the series does not fulfil the normality distribution assumption. Consequently, an alternative error distribution assumption such as Student T or generalised error distribution is required in explaining the distribution pattern of series. From the result shown in Table I, it is observed that each mean is greater than its minimum value but lower than its maximum values. Skewness (S) and kurtosis (K) provide other important information on the statistics report of the series. According to Pen and Sévi (2010), kurtosis provides information on the peak of distribution around the mean of the series.

| Model | Log price of CPO | |
	Underlying	Futures
Mean	7.8631	7.8659
Minimum	7.4989	7.5321
Maximum	8.2756	8.2827
SD	0.1608	0.1498
Skewness	0.4348	0.5276
Kurtosis	2.2748	2.5114
Jarque–Bera	102.4685*	108.0763*
Observation	1,918	1,918

Notes: The table presents log price of CPO, CPO-F. *Significant at the 5 per cent level

Table I.
Descriptive statistics
of daily closing series

Kurtosis could be a platykurtic distribution (when $K < 3$) or leptokurtic distribution (when $K > 3$). Referring to the analysis of this study, the log price of CPO and CPO-F is platykurtic. Skewness (S), on the other hand, provides information on the series which is symmetrically distributed. If the series is not symmetrically distributed, the distribution of series could be positively or negatively skewed. Skewness results for CPO and CPO-F price series are positive and less than 1 ($S < 1$) (Bollerslev *et al.*, 2015; Gil-Alana and Tripathy, 2014; Lin and Wesseh, 2013). Jarque–Bera (J–B) statistics of the series is statistically significant, thus reject the null hypothesis of the normal distribution of the error term. The J–B implies that the daily close series distribution is significantly larger than that in a normal distribution (Choudhry and Hassan, 2015).

The result from Table I concludes that the logarithm series rejects the normal distribution assumptions. The findings provide a useful guide on the series, which in turn is useful for model selection. For example, since the series provides information on non-normality, any modelling techniques that assumed normality cannot be used. As indicated in the previous empirical study, a skewness which is above zero indicates an asymmetric distribution, fat-tailed distribution of the kurtosis' price; thus, the null hypothesis of a normal distribution is refuted by J–B (Pen and Sévi, 2010).

Similarly, stationarity test of the logarithm price series is examined. Unit root tests fail to reject the null of stationarity of the logarithm price series at level. This implies that the logarithm price series is not stationary in its original form. However, the logarithm price series – CPO and CPO-F – becomes stationary at the first difference; therefore, the logarithm price series is integrated at the order of 1, $I\sim(1)$ (due to space constrain, the report is not provided here but is available upon request).

Besides the unit root test, this study also examines the correlation between CPO and CPO-F. A positive correlation is found between the CPO and CPO-F prices. A positive correlation indicates that an increase in one variable simultaneously leads to an increase in another. The correlation coefficient between the CPO and CPO-F is 0.9716. The high correlation between the underlying and futures prices is expected since the futures price is derived from the underlying price. The high correlation coefficient between the underlying and futures price supports the notion that the futures market is a good hedging instrument (Chang, 2012). In a similar manner, Narayan *et al.* (2013) supported the argument that the futures price is a good predictor of the underlying price. However, the information content of the underlying and futures market is not the same; the underlying price is usually distorted by short-term random disturbances, while futures price reveals the influence of fundamentals information of underlying price as well as the market expectation (Fan and Xu, 2011). Similarly, correlation coefficient among markets provides essential information for policymakers on the implementation of right policy (Shabri and Kassim, 2009). Prior to examining the cointegration test, data are tested for structural break using Zivot-Andrew and Perron unit root tests. A structural break is detected and series is divided according to the structural break date. Cuestas and Gil-Alana (2009) used the model that incorporates structural break.

