Physica A 416 (2014) 631–638

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Are there really bubbles in oil prices?

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HIGHLIGHTS

- The study identifies bubbles and crashes in crude oil prices.
- Exponential fitting methodology is employed to identify the bubble periods.
- Four bubble periods are identified for the WTI and Brent crude oil prices.
- The study also explains the reasons behind the bubbles and crashes.
- Exponential approximation is found to have a superior fit.

ARTICLE INFO

Article history:
Received 21 May 2014
Received in revised form 21 August 2014
Available online 11 September 2014

Keywords:
Crude oil price
Exponential fitting
Bubbles

ABSTRACT

The aim of this paper is to identify bubbles in oil prices by using the "exponential fitting" methodology proposed by Watanabe et al. (2007) [28,29]. We use the daily US dollar closing crude oil prices of West Texas Intermediate (WTI) covering the 1986:01:02–2013:07:09 and the Brent for the 1987:05:20–2013:07:09 periods. The distinguishing feature of this study from the previous studies is that this is the first study in the literature showing the existence of bubbles in crude oil prices. We found that there are four distinct periods of persistent bubbles in the crude oil prices since 1986. Two of these persistent bubbles are before 2000 and two of them are after 2000. We conclude that further research is needed to understand better how futures markets may impact the oil price formation.

1. Introduction

The crude oil price determination was subject to a radical change with the establishment of the West Texas Intermediate (hereafter, WTI) — Cushing, Oklahoma and of the Brent — Europe oil markets. They aimed to break the monopolistic power of OPEC and to switch to a more "fair" price regime. Since then, non-commercial traders became a significant market participant affecting oil prices with their commercial counterparts, such as oil companies and refineries etc. After the 2000s, increasing numbers of financial investors, started to invest in commodity, especially crude oil, futures markets. Therefore, (future) trade of crude oil became a transaction beyond the actual demand–supply interaction. Coincidentally, there were severe and persistent increases in crude oil price during the same period. Some argued that the price surges are speculative

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http://dx.doi.org/10.1016/j.physa.2014.09.020
0378-4371/

bubbles[1] caused by the financialization of the crude oil market.[2,3] The speculation argument was not made without a foundation; because the deviation between world oil consumption and production has never exceeded ±2% since 1980. In addition, the known oil reserves increased 2.3 times from 642 billion barrels to about 1.4 trillion barrels in the same period. Hence, in terms of oil-specific economic fundamentals, there were no bases for the sharp surges in oil prices.

The academia, however, by and large, took an opposite position. They argued that the huge financial inflows into the long-only commodity index funds in majority cannot be the source of price surges in crude oil price, and that it is not correct to attribute these price increases to the financial speculation.[4] Though researchers took varying positions against the idea of 'bubbles in the crude oil price', they almost unanimously agreed that the speculation was not the cause.[5] First, some of these studies raised oil-specific and non-oil specific economic fundamentals for explaining the price surges. These ranged from increasing demand from emerging and developing countries (e.g., China and India) to adverse oil supply shocks. For example, Hamilton [10] argued that a low price elasticity of oil demand and the failure of physical production to increase are the primary causes of the oil shock of 2007–2008. Kilian [11] shows evidence that oil price surges have been driven mainly by a combination of global aggregate demand shocks and precautionary demand shocks in the post-1975 period. The cumulative effects of positive global demand shocks after 2003 have also been effective. Similarly, Kilian and Hicks [12] and Kilian and Murphy [13] conjecture that increase in oil prices during 2003–2008 was not due to supply shortfall or speculative demand but due to unexpected growth in emerging economies and global business cycle.[6]

Elder et al. [14] studied the role of economic news on jumps in crude oil prices by using intra-daily data. They find a strong correspondence between high frequency jumps in oil prices and the arrival of new economic information. Hence, they reinforced the argument that the crude oil price has become open to non-oil economic fundamentals after the establishment of futures markets, consistent with economic theory. Thus, economic news, rather than speculation, drives jumps in oil prices. Second, others show that there is no (causal) relationship between the futures and spot markets. For example, Buyuksahin and Harris [15] employ Granger causality tests to analyze lead and lag relations between price and hedge funds and other non-commercial (speculator) position data at daily and multiple day intervals. They find little evidence that the position changes Granger-cause price changes; instead, the results suggest that price changes precede their position changes.[7] Similarly, Alquist and Gervais [3], conducting bivariate Granger causality tests, fail to find any conclusive evidence on whether changes in financial positions of non-commercial and commercial firms in NYMEX precede WTI price changes.[8]

