Price discovery and risk transfer in the Brent crude oil futures market

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Abstract: This paper examines price discovery and risk transfer functions in the Brent crude oil futures market. The results show that the spot and futures prices play a significant role in price discovery but the contribution of futures price are higher at different maturities. Second, the results of cross-contract analysis indicate that futures contract with longer maturity lead price discovery in the oil market. Finally, the crude oil futures price does not perform the risk transfer function in interaction with the spot price in various maturities and between different futures contracts. The findings have important implications for market participants and policy makers.

Keywords: crude oil; futures market; price discovery; risk transfer.


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1 Introduction

In this paper, we examine the price discovery and risk transfer functions of the crude oil futures market. Price discovery is the use of futures market price to determine the expected spot price (Working, 1948; Schroeder and Goodwin, 1991; Yang et al., 2010) while risk transfer is the use of futures contract by hedgers to transfer price risk to the spot market. These issues are of great importance because the high fluctuations of oil prices in recent years has led to tremendous uncertainties for oil price forecasting, oil resource investment and oil market trading (Zhang and Wang, 2013).

Whether the crude oil futures serve as benchmark towards which the prices of oil are determined is of great concern to market participants and policy makers. First, the ability of the crude oil futures market to perform price discovery implies that futures price contain all the necessary and available information which can be use to influence spot price (Chen et al., 2014). Second, hedging in futures contract can be profitable in this market because investors will be exposed to less price risk (Abdullahi, 2012). It is for these reasons that producers, marketing and processing firms use futures price when making consumption, production and inventory decisions (Figuerola-Ferretti and Gonzalo, 2010). Third, the price discovery in crude oil market can help provide information on some of the causes of high fluctuations in crude oil prices. For instance, if price innovations appear first in crude oil futures prices as opposed to spot market, then speculative activities may be the cause of fluctuations in oil prices (Kaufmann and Ullman, 2009).

The objective of this paper is to examine the price discovery and risk transfer functions of the Brent crude oil futures market. Specifically, this paper addresses three important research questions: Do Brent crude oil futures market perform its price discovery at different maturities? Do Brent crude oil futures market perform the risk transfer functions at different maturities? Finally, do Brent crude oil futures contracts for different maturities lead each other in price discovery and risk transfer?

Our empirical findings show that both the Brent crude oil spot and futures price play a significant role in price discovery but the contribution of the futures market is higher in the different maturities. We find that the three-month futures lead one-month futures in price discovery and the crude oil futures market does not perform the risk transfer function in all maturities and between different futures contracts.

The paper contribute to the literature in the following ways: First, we focus on price discovery and risk transfer in the Brent crude oil futures market. Previous studies focus mainly on price discovery in West Texas Intermediate (WTI) oil market and have ignored the risk transfer function, while investors want alternatives for risk diversification across different markets. Second, we examine price discovery and risk transfer in Brent oil market at different futures contracts to maturity. This is important because futures contract for different maturities may contain different information as they are traded for delivery on different dates, and therefore may exhibit dissimilar relationship in process of price discovery and risk transfer. Third, we provide new evidence on price discovery and risk transfer relationship between crude oil futures contract for different maturities. Hammoudeh et al. (2003) suggest that when compared with trading in the long-term on the spot contract alone, cross-contract analysis provides investors with information on whether trading in different maturities of the same underlying asset adds more diversification benefits. To our knowledge this kind of study has never been conducted in the Brent crude oil market.
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The remainder of this paper is organised as follows. Section 2 discusses the literature review. Section 3 provides discussion on the econometric methodology. Section 4 shows the data description. Section 5 provides empirical results and discussions. Section 6 concludes the research findings and suggestions.