Based on the preliminary results discussed earlier, this section proceeds with the examination of the long-term equilibrium among the series of this study using the Johansen cointegration approach. This is followed by VECM which assumes the continuous speed of adjustment and TAR and M-TAR models which assume discrete speed of adjustment. It is observed that the approach adopted in this study shares some similarities with the approach adopted in Paleologou (2013). The difference in this study and the study by Paleologou (2013) is that the TAR and M-TAR models were examined first, and the inability of establishing an asymmetric relationship may lead to a conclusion that the relationship is symmetrical. By examining the VECM prior to TAR model, this study assumes that symmetric assumption of long-run relationship cannot explain all long-run relationship situations, but a step further may provide a different result.

As this study examines the Malaysian CPO market, the report of the Johansen cointegration test is first presented and the decision on the existence of cointegration is based on the report of trace and max-Eigen statistics. Johansen and Juselius (1990) cointegration procedure is commonly used in the studies investigating linear cointegation between series (see e.g. Furió and Chuliá, 2012; Wang and Wu, 2013). The maximum number of long-run equilibrium (r) in Johansen cointegration test is one less the number of the variables (k) used in the model. This indicates that the cointegration relationship is established within the range of $0 < r < k$ (Natanelov *et al.*, 2011). Establishing one long-run equilibrium relationship among the series of study is more appropriate (Nicolau and Palomba, 2015). Previous studies have established that concluding long-run relationship among the variables of the studies supports the EMH. The result of Johansen cointegration is presented in Table II.

The long-term relationship established in Table II takes into account the price before and after the structural break. This implies that price deviation of the CPO from CPO-F in the short run attains equilibrium in the long run. This also indicates that the co-movement of the two variables shares common features. This provides important information for the market participants that the Malaysian CPO market is efficient in the long run and any form of deviation in the price is temporary. The result is consistent with the law of one price where the price of the same asset should be the same, irrespective of the market at which it is traded, provided the deviation in the short run is less or equivalent to the transaction cost. According to Wang and Wu (2013), most studies on the cointegration of the underlying and futures prices are based on the expectation that futures price may provide efficient price discovery mechanism. In addition, Furió and Chuliá (2012) explained that drifting apart the variables in the short run may not prevent from showing long-run equilibrium if those variables are cointegrated.

The consistent long-run relationship of the CPO and CPO-F prices before and after the structural break shows that structural break in the series does not distort the efficiency of the CPO and CPO-F prices. It is observed that cointegration factor of the long-run relationship between CPO and CPO-F prices reduces after the structural break from 0.0268 (before the structural break) to 0.0202 (after the structural break).

The cointegration relationship with Johansen technique is then established which fulfils the basic condition required for conducting VECM. The Johansen cointegration test is the basic condition for testing the systematic adjustment to the long run in the pricing discovery mechanism (Andani *et al.*, 2009; Beckmann *et al.*, 2014; Efimova and Serletis, 2014; Hou and Li, 2015). This study follows the suggestions by Engle and Granger (1987) and Masih and Masih (1996) in investigating cointegrated series using VECM. Hence, this study proceeds with the examination of the linear speed of adjustment using VECM. The VECM allows the use of logarithm of the series for the $I\sim(1)$ series. The short-run deviation is captured by the

Model	Variables	Hypothesised no. of CE	Coeff.	Trace value	0.05 Critical value	Max-Eigen value	0.05 Critical value
	Before SB						
	$LCPO_t$	$r = 0$	0.0268	23.1355	15.4947	21.3949	14.2646
	$LCPO\_F_t$	$r = 1$	0.0022	1.7406	3.8415	1.7406	3.8415
	After SB						
	$LCPO_t$	$r = 0$	0.0202	32.3661	25.8721	22.7336	19.3870
	$LCPO\_F_t$	$r = 1$	0.0086	9.6325	12.5179	9.6325	12.5179

Notes: The table presents the Johansen cointegration findings on the long-term relationship between the underlying and futures prices. *r*, denotes the number of cointegrating vector. If test statistical is greater than critical value, the null hypothesis is rejected. Trace (λ_{trace}) and max-Eigen (λ_{max}) statistics conclude one cointegration at 5 per cent significance level

Table II.
Johansen cointegration findings of Malaysian CPO prices based on structural breaks (SB)

error correction term (ECT) of the VECM. The model parameters as well as the ECT coefficients are presented in Table III.

