

Article

Detecting West Texas Intermediate (WTI) Prices' Bubble Periods

Theodosios Perifanis

Energy and Environmental Policy Laboratory, Department of International and European Studies, University of Piraeus, 18532 Piraeus, Greece; tperifanis@unipi.gr; Tel.: +30-210-414-2657

Received: 8 June 2019; Accepted: 8 July 2019; Published: 10 July 2019



Abstract: Oil prices have had considerable surges and bursts since the first oil crisis of 1973. Until then its price was stable, with almost zero volatility. Since then, apart from the two oil crises of 1973 and 1978/9, oil prices had consecutive bubble episodes like the surges up to 2008 and 2014 and their successive bursts, respectively. The trace of these bubble periods is of crucial importance for policymakers, since their drivers and consequences impact global economic developments. Phillips et al. and Phillips et al. methodologies are applied to detect whether West Texas Intermediate prices experienced bubble periods. Both methodologies suggest that WTI prices experienced explosive episodes, which could be fundamentally, speculatively, or politically attributed. Some suggested periods coincide for both methods, but the second methodology seems to be more sensitive than its predecessor is, leading to better bubble detection but also to identification of non-existent bubbles. The identified bubble periods are compared to relevant research in the literature concerning their presence, duration, and explosiveness. The main goal of the research, apart from the detection of bubbles' presence and duration, is to identify the causal underlying reasons for each explosive episode. Further, we compare the start and endpoints of each bubble episode with time-points when structural changes occurred. The contribution of the paper is that it clearly defines the bubble episodes with their corresponding drivers. The paper identifies the importance of market fundamentals' shifts in explaining the bubble periods. The findings of the papers can help policymakers and other stakeholders to monitor oil price shifts and their underlying reasons, and then proceed with prompt actions. Since bubble episodes are fundamentally explained, then the practical utility is that by focusing on the market fundamentals, stakeholders can avoid actions that could result in market failures.

Keywords: WTI; bubbles; explosive prices; Augmented Dickey Fuller (ADF) test; PWY (2011); PSY (2015)

1. Introduction

The global oil market suffered heavy disruptions during many periods in the past. These periods start from the first oil crisis of 1973. The second came a few years later in 1978–1979. In the 80s, it was the OPEC collapse of 1986 [1]. The oil price surged in 1990/1991; time spot coinciding with the Gulf War. The oil price was increasing from 2001 to 2008, when the global financial crisis occurred. From 2011 to 2014, it remained at high levels until a burst occurred, reaching the lowest level in 2016. Since 2016, the price has increased. It is easily understood that the oil price has followed a pattern since 1973, in which a hike is followed by a burst and vice versa. This course with structural breaks, sudden upward or downward, called jumps reflect the high volatility of the market. The duration of these movements is also not the same. It took more than three months for oil price to peak in 1991, but seven years between 2001 and 2008 (Figure 1).

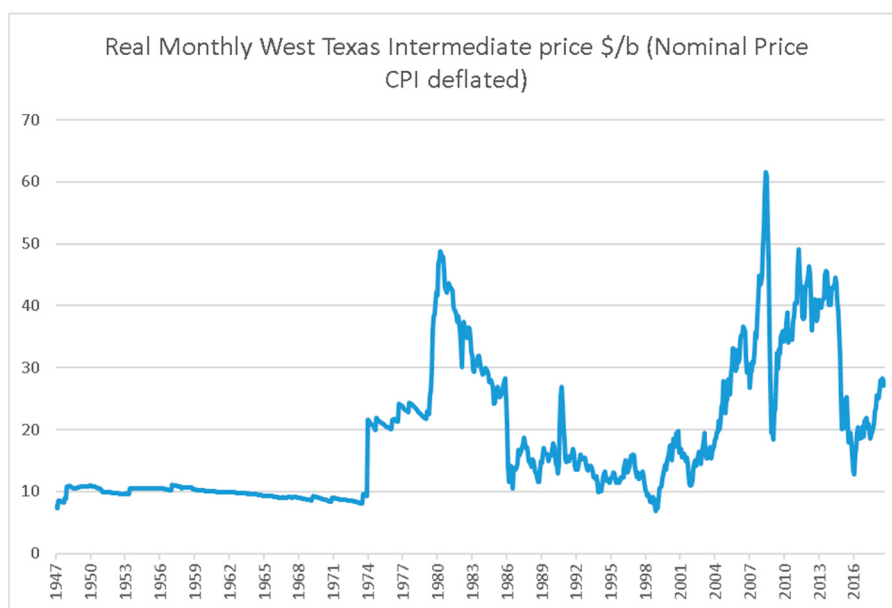


Figure 1. Real Monthly West Texas Intermediate (WTI) Price—Nominal WTI CPI (Consumer Price Index) deflated, Author’s calculations, source: FRED.

Testing of bubble episodes in financial markets is thoroughly conducted. The main debate is whether financial markets are efficient and rational, or driven by speculation and exuberance. Market participants and experts might be hesitant to explain whether a period of extreme increases or decreases has to do with rational expectations. Regulators are also in need for robust empirical tools to identify bubble periods in order to detect them, if not intervene during them. The majority of literature uses the word “bubble” to refer to periods of explosiveness. This is the period of an abrupt asset’s price increase, that ends with a collapse. Nevertheless, what is the fundamental value of oil? There are no widely accepted processes for calculating this kind of value, and it is constantly changing as new information enters the market. Apart from the liquidity, which is present in the market, oil is a storable commodity. Storages and oil glut are playing a crucial role in the oil price formulation, as Perifanis and Dagoumas [2] suggest. Many use Pindyck’s [3] method to reach the fundamental value of oil. The convenience yield is defined as the sum of discounted oil inflows or “dividends”, which is the total benefit of inventory holding for the physical holder, in contrast to the owner of a financial contract on the respective asset.

Furthermore, we do not know which the driving causal forces are, even if we know that the oil market runs a period of explosiveness. Explosive prices might be attributed to fundamental disruptions, or traders’ speculation. Kaufmann and Ullman [4] use the hypothesis that if speculation played a significant role, then futures prices should drive spot prices, and price innovations should start from future markets. Their results are mixed as price innovation stem from both spot and futures prices for different blends. Bidirectional causality between spot and futures prices is also suggested by Polanco-Martinez and Abadie [5] for intra-weekly, weekly, fortnightly, and biannual horizons. Futures only drive spot prices only in monthly horizons. Irwin and Sanders [6] support that Granger causality and long-horizon regression tests suggest no causal relationship between returns and volatility in the crude oil and the positions of exchange-traded index funds. Kilian and Murphy [7] suggest that the real oil price soar between 2003 and 2008 was entirely attributed to shifts in the global demand flow for oil. They further add that, as soon as the global economy recovers from the financial crisis, then the real oil price will start increasing again. As a result, additional regulation over oil trading will not help anyhow avoiding price soar again. Juvenal and Petrella [8] suggest that oil prices are historically driven by the strength of global demand. On the contrary, speculation played a contributory role in the oil price increase between 2004 and 2008. The following decline of the late 2008 is mainly attributed

to the negative demand shock. Speculation played an additive role again as eroded the financial statements of many market participants, which curtailed their demand for commodity assets. Knittel and Pindyck [9] even if they cannot rule out the possibility of trading as an effect on oil price, they are certain that this is not the case for the sharp changes in oil price since 2004.

Oil bubbles can be evident in the future, as rapid changes in the oil market fundamentals like demand and supply shocks can result into explosive prices. Supply and demand elasticities may also affect oil pricing, especially when they reach very low levels. Therefore, the implementation of methodologies towards identifying and explaining bubbles is very important. Market participants and policy makers need robust methodologies to identify the timing of market exuberance and act analogously. Regulatory institutions need to understand or even predict the magnitude and the duration of a price explosion, and then assert its implications to the overall market. This paper focuses on a very important oil market, namely the WTI, whose evolution affects the global economy.

