ARE WEST TEXAS INTERMEDIATE (WTI) PRICES EXPLOSIVE?

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Abstract

The oil market is widely conceived as the most liquid in the world. Crude oil is a commodity with spectacular fluctuations. Oil crises, like those of 1973 and 1978-1979, drove the prices up to considerable heights. Oil price history also had other inflationary periods like those up to 2008, and 2014, when oil reached record peaks. All hikes were followed by spectacular busts. The oil price course can be described as having temporary explosive episodes. I apply the Phillips et al. (2011) and Phillips et al. (2015) methodology to test whether West Texas Intermediate (WTI) prices had explosions, and when these happened. One can trace the possibly responsible factors by detecting these periods of explosiveness. It remains a question whether this episodes of exuberance are fundamentally or speculatively caused. Market stakeholders should examine whether fundamentals justify price explosiveness or speculation drives the market. The periods detected are periods of extreme volatility. Causes must be separately examined for each episode.

Keywords: WTI, Explosive prices, Explosiveness, Bubbles, Augmented Dickey Fuller (ADF) test

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 remained at high levels until a burst occurred reaching the lowest level in 2016. Since 2016 the price increases. It is easily understood that the oil price follows a pattern since 1973, in which a hike is followed by a burst and vice versa. This course with structural breaks, sudden

[1] Gately, D. (1986) 'Lessons from the 1986 Oil Collapse', *Oil, World Forum, Energy Modeling Workshop, International Energy States, United*, p. 284. Available at: http://www.brookings.edu/~/media/Projects/BPEA/1986-2/1986b_bpea_gately_adelman_griffin.PDF.

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.

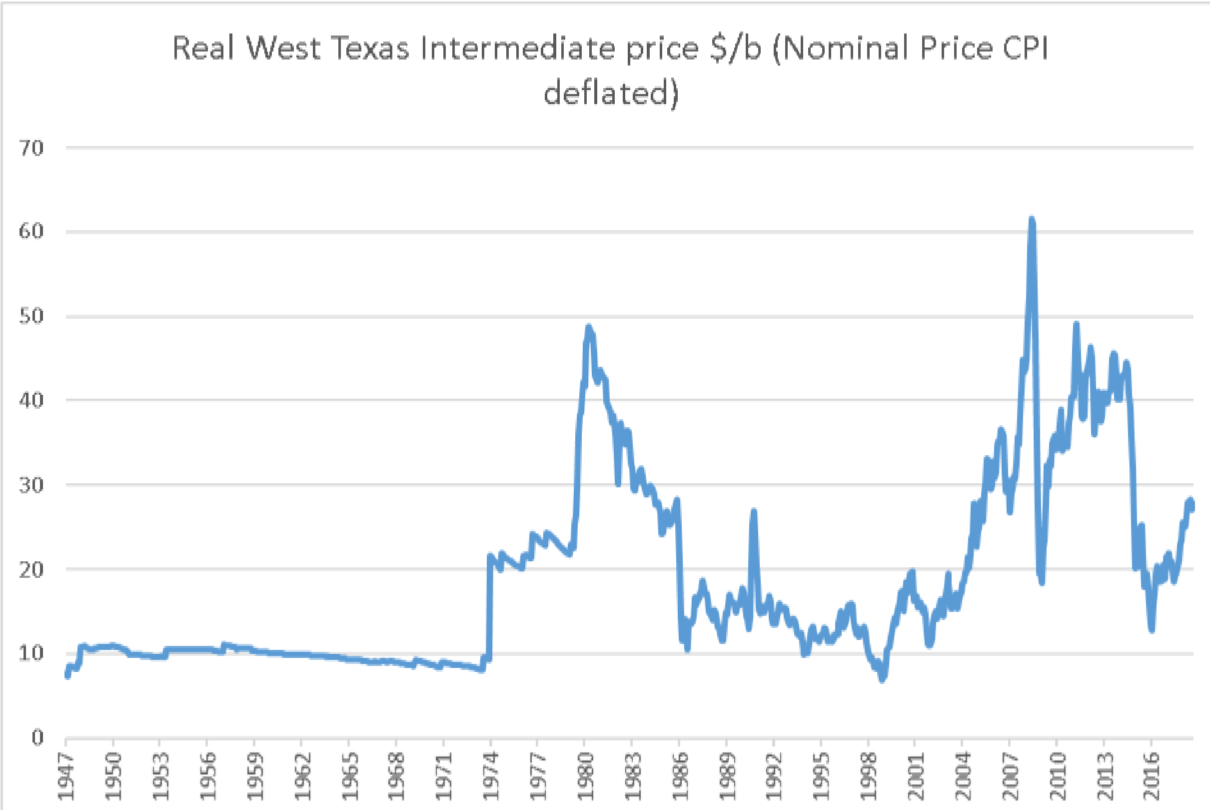

Figure 1 Real WTI Price - Nominal WTI CPI deflated

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 hesitated to explain whether a period of extreme increases or decreases has to do with rational expectations or bubble behaviour. 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 world “bubble” to refer to periods of explosiveness. Asset bubbles are deviations from an underlying fundamental value. But 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 (2019) suggest. Many use the Pindyck’s (1992) 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. I will use the term “explosiveness”, and not that of the “bubble” since we do not know even by approximate the fundamental value of the underlying commodity.