The speed of adjustment as a result of short-run deviation from the long-run is provided in Table III. The ECT result shows that short-run deviations are statistically and significantly adjusting towards the long-run except for the CPO with a coefficient of −0.0199 before the structural break. According to the result in Table III, the CPO-F leads the underlying CPO to the equilibrium as indicated by the speed of adjustment before and after the structural break of −0.0532 and −0.0232, respectively. This indicates that the Malaysian CPO-F price is consistently efficient over the period of the study. This shows that structural break does not affect the speed of adjustment of the Malaysian CPO markets.

This study proceeds further with analysing the asymmetric cointegration between the price series. The effect of the structural break on the CPO pricing is examined and the result is presented in Table IV. Asymmetric cointegration between the underlying and futures prices of the Malaysian commodity market is estimated. The details are provided in Table IV.

Table IV shows the asymmetrical long-run relationship between the underlying and futures prices of CPO for the structural break models. Therefore, this study fails to reject the null hypothesis of F-statistics; hence, symmetric relationship is also concluded in the VECM model. However, the null hypothesis of T-max statistical value of no long-run relationship between the variables is rejected. The result of the TAR model provides robustness for this study in examining the pricing efficiency of the Malaysian CPO market. This study supports the weak-form efficiency of EMH. In other words, shock due to structural break did not result in an asymmetric speed of adjustment towards long-run equilibrium of CPO pricing. The finding from Table IV suggests that short-run deviation in the CPO market

| Model | Variables | ECT result on structural break | |
		Before structural break	After Structural break
	$LCPO_t$	−0.0199	−0.0172
		(0.0285)	(0.0069)
		[−0.7003]	[−2.4989]
	$LCPO\_F_t$	−0.0532	−0.0232
		(0.0189)	(0.0104)
		[2.8121]	[−2.2282]

Notes: Lags length is suggested by the AIC information criteria and the values in the parenthesis are the standard errors. The model examines adjustment towards long-run equilibrium for the underlying and futures prices of Malaysian commodity price. Column 2 comprises the variables of study which are CPO, CPO-F, Columns 3 and 4 present the result of the speed of adjustment before and after the structural break

Table III.
ECT for a structural break on Malaysian CPO price

	Before structural break $LCPO_t = LCPO\_F_t + \varepsilon_t$	After structural break $LCPO_t = LCPO\_F_t + \varepsilon_t$
ρ_1	−0.0708 (0.0259)	−0.0269 (0.0125)
ρ_2	−0.0398 (0.0253)	−0.0188 (0.0099)
F-stat.	0.8044 [2.1250]	0.2606 [2.6489]
T-max	−1.5762 [−2.1436]	−1.8906 [−2.0737]

Notes: Asymmetric contegration is estimated according to AIC for TAR and M-TAR Models. The threshold for TAR is set to be zero, that is, system default threshold is maintained. The values in parenthesis represent the standard error, while values in square brackets represent the critical value that rejects the null hypothesis of symmetric cointegration and no long-run cointegration. ρ_1 denotes threshold above, ρ_2 denotes a threshold below. $\rho_1 = \rho_2$ denotes F-statistics, Φ denotes T-max value

Table IV.
Asymmetric cointegration findings

price is adjusting symmetrically towards long-run equilibrium. It also implies that co-movement exist between CPO and CPO-F market and any forms of deviation that exist will only be temporary and may be wiped off shortly. This implies that $\rho_1 = \rho_2 = 0$ and the speed of adjustment due to the short-run deviation is symmetrical.