Third, there are some studies which examined the impact of financialization in a broader context by analyzing the role of index funds on price surges in other commodity markets with futures markets. The main findings of these studies were (i) there were price surges in many commodity markets, whether with futures markets or not, (ii) futures markets were not the cause of price surges. For example, Stoll and Whaley [17] provide a comprehensive evaluation of wheat futures market in order to determine whether commodity index investing was a disruptive force or not. They conclude that commodity index rolls have little futures price impact, though the wheat futures price did not always converge during the 2006–2009 period. Sanders and Irwin [18] undertook bivariate Granger causality tests in a group of 14 futures markets, including energy. They investigated lead–lag dynamics between index fund positions and futures returns (price changes) or price volatility in each commodity futures market with a systems approach. They found that there is no evidence that the net positions lead market returns and volatility, except in the soybeans and natural gas markets.

On the other hand, there are also studies which argue that the financialization of the commodity markets led to bubbles in prices. For example, Gilbert [19] examines price behavior in nine commodity futures markets including crude oil over 2006–2008 and finds bubbles in seven of the nine markets for a small percentage of the sample period. He also undertakes Granger causality tests and finds that there is a significant relationship between index fund trading activity and returns

1 A bubble is simply over-pricing by the market, causing the market price deviate from the asset's intrinsic value (see also Scherbina [1]). In our technical analysis, based on the exponential growth curve, we define a bubble as an exponential increase in the price with growth parameter greater than 1.

2 The literature credits Masters [2], who was a manager of a private financial fund, with this argumentation. It was based on the one-to-one movement between the number of index-fund future contracts invested and the price of crude oil, especially after 2003 (see for example, Fig. 1 in Alquist and Gervais [3]). Ripple [4] criticizes this view, arguing that open interest in the 30-day futures contract is just a fraction of actual oil consumption when expressed as barrels per day. Irwin and Sanders [5] argue that Masters [2] is making the statistical mistake of confusing correlation with causation. Sanders and Irwin [6] also show that index position estimates generated by the Masters algorithm may contain potential inaccuracies.

3 There were also drops in oil prices following the price surges. However, they were frequently downward sticky and shorter, and rarely very sharp. In other words, price rises and falls were uneven in the sense that the former was more persistent and sharper while the latter was shorter and hardly reaching back before-rise levels. We therefore focus on bubbles.

4 See pp. 9–11 in Fattouh et al. [7] for an extensive discussion on speculation in the context of oil and Scherbina [1] on a selective survey on asset price bubbles.

5 See Irwin et al. [8] for a categorical list of the counter arguments against the speculation argument. Another very useful resource is Irwin and Sanders [9], which provides an introductory survey to the speculation debate.

6 In particular, Kilian and Murphy [13], using an SVAR model to measure the effect of speculative demand shocks on the real price of oil, conclude that there is no evidence of speculation due to the financialization of the crude oil market, although the market experienced price surges due to speculation from time to time, including in 1979, 1986, 1990 and 2002.

7 Buyuksahin and Harris [15] also calculate Working's [16] speculative index in the crude oil futures market for the period 2000–2008 and find that the index has also risen steadily from 2001 through mid-2008, but has been relatively stable in the nearby contract since the early 2006.