Furthermore, we do not know which are the driving causal forces, even if we know that the oil market runs a period of explosiveness. Explosive prices might be attributed to fundamental disruptions, or traders’ speculation. Irwin and Sanders (2012) 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 (2014) 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 (2015) 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 (2016) even if they can not 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.

As a result, 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. Finally, market participants and policy makers need robust tools and processes 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. I think that this paper importantly adds to the field of the energy markets.

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

Literature review

As mentioned before, financial bubble literature is extended due to the importance of the phenomenon. Literature’s length is not only justified by phenomenon’s importance, but also by the difficulty of testing for its presence, duration and explosiveness. Diba and Grossman (1985) 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. Evans (1991) further adds that periodically collapsing bubbles can not be identified by traditional tests, which compare the explosiveness and stationarity of stock prices to dividends.

Phillips and Yu (2011) 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 (2011) (from now referred as PWY) 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 (2015) (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 GSADF test is a rolling window right-sided ADF test with double-sup window selection criteria. They suggest that their improvement to the 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 recognise 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.

Research conducted by Gilbert (2010) suggests that even if there is strong evidence of explosiveness in the copper market, this can not 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 (2012) test the three-regime models of Brooks and Katsaris (2005) and Schaller and Van Norden (2002) 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. Lamerding et al. (2013) suggest the existence of speculative bubbles in oil price dynamics.

In this paper I apply the PWY (2011) and PSY (2015) statistics and date-stamping processes to detect and trace oil price explosive periods.

Methodology

The PWY (2011) test

First, I would like to introduce the PWY (2011) test for bubbles, which is conducted by repeated calculations of the Augmented Dickey Fuller (ADF) test (Said and Dickey, 1984) on a forward expanding sample sequence. The sup value of the corresponding ADF sequence is the test statistic. 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 r_2 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.

(1) $$SADF\ (r_0) = \sup_{r_2 \in [r_{0,1}]} ADF_0^{r_2}$$

Homm and Breitung (2012) compared alternative methods to test for speculative bubbles. They compared methods proposed by Bhargava (1986), Kim (2000), and Busetti and Taylor (2004). 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 (2012) conclude that the PWY (2011) approach is the most appropriate in detecting bubbles.

The PSY (2015) test

Phillips, Shi and Yu (2015) 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.

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

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

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

The GSADF statistic is compared to the respective critical value to investigate whether bubbles exist in the sample. PSY (2015) recognise 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

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

where T is the number of sample observations.

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 (1991) criticizes this kind of strategy, as that of Diba and Grossman (1988), 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:

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

We can tell that the PWY (2011) method is the recursive ADF for bubble detection where the backward sup ADF test in conducted with r_1=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:

$$\hat{r}_e = \inf_{r_2 \in [r_0, 1]} \left\{ r_2 : ADF_{r_2} > cv_{r_2}^{\beta_T} \right\} \quad \text{and} \tag{6}$$

$$\hat{r}_f = \inf_{r_2 \in [\hat{r}_e + \delta \log(T)/T, 1]} \left\{ r_2 : ADF_{r_2} < cv_{r_2}^{\beta_T} \right\}$$

Where $cv_{r_2}^{\beta_T}$ is the 100(1 - β_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 $\lfloor T\hat{r}_e \rfloor$ + δ log(T), where δ 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 observations points

$$\hat{r}_e = \inf_{r_2 \in [r_0, 1]} \left\{ r_2 : BSADF_{r_2}(r_0) > scv_{r_2}^{\beta_T} \right\} \quad \text{and} \tag{7}$$

$$\hat{r}_f = \inf_{r_2 \in [\hat{r}_e + \delta \log(T)/T, 1]} \left\{ r_2 : BSADF_{r_2}(r_0) < scv_{r_2}^{\beta_T} \right\}$$

with $scv_{r_2}^{\beta_T}$ to be the 100(1 - β_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

$$SADF(r_0) = \sup_{r_2 \in [r_0, 1]} \left\{ ADF_{r_2} \right\} \quad \text{and} \tag{8}$$

$$GSADF(r_0) = \sup_{r_2 \in [r_0, 1]} \left\{ BSADF_{r_2}(r_0) \right\}$$

For more details, please be advised PSY (2015).