This paper is organized as follows: the Literature review follows the Introduction, then the Methodology describes the empirical framework, the Results are presented, and then the Conclusions are reached.

2. Literature Review

There is extensive research on bubbles. Literature's length is not only justified by phenomenon's importance, but also by the difficulty of testing for its presence, duration, and explosiveness. The present research comes to add to the existing research to shed light on the causal underlying reasons for each explosive episode. The findings of the papers can help policymakers and other stakeholders to track oil price shifts and their underlying reasons and then proceed with prompt actions. The contribution of the paper is that it clearly defines the bubble episodes with their corresponding drivers. Furthermore, we compare the start and endpoints of each bubble episode with time-points when structural changes occurred. A rational asset price bubble arises when the asset's price exceeds the asset's fundamental value, which is the present value of the future dividend payments. As mentioned before, financial bubble literature is extended due to the importance of the phenomenon. Diba and Grossman [10] point out that the existence of rational bubbles means the non-stationarity of the means of differenced time series. Their hypothesis is that if rational bubbles exist, then their time series should present higher order non-stationarity. Their tests suggest that the stock prices present lower non-stationarity than observable variables for their market fundamentals, i.e., there are no rational bubbles in stock prices. Further, they add that unit root and co-integration tests may be unable to detect periods of exuberance when there are periodical bubble collapses. Tirole [11] proposes that Overlapping-Generations (OLG) models should be used for assets held for speculative purposes, and as a result, for bubble investigation. Evans [12] further adds that periodically collapsing bubbles cannot be identified by traditional tests, which compare the explosiveness and stationarity of stock prices to dividends. Kirman and Teyssiere [13] suggest that the reason behind bubbles is expectation switching by individuals' forecasting rules changes, and these kinds of changes are self-reinforced. In addition, the standard unit root test performed poorly, while their analysis in bubble detection suggested that long memory and switching regime effect act combinedly. The strong persistence in the volatility is the result of a mix of changes in regimes and long-range dependence.

Barberis et al. [14] suggest with their model that good news about fundamentals can initiate a bubble episode, and then bubble episodes are concurrent with high trading volumes, which will then be increased with past returns. Bao et al. [15] propose that bubbles arise even faster in smaller markets. Further, market participants coordinate on following trends to predict asset prices giving opportunities for bubble formation. Credit is often connected, in the literature, with the rise of bubbles in the financial markets. Werner [16] suggests that an asset price bubble can exist even when there are debt constraints induced by limited implementation of debt repayment. Jorda et al. [17] study several instances and find that not all bubbles are alike. They find that the critical factor for bubbles' danger is credit. Martin and Ventura [18] suggest that low interest rates result in credit expansions,

which cause inefficient cash flows. Albuquerque et al. [19] find that bull and bear return periods in the stock markets are highly correlated with the fundamentals. Hirano et al. [20] find that government guarantees can cause even riskier bubbles. When they overpass a critical size, they reduce production. Miao et al. [21] suggest that property taxes, Tobin's taxes, macroprudential policy, and credit policy can prevent bubbles. Moreover, collaterals relax credit constraints and can lead to bubbles.

Kunieda and Shibata [22] argue that a useless asset can extend an investor's credit, and as a result, drive to bubbles. Purchasing the asset, in order to avoid the bubble crash, is the second best option. Taxing depositors and subsidizing investors is the best in order to avoid a bubble. Nemoto [23] finds that credit availability positively affects prices, and thus the more credit is supplied the higher the asset prices. Acharya and Naqvi [24] also verify that monetary loosening induces investors to higher returns and as a result to bubble amplification. Wang et al. [25] study the banking stability in conjunction with asset bubbles. They study 26 economies. Their results are that deposit insurance and limited liability create the favorable conditions for banks to hold bubble assets for risk premium purposes. Further, supervisory intensity, leverage ratio, and credit spread affect the risk premium inducing banks to hold bubble assets. Since banks hold such kind of assets, then their stability will deteriorate due to internal leverage, cash withdrawal, credit friction and network effects. There is no difference whether the bubble asset shock is domestic or foreign, since they both affect banking stability, which is detrimental to economic growth. Wang and Chen [26] confirm that trading volume and price volatility are the driving forces behind equity bubbles. In addition, monetary policy determinates the bubble episodes. Last, credit expansion with its lag term plays an augmented role into bubble episode formation.

Gronwald [27] using a forward recursive Augmented Dickey Fuller (ADF) test detects periods of explosiveness in 2005/2006 and 2007/2008. Fantazzini [28] proposes a negative bubble in 2014/2015. Phillips and Yu [29] propose a dating procedure, which entails recursive calculations of right sided unit root tests to identify when a mild explosive period starts and ends. Their simulations were tested in finite samples with satisfactory results, if the explosive period is of a duration length and up. Phillips, Wu and Yu [30] (from now referred as PWY (Phillips Wu and Yu)) return to propose a new approach applying recursive regression, right sided unit root tests, and a method of confidence interval calculation for the growth parameter in market explosiveness. They test their method to the Nasdaq data and verify the 90s exuberance, while they are able to date-stamp its duration with significant accuracy. Phillips, Shi and Yu [31] (from now referred as PSY) improve their previous work by introducing a new recursive testing procedure and date-stamping procedure for multiple-bubble events. The Generalized Sup ADF (GSADF) test is a rolling window right-sided ADF test with double-sup window selection criteria. They suggest that their improvement to the Sup ADF (SADF) test is able to detect multiple episodes of exuberance and collapses in the sample range. Thus, GSADF is a more sensitive process. They further notice that the PWY (2011) date-stamping method fails to recognize the second bubble, when there are more than one bubbles in the sample. This is not the case with the PSY (2015) method. Their testing period is between 1871 and 2010 for the S&P 500 price-dividend ratio when there are multiple episodes of exuberance.

Harvey et al. [32] suggest a complementary date-stamping process for a single bubble. Experienced traders are thought to detect bubbles in market improving market efficiency. Shestakova et al. [33] find that in mixed-experienced markets, market efficiency is very sensitive to experienced traders' prior success. On the contrary, when they try to test the experience effect, they find that experience does not have a significant effect since all-experienced and all-inexperienced markets have almost the same market efficiency. Greenwood et al. [34] discuss the Fama [35] proposals. They agree with Fama that an abrupt increase in portfolio returns does predict low future returns. The justification is that in a portfolio even when some assets exhibit sharp increases and busts, others can continue to have positive returns. They also confirm that sharp increases are positively connected with increased probability of a future bust. Future returns, and consequently, bubble crashes, can be predicted by volatility, turnover, issuance, and run-up's price path.

Research conducted by Gilbert [36] suggests that even if there is strong evidence of explosiveness in the copper market, this cannot be stated for the oil market as the results are more problematic and test procedure outcomes can be differently interpreted. He further adds that index-based investment may have been accountable for exuberance in energy prices. The average price effect of index-based investment on energy is 3% to 5% between 2006 and 2007, but soars to 20% and 25% in the first half of 2008. Shi and Arora [37] test the three-regime models of Brooks and Katsaris [38], and Schaller and Van Norden [39] on oil prices. They conclude that their fitting is quite good and that the probability of a bubble collapse significantly increases in late 2008, early 2009. They further add that the probability increases for both expansion and collapsing regimes for very short periods i.e., bubbles are short-lived. Lammerding et al. [40] suggest the existence of speculative bubbles in oil price dynamics. Fan and Xu [41] detect the structural breaks when market fundamentals and speculation played an important role. There were swifts in 2004 and 2008. The first is justified by the strong demand by emerging economies and the entrance of speculative funds in the market, while the second was caused by the financial crisis. Further, speculation and episodic events were the main causal drivers between 2000 and 2004, while speculation was the main driver between 2004 and 2008. Market fundamentals were the main drivers after the 2008 crisis, when global economy started its slow rebound. To sum up, speculation played an increasingly important role from 2000 to 2008. Corbet et al. [42] use the Phillips et al. [30] methodology in conjunction with fundamentals to research whether Bitcoin and Ethereum experienced bubble periods. Their results confirm that Bitcoin is in a bubble phase since its price is over \$1000. Pan [43] finds that there were bubbles in gold and silver during the 2007–2009 subprime financial crisis and the European sovereign debt crisis. He also adds that the pessimistic market sentiment increases the probability of bubble creation in the gold market. Hu and Oxley [44] (2018) not only suggest there were asset price bubbles in Japan in the 80s and 90s, but they also find contagion from the equity to the real estate market. Geuder et al. [45] use the Phillips et al. [31] methodology, and suggest find that Bitcoin had several bubble periods in 2017, but since January 2018 this kind of behavior does not exist. Chaim and Laurini [46] verify that Bitcoin had bubble episodes in the period between early 2013 and mid-2014, but on the other hand, it did not have in 2017.