8 They, on the other hand, find that there is a reverse causality. That is, Granger-causality from changes in oil prices to changes in net positions, commercial or non-commercial. However, their *T*-index analysis indicates periods of speculation, especially in the years 2003, 2005 and 2010.

in three of the seven markets, including crude oil. Gilbert [20] focuses on several food prices and shows through Granger causality tests that there was a large and statistically significant impact of commodity index investment on the food price index between March 2006 and June 2009. Tang and Xiong [21] find a fundamental process of financialization among commodity markets, through which commodity prices have become more correlated with each other, since the early 2000s. In addition, they show that prices of non-energy commodities have become increasingly correlated with oil prices. Finally, Singleton [22] argues that informational frictions and the associated speculative activity may induce crude oil prices to drift away from fundamental values, and may result in booms and busts in prices. Further, he presents new evidence that there were economically and statistically significant effects of investor flows on futures prices.[9]

Several critiques can be raised against the current literature on the bubble question in commodity prices in general and in particular in crude oil prices. First, majority of these studies concentrate on the period 2006–2008, while the first crude oil futures market has been established in 1986. There might have been other instances of bubbles in the past, and if not, it is very legitimate to ask why the market experienced the bubbles in the 2000s and not before? In that respect, most of these studies are short-sighted and that the range covered may not give the right answer on the question of bubbles in crude oil price. Second, the Granger-causality test is the major, if not the only, technique that is used to test whether or not the crude oil futures market is the cause of price surges in the spot market. The literature is certainly in need of alternative techniques to ensure the existence of causality. Third, we argue that the literature must first agree on the definition of bubbles and how to measure it (in oil market)[10]: What would be the magnitude and the duration of price rise to consider it as a bubble? The motivation of this paper is to find answers to this question, which, heuristically speaking, have not yet been answered in a concrete (technical) way in the literature. This study takes a different position than the literature in the oil price bubble question. It examines the crude oil price data itself to identify whether these price surges are bubbles. That is, the question is whether or not a persistent deviation of the market price from its fundamental or intrinsic value exists. There is another reason why examining the data itself for bubbles and crashes may be required. The bubbles (and crashes) are often conclusively identified only in retrospect. The bubbled prices can fluctuate erratically, and become impossible to predict from supply and demand alone. This is perhaps why the majority of mainstream economists believe that bubbles cannot be identified in advance.

The aim of this study is to identify bubbles and crashes in crude oil prices since 1986. For this purpose, we use the exponential fitting methodology, proposed by Watanabe et al. [28,29]. The main motivation for using this methodology is to detect the bubbles and their beginning and ending dates. For matter of robustness, we use both the WTI and Brent crude oil price series, separately. The data consist of daily US dollar closing crude oil prices of WTI for the 1986:01:02–2013:07:09 period and that of Brent for the 1987:05.20–2013:07:09 period. To our best knowledge, this paper is the first of its kind, showing the existence of bubbles in crude oil prices in the literature. Our analyses show that there are periods in which there exist bubbles in the crude oil price. In particular, we find that WTI prices, of which Brent prices follow very closely, experienced bubbles in the periods April 24–October 12 1990, November 19 1998–November 17 2000, November 28 2001–July 23 2008 and January 2 2009–April 27 2011. We explain each of these bubble periods by a political and/or macroeconomic event. However, one should note that these explanations are not based on any objective measure, as the method extracts bubble periods from the data itself. Given that we can explain each of these periods by a political and/or macroeconomic event, we believe that these bubbles are not result of speculative acts but they are due to non-oil economic or political events. Such events led to distortion of relative prices to the advantage of several commodity prices, including crude oil.

The rest of the paper is organized as follows. The next section provides the methodology. Section 3 evaluates the data and the empirical findings. The final section concludes the paper.

2. Methodology

Watanabe et al. [28,29] introduced the following formula for extracting the exponential behavior:

$$P(t) - P(t-1) = (\omega_1(i;T_i) - 1)\,[P(t-1) - P_0(i;T_i)] + F(t). \tag{1}$$

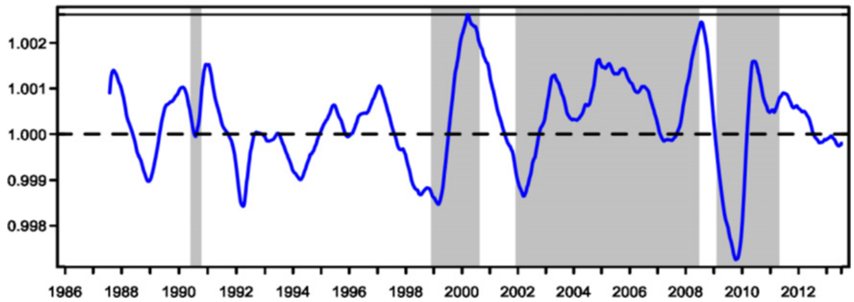
In Eq. (1), $P(t)$ is price at time t, $\omega_1(i;T_i)$ is the parameter characterizing the exponential behaviors in the ith period of length T_i, and $F(t)$ is the residual noise term. $\omega_1(i;T_i)$ and $P_0(i;T_i)$ have the following interpretations:

(i) If $\omega_1(i;T_i) = 1$, the price follows a random walk and $P_0(i;T_i)$ has no role.
(ii) If $\omega_1(i;T_i) > 1$, the price is either exponentially increasing (bubble) or decreasing (crash) and $P_0(i;T_i)$ gives the base line of the exponential divergence.
(iii) If $\omega_1(i;T_i) < 1$, the price is convergent to $P_0(i;T_i)$.

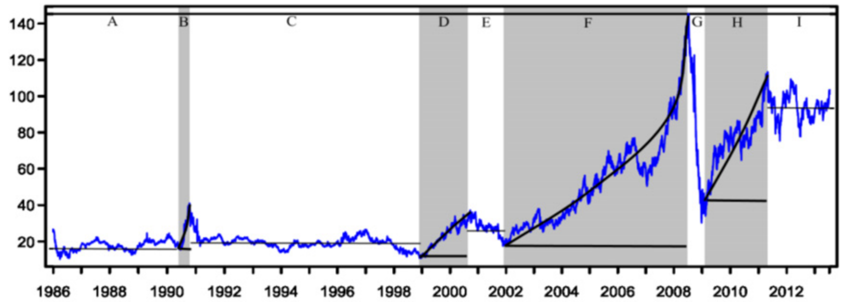
The parameters of $\omega_1(i;T_i)$ and $P_0(i;T_i)$ are determined uniquely from the past T_i data points by the condition that minimizes the root-mean-square of error terms, $F(t)$.

9 Irwin and Sanders [23] argue that the imputed data used by Singleton [22] and Gilbert [19] contain large errors, making their statistical estimates and inferences misleading.

10 It is well known that all price surges are not necessarily bubbles (Zeira [24]). There is a huge literature on bubbles, though some even deny them, e.g., Garber [25], and a majority of these studies can be collected under the rational and behavioral models. See surveys by Camerer [26], Stiglitz [27] and Scherbina [1] for more details.



(a) Estimate of $\omega_1(i, T_i)$.



(b) WTI crude oil price.

Fig. 1. Bubbles and crashes in WTI crude oil price.

To apply Eq. (1), the optimal observation period T_i must be fixed. The following AR equation is used to estimate it:

$$P(t) = \sum_{j=1}^{N=5} a_j P(t-j) + f(t). \tag{2}$$

In Eq. (2), a_j and $f(t)$ are tuned in such a way that Eq. (2) fits the actual data with minimum error.

The following steps are followed in exponential fitting method of Watanabe et al. [28,29][11]:

(i) Using (1), $\omega_1(i; T_i)$ and $P_0(i; T_i)$ are calculated from the past T_i steps, and if $\omega_1(i; T_i) > 1$ all time steps in the observing box of size T_i steps are assigned as exponential divergence; and if $\omega_1(i; T_i) \leq 1$ only the latest time step is in the box is assigned as convergence.
(ii) The box is shifted by one step and (i) is repeated.
(iii) After assignments are done, neighboring divergent time steps are connected.
(iv) A trend curve is drawn for connected divergent periods by using Eq. (3):

$$P_{\text{trend}}(t) = \omega_1(i; T_i) P_{\text{trend}}(t-1) + (1 - \omega_1(i; T_i)) P_0(i; T_i). \tag{3}$$

Finally, to check the validity of such exponential trend approximation, it is compared with a linear trend approximation for a given period by the least square method to minimize the error:

$$E(i) = \sqrt{\text{avg}\,(P(t) - P_{\text{trend}}(t))^2}. \tag{4}$$

In Eq. (4), avg $(\cdot)$ represents average.