Data

I use the monthly spot WTI prices by Federal Reserve Economic Data (FRED) for the period between January 1947 and September 2018. I deflate the nominal prices with the seasonally adjusted monthly Consumer Price Index (CPI) for all the Urban Consumers by FRED in order to avoid inflationary explosiveness. I therefore estimate a real oil price data series, consisting 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.

I first test my data for stationarity with the Augmented Dickey Fuller (ADF) (Said and Dickey 1984) test and with the Zivot and Andrews (1992) test allowing for one structural break. I find that my data are stationary at first difference I(1). I present the results of my tests in Table 1.

Table 1. Unit root tests for the WTI real price between 1/1/1947 and 1/9/2018

	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.
a *Acceptance of the null hypothesis for 1%, 5% and 10%.*
b *Rejection of the null hypothesis for 1%, 5% and 10%.*

Empirical Results

I test the WTI price explosiveness for the period between 1947 and 2018. This is a long period with oil crises like those of 1973 and 1978/79, price collapses as 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 my 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 (1992) tests. But this does not preclude explosiveness in my data.

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

Table1. The SADF TEST and the GSADF TEST of the WTI Price

		Finite Sample Critical Values		
	Test Stat.	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.

I try next to detect when these explosive sub periods existed. I start with the PWY (2011) date-stamping method. The periods suggested by the PWY (2011) methods are those when the BADF sequence is over the 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 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.

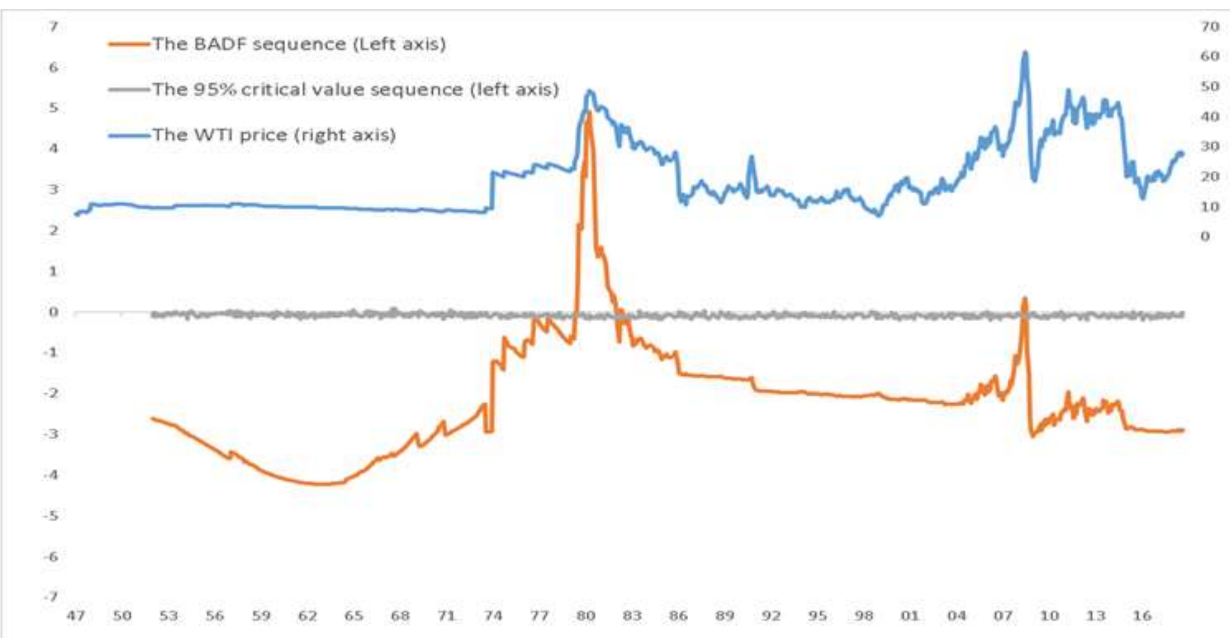

Figure 2 Date-Stamping Explosive periods in the WTI prices: the SADF Test

More periods are suggested when I apply the PSY (2015) date-stamping strategy, 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. But 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, I 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.