Having explained the analysis of this study, we concluded that shock in the price does not distort CPO price pattern in the long run and also the market efficiency is maintained before and after the structural break.

5. Conclusion

Pricing of the agricultural commodity is crucial to the industries that use the commodity as a major input of production. Consistent fluctuation in the market price will have a significant effect on firms' revenue, as the cost of production will adjust upward consequently reducing the net profit. However, taking a position in the CPO market necessitates simultaneously offsetting the position in the CPO-F. Price fluctuation in the CPO market may be normalised in the CPO-F market through simultaneously offsetting the position especially in the case of CPO which is one of the 17 globally recognised vegetables oils.

The long-run relationship between the underlying and futures prices is symmetrically established before and after the structural break. The finding of this study consistently shows that price deviation adjustment in the short-run is continuous as indicated by symmetric and asymmetric models. Consistency in the findings of VECM and TAR supports robustness in the finding. Similarly, the result shows that shock in structural break does not distort symmetrical short-run deviation adjustment towards long-run equilibrium. This finding supports the weak form of EMH. The efficiency of the market plays an essential role in investors' decision making, and this finding might supports the trading of Malaysian CPO-F on the Globex platform. Such trading extension is expected to enhance the efficiency and ease foreign participation in the market. This is consistently supported as Malaysian CPO price remains efficient even at the event of structural breaks. Similarly, the finding supports Malaysian CPO price as a reference price for other countries trading CPO and the validity of EMH on the CPO pricing.

As most of the earlier studies on Malaysian CPO price did not incorporate the effect of structural break, this implies that the effect of abrupt change in time series at a point in time (structural break) on their findings is ignored. Ignoring such a meaningful shock could lead to questionable findings as structural break has implication on the findings. In a similar manner, ignoring price pattern after structural break may hinder meaningful implication on such price changes to the policymakers as well as participants in the Malaysian CPO market.

This study, hence, has implication. As this study accounts for the impact of structural break on the Malaysian CPO price, we are able to examine whether distortion in price pattern due to shocks in price affects the long-run relationship between CPO and CPO-F prices. As documented, the price can be distorted upward or downward. Upward price distortion will affect manufacturers (buyers) because the cost of production will increase, while downward price distortion will affect the CPO producers (sellers) due to the reduction in revenue because of lower CPO price. This implies that if there is distortion in the price due to shocks, both manufacturers and producers need to hedge their positions in the futures market (subject to their positions in the underlying market). By entering into the futures market, pricing is locked in advance, hence price risk is eliminated. Such a distortion could also affect the efficiency of the CPO price, therefore this study also addresses the issue of efficiency of the local CPO market. By looking at price distortion and its implication on risk management and also examining the pricing efficiency, this study therefore contributes significantly to the body of knowledge and fills the gap in the literature.

Despite the robustness of findings in this study following the consistent results using VECM and TAR, this study has limitation as it focuses only on Malaysian CPO and CPO-F prices.

For future works, researchers may also examine CPO prices in other major CPO producing countries such as Indonesia, Thailand, Colombia and Nigeria. Besides, researchers can also look at the integration of CPO prices between those countries.

References

Ali, N., Nassir, A.M., Hassan, T. and Abidin, S.Z. (2010), "Short run stock overreaction: evidence from Bursa Malaysia", *International Journal of Economics and Management*, Vol. 4 No. 2, pp. 319-333.

Alvarez-Ramirez, J., Alvarez, J. and Rodríguez, E. (2015), "Asymmetric long-term autocorrelations in crude oil markets", *Statistical Mechanics and its Applications*, Vol. 424 No. 1, pp. 330-341.

Andani, A., Lafuente, J.A. and Novales, A. (2009), "Liquidity and hedging effectiveness under futures mispricing: international evidence", *The Journal of Futures Markets*, Vol. 29 No. 11, pp. 1050-1066.