Matsuoka and Shibata [47] suggest that bubbles can divert from optimal productivity technology choices. Hirano et al. [20] suggest that the relationship between the bubble size and production level is non-monotonic, meaning bubbles increase production levels until they become too big. If they surpass a certain threshold, then they decrease production levels. As a result, state bailouts improve production efficiency initially, but after a certain level they can increase the boom-bust cycles requiring even larger amounts by taxpayers. The optimal policy for taxpayers is neither the no-bailouts nor the full-bailouts, but the partial bailouts. Narayan et al. [48] find that asset bubbles both positively and negatively affect the economic welfare. There is an asymmetry, as asset bubbles more positively influence welfare than negatively.

Ways to avoid bubbles in the financial markets are proposed by Wan [49], who proposes that capital gain taxes, transaction taxes, rebate options, and fixed periods of asset usage can prevent the occurrence of rational asset bubbles. Moreover, since regulators and policymakers are sure for the existence of an asset bubble, then they can choose between a hard or soft landing. Hard is landing is when policymakers decide to use financial or tax tools to cause a bubble crash. If this is the case, then the market value after the crash might be lower than the fundamental value, which is a second policy failure. On the other hand, soft landing is when regulators use capital gain taxes to make the rising bubble a constant value. Wan [49], last, concludes that a mixture of heterogeneous beliefs, market frictions and speculative trading motives can be accountable for bubbles. Fenig et al. [50] propose that leverage constraints do not only not prevent asset price bubbles but also drive prices higher. This is why participants supply more labor to obtain a wealth buffer stock. Investors' wealth then flows into the asset markets inflating prices, thus diverging them from the fundamental values. Inflation targeting is more successful at bubble deflation. Ciccarone et al. [51] suggest, under sticky prices and credit frictions, that the policy of a central bank adjusting the nominal rate to prevent the formation of

asset bubbles in the financial markets is optimal when its reaction to inflation and output deviations are small. If this does not hold, then the central bank is in danger of increasing bubble volatility and putting the economy into recession.

Zhang and Yao [52] identify positive oil price bubbles between 2001 and 2008. In detail, they find that bubbles drove Brent, WTI, and diesel prices, while gasoline was driven by fundamentals. Zhang and Wang [53] find that WTI fundamental prices do not present the volatility of market-trading prices, and thus bubbles in crude oil price exist. They suggest that a speculative bubble was present in the pre-2008 burst. Figuerola-Ferretti et al. [54] suggest two bubbles in Brent and WTI prices, one positive prior the 2008 crisis and a negative one between 2014 and 2016. Global economic activity can well explain the first one, but speculation cannot. As for the second, US shale production contributes to the price decline, but it is not among the decisive factors. Further, VIX did not decisively influence oil prices. Su et al. [55] detect oil price bubbles in 1990, 2005, 2006, 2008, and 2015. They suggest that long-term bubbles in WTI prices have speculation as a driving force. Geopolitical events such as wars drive oil prices between prior their outbreak and until their end. As a result, they have short-lived implications. Garcia-Carranco et al. [56] suggest that oil price bubbles do not influence the intrinsic time of volatility, but they do influence the metric of volatility horizons.

The review undertaken revealed that there is an extensive research on crude oil price bubbles. Different methodologies are applied over different time periods. This paper contributes to the literature by applying recent methodologies, namely the PWY (2011) and PSY (2015) statistics and date-stamping processes, to detect and trace WTI oil price explosive periods. Moreover, the results of the methodologies are explained and compared to each other and to relevant research in the literature, as well as to provide suggestions for policy makers.

3. Methodology

3.1. The PWY (2011) Test

First, the PWY (2011) test for bubbles should be introduced, which is conducted by repeated calculations of the Augmented Dickey Fuller (ADF) test (Said and Dickey [57]) on a forward expanding sample sequence. The sup value of the corresponding ADF sequence is the test statistic. As for the window size for the sample, suppose that it is denoted as r_w , is between r_0 the minimum sample window and 1, which is the total sample size. The test is calculated with starting point r_1 of the sample sequence at 0, in order for the r_2 the endpoint of each point, to equal r_w . The r_2 or endpoint of each sample moves from r_0 to 1. The first calculation of the ADF test from point 0 to

is defined as $ADF_0^{r_2}$. Since we have a sequence of ADF statistics, then the PWY (2011) test is the sup statistic calculated on the forward recursive regression.

$$SADF(r_0) = \sup_{r_2 \in [r_0, 1]} ADF_0^{r_2} \quad (1)$$

Homm and Breitung [58] compared alternative methods to test for speculative bubbles. They compared methods proposed by Barghava [59], Kim [60], and Buseti and Taylor [61]. What can be stated for the aforementioned methods is that they are close to the approach spirit of SADF of PWY (2011). Initially, the recursive calculation of the statistic is conducted, in order for the calculation of the sup functional of the recursive statistics to follow. Homm and Breitung [58] conclude that the PWY (2011) approach is the most appropriate in detecting bubbles.

3.2. The Phillips, Shi and Yu (PSY) (2015) Test

Phillips, Shi and Yu [31] propose an improvement of the previous test with the Rolling Window GSADF test for bubbles. This is based on repeated ADF regressions on subsamples in a recursive mode.

$$\Delta y_t = \hat{\alpha}_{r_1, r_2} + \hat{\beta}_{r_1, r_2} y_{t-1} + \sum_{i=1}^k \hat{\psi}_{r_1, r_2}^i \Delta y_{t-i} + \hat{\varepsilon}_t \quad (2)$$

where k is the lag order.

The improvement has relationship with the starting point r_1 in (2), which changes within the feasible range from 0 to $r_2 - r_0$. The GSADF statistic is the largest ADF value in all feasible ranges from r_1 to r_2 by the double recursion calculation. The GSADF (r_0) is then summarised by

$$GSADF(r_0) = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} \left\{ ADF_{r_1}^{r_2} \right\} \quad (3)$$

The GSADF statistic is compared to the respective critical value to investigate whether bubbles exist in the sample. PSY (2015) recognize that the asymptotic GSADF distribution is dependable on the smallest window size r_0 . This is again dependable on the sample size as the smallest window has to be relatively large for small samples and small for samples consisted of many observations. Many simulations later PSY (2015) suggest that the minimum window r_0 based on a lower bound of 1% of the full sample can be calculated by the

$$r_0 = 0.01 + 1.8 / \sqrt{T} \quad (4)$$

where T is the number of sample observations.

3.3. Date-Stamping Strategies

The PWY (2011) process for bubble date-stamping is the conduct of right-tailed recursive ADF tests from the beginning of the sample to the latest chronological observation τ . Evans [12] criticizes this kind of strategy, as that of Diba and Grossman [62], due to the fact that if multiple collapsing bubble episodes exist in the sample, then pseudo-stationary behavior might be detected in the data. The improvement of PSY (2015) is to conduct a double recursive test with a flexible window called backward sup ADF for better bubble detection.