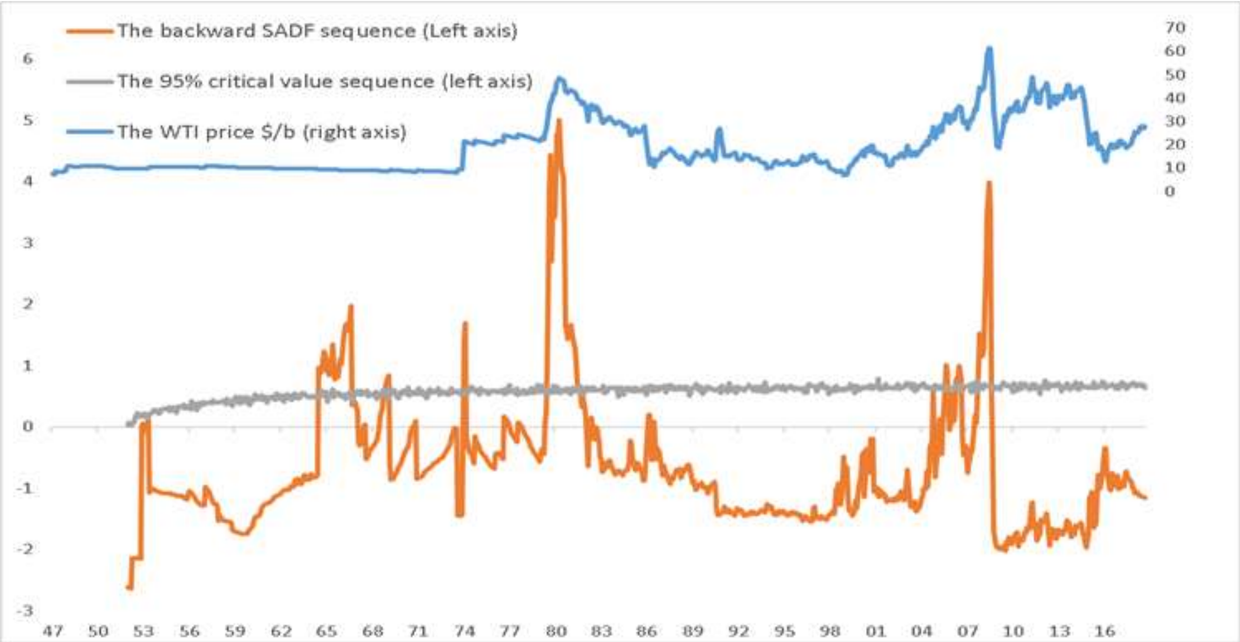

Figure 3 Date-Stamping Explosive periods in the WTI prices: the GSADF Test

Conclusions

I try to examine whether periods of price exuberance for the WTI prices existed and detect their duration for the period between 1/1/1947 and 1/9/2018. This is a period with several different characteristics. Oil prices entered an era of high volatility and interest since the first oil crisis of 1973. From 1947 to 1973 the real WTI price experienced extremely low volatility. Since 1973, oil prices entered a period of low and high volatility sub periods. These two different time frames have their own characteristics and causal drivers.

In an effort to test for and detect these periods, I used the results of two methodologies, 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 suggest the occurrence of explosive episodes.

PSY (2015) suggest that the PWY (2011) date-stamping strategy fails to detect a second episode of exuberance, when more than one occurred in a time frame. We compared their results in the corresponding figures. The PWY (2011) detects only two periods of explosiveness in my example of WTI real prices. On the contrary, PSY (2015) suggests seven. They both agree on the 1978 oil crisis period as a period explosiveness. The PSY (2015) detects more periods of explosiveness from 2005 to 2008, when oil was on the course to reaching its highest price until its abrupt end due to the financial crisis, something that might better present the whole duration of the episode. The PWY (2011) suggests only a very short-lived period of exuberance in 2008. In addition, the PSY (2015) detects the 1973 oil crisis. What it can be concluded is that the PSY (2015) date-stamping strategy better follows the course of oil price since it detects more periods of exuberance. What is hard to explain is that the PSY (2015) suggests two explosive episodes when there was extremely low volatility. Its sensitivity might propose non-existent episodes. The last might be explained by the nature of our time series since we have two large periods, one of low volatility and one with multiple explosive episodes. What can be advised for the future is that both methods should be used in combination for the real time explosiveness detection. Finally, I tried the statistic values and their respective critical values and sequences with different lags, always with a constant and without trend, and the conclusions were identical.

Even if we detect episodes of explosiveness, we should be extremely careful about their causal drivers. These might be fundamentally or speculatively driven. The responsible institutions and policy makers should first determine whether the market is in exuberance, and what causes this kind of state. By this, regulators, market participants and other parties might be able to avoid wrong decision making. It is of crucial importance to avoid market episodes which might result in extreme market anomalies, which will harm the long-term prospects.

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