Arouri, M.E.H., Hammoudeh, S., Lahiani, A. and Nguyen, D.K. (2013), "On the short- and long-run efficiency of energy and precious metal markets", *Energy Economics*, Vol. 40 No. 1, pp. 832-844.

Balke, N.S. and Fomby, T.B. (1997), "Threshold cointegration", *Interrnational Economic Review*, Vol. 38 No. 3, pp. 627-645.

Beckmann, J., Belke, A. and Czudaj, R. (2014), "Regime-dependent adjustment in energy spot and futures markets", *Economic Modelling*, Vol. 40 No. 1, pp. 400-409.

Bohl, M.T., Salm, C.A. and Schuppli, M. (2011), "Price discovery and investor structure in stock index futures", *Journal of Futures Markets*, Vol. 31 No. 3, pp. 282-306.

Bollerslev, T., Xu, L. and Zhou, H. (2015), "Stock return and cash flow predictability: the role of volatility risk", *Journal of Econometrics*, Vol. 187 No. 2, pp. 458-471.

Bumpass, D., Ginn, V. and Tuttle, M.H. (2015), "Retail and wholesale gasoline price adjustments in response to oil price changes", *Energy Economics*, Vol. 52 No. 1, pp. 49-54.

Çağli, E.Ç. and Mandaci, E.P. (2013), "The long-run relationship between the spot and futures markets under multiple regime-shifts: evidence from Turkish derivatives exchange", *Expert Systems with Applications*, Vol. 40 No. 10, pp. 4206-4212.

Camilleri, J.S. and Green, J.C. (2014), "Stock market predictability", *Studies in Economics and Finance*, Vol. 31 No. 4, pp. 354-370.

Chang, C.L., Chen, L.H., Hammoudeh, S. and McAleer, M. (2012), "Asymmetric adjustments in the ethanol and grains markets", *Energy Economics*, Vol. 34 No. 6, pp. 1990-2002.

Chang, K.L. (2012), "The time-varying and asymmetric dependence between crude oil spot and futures markets: evidence from the Mixture copula-based ARJI-GARCH model", *Economic Modelling*, Vol. 29 No. 6, pp. 2298-2309.

Chetan, G.K. and Nagaraj, B.V. (2018), "Price discovery and volatility spillover among selected commodity spices: an evidence from NCDEX", *Wealth: International Journal of Money, Banking and Finance*, Vol. 7 No. 1, pp. 4-11.

Choudhry, T. and Hassan, S.S. (2015), "Exchange rate votality and UK imports from developing countries: the effect of the global financial crisis", *Journal of International Financial Markets, Institutions and Money*, Vol. 39 No. 1, pp. 89-101.

Cuestas, J.C. and Gil-Alana, L.A. (2009), "Further evidence on the PPP analysis of the Australian dollar: non-linearities, fractional integration and structural changes", *Economic Modelling*, Vol. 26 No. 6, pp. 1184-1192.

Dolatabadi, S., Narayan, P.K., Nielsen, M.O. and Xu, K. (2018), "Economic significance of commodity return forecasts from the fractionally cointegrated VAR model", *Journal of Futures Markets*, Vol. 38 No. 2, pp. 219-242.

Efimova, O. and Serletis, A. (2014), "Energy markets volatility modelling using GARCH", *Energy Economics*, Vol. 43 No. 1, pp. 264-273.

Engle, R.F. and Granger, C.W.J. (1987), "Co-integration and error correction: representation, estimation, and testing", *Econometrica*, Vol. 55 No. 2, pp. 251-276.

Fan, Y. and Xu, J.H. (2011), "What has driven oil prices since 2000? A structural change perspective", *Energy Economics*, Vol. 33 No. 6, pp. 1082-1094.

Figuerola-Ferretti, I. and Gonzalo, J. (2010), "Modelling and measuring price discovery in commodity markets", *Journal of Econometrics*, Vol. 158 No. 1, pp. 95-107.