2 Literature review

Several studies have examined price discovery between the crude oil spot and futures market using different approaches. Majority of previous studies explore the lead-lag relationship between the spot and futures prices as evidence of price discovery. For example, Quan (1992) investigate price discovery and risk transfer in WTI futures market using linear causality and Garbade-Silber approach and find unidirectional causality running from WTI spot to futures prices at one, three, six and nine-month maturities, and the futures market does not perform the risk transfer function in all maturities. In contrast, Schwarz and Szakmary (1994) find unidirectional linear causality from WTI one-month futures price to spot price suggesting the dominant role of the futures market to price discovery. Silvapulle and Moosa (1999) applying the linear and nonlinear causality test on daily spot and futures prices of WTI at one, three and six-month contracts find linear unidirectional causality from futures price to spot price, and bi-directional nonlinear causality between the two prices in the different maturities. Bekiros and Diks (2008) in contrast find bidirectional linear and nonlinear causality between WTI spot and futures contract prices at one to four-months maturities, and observe that if nonlinear effects are accounted for neither markets lead or lag the other in price discovery. Similarly, Lee and Zeng (2011) find linear and nonlinear bi-directional causality between WTI spot and various futures oil prices. They find that futures oil prices significantly lead spot oil prices in the lowest quantile while under the long futures contracts maturing in 2, 3, and 4 months, futures oil prices do not lead spot prices in high quantiles, except for the short one-month contracts. Alzahrani et al. (2014) using wavelet transformed spot and futures oil prices find bidirectional causality between WTI spot and one-month futures prices at different time scales, under linear and nonlinear causality assumptions and during the recent financial crisis supporting the contribution of both markets to price discovery. Huang et al. (2009) using a multivariate threshold autoregressive model find unidirectional linear and nonlinear causality from WTI futures price to spot price over the period 1986 to 2007. They find that even if the data is divided into three different periods, majority of the results are consistent in support of the larger contribution of the futures price to price discovery. Zhang and Wang (2013) empirically investigate the functions of price discovery and risk transfer in crude oil and gasoline futures markets using causality and Garbade-Silber models, and find that the futures in crude oil and gasoline markets performed price discovery with about 95.71% and 59.41%, respectively. They also observed that the futures market perform the risk transfer function much better than gasoline futures price in interactions with their respective spot prices. Chen et al. (2014) investigate the linear and nonlinear causality relationship between the WTI spot and futures prices, and find that after accounting for structural breaks the futures oil price lead spot price over the sample period 1986 to 2012, whereas, there exists unidirectional linear causality from spot to futures prices in the subsample period.
Other studies have measured price discovery using different research methods. For example, Foster (1996) examine price discovery in WTI and Brent one-month oil futures contract using the generalised dominance model, and find that the futures price lead spot price in both markets before the Gulf War while the relationship changes with spot price been the price leader after the War. Lean et al. (2010) using the stochastic dominance approach show that WTI spot and futures prices at 1, 2, and 3 months make equal contribution to price discovery. Silvério and Szklorenan (2012) using the Kalman filter technique report that WTI futures price lead spot price and its contribution has been increasing in recent years especially between 2003 and 2008, and after 2009. There are few studies that examine price discovery between crude oil futures contracts in the same market and between contracts of different markets. Hammoudeh et al. (2003) using the error correction and GARCH models show that WTI one-month futures price leads spot price and three-month futures prices in the process of price discovery. Kaufmann and Ullman (2009) investigate causality relationships among prices for crude oils from North America, Europe, Africa, and the Middle East on both spot and futures markets and find that innovations first appear in spot prices for Dubai-Fateh and spread to other spot and futures prices while other innovations first appear in the far month contract for WTI and spread to other exchanges and contracts. Kim (2011) using some econometric models examine price discovery in WTI daily spot and futures prices at one- to four-month and find mixed results across the methods and maturities. The results show strong evidence that futures contract with longer maturity lead short contracts in price discovery process.

In sum, we can see that majority of the existing studies in this area of research has concentrated on price discovery in WTI crude oil futures market, and has ignored the risk transfer function of the crude oil futures market. Additionally, there is little evidence on price discovery and risk transfer between oil futures contracts of the same and different underlying asset. This paper examines the functions of price discovery and risks transfer in Brent crude oil futures market.

3 Methodology

This section discussed the econometric methodologies used to examine the contribution of the Brent crude oil futures market to price discovery and risk transfer. Following Zhang and Wang (2013) we examine the long run relationship between the crude oil futures and spot prices using the Johansen (1991) cointegration approach. The cointegrating equation can be written as follows.

\[ f_t = \alpha_1 + \beta_1 s_t + \epsilon_{1t} \]  
\[ s_t = \alpha_2 + \beta_2 f_t + \epsilon_{2t} \]

where

- $f_t$: logarithm of Brent futures price
- $s_t$: logarithm of Brent spot price
- $\beta_1$ and $\beta_2$: coefficients of cointegration
- $\alpha_1$ and $\alpha_2$: coefficient for constant term
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$\varepsilon_{1t}$ and $\varepsilon_{2t}$ uncorrelated residuals of regression.