3. Data and empirical results

In this paper, we use the daily US dollar closing crude oil prices of West Texas Intermediate (WTI) — Cushing, Oklahoma and that of Brent — Europe. The sample period is from 1987-05-20 to 2013-07-09 for Brent crude oil prices, while it is from 1986-01-02 to 2013-07-09 for WTI. The data used in this study is obtained from Energy Information Administration of US

[11] The rolling estimation of the parameter $\omega_1(i; T_i)$ does not assume any parameter stability. This approach, given the optimal observation window, tracks the changes in $\omega_1(i; T_i)$.

Table 1
Descriptive statistics.

	WTI crude oil price	Brent crude oil price
N	6942	6631
Mean	39.78	41.2505
S.D.	29.1821	32.6523
Min	10.25	9.1
Max	145.31	143.95
Skewness	1.171	1.2143
Kurtosis	0.1574	0.1756
JB	1594.3920***	1639.0710***
Q(1)	6929.5575***	6622.5018***
Q(4)	27 638.7255***	26 425.2140***
ARCH(1)	6887.4405***	6600.0283***
ARCH(4)	6885.0270***	6597.3251***

Notes: In addition to the mean, the standard deviation (S.D.), minimum (min), maximum (max), skewness, and kurtosis statistics, the table reports the Jarque–Bera normality test (JB), the Ljung–Box first [$Q(1)$] and the fourth [$Q(4)$] autocorrelation tests, and the first [ARCH(1)] and the fourth [ARCH(4)] order Lagrange multiplier (LM) tests for the autoregressive conditional heteroskedasticity (ARCH).
*** Represents significance at the 1% level.

Table 2
The beginning and ending dates of bubbles identified by the exponential fitting method for WTI and Brent crude oil price series.

Bubble dates			
WTI crude oil price series		Brent crude oil price series	
Start	End	Start	End
24-Apr-1990	12-Oct-1990	23-Apr-1990	7-Nov-1990
19-Nov-1998	17-Nov-2000	23-Nov-1998	2-Nov-2000
28-Nov-2001	23-Jul-2008	15-Nov-2001	18-Jul-2008
2-Jan-2009	27-Apr-2011	15-Dec-2008	6-May-2011

Department of Energy. Panel B of Figs. 1 and 2 respectively plots the WTI crude oil price and Brent crude oil price for the sample period.

Descriptive statistics for both WTI and Brent crude oil prices are given in Table 1. Estimates of the skewness and kurtosis parameters show that both series are right skewed and more peaked compared to the normal distribution. The Jarque–Bera (JB) test also rejects the normal distribution for both series. Therefore, both series are fat tailed and probability of extreme (particularly positive extreme) values is higher compared to the normal distribution. The autoregressive conditional heteroskedasticity (ARCH) tests indicate strong ARCH effect in both series, implying volatility persistence and clustering. In Figs. 1(b) and 2(b) we observe apparent periods of exponential growth in both the WTI and Brent series during 1990–1991, 1998–2000, 2001–2008, and 2008–2011 periods. Each of these exponential growth periods ends with a sudden crash in prices. All these features point towards existence of bubbles.

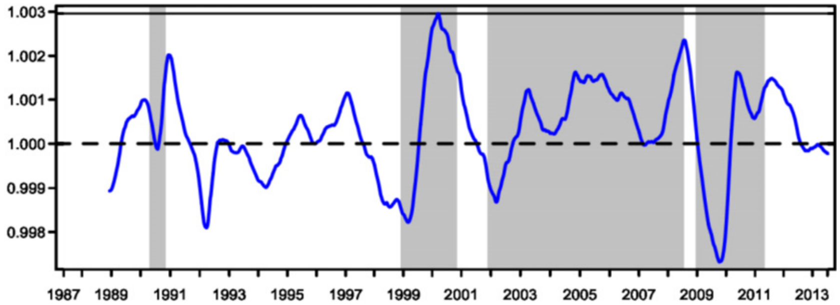
The main objective of this study is to investigate the bubbles in WTI crude oil price and Brent crude oil price separately. For this purpose we specify the $\omega_1(i; T_i)$ and $P_0(i; T_i)$ given in Eq. (1). The plot of estimates of $\omega_1(i; T_i)$ for the WTI and Brent oil price series are reported in panel A of Figs. 1 and 2.[12] It is the $\omega_1(i; T_i)$ that identifies the exponential behavior of price series. Clearly, the first 400 observations for both series are lost due to the first estimation of T_i in panel A of Figs. 1 and 2. The $\omega_1(i; T_i)$ paths show that there are periods of divergence (bubbles and crashes) in WTI and Brent crude oil price series. This evidence supports the argument that oil price determination is not only determined by oil-specific economic fundamentals.