Fowowe, B. (2016), "Do oil prices drive agricultural commodity prices? Evidence from South Africa", *Energy*, Vol. 104 No. 1, pp. 149-157.

Furió, D. and Chuliá, H. (2012), "Price and volatility dynamics between electricity and fuel costs: some evidence for Spain", *Energy Economics*, Vol. 34 No. 6, pp. 2058-2065.

Ghosh, S. and Kanjilal, K. (2016), "Co-movement of international crude oil price and the Indian stock market: evidence from nonlinear cointegration tests", *Energy Economics*, Vol. 53 No. 1, pp. 111-117.

Gil-Alana, L.A. and Tripathy, T. (2014), "Modelling volatility persistence and asymmetry: a study on selected Indian non-ferrous metals markets", *Resources Policy*, Vol. 41 No. 1, pp. 31-39.

Gil-Alana, L.A. and Yaya, O.S. (2014), "The relationship between oil prices and the Nigerian stock market: an analysis based on fractional integration and cointegration", *Energy Economics*, Vol. 46 No. 1, pp. 328-333.

Haron, R. and Salami, M.A. (2015), "Malaysian crude palm oil market volatility : a GARCH approach", *International Journal of Economics and Management*, Vol. 9 No. 1, pp. 103-120.

Haughton, A.Y. and Iglesias, E.M. (2012), "Interest rate volatility, asymmetric interest rate pass through and the monetary transmission mechanism in the Caribbean compared to the US and Asia", *Economic Modelling*, Vol. 29 No. 1, pp. 2071-2089.

Honarvar, A. (2009), "Asymmetry in retail gasoline and crude oil price movements in the United States: an application of hidden cointegration technique", *Energy Economics*, Vol. 31 No. 3, pp. 395-402.

Hou, Y. and Li, S. (2015), "Information transmission between US and China index futures markets: an asymmetric DCC GARCH approach", *Economic Modelling*, Vol. 52 No. 1, pp. 884-897.

Johansen, S. and Juselius, K. (1990), "Maximum likelihood estimation and inference on cointegration – with applications to the demand for money", *Oxford Bulletin of Economics and statistics*, Vol. 52 No. 2, pp. 169-210.

Kolodziej, M., Kaufmann, R.K., Kulatilaka, N., Bicchetti, D. and Maystre, N. (2014), "Crude oil: commodity or financial asset?", *Energy Economics*, Vol. 46 No. 1, pp. 216-223.

Koto, P.S. (2015), "Are retail prices of ethanol, gasoline and natural gas in the midwest cointegrated? An asymmetric threshold cointegration analysis", *Journal of Economics and Business*, Vol. 77 No. 1, pp. 79-93.

Lin, B. and Wesseh, P.K. (2013), "What causes price volatility and regime shifts in the natural gas market", *Energy*, Vol. 55 No. 1, pp. 553-563.

Liu, L., Chen, C.C. and Wan, J. (2013), "Is world oil market one great pool? An example from China's and international oil markets", *Economic Modelling*, Vol. 35 No. 1, pp. 364-373.

Liu, T., Hammoudeh, S. and Thompson, M.A. (2013), "A momentum threshold model of stock prices and country risk ratings: evidence from BRICS countries", *Journal of International Financial Markets, Institutions and Money*, Vol. 27 No. 1, pp. 99-112.

Masih, A.M.M. and Masih, R. (1996), "Energy consumption, real income and temporal causality: results from a multi-country study based on cointegration and error-correction modelling techniques", *Energy Economics*, Vol. 18 No. 3, pp. 165-183.

Murphy, D.J. (2014), "The future of oill palm as a major global crop: oppurtunities and challenges", *Journal of Oil Palm Research*, Vol. 26 No. 1, pp. 1-24.

Nambiappan, B., Ismail, A., Hashim, N., Ismail, N., Nazrima, D., Abdullah, N.I.K., Idris, N.I.K., Omar, N., Salleh, K.M., Ain, N.U.R., Hassan, M. and Kushairi, A. (2018), "Malaysia: 100 years of resilient palm oil economic performance", *Journal of Oil Palm Research*, Vol. 30 No. 1, pp. 13-25.

