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Testing explosive behavior in the gold market

Wei Long[1] · **Dingding Li**[2] · **Qi Li**[3,4]

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Abstract This paper examines the explosive behavior in the gold market. Using the generalized sup ADF (GSADF) test introduced by Phillips et al. (Testing for multiple bubbles. Cowles Foundation Discussion Paper No. 1843, 2012), we quantitatively examine the existence of explosive periods in the gold market during the period between 1968 and 2013. The date-stamping strategy associated with the test provides a real-time estimation for the origination and termination dates of each explosive period in the gold market, and several explosive periods, including both the famous 1980 explosion and the most recent 2011 explosion, are identified. Our results also demonstrate that, when multiple explosive periods exist within a specific time interval, the GSADF test is more accurate and effective in detecting them than the approach introduced by Phillips et al. (Int Econ Rev 52(1):201–226, 2011), which is relatively conservative. This paper provides further evidence that gold is the safe haven for assets under huge risk and the gold price reacts to political and economic uncertainties relatively faster than other selected commodities do.

✉ Qi Li
qi-li@tamu.edu

Wei Long
wlong2@tulane.edu

Dingding Li
dli@uwindsor.ca

1 Department of Economics, Tulane University, 6823 St. Charles Avenue, New Orleans, LA 70118, USA

2 Department of Economics, University of Windsor, Windsor, ON N9B 3P4, Canada

3 International School of Economics and Management, Capital University of Economics and Business, Beijing 100070, China

4 Department of Economics, Texas A&M University, College Station, TX 77843, USA

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1 Introduction

One old saying about gold states that "The beauty of gold is, it loves bad news."[1] Gold always goes with misfortune, whether economic uncertainty or political instability. Even though used as a medium for trade and exchange for thousands of years, the price of gold has never fluctuated as it has done in the past 45 years.[2] Since 1971 when the US government unilaterally terminated the convertibility between US dollar and gold, dollar has lost its ability to stabilize the gold price. Since then, the international gold market has witnessed several waves of fluctuation. Although the reasons for those fluctuations are not exactly the same, as a tool to hedge risk, gold has always been recognized as a safe haven when economic turmoil and political uncertainty become big concerns. A recent example for the fluctuating gold price could be found after 2008, when the world economy and the global financial market have been shocked by both the American subprime mortgage crisis and the European sovereign debt crisis. As a reaction to the financial crisis, the gold price stayed at a high level and reached its historical high at \$1895 per Troy Ounce on September 5, 2011, bringing big concerns about the existence of "bubbles" in the gold market. However, on April 15, 2013, the gold price in the spot market drastically plummeted by more than 9 %, from \$1535 per Troy Ounce to \$1395 per Troy Ounce.[3] After that, the gold price just hovered at the \$1400 level and even decreased to \$1200 level in late June.

The literatures on bubble detection and bubble estimation in financial markets are voluminous (see Shiller 1981; Blanchard and Watson 1982; Flood et al. 1986; West 1987, 1988). Speculative bubbles are generally evidenced by systematic deviations from the fundamental price of an asset. Under the standard no-arbitrage condition, Blanchard and Watson (1982) defined the fundamental price of the asset as $p_t = \frac{E_t[p_{t+1}+d_{t+1}]}{1+r}$, where p_{t+1} and d_{t+1}, respectively, indicate the stock price and the dividend payoff at time $t+1$, r is the risk-free interest rate, and $E_t[\cdot]$ represents the expectation conditional on the information set based on time t. In the literature, some co-integration-based tests are proposed to detect bubbles (see Diba and Grossman 1984, 1988; Hamilton and Whiteman 1985; Campbell and Shiller 1987). Evans (1991) criticized these methods as they fail to detect bubbles when there are period-

[1] Harry 'Rabbit' Angstrom, the central character in John Updike's 1970s novels about American suburban life.