Second, using a vector error correction model (VECM) we investigate the causality relationship between the crude oil spot and futures prices. The model can be express as:

\[
\Delta f_t = \lambda_0 + \sum_{i=1}^{k} \beta_i \Delta f_{t-i} + \sum_{i=1}^{k} \delta_i \Delta s_{t-i} + \alpha_f \varepsilon c t_{1,t-1} + \varepsilon_{ft} 
\]

(3)

\[
\Delta s_t = \lambda_0 + \sum_{i=1}^{k} \beta_i \Delta s_{t-i} + \sum_{i=1}^{k} \delta_i \Delta f_{t-i} + \alpha_s \varepsilon c t_{2,t-1} + \varepsilon_{st} 
\]

(4)

where

- $\Delta s_t$ changes in Brent spot price
- $\Delta f_t$ changes in Brent futures price
- $\alpha_s$ coefficients of error correction terms for the spot price
- $\alpha_f$ coefficients of error correction terms for the futures price
- $\varepsilon_{ft}$ and $\varepsilon_{st}$ are the residuals.

From equations (3) and (4), we test the null hypothesis $H_0: \delta_1 = 0$, that change in spot price does not causes change in futures price in the short run, whereas, $H_0: \delta_2 = 0$, that change in futures price does not causes change in spot price in the short run. The ratio of the error correction terms can also be use to estimate the contribution of spot and futures markets in price discovery because it shows the magnitude at which the prices adjust to the long run equilibrium position (see Cabrera et al., 2009; Schlusche, 2009; Chen and Gau, 2010). If $\alpha_s$ is insignificant and $\alpha_f$ is positive and significant the spot market lead price discovery, whereas, if $\alpha_f$ is insignificant and $\alpha_s$ is negative and significant the futures market leads in price discovery. Both market contribute to price discovery when $\alpha_s$ and $\alpha_f$ have the correct signs and are significant. However, the market with smaller value of the adjustment coefficient (in absolute value) would lead because that market impounds more information and therefore adjusts faster to the long-run equilibrium.

Third, we measure price discovery between the crude oil spot and futures market using the Granger-Gonzalo (Gonzalo and Granger, 1995) common factor weight approach. The model assumes that when prices in $n$ markets are cointegrated that is having a common trend; the proportion of each market in the common efficient market price determines its contribution to price discovery. Baillie et al. (2002) and Figuerola-Ferretti and Gonzalo (2010) proposed that the contribution of the spot and futures markets to price discovery by the model can be measured from the error correction terms in equations (3) and (4) as follows.

\[
C F W_f = \frac{\alpha_f}{(\alpha_f - \alpha_s)} \quad C F W_s = \frac{-\alpha_s}{(\alpha_f - \alpha_s)}
\]

(5)

where

- $\alpha_s$ adjustment coefficient or error correction term for the spot price
The contribution of each market to price discovery is determined by the value of its common factor weight. The model proposed that if $CWF_f > CWF_s$, we may say the futures market lead spot market in price discovery, similarly, if $CWF_s > CWF_f$, we may say the spot market lead in price discovery. Both $CWF_f$ and $CWF_s$ will be 0.5 when the spot and futures market make an equal contribution to price discovery.

Finally, we employ the Garbade-Silber (Garbade and Silber, 1983) model to measure the contribution of the crude oil futures market to price discovery and risk transfer functions. The model can be specified as:

$$
\begin{bmatrix}
    s_t \\
    f_t
\end{bmatrix} =
\begin{bmatrix}
    \alpha_s \\
    \alpha_f
\end{bmatrix} +
\begin{bmatrix}
    1-\alpha_s & \alpha_s \\
    \alpha_f & 1-\alpha_f
\end{bmatrix}
\begin{bmatrix}
    s_{t-1} \\
    f_{t-1}
\end{bmatrix} +
\begin{bmatrix}
    \epsilon_s \\
    \epsilon_f
\end{bmatrix}
$$

where $\alpha_s$, coefficient which reflect the current crude oil spot market price that is influenced by the past price change in the futures market

$\alpha_f$, coefficient which reflect the current crude oil futures market price that is influenced by the past price change in the spot market

$\beta_s$, constant coefficient which reflect secular trends in the spot price

$\beta_f$, constant coefficient which reflect secular trends in the futures price

$\epsilon_{st}$ and $\epsilon_{ft}$, uncorrelated residuals.

