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## Article

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## Examining Rational Bubbles in Oil Prices: Evidence from Frequency Domain Estimates

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### ABSTRACT

This study examined the existence of rational bubbles in oil prices by employing a frequency domain econophysics technique that have capacity to identify both explosive behaviour and bubbles in oil prices for the three largest oil future markets – WTI, Brent and OPEC basket. Our results show that the three prices experienced bubbles in four distinct periods. We attempt to provide some explanations on each of these bubbles using geopolitical, war and economic events. We equally noted that oil prices bubbles are largely influenced by the fact that oil is a major source of energy and is non-renewable. The study observed that existence of bubbles have some economic consequences such as welfare loss resulting from distortion in prices and economic instability among others. We provide some policy recommendation.

**Keywords:** Oil Prices, Rational Bubbles, Energy

**JEL Classifications:** C22, C50, G10, G12

### 1. INTRODUCTION

Over the years, financial and energy experts has devoted time to investigate the existence or otherwise of rational bubbles in asset prices<sup>1</sup> (oil prices inclusive). This is premised on the fact that most recent financial crises are preceded by bubbles in real asset prices (Miao and Wang, 2015; Miao, 2014; Miao et al., 2015a; Lammerding et al., 2013; Escobari et al., 2017; Lawal et al., 2017; Sharma and Escobari, 2018; Branch, 2016; Caspi and Graham, 2018; Branch, 2016; Escobari et al., 2017). The impact of rational bubbles on economic growth management, employment and the financial system cannot be over-emphasized, given the recent evidence from global financial crisis (Kilian, 2008; Leung, 2010;

Babajide et al., 2015; Babajide et al., 2016; Baur and Heaney, 2017; Lawal et al., 2018; Fashina, et al., 2018; Lawal et al., 2018; Lawal et al., 2016; Madsen et al., 2018; Babajide et al., 2016; Madsen et al., 2018; Ibrahim and Alagidede, 2018). For instance, overshooting oil prices may induces erroneous adjustment of monetary policy framework; it may expose market participants to significant financial losses (Lammerding et al., 2013), thus policy makers, investors and other economic agents are expected to pay keen attention to timely identification of rational bubbles in asset prices so as to harness the windows of opportunity in preventing losses to investments and distortions in the economy.

The current study investigates the existence or otherwise of rational bubbles in the oil prices by employing a frequency domain model capable of accounting for heteroskedasticity; allows for nonlinear structure in data with breaks; can detect multiple breaks; and can detect explosive behavior and bubbles. These models can be

1 Evidence of rational bubbles implies that no long run relationship exist between asset prices and dividends (Kilian, 2008; Leung, 2010; Ye, et al., 2011; Coleman, 2012; Zhang et al, 2014; Narayan and Narayan, 2014; Maio et al., 2015; Martins and Ventura, 2015; Su et al., 2017)

applied to data at any frequency and is more objective for real time bubble detection. The study also employed (Engle, 2002) simple dynamic conditional correlation model (DCC) to examine the links between bubbles across of oil market prices.

Our interest in oil is motivated by the fact that oil play strategic role in economic growth of nations as it often act as predictor variable (Lorusso and Pieroni, 2018; Lee et al., 2017; Cuestas and Gil-alana, 2018; Lawal et al., 2018; Su et al., 2017; Cuestas and Gil-Alana, 2018; Shah, et al., 2018; Degiannakis et al., 2018). Over the years, it has been observed that wild fluctuation in oil prices induces huge shocks on economic development with impact depending on the side of the divide an individual economic is. For instance, with sharp decline in prices, oil exporting countries experience drastic reduction in income while oil importing countries experience positive/upward shift in purchasing power. On the other hand, a sudden upward surge in price inflicts suffering on oil importing economies characterized by fall in her purchasing power with a possibility of downward presume on economic growth. Under this condition, for the oil exporting economies, upward surge in price connotes increase in income (all things seeing equal). Furthermore, evidence abound to show that oil is an important input factor of many products, thus, increases in oil prices may distort production with significant effect on product prices, it may also induce inflationary pressure, causes recessions and bearish stock market (Domínguez-gijón et al., 2018; Fantazzini, 2016; Lorusso and Pieroni, 2018).