The backward sup ADF is the application of the sup ADF tests on backward expanding sample sequence. The samples have as starting points the 0 to $r_2 - r_0$ observations where r_2 is the endpoint.

The respective ADF statistic sequence is $\left\{ ADF_{r_1}^{r_2} \right\}_{r_1 \in [0, r_2 - r_0]}$. Then we obtain the backward SADF statistic as the sup value of the ADF statistic sequence:

$$BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} \left\{ ADF_{r_1}^{r_2} \right\} \quad (5)$$

We can tell that the PWY (2011) method is the recursive ADF for bubble detection where the backward sup ADF test is conducted with $r_0 = 0$. For both methods, we can spot a bubble between the first chronological observation with ADF statistic over the critical value and the last chronological

observation with ADF statistic below the critical value. We can denote the starting point of a bubble as $\lfloor T\hat{r}_e \rfloor$, and the termination date as $\lfloor T\hat{r}_e \rfloor + L_T$, where $L_T = \log(T)$, to avoid short-lived jumps. The starting and termination date observation for PWY (2011) can then be expressed as:

$$\begin{aligned}\hat{r}_e &= \inf_{r_2 \in [r_0, 1]} \left\{ r_2 : ADF_{r_2} > cv_{r_2}^{\beta_T} \right\} \text{ and} \\ \hat{r}_f &= \inf_{r_2 \in [\hat{r}_e + \delta \log(T)/T, 1]} \left\{ r_2 : ADF_{r_2} < cv_{r_2}^{\beta_T} \right\}\end{aligned}\quad (6)$$

where $cv_{r_2}^{\beta_T}$ is the $100(1 - \beta_T)\%$ critical value sequence of the ADF statistic depending on the $\lfloor Tr_2 \rfloor$ observations.

The respective duration for the PSY (2015) method can be written as $\lfloor T\hat{r}_e \rfloor + \delta \log(T)$, where $\delta \log(T)$ is the minimal bubble period with δ being a frequency-dependent parameter. The bubble for the GSADF method is then identified between the observation points

$$\begin{aligned}\hat{r}_e &= \inf_{r_2 \in [r_0, 1]} \left\{ r_2 : BSADF_{r_2}(r_0) > scv_{r_2}^{\beta_T} \right\} \text{ and} \\ \hat{r}_f &= \inf_{r_2 \in [\hat{r}_e + \delta \log(T)/T, 1]} \left\{ r_2 : BSADF_{r_2}(r_0) < scv_{r_2}^{\beta_T} \right\}\end{aligned}\quad (7)$$

with $scv_{r_2}^{\beta_T}$ to be the $100(1 - \beta_T)\%$ critical value sequence of the sup ADF statistic.

The SADF test is conducted by the repeated application of the ADF test for each $r_2 \in [r_0, 1]$, when the GSADF test applies the repeated backward sup ADF test for each $r_2 \in [r_0, 1]$. The PWY (2011) and PSY (2015) date stamping methods can now be respectively noted as

$$\begin{aligned}SADF(r_0) &= \sup_{r_2 \in [r_0, 1]} \left\{ ADF_{r_2} \right\} \text{ and} \\ GSADF(r_0) &= \sup_{r_2 \in [r_0, 1]} \left\{ BSADF_{r_2}(r_0) \right\}\end{aligned}\quad (8)$$

For more details, please be advised PSY (2015). The research was conducted in R programming language using the packages MultipleBubbles and strucchange.

4. Data

The monthly spot WTI prices by Federal Reserve Economic Data (FRED) for the period between January 1947 and September 2018 are used. The nominal prices are deflated with the seasonally adjusted monthly Consumer Price Index (CPI) for all the Urban Consumers by FRED in order to avoid inflationary explosiveness. Monthly prices are used only due to the monthly calculation of CPI, as daily data deflated by monthly aggregate could bias our results. Therefore, the estimation of real oil prices are calculated, consisted of 861 observations. Oil had several hikes and busts during this long period. From 1947 to 1973, the first oil crisis, WTI had very stable real prices. Since 1973 oil became a global commodity with extraordinary volatility. Oil is the most traded commodity with gold. The summary statistics of our data are presented in Table 1.

Table 1. Descriptive Statistics.

Summary Statistics	Values
Mean	18.6531
Median	14.1688
Maximum	61.5874
Minimum	6.8613
Std. Deviation	11.1339
Skewness	1.2091
Kurtosis	3.5496
Jarque–Bera	220.6267
Probability	0.0000

The positive skewness means that our data's distribution has a long right tail. Kurtosis is above 3 (of the normal distribution), and as a result is peaked (leptokurtic), Author's calculations.

Data are first tested for stationarity with the Augmented Dickey Fuller (ADF) (Said and Dickey [57]) test and with the Zivot and Andrews [63] test allowing for one structural break. It is confirmed that the data are stationary at first difference I(1). Results are presented in Table 2.

Table 2. Unit root tests for the West Texas Intermediate (WTI) real price between 1/1/1947 and 1/9/2018.

Stationarity Tests	Augmented Dickey Fuller (ADF) Test	Critical Values			Zivot and Andrews (1992) Test	Critical Values		
		1%	5%	10%		1%	5%	10%
WTI real oil prices	−1.1941 ^a	−2.58	−1.95	−1.62	−3.2715 ^a	−5.34	−4.80	−4.58
Δ (WTI real oil prices)	−16.1597 ^b				−20.8989 ^b			

Both tests have as a null hypothesis (H_0) that a unit root exists, (Author's calculations). ^a: Acceptance of the null hypothesis for 1%, 5% and 10%. ^b: Rejection of the null hypothesis for 1%, 5% and 10%.

5. Empirical Results

The WTI price explosiveness for the period between 1947 and 2018 is tested. This is a long period with oil crises like those of 1973 and 1978/79, price collapses like that of the 80s, peaks like that of the first half of 2008, and financial crises like the one which occurred in the second semester of 2008. It is easily expected that the statistical properties of the time series (mean, variance, and autocorrelation) are not constant over time. This is again verified by both unit root tests, ADF, and Zivot and Andrews [63] tests. But this does not preclude explosiveness in the data. In addition, the rapid swifts in the oil market prelude structural breaks. The preliminary detection of when these structural breaks occurred, and their potential causes are presented in Table 3. Structural breaks coincide with important events in the market which caused high volatility.

Table 3. Structural oil price breakpoints and important events.

Date	Important Events in the Oil Market
1/2/1973	First Oil Crisis
1/7/1979	Second Oil Crisis
1/12/1985	Near OPEC collapse
1/2/2005	Beginning of Oil price surge until Financial Crisis
1/3/2012	Oil price rebound until 2014

Events are presented in conjunction with breakpoints. Events' dates are not identical with that of breakpoints. Author's calculations.

The whole sample SADP and GSADF tests are applied in order to test for such explosiveness. The two statistic values with their corresponding critical values are compared. The finite sample critical values are obtained by Monte Carlo simulations with 2000 replications and for a sample size of 861 observations. The rule for the smallest window of $r_0 = 0.01 + 1.8/\sqrt{861}$ is applied, and this is

61 observations. Both SADF and GSADF statistics for the whole sample period exceed their 1% right tail critical values, $4.91 > 1.99$ and $5.01 > 2.70$ respectively, thus suggesting the existence of explosive sub periods. The calculations are conducted with transient dynamic lag order $k = 0$. The results are presented in Table 4.

Table 4. The SADF TEST and the GSADF TEST of the West Texas Intermediate (WTI) Price.