Table 2 presents the beginning and ending dates of bubbles identified by the exponential fitting method. We argue that the nature of the bubbles in crude oil price is different from each other. The first bubble, for instance, took place due to rising uncertainties in the supply of oil in response to the occupation of Kuwait by Iraq and the subsequent war between US-led forces and Iraq.[13,14] During the tension, average monthly price of oil rose from about $17 per barrel in April 1990 to its peak $33 per barrel in October 1990 and down to about $18 by the end of February 1991. The rapid intervention of US and subsequent military success helped to mitigate the potential risk to future oil supplies, thereby calming the market

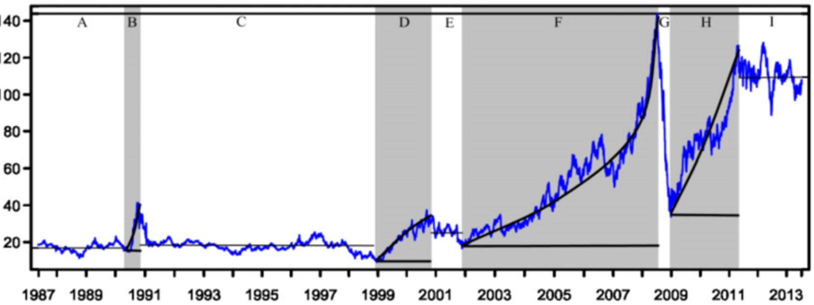
[12] The procedure requires estimating the first $\omega_1(i; T_i)$ in ith period of length T_i. In our case, each T_i is 400 and $\omega_1(1; T_1)$ is estimated from the first observing box of 400. Following Watanabe et al. [28,29], this estimate is assigned to date of observation 400 in Figs. 1(a) and 2(a). However, the exponential behavior identification based on $P_{\text{trend}}(t)$ starts at observation 1 and covers the whole sample period.

[13] On August 2, 1990, Iraq invaded Kuwait, leading to a 7-month occupation of Kuwait. The US-led coalition defeated military forces of Iraq and forced to vacate Kuwait. The so-called Gulf-war ended in 28 February 1991.

[14] See, for example, Hamilton [10] and Kilian [11], having the same argument.



(a) Estimate of $\omega_1(i, T_i)$.



(b) Brent Europe crude oil price.

Fig. 2. Bubbles and crashes in Brent crude oil price.

and restoring confidence. In less than one year, the spike had subsided and by March 1991, price declined back to about \$17 per barrel, as concerns about long-term supply shortages eased. According to our analysis, the bubble lasted about 5.7 months (170 days) in WTI and 6.6 months (198 days) in Brent prices. The duration is consistent with Kilian [11] in that "unanticipated oil supply disruptions have only a small positive effect on the real price of oil".[15]

The 1997–1998 East Asian Financial Crisis caused a sharp decline in oil prices from about \$23 per barrel in January 1997 to below \$10 in December 1998.[16] The price fall due to the East Asian Financial crisis in 1997–1998 is augmented by the quota increases by OPEC. Prices began to recover in early 1999. The recovery of East Asian countries and cuts in quotas moved prices above \$25 per barrel by the end of December 1999. Hence, the second bubble, which happened after the crisis, was due to the rising demand for oil during recovery of East Asian economies. According to our analysis, the bubble started in November 2008 and lasted about 24.3 months (729 days) in WTI and 23.6 months (710 days) in Brent prices.[17]