(Balcilar et al., 2014) noted that oil prices bubbles and crashes are induced by a number of factors which includes political, military, financial or economic shocks. The authors further classified the causes into two categories that subjects crude oil prices to a level of sensitivity to all manner of information, given that the investors in the market are ready to capitalize on available information so as to maximize profit. These categories are: Over dependent of global economic activities on crude oil as the source of energy; and depletive nature of oil. They stresses that welfare loss owing to distortion in relative prices and economic instability, increase in employment resulting from job loss, wages and price level fluctuating among others are the consequences of occurrence of erratic bubbles and burst in crude oil. The authors suggested investment in alternative source of energy as crucial to curbing oil price bubbles stressing that total welfare gain that will accrue from preventing national bubbles outweigh the cost of investing in alternative energy sources.

Given this important role that oil plays, attention of huge investors has been drawn to the sector (Lawal et al., 2018; Sanders and Irwin, 2017; Zhang and Wang, 2015; Sanders and Irwin, 2017). As noted by the US Energy information Administration (2015) oil prices responds to a number of geopolitical, economic events, changes in expectations on economic growth, non-economic fundamental factors that distorts the long run cointegration between oil prices and the fundamentals suggesting the existence of rational bubbles.

(Lucas, 1978) pioneered empirical work on identification of rational bubbles in asset prices. Ever since, a number of studies (Su et al., 2017; Brunnermeier, 2008; Wachira, 2013) have

attempted to investigate the presence or otherwise of asset bubbles with majority employing linear base models like (Johansen and Juselius, 1992; Johansen, et al, 2000; Johansen and Juselius, 1992) with symmetric adjustment which fails to capture asymmetries property of the data generating process as it has lower power in an asymmetric adjustment process (Escobari et al., 2017); Su et al., 2017; Miao and Zhou, 2015b); these methods also fail to incorporate structural breaks into the model, implying that the power to reject a unit decreases when stationary alternative is true and structural break is ignored. Other methods includes Markov-switching model that fails to distinguish between periods likely to appear spuriously explosive resulting from high variance and periods with genuine explosive behavior (Funke et al., 1994; Phillips, 2011) PSY; (Phillips et al., 2015) (PWY) that have high chances of erroneously interpreting the presence of explosive behaviour for the presence of rational bubbles (Balcilar et al., 2016; Caspi and Graham, 2018; Ye et al., 2011). We extends extant literature by employing (Herzog, 2015) econophysics frequency domain model that allows for stochastic bubbles, not prone to model identification problem to examine the existence of bubbles in the three leading oil market price indexes. The models allow for nonlinear structure in data with breaks, can detect multiple breaks. These models can be applied to data at any frequency and is more objective for real time bubble detection (Bahmani-Oskooee et al., 2016; Almudhaf, 2017; Lee and Phillips, 2016; Caspi and Graham, 2018). We equally employed the DCC to analyses the correlations between bubbles across oil markets.

For shadowing our results, it was observed that strong evidence of bubbles occur in all the three oil markets prices. We also noted a clear overlap of bubbles periods across markets prior to the 2007 global economic meltdown. Our results also show that there are strong relationships among each of the studied oil markets, with high level of correlation when the three oil markets exhibits bubbles. The same was noted when none of the markets exhibits bubble suggesting huge potential for diversification of investment during periods of bubbles in the markets.

The remaining part of this study is structured as follows: Section 2 provides a brief literature review; section three presents the material and methods; section 4 presents the results, while section five concludes the study.

## 2. LITERATURE REVIEW

The theoretical note for this study is based on the (Lucas, 1978) framework that postulates existence of rational bubbles in asset prices. According to the narrative, rational bubbles exists when there is no long run relationships between asset prices and dividends. (Campbell, 2012; Caspi and Graham, 2018; Ye et al., 2011, Branch, 2016) extended the model by relying on (Gordon, 1962) framework to calibrate the dividend demising yield into the study on rational bubble. The author stressed that dividend growth and return rate changes overtime. (Phillips, 2011; Phillips, et al., 2015) extends literature on rational note by introducing models that can detect change of dynamics from I (1) to an explosive process in the asset price time series by calibrating the present value model of the asset prices.