[2] The US gold standard ended in 1933. During 1934–1973, which Elwell (2011) called a "quasi gold standard" period, "although there was no private market for gold in the USA, such markets did exist abroad. By the late 1960s, prices in these markets were tending to deviate from official currency prices." By abandoning its commitment of convertibility between dollar and gold and stopping the endeavor of stabilizing the exchange rate between the dollar and other currencies, the US ended the Bretton Woods System established after the WW II. Since then, the gold price fluctuates based on the supply and demand relationship.

[3] Source: London Bullion Market Association. Otherwise specified, the unit for the gold price in this paper is US Dollars per Troy Ounce.

ically collapsing bubbles. In a recent work, Engsted and Nielsen (2012) proposed a multivariate framework to test the existence of a rational bubble and found that real stock prices in the US stock market from 1974 to 2000 contain an explosive component.[4]

However, the existing works on the behavior of the gold price are relatively rare comparing with other financial assets. The reason, as argued by Blanchard and Watson (1982), may be partly because of the difficulty in assessing the fundamentals of the gold price. They assumed that gold had two uses—one for industrial uses and the other for risk-hedging purposes—so that the market fundamentals are those which affect the future variations in gold demand/supply and probabilities of disasters. However, both are hard to predict in the real world. Thus, investors have to rely more on gold's recent returns and their personal perceptions rather than analyzing its market fundamentals, and they might even choose to hold gold at a high price as long as gold was still able to generate satisfactory capital gains in the near past.

As we will demonstrate in Sect. 3, there are multiple times that the gold price increased sharply. But not every sharp increase is called a "bubble." Stiglitz (1990) argued that a bubble is caused by investors' speculative motivations even though the fundamental factors do not justify the high price in the future.[5] One referee suggested that "an explosive regime is considered to be a necessary condition for a (rational) bubble [but] it is not sufficient," and the identification of a bubble lies in the comparison between the price series and the fundamental value, which is determined based on Pindyck (1993)'s present value model. However, as we have argued, the fundamental factors for the gold price are hard to define as gold itself does not generate dividends as a stock does. Therefore, in this paper we contribute to the literature by formally and quantitatively testing the *explosive behavior* in the gold price over a longer period. As we will present in the empirical part, all the detected explosive periods are backed by either political turmoil or economic recessions, so that investors' psychological factors lead to the sharp increase in the gold price. Technically, in this paper we employ the generalized sup ADF test (GSADF) proposed by Phillips et al. (2012, PSY hereafter) to examine the explosiveness in the gold market. PSY approach carries out the ADF test recursively in a forward expanding manner and is able to detect the existence of multiple explosiveness during a specific period. A date-stamping strategy associated with PSY approach gives consistent estimations of the origination and termination dates of all the detected explosiveness. Checking the biweekly gold price during 1968–2013, we identify several explosive periods in the gold price path. The estimated origination dates for those explosive periods indicate that the gold price fluctuates drastically when huge political turmoil (e.g., 1973 oil crisis) and economic uncertainty (e.g., 2007 financial crisis) emerge, which threaten the safety of investors' portfolios. In addition, as a safe heaven for assets under risk, the gold market reacts to the recent financial crisis more efficiently compared with some other commodity markets selected by Phillips and Yu (2011). According to their hypothetical timeline for the financial collapse, the gold price rose up almost immediately after the property market collapsed at the end of

[4] We thank a referee for pointing out this.

[5] We thank a referee for pointing out Stiglitz's definition for a bubble.

2007, indicating that investors are selective in transferring their assets when recession happens. This finding makes our conclusion more meaningful to regulators: The test for the existence of explosive behavior in the gold market and the estimation of its origination date would provide an anticipatory warning for the irregular movements in other markets, such as the property market and the stock market.