From equation (6) change in price for each market depend on the amount of mispricing $(f_{t-1} - s_{t-1})$ that occurs between the crude oil spot and futures markets, and price discovery is perform by the market in which the mispricing begins (Schwarz and Szakmary, 1994). The model postulate that each market share in price discovery can be measured by the ratio $\theta = \frac{\alpha_s}{\alpha_s + \alpha_f}$, which values range between zero and one. If $\alpha_f = 0$, the ratio would be unity and the futures market will perform price discovery, similarly, if $\alpha_s = 0$ the spot market lead and the ratio would be zero. However, when $\theta$ has its value between 1 and 0, a bi-directional (feedback effect) relationship would exist between the markets in price discovery process.

Garbade and Silber (1983) proposed that the mispricing between the markets in equation (6) can be solved to estimate the risk transfer function of the crude oil futures market.

$$
\begin{align*}
    f_t - s_t &= \beta + \delta \left( f_{t-1} - s_{t-1} \right) + \epsilon_t
\end{align*}
$$

where $\beta = \beta_f - \beta_s$, $\delta = 1 - \lambda_f - \lambda_s$ and $\epsilon_t = \epsilon_{ft} - \epsilon_{st}$. The coefficient $\delta$ measures the speed of convergence between the spot and futures prices and the inverse relationship of the supply of arbitrage services. The smaller value of $\delta$ implies that convergence between the spot and futures prices occur more rapidly because small proportion of the price difference on time $t-1$ persists to time $t$ and vice versa.
4 Data and its properties

The data used consist of daily closing spot and futures prices at one- and three-month contracts to maturity for Brent crude oil market from January 2000 to October 2013. The choice of the sample period is based on the availability of data. Data is obtained from the Data stream International. All prices are adjusted for public holidays and other non-trading days, and are transformed into natural logarithm form. This paper used the following notations: Brent-S, Brent-C1 and Brent-C3 to denote spot and futures prices at one and three-month maturity, respectively. Table 1 shows the summary statistics of the crude oil spot and futures prices. The results indicate that the standard deviation is larger for three-month futures contract, negative skewness and excess kurtosis in each of the prices series. The Jarque-Bera test indicates that the crude oil spot and futures prices are not normally distributed at the 5% significant level. The Augmented Dickey Fuller (ADF) test show that each of the price series have a unit root which suggest that they are integrated to order one denoted I (1).

Table 1 Summary statistics for crude oil spot and futures prices

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>Std. dev.</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Jarque-Bera prob.</th>
<th>ADF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brent-S</td>
<td>4.004</td>
<td>0.5675</td>
<td>-0.2018</td>
<td>1.6849</td>
<td>266.75(0.0)</td>
<td>-2.863</td>
</tr>
<tr>
<td>Brent-C1</td>
<td>3.991</td>
<td>0.5661</td>
<td>-0.1716</td>
<td>1.6523</td>
<td>272.63(0.0)</td>
<td>-2.717</td>
</tr>
<tr>
<td>Brent-C3</td>
<td>3.998</td>
<td>0.5736</td>
<td>-0.2056</td>
<td>1.6247</td>
<td>290.44(0.0)</td>
<td>-2.320</td>
</tr>
</tbody>
</table>

Notes: All the crude oil prices series are in natural logarithmic form. Figures in bracket are probabilities of the Jarque-Bera test which indicate that all the crude oil price series are not normally distributed. The ADF test t-statistic results indicate unit root at 5% level in all the crude oil prices.

5 Empirical results and discussions

5.1 Result of the cointegration test

To test whether there exist long run equilibrium relationship between the crude oil spot and various futures prices, and between futures contracts for different maturities, we apply the Johansen cointegration approach. Table 2 present the results of the Johansen cointegration test. The results indicate that the maximum eigenvalues tests reject the null of no cointegration between the spot and futures prices at one and three-month contracts but cannot reject the null hypothesis of atmost one cointegration equation at the 5% significant level. This implies that there is cointegration relationship between the crude oil spot and the various futures prices. In other word, there is a long run equilibrium relationship between the crude oil spot and futures prices in each case consistent with Bekiros and Diks (2008), Zhang and Wang (2013) and Chen et al. (2014). The results also show significant long-run equilibrium relationship between futures contract for different maturities which is consistent with the findings of Hammoudeh et al. (2003) and
Kaufmann and Ullman (2009). The implication of this finding is that the co-movement between the spot and futures prices suggest that both the determinants of spot prices (supply and demand factors) and futures prices (investors behaviour or speculators) may have affected each other’s price in driving them toward long term equilibrium level (see Wang and Yu, 2014).