Extant literatures on rational bubble mainly focus on asset prices. For instance, (Tran, 2017) examined the existence or otherwise of rational bubbles in Latin America stock markets focusing on Argentina, Brazil, Chile, Colombia, Mexico and Peru based on data sourced from 1990-2009, and observed that collapsing bubbles exist in the studied markets, with bubbles majorly influenced by the presence of foreign investors. His findings are similar to earlier findings like (Diego et al., 2015; Sharma and Escobari, 2018; Adämmer and Bohl, 2015) for the Latin America markets.

In a related development, (Balcilar et al., 2016; Almudhaf, 2017) among others have documented existence of explosive behavior (rational behavior) for some selected African markets.

Besides, the examination of rational bubble existence in stock markets, other applications have been found in real estate (Escobari and Jafarinejad, 2016; Xie and Chen, 2015; Wu, et al., 2017; Versmissen and Zietz, 2017); banking crises (Miao and Wang, 2015; Virtanen et al., 2018; Drehmann and Juselius, 2014); Debt-to-GDP (Hong and Sraer, 2013; Bidian, 2015); Portfolio (Bidian, 2015; Bejan and Bidian, 2014; Bidian, 2016); Credit-to-GDP (Ftiti et al., 2016; Martin and Ventura, 2015) among others.

Literature on the investigation of rational bubbles as it relates to commodity futures includes: (Ozdemir, 2016; Bohl et al., 2018; Barbaglia et al., 2016; Sanders and Irwin, 2017; Brooks et al., 2015; Algieri and Leccadito, 2018; Paris, 2018; Chen, 2015; Tsvetanov et al, 2016; Zhang and Yao, 2016; Lammerding et al., 2013; Brooks et al., 2015; Baldi et al., 2016; Balcilar et al., 2014; Su et al., 2017; Tsvetanov et al., 2016; Zhang and Wang, 2015; Sharma and Escobari, 2018; Su et al., 2017; Sharma and Escobari, 2018; Balcilar et al., 2014), oil inclusive. A major flaw of these studies is that they focused only on the period 2006-2008; despite the fact that crude oil markets predates this periods, suggesting the possibilities of bubbles before those periods. Furthermore, most of these studies employed Granger - causality and Johansen tests that are weak in capturing nonlinear structure and bubbles in the data set. A critical review of these studies also shows that besides, (Balcilar et al., 2014; Ye et al., 2018) and (Sharma and Escobari, 2018) that focused only on oil, other discussed bubbles in oil alongside other commodities. The issue here is that the salient features of each of the baskets of commodities that form the samples used in the studies is ignored (Enders and Lee, 2012). It is also important to state that though (Balcilar et al., 2014; Sharma and Escobari, 2018; Su et al., 2017) focused on oil, none of them considered OPEC series in their analysis. This creates a gap in literature. The current study therefore fills these gaps by first extending the scope of the period of our analysis from February 1, 1986 to October 30, 2018. We equally followed (Herzog, 2015) to employ a more appropriate estimation techniques - Econophysics frequency domain model that allows for stochastic bubbles, not prone to model identification problems to test for the existence of bubble as well as to identify the periods of explosive pricing behavior with focus on obtaining the dates of the beginning and the end of explosive behavior in the WTI, Brent and OPEC oil prices. Furthermore the study attempted to examine the linkages among the series by employing the DCC-GARCH model.

### 3. MATERIAL AND METHODS

This study used daily data for the three world largest oil prices: WTI; OPEC oil price index; and the BRENT Oil prices sourced from 01/02/1986 to 30/10/2018; obtained from the US EIA. As stated earlier, we followed Herzog (2015) to employ an econophysics frequency domain model to conduct our analysis. The strength of our frequency domain model like SADP, GSADF, SPP and GSPP is that it is not mandatory to have information on market fundamental when employing it (Diego et al., 2015); (Harvey et al., 2015). A major flaw of SADP, GSADF, SPP and GSPP methods is that they may lead to hasty conclusion that there is an asset bubble, if they discover that market fundamental, that is positively correlated with the price of an asset is growing unprecedentedly above the existing level, whereas finding empirical evidence of explosive behavior does not necessarily imply evidence of bubbles (Escobari et al., 2017).

(Herzog, 2015) frequency domain model have the capacity to identify the beginning and ending of explosive behavior in a random walk, it can also identify multiple periods of explosive behavior within the historical as well as when new information arrives in asset prices. These features make the model of significant relevant to policy makers and investors. The model is as presented below.