Another motivation of our paper is that some of the current works are still hesitant about how to determine explosive behavior in the gold market. Bertus and Stanhouse (2001) found several fluctuations which were associated with notable socioeconomic events such as the Black Monday and the Gulf War. But the explosiveness they found has low levels of significance and lasts only for very short periods and the gold price went back very soon, undermining the credibility of their ultimate conclusion. Using the daily data, Mills (2004) systematically examined the statistical behavior of the gold price from 1971 to 2002. But his interpretations for the three obvious "spikes" in the path of the gold price are qualitative. Cai et al. (2001) and Khalifa et al. (2011) took advantage of the high-frequency data to check the volatility and the return distributions of the intraday patterns for the gold price and both confirmed that gold future price was sensitive to exogenous events. However, both works cover only a short time period and are not able to provide more general images of the gold price's historical explosive behaviors. In a recent paper, Baur and McDermott (2010) employed both descriptive and econometric approaches to identify strong stabilizing forces of gold in reducing losses when extreme financial crisis shocks hit the stock markets, especially for the markets in the developed countries. But they did not find significant risk-hedging effects in the emerging markets. In this paper, we concentrate on explosive behaviors which last at least 24 weeks and omit the short-term "spikes," which might be temporary fluctuations and should not be regarded as explosiveness. In a work which is more related to our current analysis, Baur and Glover (2012) used the approach proposed by Phillips et al. (2011, PWY hereafter) and found strong evidence for bubble-like characteristics in the gold price based on the recent 10 years observations. However, when multiple explosive periods exist, PWY may give inconsistent estimate of the beginning and ending dates for the detected explosiveness. A brief comparison between the two methods is presented in Sect. 3. Combining with the socioeconomic background for each detected explosive period, we will investigate the causes of these detected explosiveness.

The remaining part of the paper is organized as follows: Section 2 briefly reviews the method proposed by Phillips et al. (2012). Section 3 introduces the data used and the empirical results obtained. The existence of explosiveness in the gold market is tested, and the origination and termination dates of those detected periods are examined. Section 4 concludes the paper.

2 Theoretical model

Under PSY method, we apply the augmented Dickey–Fuller (ADF) test (Dickey and Fuller 1979) and estimate the following autoregressive model by recursive least squares:

$$y_t = \mu + \rho y_{t-1} + \sum_{i=1}^{k} \psi_i \Delta y_{t-i} + \epsilon_t, \tag{1}$$

where y_t represents the gold price at time t, μ is a constant, ϵ_t is the white noise and is distributed to an i.i.d $N(0, \sigma^2)$. In the GSADF test, under the null hypothesis, y_t is a random walk. That is, $H_0 : \rho = 1$. Under the alternative hypothesis, y_t becomes an explosive series, i.e., $H_1 : \rho > 1$.

Phillips et al. (2012) employed the ADF test recursively in a forward expanding manner. The width of the window, τ_w, expands from τ_0 to 1, where τ_0 represents the minimum width of the window (in fraction) and 1 represents the whole sample. If the sample size is T and at least t_0 observations are required to be included to guarantee that we have sufficient observations for a reasonable initial estimation, we have $\tau_0 = \frac{t_0}{T}$. The choice of the minimum width of window τ_0 is inevitably arbitrary. Phillips et al. (2012) suggested that one might set τ_0 to be small if the sample size is relatively large. In this paper, our sample contains 1183 observations. We set $\tau_0 = 26/1183 \approx 2\,\%$. Since the frequency of our data is biweekly, the selection of $t_0 = 26$ indicates that the sample sequence begins almost 1 year after the starting point 0. Additionally, Phillips et al. (2012) denoted that the starting and the ending point of the sample sequence to be τ_1 and τ_2, respectively, where $\tau_1 \in [0, \tau_2 - \tau_0]$ and $\tau_2 \in [\tau_0, 1]$. Thus, for each sample sequence, both the starting point and the ending point are varying rather than fixed. Estimating the ADF statistic in each regression, Phillips et al. (2012) defined the GSADF statistic to be the supremum ADF statistic over the range between τ_1 and τ_2. Specifically,

$$GSADF(\tau_0) = \sup_{\substack{\tau_1 \in [0, \tau_2 - \tau_0] \\ \tau_2 \in [\tau_0, 1]}} \left\{ ADF_{\tau_1}^{\tau_2} \right\}.$$

Phillips et al. (2012) further derived the limiting distribution of the GSADF statistic and proved that PWY is actually a special case of PSY.