According to our analysis, the third bubble started in November 2001 and lasted about 80.9 months (2429 days) in the WTI and 81.2 months (2437 days) in the Brent prices. It is very common in the literature to treat the post-2000 period all together. Our analysis however signals two different bubble periods in the 2000s that might have been nourished from different sources. We argue that the main reason behind the bubble in the period November 2001 and July 2008 was the surge in real economic activity in the global economy, as the literature also argues.[18]

The fourth bubble arose almost immediately after the end of the third one, again driven by global aggregate demand, but perhaps with different dynamics. In order to differentiate the fourth bubble from the third one, we first need to recall what did happen in the US housing market, which indeed ended the third bubble. In the US, the home prices started to fall after a period of bubble, which peaked in mid-2006. The fall inaugurated a vicious cycle: lenders increased (adjustable) mortgage rates and made it difficult to renew loans, which accelerated failures and further falls in the home prices. This caused a lost in value of mortgage-backed derivatives due to high leverages, which led to a drastic fall in the appetite of

15 One must note that Kilian [11] made a very clear distinction between the effects of physical disruptions on oil supply and the rise in precautionary demand due to political events that rise uncertainty in oil supply.

16 The crisis began in July 1997 and gripped much of East Asia. It started with the currency crisis and subsequent financial collapse of Thailand. It spread in time to many East Asian countries, including Indonesia, South Korea, Hong Kong, Malaysia, Laos and the Philippines. Most of Southeast Asia and Japan experienced devaluing currency, falling stock and other asset prices, and a rise in private debt. Only by 1999, the Asian economies started to begin to recover.

17 It is very instructive to examine Figs. 2 and 4 in Kilian [11], showing the role of oil-specific demand shock in the period.

18 See, for example, Kilian [11], Buyuksahin et al. [30], Alquist and Kilian [31] and Fattouh [32], having the same argument. Hamilton [10], on the other hand, argues that the reason behind the rise in the 2000s has been the strong growth in global demand and failure of production to accompany that demand, especially between 2005 and 2007 that he labels as 'stagnation in global production'.

Table 3
Comparison of the linear model approximation and the exponential model approximation errors.

Period	*WTI crude oil series*		
	Linear approximation [Lin. $E(i)$]	Exponential approximation [Exp. $E(i)$]	Exp. $E(i)$/Lin. $E(i)$
Bubble periods			
24-Apr-1990/12-Oct-1990	2.4785	0.4485	0.1809
19-Nov-1998/17-Nov-2000	3.1128	0.5365	0.1723
28-Nov-2001/23-Jul-2008	10.7569	1.2741	0.1184
2-Jan-2009/27-Apr-2011	7.5678	1.6261	0.2149
Non-bubble periods			
2-Jan-1986/23-Apr-1990	3.6236	1.0940	0.3019
15-Oct-1990/18-Nov-1998	1.8972	0.6637	0.3498
20-Nov-2000/27-Nov-2001	2.1108	0.7786	0.3688
24-Jul-2008/31-Dec-2008	6.2977	3.9761	0.6314
28-Apr-2011/9-Jul-2013	6.6465	1.6332	0.2457
	Brent crude oil series		
	Linear approximation [Lin. $E(i)$]	Exponential approximation [Exp. $E(i)$]	Exp. $E(i)$/Lin. $E(i)$
Bubble periods			
23-Apr-1990/7-Nov-1990	2.4792	0.4482	0.1808
23-Nov-1998/2-Nov-2000	2.8891	0.4956	0.1715
15-Nov-2001/18-Jul-2008	10.6611	1.2643	0.1186
15-Dec-2008/6-May-2011	7.7365	1.7083	0.2208
Non-bubble periods			
2-Jan-1986/20-Apr-1990	3.6776	1.3124	0.3569
8-Nov-1990/20-Nov-1998	1.9044	0.6674	0.3505
3-Nov-2000/14-Nov-2001	2.0283	0.7651	0.3772
21-Jul-2008/12-Dec-2008	6.3603	4.0329	0.6341
9-May-2011/9-Jul-2013	6.4988	1.5809	0.2433

Notes: Table reports the estimates of the approximations errors given in Eq. (4).