	Test Stat.	Finite Sample Critical Values		
		90%	95%	99%
SADF	4.91	1.25	1.49	1.99
GSADF	5.01	2.07	2.28	2.70

Notes: Critical values calculated by 2000 replications of Monte Carlo simulation and sample size of 861 observations. The minimum window has 61 observations. Author's calculations.

The detection of when these explosive sub periods existed follows. The PWY (2011) date-stamping method is first applied. The periods suggested by the PWY (2011) methods are those when the BADF sequence is over its corresponding 95% critical value. The PWY (2011) based on the SADF test detects only two periods of exuberance. These are between July 1979 and January 1982, a period coinciding with the second oil crisis, and between May 2008 and July 2008, which coincides with the period when oil reached its highest price. As PSY (2015) suggest, PWY (2011) is a conservative tool, which proposes only two periods (one extremely short-lived) for the WTI prices. What the PWY (2011) date-stamping procedure might miss, as episodes of exuberance are the first oil crisis of 1973, and the oil price collapse of the 80s. The results are presented in Figure 2.

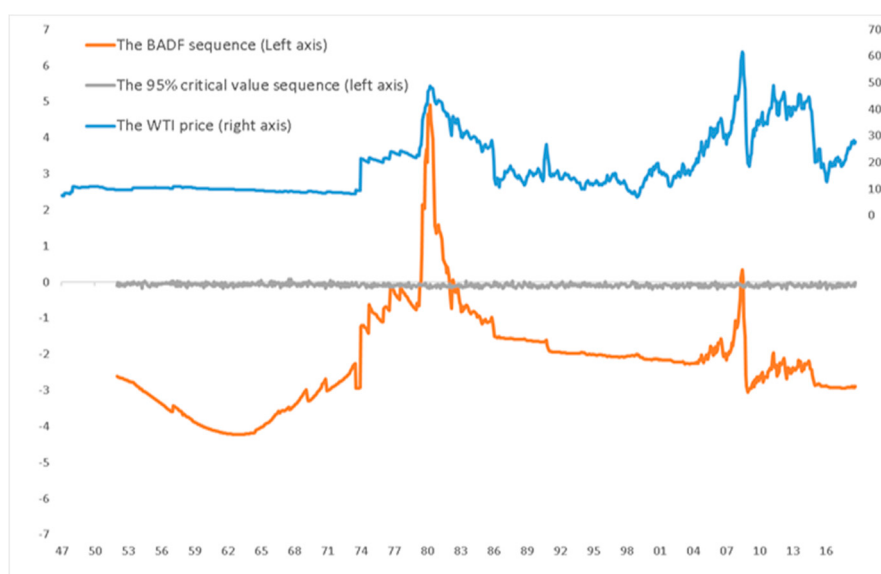


Figure 2. Date-Stamping Explosive periods in the West Texas Intermediate (WTI) prices: the SADF Test, Author's calculations.

More periods are suggested when the PSY (2015) date-stamping strategy is applied, by comparing the backward SADF statistic sequence with the corresponding 95% SADF critical value sequence. More precisely, these seven periods are between July 1964 and August 1966, December 1968 and February 1969, January 1974 and February 1974, July 1979 and July 1981, August 2005 and September 2005, April 2006 and August 2006, and October 2007 and August 2008. What can be noted is that the two methods suggest two common periods. PWY (2011) suggests that an episode of exuberance exists between July 1979 and January 1982, when PSY (2015) suggests that again it starts from July 1979 to July 1981 for the first period, while for the second period PWY (2011) suggests that it occurred between May 2008

and July 2008, while PSY (2015) proposes between October 2007 and August 2008. However, the PSY (2015) is a much more sensitive tool suggesting seven periods. The period between January 1974 and February 1974 coincides with the first oil crisis of 1973. For the periods between August 2005 and August 2008, one can say that they coincide with the period from 1/1/2004 to end of 2008, when the oil had an increasing price course until the financial crisis. What is hard to explain is that the PSY (2015) date-stamping strategy suggests two periods prior the 1973 era when the volatility was extremely low. The results are presented in Figure 3.

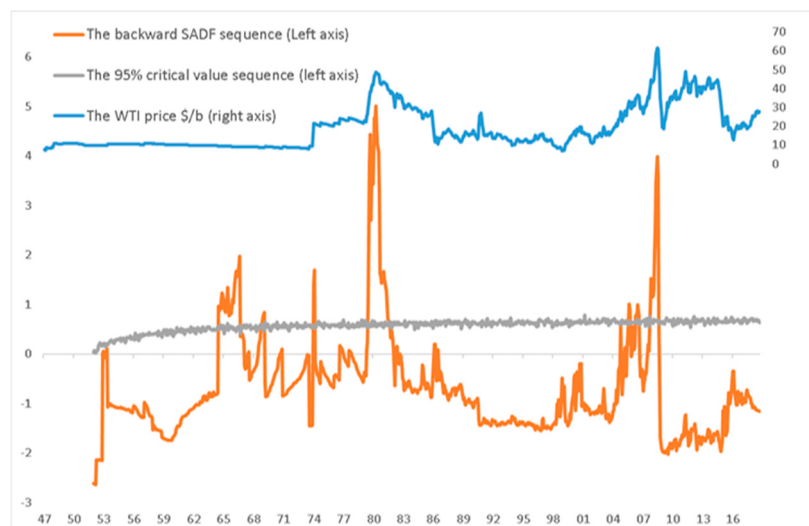


Figure 3. Date-Stamping Explosive periods in the West Texas Intermediate (WTI) prices: the GSADF Test, Author's calculations.

The periods should be separately examined to identify the causal drivers. The periods in 1974 and later than 1978 are mainly driven by the supply shocks of the two Oil Crises. Cremer and Weitzman [64] and Pindyck [65] considers OPEC as a strong monopolist accruing revenues. Johany [66] proposes that OPEC just refuse to continue expanding its production. Pierru et al. [67] examine OPEC's strategy as world price stabilizer. OPEC holds spare capacity and its production can vastly change. The impact which OPEC can inflict on prices is dependable on the short-term demand and elasticity. Under Pierru et al. [67] results, and OPEC's ability to change its production, OPEC could also play the role of the swing producer, cutting production without great costs to raise the price. This was the decision back in 1973. Furthermore, in that period there were not enough oil inventories to act as a security buffer in case of a sudden supply disruption. Chevillon and Riffart [68] find that two cointegration relationships affect price changes. First, OPEC's quotas, and second, the OECD inventories. Cologni and Manera [69] propose a long-term relationship between countries' production and demand. The binary role of OPEC production is studied by D' Ecclesia et al. [70]. They find that production swifts are occurred between two thresholds for OPEC. OPEC refuses to curtail production under a threshold to cover fixed costs, and does not increase its production over a threshold, as this would deplete reserves faster, let alone the maintenance costs. Dagoumas et al. [71] find evidence of production sharing by Saudi Arabia, which is among the most important, if not the most important producer. Bataa et al. [72] suggest that supply shocks prior to 1980 do not have permanent effect on production, and that two years later their effect disappears. Furthermore, production affects demand. Until 1990, demand shocks have decreased production. Espinasa [73] highlights Saudi Arabia's sensitivity to prices, especially in the first six months. Drachal [74] suggests the important deflation role of inventories even in 1991. Perifanis and Dagoumas [4] find that OECD inventories deflate prices 0.45%, when they increase 1%. Overall, the two bubble periods can be attributed to the supply shocks caused by the OPEC Arab members' decision to cut exports in 1973, and the Iranian Revolution. The already tight market due to the low substitutability of oil, the increased demand, and the absence of oil inventories drove the