Table 2 The Johansen cointegration test results

<table>
<thead>
<tr>
<th>Variables</th>
<th>$\lambda_{trace}$</th>
<th>$\lambda_{trace}$</th>
<th>$\lambda_{Max}$</th>
<th>$\lambda_{Max}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r = 0$</td>
<td>$r \leq 1$</td>
<td>$r = 0$</td>
<td>$r \leq 1$</td>
</tr>
</tbody>
</table>

Notes:* Indicates that the null hypothesis of no cointegration is rejected at 5% level of significance. The t-statistics are shown in parentheses beside the critical values at 5% level are taken form $\lambda_{trace}$ and $\lambda_{max}$, MacKinnon-Haug-Michelis (1999). The results indicate cointegration relationship between the spot and futures prices at one-month and three-month contracts, and between the two futures contract.

5.2 Results of the price discovery and risk transfer functions

Table 3 presents the results of the causality test estimates which show bidirectional causality between the spot and futures prices at one and three-month maturities in the long run. This implies that changes in spot price and futures price can causes changes in each other’s price consistent with Bekiros and Diks (2008), Lee and Zeng (2011) and Alzahrani et al. (2014). The results suggest that the crude oil spot and futures prices respond to new pricing information instantaneously and therefore perform an equal contribution to price discovery at the different maturities. However, the absolute values of the error correction coefficients is lower for futures price at three-month maturity compared to spot price which suggest that it adjust faster to the long-run equilibrium and contributes more to price discovery. But, the significant role of the spot price in price discovery cannot be neglected given the higher value of its adjustment coefficient which shows that some market participants used the changes in this price to predict futures prices in Brent oil market. Further, the cross-contract analysis indicates significant unidirectional causality running from three-month futures to one-month futures contract price in the long run. This suggest that three-month oil futures contract price lead price discovery because changes in this price can causes changes in one-month contract price. The result contrast that of Hammoudeh et al. (2003) who report that one-month futures lead three-month futures contract in WTI market.
**Table 3**  Estimated results of the causality test

<table>
<thead>
<tr>
<th>Null hypothesis</th>
<th>Long run t-statistic</th>
<th>Short run chi-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brent-C1 does not cause change in Brent-S</td>
<td>0.0367[2.828]</td>
<td>452.2(0.000)</td>
</tr>
<tr>
<td>Brent-S does not cause change in Brent-C1</td>
<td>–0.0365[–2.911]</td>
<td>87.90 (0.000)</td>
</tr>
<tr>
<td>Brent-C3 does not cause change in Brent-S</td>
<td>0.0226[2.313]</td>
<td>425.7 (0.000)</td>
</tr>
<tr>
<td>Brent-S does not cause change in Brent-C3</td>
<td>–0.0357[–3.410]</td>
<td>11.98(0.008)</td>
</tr>
<tr>
<td>Brent-C1 does not cause change in Brent-C3</td>
<td>–0.0436[–2.587]</td>
<td>20.69 (0.002)</td>
</tr>
<tr>
<td>Brent-C3 does not cause change in Brent-C1</td>
<td>0.0133[0.8433]</td>
<td>153.3(0.000)</td>
</tr>
</tbody>
</table>

Notes: t-statistics is shown in parenthesis besides the error correction coefficients. * and ** denotes the rejection of the null hypothesis of no causality at the 1% and 5% significance level respectively; p-values are reported in parentheses. The results indicate bidirectional causality between the crude oil futures and spot prices in all maturities and unidirectional causality running from three-month futures to one-month futures contract price.

In the short run, the results indicate that there is no significant causality between the crude oil spot and futures prices at one-month and three-month maturity, and between the futures contract for different maturities. The results implies that the spot and futures prices are independent because neither changes in spot price nor futures price influence the each other price and therefore the futures market does not perform the price discovery role at various maturities in the short run. The findings contrast Zhang and Wang and Alzahrani et al. (2014) who report bi-directional causality in WTI market.