global investors and the trust to the US credit and financial markets. The US and the world economy were at the risk of a long-lasting recession. The Fed responded to this risk in a very radical way by shifting to expansionary fiscal and monetary policies. This led to an unprecedented increase in liquidity and very low real interest rates both in the US and across the globe, resulting in very cheap dollar in the world. We believe that the source of high global aggregate demand was high liquidity, low interest rates and cheap dollar. They caused huge financial inflows to many (storable) commodity markets, including the crude oil market, and triggered the bubble. See, for example, Frankel and Rose [33]. Other studies, like Alquist and Gervais [3], on the other hand, argue that it is not the high liquidity but the global demand conditions that may cause the oil price spikes in the 2000s. We conjecture that there would not have been a crash in oil price in 2008, if the price had spiked due to the global demand (recall that the global financial crisis mainly affected advanced economies and not for example emerging economics). Therefore, the nature of oil price bubbles in the third and fourth tides must have been different. We indeed believe that the high global demand to crude oil was due to the high global demand for intermediate and final goods, which was induced by the high liquidity and low interest rates. Our analysis shows that the fourth bubble started in December 2008 and lasted about 28.1 months (845 days) in WTI and 29 months (872 days) in Brent prices. As is clear from Figs. 1 and 2, the liquidity rise caused crude oil prices to stay in a plateau since then.

Table 3 gives the estimates of the exponential trend approximation error along with the error of the usual linear trend approximation for the bubble non-bubble periods.

The error estimates in Table 3 show that exponential approximation has much lower error than the linear approximation in all periods. In the bubble periods, the error of the exponential approximation relative to the linear approximation varies between 12% and 22% for both the WTI and Brent series. In the non-bubble periods, the error of the nonlinear approximation relative to the linear approximation is higher and varies between 25% and 63% for the WTI series and 24%–63% for the Brent series. Overall, the results in Table 3 show that exponential approximation has superior fit.

4. Concluding remarks and policy implications

In this study, we apply the exponential fitting methodology, proposed by Watanabe et al. [28,29], on daily oil prices in order to identify bubbles and crashes in crude oil prices since 1986. The distinguishing feature of this study from the previous studies is that this paper is the first of its kind, showing the existence of bubbles in crude oil prices in the literature. We found four periods of bubbles since then. Our analyses showed that WTI prices, which is closely followed by Brent prices, experienced bubbles in four periods: April 24–October 12 1990, November 19 1998–November 17 2000, November 28 2001–July 23 2008 and January 2 2009–April 27 2011. We explained each of these bubble periods by a political and/or macroeconomic event, consistent with the literature.

The establishment of futures markets in crude oil market was useful for an efficient determination of crude oil prices. It is actually this increase in efficiency that oil prices respond rapidly to economic or political news which appears consistent with economic theory (Elder et al. [14]). Our analysis showed that the crude oil price data itself suggests the existence of bubbles. We, nonetheless, consider the surges in oil prices as a reflection of the efficiency of the market to all kinds of information rather than speculation. The so-called financialization process, that is, the interest of non-commercial investors to crude oil market, signals that the price of crude oil is no longer determined solely by its supply and demand but instead by the risk appetite and that the investment behavior of commodity index investors has become important. Therefore, further research in this direction would be useful in order to explain the fundamentals of oil price determination.

Our study shows that there are bubbles and crashes in crude oil prices, triggered by various reasons. On surface, it may be a political, military, financial, or economic shock. At its roots, the causes of bubbles (and crashes) in crude oil price are twofold. First, all types of economic activities are over-dependent on crude oil as an energy source. Second, crude oil is subject to depletion. These two causes make the crude oil market very sensitive to any kind of information; the investors in crude oil futures market are ready to use any kind of information to make profit. The implication of bubbles and crashes is the welfare loss caused by distorted relative prices and economic instability: (severe) fluctuations in employment, real wages, price level, and etc. Hence, the obvious policy suggestion implied by this paper is to reduce the over-sensitiveness of crude oil futures market to information. One strategy to make this happen is to support, even to subsidize, the development of substitutes of crude oil, especially renewable energy resources, in order to reduce price bubbles and crashes and to sustain a stable economic activity. The total social welfare gain by reducing price bubbles and economic instability may be higher than the cost of subsidizing more expensive yet promising to have more stable prices.

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