prices up. The paper suggests that the detected periods are fundamentally explained. Furthermore, the surge from 2005 to 2008, when the financial crisis occurred, can again be fundamentally explained. He et al. [75] (2009) suggest that real futures oil prices are cointegrated with real economic activity (Kilian Index) and US dollar index. Jadidzadeh and Serletis [76] find that aggregate demand and specific demand shocks added more than the supply shocks. Guntner [77] separates the demand shocks into two categories, the flow and speculative demand shocks. The former are caused by the increased demand. When the demand increases, both OPEC and non-OPEC producers keep their production stable. Only Saudi Arabia and the United Arab Emirates increase their production during high demand periods. They can do so due to the spare capacity they hold. Perifanis and Dagoumas [4] propose the positive contribution of demand to prices. Lorusso and Pieroni [78] find that political events and consequential supply shocks did not affect prices since the mid-1970's. This role was played by the precautionary oil demand shifts, which are the main contributors to oil price formulation. Liu et al. [79] suggest that the Chinese and the US demand are the oil price drivers. Byrne et al. [80] suggest the time-varying relationship between demand and oil price. Oil prices always adjusted to demand shifts, this is more intense since mid-2000s, since emerging economies' demand increased. All in all, world economic activity drove the oil prices, since economic development requires more energy. The financial crisis of 2008 came to halt the economic development, and as a matter of fact to throw economies into recession. The coinciding bubble is the aftermath of the demand shocks which were caused by the economic evolution in this period.

Gronwald [27] used a forward recursive ADF test detects periods of explosiveness in 2005/2006 and 2007/2008, something which agrees with our results. He does not use the term “bubble” because it is hard to calculate the fundamental value of the oil. He proposes that the explosive episodes are fundamentally driven as we suggested above. Fantazzini [28] proposes a negative bubble in 2014/2015. The value, according to him, was not explained by the fundamentals. This is something that does not agree with the present paper's result, as no bubble episode is detected in 2014/2015. This controversy might be explained by the nature of the time series, since we have two large periods, one of low volatility until 1973, and one with multiple explosive episodes later than 1973. It is advisable to use both methods in combination and for different periods for real time bubble detection. Finally, both methodologies were also applied with different lags, always with a constant and without trend, and the conclusions were identical.

6. Conclusions

The paper is about bubbles and their duration in the WTI prices between 1/1/1947 and 1/9/2018. This is an extended period, which can be divided into two sub periods. That of almost zero volatility until 1973, and that of high volatility since 1973. The two sub periods have their own unique characteristics and causal drivers. Since the milestone of the 1973 oil crisis, which separated the market into these periods, many researchers tried to detect when the market was in exuberance and whether it was explained fundamentally, politically, or speculatively.

Two methodologies are used to detect whether bubbles existed in oil prices, and when these happened. These methodologies are that of PWY (2011) and PSY (2015). The newly proposed GSADF test came as an improvement and it is a rolling window right-sided ADF test with double-sup window criteria. This was proposed to overcome the SADF test's shortcomings when it was to detect multiple bubbles in the sample. Both SADF and GSADF tests statistics suggest the occurrence of bubble episodes.

PSY (2015) was developed to detect more episodes of exuberance in a period, since PWY was considered to fail in this issue. Their date-stamping results are presented in the paper and compared. The PWY (2011) date-stamping process detects only two bubble periods in WTI real prices. In comparison, PSY (2015) suggests seven bubbles. Both of them suggest the 1978 oil crisis period as a period explosiveness. The PSY (2015) detects more periods of exuberance from 2005 to 2008, when oil was on the course of reaching its peak until its abrupt end due to the financial crisis, something that might better present the whole duration of the episode. The PWY (2011) only detects a very short-lived

period of price explosion in 2008 and none prior to it from 2005. In addition, the PSY (2015) succeeds in detecting the 1973 oil crisis. Furthermore, the suggested periods of exuberance coincide with structural breakpoints (Table 5). Suggested structural changes occurred in periods of exuberance, something strengthening our results. The PWY (2011) includes one and the PSY (2015) three structural changes in the suggested periods. What it can be concluded is that the PSY (2015) date-stamping strategy is more sensitive in bubble detection as it follows better the volatility outbursts. However, its sensitivity might imply application disadvantages, since it is hard to explain its suggestions of two explosive episodes when there was extremely low volatility. Its sensitivity might identify non-existent bubble episodes.

Table 5. Bubble periods.

PWY (2011)	PSY (2015)
July 1979–January 1982	July 1964–August 1966
May 2008–July 2008	December 1968–February 1969
	January 1974–February 1974
	July 1979–July 1981
	August 2005–September 2005
	April 2006–August 2006
	October 2007–August 2008

Author's calculations.

The aforementioned methodologies should be applied in a complementary way. Their results then further compared with time-points when structural changes occurred. The contribution of the paper is that it clearly defines the bubble episodes with their corresponding drivers in this research procedure. The identified bubble periods in the paper agree with the results of Gronwald [27], but not with Fantazzini's [28]. Moreover, the paper contributes by attributing the bubble periods on market fundamentals. The surges and bursts are the consequences of fundamentals' swift. The two methodologies should be used combinedly, because PSY (2015) is more sensitive and can identify non-existent periods of exuberance. Furthermore, apart from bubble detection, the policymakers should detect the driving forces behind the rapid price swifts. Hamilton [81] and Hamilton [82] suggest the negative effect of oil price swifts on economy. Especially, Hamilton [82] proposes the effect's asymmetry of oil price spikes, compared to the price declines. Wrong perception of the market can drive to serious market failures. Bernanke et al. [83] challenge causality issues, proposing that it was the implemented monetary policy during high oil price periods, which drove to output decreases, and not the high oil prices themselves. Kilian and Murphy [9] suggest that additional regulations would not improve anything since speculation had minor influence.

Since policymaking is strongly linked to the understanding of dynamics, then the paper can contribute by both detecting bubble periods as well as the main drivers of the price course, and as a matter fact improve the decision making. Prudent actions will contribute to more liquid and effective markets, since market design can avoid market failures, which in turn can drive to output declines. Since new market developments like unconventional production enter, and market volatility becomes even higher, then market stakeholders and policymakers should aim to market transparency and efficiency. Considering that this analysis provides a clear signal concerning the importance of market fundamentals on explaining the existence, duration, and explosiveness of bubble periods, the robust analysis of market dynamics can lead to optimum decision-making for each market participant, policy maker, and stakeholder.

Further, research could be supplemented by estimating the effect of inflation over price bubbles (comparison between nominal and real prices' results). The applied methodology could be further enhanced with volatility modelling. Moreover, daily data could be used to investigate whether there are differences with the results of monthly prices.

Funding: This work has been supported by the Horizon 2020 research project INTERFACE: TSO-DSO-Consumer Interface architecture to provide innovative grid services for an efficient power system (Project Grant Agreement No. 824330).

Conflicts of Interest: The authors declare no conflicts of interest.