The critical values of PSY and PWY at each level with different sample sizes and τ_0 can be found from Table 1 in Phillips et al. (2012). By Monte Carlo simulations, Phillips et al. (2012) concluded that (1), as τ_0 decreases, the critical values for both methods increase; (2), the finite sample critical values of the test statistic are almost invariant when τ_0 is fixed; and (3), the critical values of PSY are greater than PWY's for a given T and τ_0.

Phillips et al. (2012) also includes a date-stamping strategy to consistently estimate the beginning and ending dates of the detected explosive periods. Even though Phillips et al. (2011) also proposed a similar date-stamping method, Phillips et al. (2012) proved that when there is more than one explosive period, a scenario which is very common in the real world, the date-stamping strategy associated with PWY may give inaccurate estimation results. Alternatively, Phillips et al. (2012) suggested a *backward sup ADF* (BSADF) test. This test implements sup ADF test backwardly—starting at the termination point of the sample size, τ_2, and ending at the origination point τ_1, which varies within the interval $[0, \tau_2 - \tau_0]$. We denote the backward ADF statistic obtained from each regression using the sample from τ_1 to τ_2 as $BADF_{\tau_1}^{\tau_2}$, the BSADF is then defined to be the supremum of the sequence of the BADF statistic. That is to say, $BSADF_{\tau_2}(\tau_0) = \sup_{\tau_1 \in [0, \tau_2 - \tau_0]} \left\{ BADF_{\tau_1}^{\tau_2} \right\}$. Let $\lfloor T\tau_2 \rfloor$ represent the number of observation included in the sample if the ending point is τ_2, where $\lfloor a \rfloor$ represents the integer part of a. Phillips et al. (2012) defined the origination date for an explosive period, denoted by $\lfloor T\tau_{start}\rfloor$, as the first observation whose backward sup ADF statistic exceeds the corresponding critical value of the backward sup ADF statistic. To exclude some short-lived abnormal behaviors, Phillips et al. (2012) additionally required that the duration of an explosiveness should last for at least $\pi \log(T)$, where π represents the frequency-dependent parameter so that we could adjust the requirement for the minimum duration of an explosiveness under various circumstances. Correspondingly, the termination date of an explosive period could be defined as the first chronological observation that falls below the critical value of the backward sup ADF statistic after $\lfloor T\hat{\tau}_{start} + \pi \log(T)\rfloor$ period. Specifically, the estimated fractional origination and termination dates of an explosive period could be determined by finding the first point which satisfy the following two equations:

$$\hat{\tau}_{start} = \inf_{\tau_2 \in [\tau_0, 1]} \left\{ \tau_2 : BSADF_{\tau_2}(\tau_0) > cv_{\tau_2}^{\beta_T} \right\}, \qquad (2)$$

$$\hat{\tau}_{end} = \inf_{\tau_2 \in [\hat{\tau}_{start} + \pi \log(T)/T, 1]} \left\{ \tau_2 : BSADF_{\tau_2}(\tau_0) < cv_{\tau_2}^{\beta_T} \right\}, \qquad (3)$$

where $cv_{\tau_2}^{\beta_T}$ represents the critical value of the sup ADF statistic at the significance level β_T, which depends on the sample size T. Phillips et al. (2012) proved that, under some general regularity, both $\hat{\tau}_{start} \xrightarrow{p} \tau_{start}$ and $\hat{\tau}_{end} \xrightarrow{p} \tau_{end}$. A constructed situation with two explosive periods in Phillips et al. (2012) further proved the consistency of the date-stamping strategy proposed by PSY, while the date-stamping strategy associated with PWY fails to consistently estimate both origination and termination dates for the second explosive period.