Given that a functional relationship exist between trade volume, trading density and benefit-loss-field, the fundamental law of Physics suggests that

$$q(p,t) = \rho(p,t) * u(p,t) \tag{1}$$

Where trading volume equals  $q(p,t) = \rho(p,t) * u(p,t)$ ,  $\rho(p,f,t)$ ,  $t$  given that  $p_a < p_i < p_b$ . Factoring in the impact of news into our model based on the concept of a jump-discontinuity, we obtained

$$\dot{I}(t) = \int_{p_a}^{p_b} \rho(p,t) dp \tag{2}$$

Here, the integral is well define though  $\rho(p,t)$  has a jump-discontinuity given that a jump connotes a trading stop or news.

In line with equation (1),  $q = \rho * u$ ,  $t$ . We derived equation (3) to dt yields such that:

$$\frac{d}{dt} \int_{p_a}^{p_b} \rho(p,t) dp = \left[ q(p_a,t) - \rho(p_b,t) \frac{dp_a}{dt} \right] - \left[ q(p_a,t) - \rho(p_b,t) \frac{dp_b}{dt} \right]$$

As noted by (Herzog, 2015), if the trading density on both sides changes

proportional, such that  $\frac{dp_a}{dt} = \frac{dp_b}{dt} = \frac{dp_s}{dt}$  and we equate equation

(3) to zero such that  $\frac{dp_s}{dt} [\rho(p_a,t) - \rho(p_b,t)] = q(p_b,t) - q(p_a,t)$ ,

we obtain



$$\frac{dp_s}{dt} = \frac{[q(p_a, t) - q(p_b, t)]}{[\rho(p_a, t) - \rho(p_b, t)]} = \frac{[q]}{[\rho]} \quad (3)$$

Here,  $[q] := q(p_s, t) - q(p_s^+, t)$  and  $[\rho] := \rho(p_s, t) - \rho(p_s^+, t)$ . If we substitute this into equations (3) and (2), we obtain

$$\frac{dp_s}{dt} = \frac{[q(p_a, t) - q(p_b, t)]}{\rho(p_a, t) - \rho(p_b, t)} = \frac{\rho_{max} * u_{max} - \rho_o * u(\rho_o)}{\rho_{max} - \rho_o} \quad (4)$$

Given that efficient markets characterized by many news have potentials to induce on small bubbles; and that inefficient markets characterized by high asymmetric information with little news may induce large bubbles cum with established state of inefficiency in global oil prices (see for instance, Lawal et al., 2018), it is important to account for the sources, types and signals of rational bubbles, thus we employed

$$p_s = -\frac{\rho_o * u(\rho_o)}{\rho_{max} - \rho_o} * t \quad (5)$$

Equation (5) suggests that increasing time,  $t$ , enforces an automatic fall in prices on asset prices as a result of news lag. Thus, more agents access the market to transact on asset, which induces herd behaviour and rational bubble.

The study also examined the bubble periods inter-link among the three oil markets by following (Escobari et al., 2017) to employ a DCC - Generalized Autoregressive Conditional Heteroskedascity (DCC-GARCH). The model is presented as follows:

$$\beta \mu_t = \delta_0 + \delta_1 \beta \mu_t^k + \varepsilon_t \quad (6)$$

Where  $\beta \mu_t^k = (\beta \mu_t^{WTI}, \beta \mu_t^{Brent}, \beta \mu_t^{OPEC})$ ;  $\varepsilon_t = (\varepsilon_t^{WTI}, \varepsilon_t^{Brent}, \varepsilon_t^{OPEC})$ . We model the time-variation of the variance-covariance matrix

$$H_t = G_t C_t G_t$$

$$H_t = G_t C_t G_t \quad (7)$$

Given that  $G_t C_t$  are time varying,  $C_t$  is a (3\*3) correlation matrix and  $G_t$  is a (3\*3) diagonal matrix.

#### 4. RESULTS AND DISCUSSION

Table 1 presents the descriptive statistics of the series used in this research. From the results, it can be deduced that the series are right skewed (in terms of skewness and kurtosis) towards the right, while the Jarque-Bera normality test result shows that all the series are non-normally distributed suggesting that the series are fat tailed with a probability of extreme values higher than normal distribution. The results of the ARCH tests show strong ARCH effect suggesting volatility persistence and clustering.