References

- Gately, D. Lessons from the 1986 Oil Collapse. Oil, World Forum, Energy Model. Work. Int. Energy States, United 284. 1986. Available online: http://www.brookings.edu/~{}media/Projects/BPEA/1986-2/1986b_bpea_gately_adelman_griffin.PDF (accessed on 10 July 2019).
- Perifanis, T.; Dagoumas, A. Living in an Era when Market Fundamentals Determine Crude Oil Price. *Energy J.* **2019**, *40*.
- Pindyck, R.S. *The Present Value Model of Rational Commodity Pricing*; National Bureau of Economic Research: Cambridge, MA, USA, 1992.
- Kaufmann, R.K.; Ullman, B. Oil prices, speculation, and fundamentals: Interpreting causal relations among spot and futures prices. *Energy Econ.* **2009**, *31*, 550–558. [[CrossRef](#)]
- Polanco-Martínez, J.M.; Abadie, L.M. Analyzing crude oil spot price dynamics versus long term future prices: A wavelet analysis approach. *Energies* **2016**, *9*, 1089. [[CrossRef](#)]
- Irwin, S.H.; Sanders, D.R. Testing the Masters Hypothesis in commodity futures markets. *Energy Econ.* **2012**, *34*, 256–269. [[CrossRef](#)]
- Kilian, L.; Murphy, D.P. The Role of Inventories and Speculative Trading in. *J. Appl. Econom.* **2014**, *478*, 454–478. [[CrossRef](#)]
- Juvenal, L.; Petrella, I. Speculation in the oil market. *J. Appl. Econom.* **2015**, *30*, 621–649. [[CrossRef](#)]
- Knittel, C.R.; Pindyck, R.S. The simple economics of commodity price speculation. *Am. Econ. J. Macroecon.* **2016**, *8*, 85–110. [[CrossRef](#)]
- Diba, B.T.; Grossman, H.I. *Rational Bubbles in Stock Market*; National Bureau of Economic Research: Cambridge, MA, USA, 1985.
- Tirole, J. Asset Bubbles and Overlapping Generations. *Econometrica* **1985**, *53*, 1499–1528. [[CrossRef](#)]
- Evans, G.W. Pitfalls in testing for explosive bubbles in asset prices. *Am. Econ. Rev.* **1991**, *81*, 922–930. [[CrossRef](#)]
- Kirman, A.; Teyssiere, G. Testing for Bubbles and Change—Points. *J. Econ. Dyn. Control.* **2005**, *29*, 765–799.
- Barberis, N.; Greenwood, R.; Jin, L.; Shleifer, A. Extrapolation and bubbles. *J. Financ. Econ.* **2018**, *129*, 203–227. [[CrossRef](#)]
- Bao, T.; Hennequin, M.; Hommes, C.; Massaro, D. Coordination on bubbles in large-group asset pricing experiments. *J. Econ. Dyn. Control.* **2019**. [[CrossRef](#)]
- Werner, J. Rational asset pricing bubbles and debt constraints. *J. Math. Econ.* **2014**, *53*, 145–152. [[CrossRef](#)]
- Jordà, Ò.; Schularick, M.; Taylor, A.M. Leveraged bubbles. *J. Monet. Econ.* **2015**, *76*, S1–S20. [[CrossRef](#)]
- Martin, A.; Ventura, J. The international transmission of credit bubbles: Theory and policy. *J. Monet. Econ.* **2015**, *76*, S37–S56. [[CrossRef](#)]
- Albuquerque, R.; Eichenbaum, M.; Papanikolaou, D.; Rebelo, S. Long-run bulls and bears. *J. Monet. Econ.* **2015**, *76*, S21–S36. [[CrossRef](#)]
- Hirano, T.; Inaba, M.; Yanagawa, N. Asset bubbles and bailouts. *J. Monet. Econ.* **2015**, *76*, S71–S89. [[CrossRef](#)]
- Miao, J.; Wang, P.; Zhou, J. Asset bubbles, collateral, and policy analysis. *J. Monet. Econ.* **2015**, *76*, S57–S70. [[CrossRef](#)]
- Kunieda, T.; Shibata, A. Asset bubbles, economic growth, and a self-fulfilling financial crisis. *J. Monet. Econ.* **2016**, *82*, 70–84. [[CrossRef](#)]
- Nemoto, H. Credit availability and asset price: Empirical analysis of the Japanese bubbles in 1980s. *J. Jpn. Int. Econ.* **2017**, *44*, 90–98. [[CrossRef](#)]
- Acharya, V.; Naqvi, H. On reaching for yield and the coexistence of bubbles and negative bubbles. *J. Financ. Intermediation* **2018**, *38*, 1–10. [[CrossRef](#)]
- Wang, S.; Chen, L.; Xiong, X. Asset bubbles, banking stability and economic growth. *Econ. Model.* **2019**, *78*, 108–117. [[CrossRef](#)]
- Wang, S.; Chen, L. Driving factors of equity bubbles. *N. Am. J. Econ. Financ.* **2019**, *49*, 304–317. [[CrossRef](#)]
- Gronwald, M. Explosive oil prices. *Energy Econ.* **2016**, *60*, 1–5. [[CrossRef](#)]

28. Fantazzini, D. The oil price crash in 2014/15, Was there a (negative) financial bubble? *Energy Policy* **2016**, *96*, 383–396. [[CrossRef](#)]
29. Phillips, P.C.B.; Yu, J. Dating the Timeline of Financial Bubbles During the Subprime Crisis. *Quant. Econ.* **2011**, *2*, 455–491. [[CrossRef](#)]
30. Phillips, P.C.B.; Wu, Y.; Yu, J. Explosive behavior and the Nasdaq Bubble in the 1990s: When does irrational exuberance have escalated asset values? *Int. Econ. Rev.* **2011**, *52*, 201–226. [[CrossRef](#)]
31. Phillips, P.C.B.; Shi, S.; Yu, J. Testing for multiple bubbles: Historical episodes of exuberance and collapse in the S&P 500. *Int. Econ. Rev.* **2015**, *56*, 1043–1078. [[CrossRef](#)]
32. Harvey, D.I.; Leybourne, S.J.; Sollis, R. Improving the accuracy of asset price bubble start and end date estimators. *J. Empir. Financ.* **2017**, *40*, 121–138. [[CrossRef](#)]
33. Shestakova, N.; Powell, O.; Gladyshev, D. Bubbles, experience and success. *J. Behav. Exp. Financ.* **2019**, *22*, 206–213. [[CrossRef](#)]
34. Greenwood, R.; Shleifer, A.; You, Y. Bubbles for Fama. *J. Financ. Econ.* **2019**, *131*, 20–43. [[CrossRef](#)]
35. Fama, E.F. Two pillars of asset pricing. *Am. Econ. Rev.* **2014**, *104*, 1467–1485. [[CrossRef](#)]
36. Gilbert, C.L. *Speculative Influences on Commodity Futures Prices 2006–2008*; United Nations Conference on Trade and Development: Madison, WI, USA, 2010.
37. Shi, S.; Arora, V. An application of models of speculative behaviour to oil prices. *Econ. Lett.* **2012**, *115*, 469–472. [[CrossRef](#)]
38. Brooks, C.; Katsaris, A. A three-regime model of speculative behaviour: Modelling the evolution of the S&P 500 composite index. *Econ. J.* **2005**, *115*, 767–797. [[CrossRef](#)]
39. Schaller, H.; Norden, S. Van, Fads or bubbles? *Empir. Econ.* **2002**, *27*, 335–362. [[CrossRef](#)]
40. Lammerding, M.; Stephan, P.; Trede, M.; Wilfling, B. Speculative bubbles in recent oil price dynamics: Evidence from a Bayesian Markov-switching state-space approach. *Energy Econ.* **2013**, *36*, 491–502. [[CrossRef](#)]
41. Fan, Y.; Xu, J.H. What has driven oil prices since 2000? A structural change perspective. *Energy Econ.* **2011**, *33*, 1082–1094. [[CrossRef](#)]
42. Corbet, S.; Lucey, B.; Yarovaya, L. Datestamping the Bitcoin and Ethereum bubbles. *Financ. Res. Lett.* **2018**, *26*, 81–88. [[CrossRef](#)]
43. Pan, W.F. Sentiment and asset price bubble in the precious metals markets. *Financ. Res. Lett.* **2018**, *26*, 106–111. [[CrossRef](#)]
44. Hu, Y.; Oxley, L. Bubble contagion: Evidence from Japan's asset price bubble of the 1980-90s. *J. Jpn. Int. Econ.* **2018**, *50*, 89–95. [[CrossRef](#)]
45. Geuder, J.; Kinateder, H.; Wagner, N.F. Cryptocurrencies as financial bubbles: The case of Bitcoin. *Financ. Res. Lett.* **2018**. [[CrossRef](#)]
46. Chaim, P.; Laurini, M.P. Is Bitcoin a bubble? *Phys. A Stat. Mech. Its Appl.* **2019**, *517*, 222–232. [[CrossRef](#)]
47. Matsuoka, T.; Shibata, A. Asset bubbles, credit market imperfections, and technology choice. *Econ. Lett.* **2012**, *116*, 52–55. [[CrossRef](#)]
48. Narayan, P.K.; Sharma, S.S.; Phan, D.H.B. Asset price bubbles and economic welfare. *Int. Rev. Financ. Anal.* **2016**, *44*, 139–148. [[CrossRef](#)]
49. Wan, J. Prevention and landing of bubble. *Int. Rev. Econ. Financ.* **2018**, *56*, 190–204. [[CrossRef](#)]
50. Fenig, G.; Mileva, M.; Petersen, L. Deflating asset price bubbles with leverage constraints and monetary policy. *J. Econ. Behav. Organ.* **2018**, *155*, 1–27. [[CrossRef](#)]
51. Ciccarone, G.; Giuli, F.; Marchetti, E. Should central banks lean against the bubble? The monetary policy conundrum under credit frictions and capital accumulation. *J. Macroecon.* **2019**, *59*, 195–216. [[CrossRef](#)]
52. Zhang, Y.J.; Yao, T. Interpreting the movement of oil prices: Driven by fundamentals or bubbles? *Econ. Model.* **2016**, *55*, 226–240. [[CrossRef](#)]
53. Zhang, Y.J.; Wang, J. Exploring the WTI crude oil price bubble process using the Markov regime switching model. *Phys. A Stat. Mech. Its Appl.* **2015**, *421*, 377–387. [[CrossRef](#)]
54. Figuerola-Ferretti, I.; McCrorie, J.R.; Paraskevopoulos, I. Mild explosivity in recent crude oil prices. *Energy Econ.* **2019**. [[CrossRef](#)]
55. Su, C.W.; Li, Z.Z.; Chang, H.L.; Lobont, O.R. When Will Occur the Crude Oil Bubbles? *Energy Policy* **2017**, *102*, 1–6. [[CrossRef](#)]
56. García-Carranco, S.M.; Bory-Reyes, J.; Balankin, A.S. The crude oil price bubbling and universal scaling dynamics of price volatility. *Phys. A Stat. Mech. Its Appl.* **2016**, *452*, 60–68. [[CrossRef](#)]