Narayan, P.K., Narayan, S. and Sharma, S.S. (2013), "An analysis of commodity markets: what gain for investors?", *Journal of Banking and Finance*, Vol. 37 No. 10, pp. 3878-3889.

Natanelov, V., Alam, M.J., McKenzie, A.M. and Van Huylenbroeck, G. (2011), "Is there co-movement of agricultural commodities futures prices and crude oil?", *Energy Policy*, Vol. 39 No. 9, pp. 4971-4984.

Nicolau, M. and Palomba, G. (2015), "Dynamic relationships between spot and futures prices: the case of energy and gold commodities", *Resources Policy*, Vol. 45 No. 1, pp. 130-143.

Paleologou, S.M. (2013), "Asymmetries in the revenue-expenditure nexus: a tale of three countries", *Economic Modelling*, Vol. 30 No. 1, pp. 52-60.

Pandey, V. and Vipul, J.J. (2017), "Market efficiency and information content of Indian commodity futures markets", *International Journal of Indian Culture and Business Management*, Vol. 14 No. 3, pp. 274-293.

Pen, Y. and Sévi, B. (2010), "Volatility transmission and volatility impulse response functions in European electricity forward markets", *Energy Economics*, Vol. 32 No. 4, pp. 758-770.

Peri, M. and Baldi, L. (2010), "Vegetable oil market and biofuel policy: an asymmetric cointegration approach", *Energy Economics*, Vol. 32 No. 3, pp. 687-693.

Radha, K. and Balakrishnan, S. (2017), "The role of commodity futures in risk management: a study of select agricultural commodities", *Journal of Financial Risk Management*, Vol. 14 No. 4, pp. 7-29.

Rittler, D. (2012), "Price discovery and volatility spillovers in the European Union Emissions Trading Scheme: a high-frequency analysis", *Journal of Banking and Finance*, Vol. 36 No. 3, pp. 774-785.

Sehgal, S., Ahmad, W. and Deisting, F. (2015), "An investigation of price discovery and volatility spillovers in India's foreign exchange market", *Journal of Economic Studies*, Vol. 42 No. 2, pp. 261-284.

Shabri, M. and Kassim, S.H. (2009), "Impact of the 2007 US financial crisis on the emerging equity markets", *International Journal of Emerging Markets*, Vol. 4 No. 4, pp. 341-357.

Subervie, J. (2011), "Producer price adjustment to commodity price shocks: an application of threshold cointegration", *Economic Modelling*, Vol. 28 No. 5, pp. 2239-2246.

Tuyon, J. and Ahmad, Z. (2016), "Behavioural finance perspectives on Malaysian stock market efficiency", *Borsa Istanbul Review*, Vol. 16 No. 1, pp. 43-61.

Valadkhani, A. (2013), "Do petrol prices rise faster than they fall when the market shows significant disequilibria?", *Energy Economics*, Vol. 39 No. 1, pp. 66-80.

Wang, Y. and Wu, C. (2012), "Long memory in energy futures markets: further evidence", *Resources Policy*, Vol. 37 No. 3, pp. 261-272.

Wang, Y. and Wu, C. (2013), "Are crude oil spot and futures prices cointegrated? Not always!", *Economic Modelling*, Vol. 33 No. 1, pp. 641-650.

Zhu, H.M., Li, S.F. and Yu, K. (2011), "Crude oil shocks and stock markets: a panel threshold cointegration approach", *Energy Economics*, Vol. 33 No. 5, pp. 987-994.

Further reading

Chang, T. and Tzeng, H-W. (2011), "Long-run purchasing power parity with asymmetric adjustment: evidence from Mainland China and Taiwan", *Economic Modelling*, Vol. 14 No. 3, pp. 59-70.

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