In Table 2; we present the results of the beginning and ending dates of bubbles identified by our model. Our results show that the pattern of bubbles in each of these series differs from one another.

**Table 1: Descriptive statistics**

Parameters/Series	WTI	Brent	OPEC
Mean	49.87	47.245	48.102
SD	28.814	31.426	32.413
Minimum	10.345	10.142	9.423
Maximum	156.42	159.28	160.294
Skewness	1.190	1.2114	1.282
Kurtosis	0.1548	0.1734	0.1744
Jarque-Bera	1682.394***	1684.244***	1689.401***

Source: Authors, computation 2018. \*\*\*Implies 1% significance level

For instance the first bubble can be traced to uncertainly traceable to fluctuation in supply of oil because of 7 months Kuwait (Gulf) war of 1990/1991. This period was characterized with sharp swings in oil price, for instance oil prices surge up from about \$17 per barrel (p/b) in April 1990 to a peak of \$33 p/b in October, 1990; and fell sharply to about \$17 p/b in March 1991. This development created bubbles in the oil market with various bubbling duration, for instance, the bubble lasted for 5.8 months (i.e., 180 days) for WTI, 7.1 months (i.e., 213 days) for Brent and 6.5 months (i.e., 201 days) for OPEC basket. The results on the duration are consistent with (Kilian, 2008; Balcilar et al., 2014) among others.

Another sharp decline was noticed in between January 1997 and December 1998 as shown in Figure 1b. There was a sharp fall in oil price from \$23 p/b in January 1997 to \$10 p/b in December, 1998. This could be traced to the effect of East Asian Financial crisis of 1997/1998. OPEC responded to this fall in price by augmenting her quota system. This induced an upward shift in price toward recovery in the early part of 1999. Another bubble spring up in November, 2001 and spanned for 2432 days for WTI, 2441 days for Brent and 2424 days for OPEC prices, for instance price rose above \$40 in 2004 from \$25/b in September, 2003. As at August 11, 2005 oil price stood at \$60 and \$75 by the middle of 2006. It reached its highest level at \$147.02 p/b on the 11<sup>th</sup> of July, 2008. The bubble burst such that price fell to as low as \$60 on November 6, 2008, and to \$32/b at the end of December, 2008. The fluctuation in price could be traced to Libya's threat to cut output and OPEC's President prediction of prices regarding events around Northern Summer, and the Lehman Brothers bankruptcy. Other factors that influenced the sharps decline in price include increasing strength of the US Dollar cum with a fall in European demand for oil.

From the curves, it can be seen that a temporary rise in price was noted in 2009 beginning in January to 13<sup>th</sup> February with price rising to as \$35 p/b. This coincides with tensions in Gaza strip.

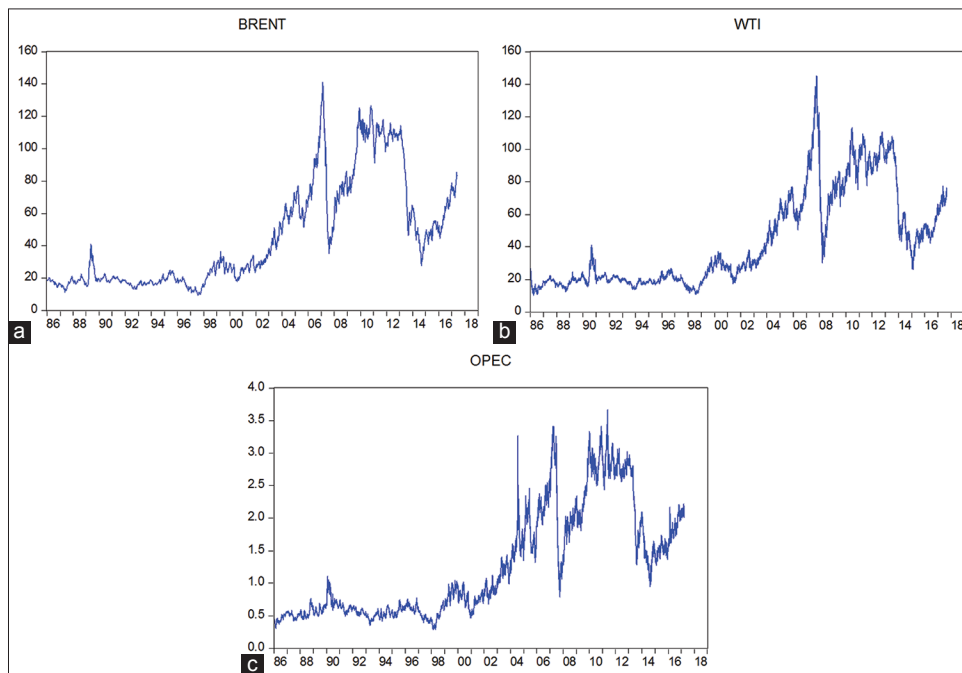
The periods 2010-2013 was characterized with some forms of steady price increase largely influenced political crisis in Egypt, Libya, Yemen, and Bahrain. Other factors are European Debt crisis; sanction on Iran over nuclear claims, refineries problems especially the August 7 California refinery fire, Tropical Storm Ernesto, good news about US economic which all contributed to about 20% hike in prices. On July 10, 2013, oil prices reached \$108.51 p/b and continue to grow to \$116.61 on August 28, 2013 owing to crises in the Middle East and blockage of the Suez Canal.