57. Said, E.; Dickey, D.A. Testing for Unit Roots in Autoregressive-Moving Average Models of Unknown Order: Critical Comments. *Biometrika* **1984**, *71*, 599–607. [\[CrossRef\]](#)
58. Homm, U.; Breitung, J. Testing for speculative bubbles in stock markets: A comparison of alternative methods. *J. Financ. Econom.* **2012**, *10*, 198–231. [\[CrossRef\]](#)
59. Barghava, A. On the Theory of Testing for Unit Roots in Observed Time Series. *Rev. Econ. Stud.* **1986**, *53*, 369–384. [\[CrossRef\]](#)
60. Kim, J.Y. Detection of change in persistence of a linear time series. *J. Econom.* **2000**, *95*, 97–116. [\[CrossRef\]](#)
61. Buseti, F.; Taylor, A.M.R. Tests of stationarity against a change in persistence. *J. Econom.* **2004**, *123*, 33–66. [\[CrossRef\]](#)
62. Diba, B.T.; Grossman, H.I. Explosive Rational Bubbles in Stock Prices? *Am. Econ. Rev.* **1988**, *78*, 520–530. [\[CrossRef\]](#)
63. Zivot, E.; Andrews, D.W.K. Evidence on the Great Crash the oil price shock and the unit root hypothesis. *J. Bus. Econ. Stat.* **1992**, *10*, 251–270.
64. Cremer, J.; Weitzman, M.L. OPEC and the monopoly price of world oil. *Eur. Econ. Rev.* **1976**, *8*, 155–164. [\[CrossRef\]](#)
65. Pindyck, R.S. Gains to Producers from the Cartelization of Exhaustible Resources. *Rev. Econ. Stat.* **1978**, *60*, 238–251. [\[CrossRef\]](#)
66. Johany, A.D. *The Myth of the OPEC Cartel: The Role of Saudi Arabia*; University of Petroleum and Minerals: Chichester, NY, USA, 1980. [\[CrossRef\]](#)
67. Pierru, A.; Smith, J.L.; Zamrik, T. OPEC's Impact on Oil Price Volatility: The Role of Spare Capacity. *Energy J.* **2018**, *39*, 103–122. [\[CrossRef\]](#)
68. Chevillon, G.; Riffart, C. Physical market determinants of the price of crude oil and the market premium. *Energy Econ.* **2009**, *31*, 537–549. [\[CrossRef\]](#)
69. Cologni, A.; Manera, M. On the economic determinants of oil production: Theoretical analysis and empirical evidence for small exporting countries. *Energy Econ.* **2014**, *44*, 68–79. [\[CrossRef\]](#)
70. D'Ecclesia, R.L.; Magrini, E.; Montalbano, P.; Triulzi, U. Understanding recent oil price dynamics: A novel empirical approach. *Energy Econ.* **2014**, *46*, S11–S17. [\[CrossRef\]](#)
71. Dagoumas, A.; Perifanis, T.; Polemis, M. An econometric analysis of the Saudi Arabia's crude oil strategy. *Resour. Policy* **2018**, *59*, 265–273. [\[CrossRef\]](#)
72. Bataa, E.; Izzeldin, M.; Osborn, D.R. Changes in the global oil market. *Energy Econ.* **2016**, *56*, 161–176. [\[CrossRef\]](#)
73. Espinasa, R.; ter Horst, E.; Reyes, S.G.; Manzano, O.; Molina, G.; Rigobon, R. A micro-based model for world oil market. *Energy Econ.* **2017**, *66*, 431–449. [\[CrossRef\]](#)
74. Drachal, K. Forecasting spot oil price in a dynamic model averaging framework—Have the determinants changed over time? *Energy Econ.* **2016**, *60*, 35–46. [\[CrossRef\]](#)
75. He, Y.; Wang, S.; Lai, K.K. Global economic activity and crude oil prices: A cointegration analysis. *Energy Econ.* **2010**, *32*, 868–876. [\[CrossRef\]](#)
76. Jadidzadeh, A.; Serletis, A. How does the U.S. natural gas market react to demand and supply shocks in the crude oil market? *Energy Econ.* **2017**, *63*, 66–74. [\[CrossRef\]](#)
77. Güntner, J.H.F. How do oil producers respond to oil demand shocks? *Energy Econ.* **2014**, *44*, 1–13. [\[CrossRef\]](#)
78. Lorusso, M.; Pieroni, L. Causes and consequences of oil price shocks on the, U.K. economy. *Econ. Model.* **2018**, *72*, 223–236. [\[CrossRef\]](#)
79. Liu, L.; Wang, Y.; Wu, C.; Wu, W. Disentangling the determinants of real oil prices. *Energy Econ.* **2016**, *56*, 363–373. [\[CrossRef\]](#)
80. Byrne, J.P.; Lorusso, M.; Xu, B. Oil prices, fundamentals and expectations. *Energy Econ.* **2018**, *79*, 59–75. [\[CrossRef\]](#)
81. Hamilton, J.D. Oil and the Macroeconomy since World War, I.I. *J. Polit. Econ.* **1983**, *91*, 228–248. [\[CrossRef\]](#)
82. Hamilton, J.D. What is an oil shock? *J. Econom.* **2003**, *113*, 363–398. [\[CrossRef\]](#)
83. Bernanke, B.S.; Gertler, M.; Watson, M.; Sims, C.A.; Friedman, B.M. Systematic monetary policy and the effects of oil price shocks. *Brook. Pap. Econ. Act.* **1997**, *1997*, 91–157. [\[CrossRef\]](#)