**Table 4**  Estimated results of the common factor weights approach

<table>
<thead>
<tr>
<th></th>
<th>VECM</th>
<th>CFW</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta \text{Brent} – S )</td>
<td>–0.0365[–2.911]</td>
<td>0.4986</td>
</tr>
<tr>
<td>( \Delta \text{Brent} – C1 )</td>
<td>0.0367[2.828]</td>
<td>0.5014</td>
</tr>
<tr>
<td>( \Delta \text{Brent} – C3 )</td>
<td>–0.0357[–3.410]</td>
<td>0.6119</td>
</tr>
<tr>
<td>( \Delta \text{Brent} – S )</td>
<td>0.0226[2.313]</td>
<td>0.3881</td>
</tr>
<tr>
<td>( \Delta \text{Brent} – C3 )</td>
<td>–0.0436[–2.587]</td>
<td>0.2344</td>
</tr>
<tr>
<td>( \Delta \text{Brent} – C3 )</td>
<td>0.0133[0.8433]</td>
<td>0.7656</td>
</tr>
</tbody>
</table>

Notes: t-statistics is shown in parenthesis besides the error correction coefficients estimated from equations (3) and (4). The results of the common factor weights indicate that the crude oil spot and futures markets make equal contribution to price discovery at one-month maturity while at three-months the spot market is the price leader. The three-month contract lead price discovery between the two maturities in Brent market.

Second, the contribution of the spot and futures markets to price discovery is estimated using the common factor weights approach. Table 4 reports the results of the common factor weights which are 50% for both the spot and futures markets at one-month maturity. Therefore, the spot and one-month futures prices make an equal contribution to price discovery. In the second case, the common factor weights are 61% for the spot market and 39% for the futures markets at three-month maturity which suggest that the spot market incorporates more pricing information and therefore plays
the price discovery function. The estimated results of the cross-contract analysis indicate that the common factor weight of the three-month contract is much larger than the one-month contract. The values reported are 77% for the three-month contract while for the one-month contract is 23%, suggesting that the former impound more information and leads price discovery between the two maturities. The findings support Kim (2011) who using the same model reported that futures with longer maturities perform the highest role in price discovery in WTI market.

Table 5  Estimated results of the Garbade-Silber approach

<table>
<thead>
<tr>
<th></th>
<th>$\beta_s$</th>
<th>$\beta_f$</th>
<th>$\beta_1$</th>
<th>$\beta_3$</th>
<th>$\theta$</th>
<th>$\delta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brent-S and Brent-C1</td>
<td>0.109**</td>
<td>0.078**</td>
<td>-</td>
<td>-</td>
<td>1.10</td>
<td>0.810</td>
</tr>
<tr>
<td></td>
<td>[9.279]</td>
<td>[6.668]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brent-S and Brent-C3</td>
<td>0.069**</td>
<td>0.032**</td>
<td>-</td>
<td>-</td>
<td>0.68</td>
<td>0.899</td>
</tr>
<tr>
<td></td>
<td>[6.920]</td>
<td>[3.486]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brent-C1 and Brent-C3</td>
<td>-</td>
<td>-</td>
<td>-0.859**</td>
<td>-0.021</td>
<td>0.97</td>
<td>1.880</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[5.749]</td>
<td>[1.526]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: The coefficients $\beta_s$ and $\beta_f$ are error correction terms for spot and futures markets respectively, while $\beta_1$ and $\beta_3$ are for futures contract at one and three-month maturity, respectively. The values in parentheses beside the parameters are the t-statistics and asterisk (*) and (**) indicate significance at the 1% and 5% level. The value of $\theta$ shows that the crude oil futures price lead price discovery in all maturities. Also, the result shows that three-month contract leads one-month contract in price discovery. However, the Brent crude oil futures markets do not perform its risk transfer function in both single and cross contract analysis.