There was a sharp fall in price on January 2, 2014 from \$110.53 p/b in 2013 to \$95.44 p/b due to relative peace experience in the Middle

**Table 2: Beginning and ending dates of bubbles**

Bubbles dates					
WTI		Brent		OPEC	
Start dates	End dates	Start dates	Ending dates	Start dates	Ending dates
24/04/1990	22/10/1990	20/04/1990	25/11/1990	10/08/1990	01/03/1991
04/11/2001	24/06/2008	06/11/2001	30/06/2008	05/12/2001	08/07/2008
18/12/2010	25/11/2013	23/12/2010	27/12/2013	19/12/2010	27/12/2013
16/01/2015	01/10/2018	23/01/2015	01/10/2018	30/01/2015	01/10/2018

Sources: Authors' computation 2018

**Figure 1:** (a) BRENT prices behaviour, (b) WTI prices behaviour, (c) OPEC prices behaviour

East<sup>2</sup>. By May 24, oil rose to \$107.41 (Brent) due to re-surfing problems in Libya, Houston ship channel collision among others. The period 2015 to the second quarter of 2018 was characterized with low oil prices as prices hovers below \$80 p/b. In some cases it was as low as \$36.46 p/b as noted on the December 30, 2015.

The result of the DCC-GARCH estimation techniques are presented in Table 3. From the result, it can be deduced that the correlations among bubbles in the three series are greater than the unconditional correlations. This suggests strong evidence of interdependence among bubbles periods across these oil markets. It also implies that common macroeconomic shocks impact these series and there is evidence of clustering of prices. We equally observed that correlations among the markets are higher when all prices are either experiences bubble period or when none is experienced. This type of behaviour has been document for stock markets (Lawal et al., 2017; Escobari et al., 2017; Leone and de Medeiros, 2015; Ye et al., 2011).

## 5. POLICY IMPLICATIONS

These results have some policy implications for various economic agents. For instance, as earlier stated, a bubble in oil market could

imply a potential economic slide among investors which usually precedes financial crises, thus, policy makers should pay keen attention to bubble occurrence in oil markets as it may induce financial crisis (Baur and Heaney, 2017; Wang and Wong, 2015; Miao and Wang, 2015; Su et al., 2017; Kunieda and Shibata, 2016; Acharya and Naqvi, 2018). The monetary policy makers (Central bankers) should always be cautious of the tin link between the US dollar and oil prices and the impact of the former on the latter's bubbles, thus, make concerted efforts to achieve exchange rate stability so as to avoid taking unsound decision when making monetary policy decision. Furthermore, since bubbles in the oil price markets are systemic (resulting from war, geopolitical crisis, economic crises) which is difficult to prevent, policy makers should focus on investing in alternative sources of energy especially renewable energy so as to reduce the bubble tendency of oil prices as crude oil responds rapidly to information about these events.

On the part of investors, as argued by (Balcilar et al., 2014) oil bubbles are essentially influenced by two points; first, oil as a significant source of energy impacts global economic activities; second, crude oil is a non renewable energy. These points make crude oil market to be highly sensitive to fluctuation in expectations on economic, geopolitical, wars, and other events that shapes global demand and supply of energy. Investors in the

<sup>2</sup> The relative peace stimulates production in Iran, Libya and North Sea.

**Table 3: Estimation results of DCC-GARCH model**

Series	WTI	Brent	OPEC
Panel A: Mean equation			
$\delta_0$	0.430* (0.0107)	0.164* (0.0524)	0.178 (0.0504)
$\delta_1$	-0.0399* (0.0501)	-0.135* (0.0679)	-0.147* (0.0778)
Panel B: Mean equation			
c	0.00445* (0.000701)	0.0504* (0.0168)	0.0304* (0.00541)
A	0.527* (0.0128)	0.482* (0.0842)	0.304* (0.0744)
B	0.487* (0.0415)	0.473* (0.142)	0.642* (0.138)
Panel C: Multivariate DCC equation			
$\theta_1$		0.428* (0.0472)	
$\theta_2$		0.137* (0.0342)	
Observations		11675	
$\chi^2$		16.59	
$\chi^2$ (P-value)		0.00544	

Source: Authors' computation 2018. \*Represents 1% significant level, figures in parentheses are standard errors  $\beta\mu_i = \delta_0 + \delta_1\mu_i^k + \varepsilon_i$ , where  $\beta\mu_i^k = (\beta\mu_i^{WTI}, \beta\mu_i^{Brent}, \beta\mu_i^{OPEC})$ ;  $\varepsilon_i = (\varepsilon_i^{WTI}, \varepsilon_i^{Brent}, \varepsilon_i^{OPEC})$ . The variance equation is expressed as  $h_i^k = c^k + a^k h_{i-1}^k + b^k (\varepsilon_{i-1}^k)^2$  follows: for  $i =$  (WTI, Brent, OPEC)

crude oil markets should speculate in the product by effectively accommodating and calibrating the news from these events into their investment decision endeavors.

## 6. CONCLUSION AND RECOMMENDATION

The current study employed a frequency domain estimation technique to examine the existence or otherwise of rational bubbles in the global oil prices covering the three major oil price indices – WTI, Brent and the OPEC Basket using daily data source from February 11, 1986 to October 30, 2018. We extend existing literature in three ways - Methodology, Data coverage and Series coverage. For instance, the study employed an econophysics frequency domain framework to examine the existence or otherwise of rational bubbles in the series. Existing studies employed time domain PSY, GSADF, BADF among others. As argued by (Escobari et al., 2017) though these techniques are good at testing for explosive behavior in asset prices, finding explosive behavior does not necessarily state that bubbles exist. Our study extends literature by building a mathematical model of bubbles from an econophysics frequency domain framework that has the capacity to identify both explosive behavior and bubbles in oil price indices.

In terms of data coverage, the current study employed daily data on the three most popular oil series - WTI, Brent and OPEC basket. Existing literature often uses one of the series or at best two - WTI, BRENT. Hardly will one see a literature that considered the three as used in the current study. OPEC Basket is key in determining global oil behavior as OPEC is a key player in the global oil market. It is also interesting to state that we employed daily data from February 01, 1986 to October 30, 2018 making our work cover the most current trends in the global oil market.

Our findings show that the three prices experienced bubbles in four periods, 20<sup>th</sup> April 1990 to 10<sup>th</sup> August, 1<sup>st</sup> March 1991; 4<sup>th</sup> November, 2001 to 8<sup>th</sup> July, 2008; 18<sup>th</sup> December, 2010 to 27<sup>th</sup> December, 2013; and 16<sup>th</sup> January, 2015 to 1<sup>st</sup> October, 2018. We attempt to provide explanations on each of these bubble dates using geopolitical and economic events as a practice in literature. Our findings reveal that crude oil prices respond rapidly to

information on geopolitical, war and economic events; and that investors in the crude oil markets are eager to beat the market. We also noted that oil price bubbles are largely influenced by the fact that oil is a major source of energy for global economic activities and that oil is non-renewable.

We noted that bubbles have some economic consequences like welfare loss resulting from distortion in prices and economic instability, increase in unemployment, inflation among others. We recommend that to enjoy stability in oil prices, concerted efforts should be made to reduce the over-sensitivity of crude oil future market to information by increasing production of alternative sources of energy.

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