Table 5 reports the results of the Garbade-Silber approach estimated using the regression approach. The results show that $\beta_s$ and $\beta_f$ are significant at both one- and three-month maturities, implying that the spot and futures prices incorporate new information instantaneously. However, the measure of price discovery estimate indicated the value of $\theta$ is 1.00% and 0.68 at one- and three-month futures contracts respectively. Therefore, the crude oil futures price lead price discovery in all maturities. When compared with previous studies the estimates are higher than the value obtained by Quan (1992), who reported 0.52 and 0.70 for WTI at one-and three-month futures contracts, respectively and Schwarz and Szakmary (1994) reported the value of 0.55. They are close to Zhang and Wang (2013) who reported 95.71% for WTI one-month futures. The implications of these results is that firstly, investors can benefit from portfolio diversification between the one-month and three-month futures contract because their prices impound more information than spot price. Secondly, hedgers can minimise unsystematic risk because the futures contracts prices contain available information about market conditions and therefore they can avoid adopting expensive hedging strategies since the crude oil futures market have efficient price that can determine spot price. Thirdly, we can say that speculative activities rather than market fundamentals may be the driving factors in changing oil prices because innovations appear first in crude oil futures prices as suggested by Alzahrani (2014) and Kaufmann and Ullman (2009). Finally, the results support the arguments that the futures market should respond first to pricing information before the spot market given its lower transaction costs, less friction and flexibility of short selling (Schwarz and Szakmary, 1994; Figuerola-Ferretti and Gonzalo, 2010; Huang et al., 2009) and high liquidity (Foster, 1994).
For the cross-contract analysis, the results show that the values of $\beta_1$ and $\beta_3$ for futures prices at one- and three-month contracts are both negative but significant and insignificant, respectively which suggest no or little feedback of information between the two different contract prices. The estimated value of $\theta$ is 0.97 which show that three-month contract leads one-month contract in price discovery process consistent with the results of Kim (2011). Both the causality test, common factor weight and Garbade-Silber support that the three-month futures lead one-month futures in price discovery. The implications for the findings is that the three-month futures contract respond faster and incorporate more information than one-month contract which suggest that investors can minimise price risk by investing in contract with long term (or three-month) maturity. Second, speculative opportunities can easily be exploited between the contracts because information on three-month futures price can be used to predict one-month price in the crude oil market. Thirdly, evidence shows that crude oil market is more efficient at three-month futures contract because the price impound more and necessary information about market conditions while market participants will be exposed to high price risk at one-month maturity.

Table 5 report the results of the risk transfer function between the crude oil spot and futures markets and different futures contracts computed using the Garbade and Silber (1983) model. As stated earlier in equation (7) the value of $\delta$ measures the risk transfer function between the oil markets. The results report the values of 0.81 and 0.90 for $\delta$ at one- and three-month contracts respectively, indicating that approximately about 81% and 90% of the mispricing between the spot and futures markets disappears the next trading day. The findings implies that the risk transfer function is not perform well by the crude oil futures market which suggest the presence of high risks of investment between the spot and futures prices. Similarly, the results of the cross-contract analysis show the value of 1.10% for $\delta$. The high value of $\delta$ suggests that the risk transfer function is not performed by the crude oil futures market at the different maturities and between different futures contracts. The implication of these results is that hedgers will be exposed to high risk because arbitrage is undertaken slowing before the crude oil spot and futures markets to converge together, whereas, speculative activities will be profitable between the spot and futures markets. Similarly, the results suggest the same thing between the crude oil futures contracts for different maturities.

6 Conclusions

This paper investigate price discovery and risk transfer functions in Brent crude oil daily spot and futures prices for one-and three-month contract to maturities, and between futures contracts of different maturities over the sample period 2000 to 2013. We use the Granger causality, common factor weight approach and Garbade-Silber approach. Our empirical results show that both the spot and futures prices play a significant role in price discovery but the contribution of the futures prices is higher in price formation although results are mixed among the models. The results indicate that the three-month futures lead one-month contract in price discovery, and the risk transfer function is not well perform by the crude oil futures market at different maturities and between different contracts.
Our results are important to investors and policy makers. First, we find that crude oil futures market contributes in determining oil prices because it perform the price discovery function at different maturities. In addition, we can suggest that speculative activities may be the driving factors that cause fluctuations in oil. Second, the findings show that oil futures contract prices with longer maturity can be useful to predict short term contract. It is important for investors who want to hedge risk in oil futures contract to consider the length of maturity of the futures contract, and this can also provide information to speculators about the relationship between the two contracts. Third, according to our analysis of risk transfer function, the crude oil futures market does not perform this role in all maturities and between different futures contracts. As a result, hedgers and investing firms should take this into account when making arbitrage and diversifying across futures contracts of different maturities. Finally, our results based on the interaction between crude oil futures contracts of different maturities show that the prices do not respond to new information at the same time. Policy makers should take this into account when making oil price forecast, analysing market conditions and developing new policies. We suggest future work to examine price discovery and risk transfer functions in crude oil futures market taking account structural changes and nonlinearity over different subsample period in order to provide more insight on these issues.

References