3 Empirical results

3.1 Data

In this paper, we use the biweekly Gold Fixing Price 3:00 P.M. (London time) in London Bullion Market from April 1, 1968, to August 6, 2013.[6] The quotes are retrieved from FRED. The London gold fixing is a procedure by which the price of gold is determined twice each business day[7] on the London market by the five original founding members of The London Gold Market Fixing Ltd via a dedicated conference call facility.[8] The price published is widely used as a benchmark price. For comparing purposes, we transform these nominal dollar prices for gold into real price by considering the yearly pricing level from 1968 to 2013.[9] Figure 1 demonstrates the path of the biweekly real price for gold (in 1982–1984 dollars) and we can see

[6] The quotes are obtained by averaging the daily price within biweekly ending on Wednesday.

[7] One is at 10:30 A.M. and the other is at 3:00 P.M.

[8] The official Web site of London Gold Fixing provides more details.

[9] The base year is 1983. The data are retrieved from the Bureau of Labor Statistics. One referee has suggested to consider some other pricing deflators. We additionally considered the Producer Price Index (PPI) and obtained quite similar empirical results, which are available upon request.

Fig. 1 Biweekly real gold price from April 1968 to August 2013, Federal Reserve Economic Data (FRED)

Table 1 Test of existence of explosiveness in the gold price: PWY versus PSY

Sup ADF (%)	PWY 6.9389	PSY 8.7600
10	1.3204	2.5827
5	1.5975	2.8069
1	2.0870	3.3111

The finite empirical critical values at each level are calculated by Monte Carlo simulation with 5000 replications. The sample size is 1183, and the smallest sample window contains 26 observations

substantial fluctuation in the gold price during this period. Gold price is sensitive to any signal that affects investors' perspectives to the safety of their holdings. Thus, it would be meaningful to quantitatively test whether there are explosive periods in the gold market during the past 45 years and if there are, when they begin to emerge and when they burst. This will be discussed as follows.

3.2 Explosiveness in gold price: detection and identification

We first formally test the existence of explosive behaviors in the gold price during 1968 to 2013 period by employing both the PSY and PWY approaches. According to Table 1, both the two test procedures confirm the existence of explosiveness in the gold market—the test statistic for PWY is 6.9389 and for PSY is 8.7600: Both are significantly greater than their respective 1 % right-tailed critical value, which is 2.0870 and 3.3111, respectively. These right-tailed critical values for the two methods are calculated by Monte Carlo simulation with 5000 replications (sample size = 1183). This result is expected since several explosive periods in the gold market such as the one in 1980 have already been widely recognized by both academia and industry.

Explosiveness in one market could be triggered by the exuberance or collapse in another market. As discussed in Sect. 1, gold does not generate dividends or capital gains as stocks and bonds do and over-demands for gold are always triggered by panic in other markets or speculative purposes. This migration could be observed more clearly during the recent gold explosiveness if we take a closer examination on the timeline for the formation of the crisis. Following Caballero et al. (2008, hereafter CFG), Phillips and Yu (2011) generalized a hypothetical timeline for the subprime mortgage crisis which began from August of 2007.[10] According to Phillips and Yu (2011), there are three phases in this crisis: At the beginning, housing bubbles emerged before the formation of the subprime crisis and collapsed soon after the crisis becomes publicly known; investors then transferred their money from the property market to some selected commodity markets and bonds for protection and thus triggered over-demands or exuberance in these markets; in the end, as the crisis escalated and extended to more economies, bubbles in both commodity markets and bonds also collapsed due to the erosion of investors' confidence. Using the US rental-adjusted home price, the crude oil price and the spread between the Baa and Aaa bond rates, Phillips and Yu (2011) argued that their hypothetical timeline is consistent with how the crisis has evolved in the real world. Their arguments clarified the mechanism of volatility transmission.

However, Phillips and Yu (2011) did not observe similar explosiveness or bubbles in some other commodity markets such as coffee and sugar, and they thus concluded that investors are selective in transferring their assets after realizing the crisis. In this paper, we concentrate on gold, another important commodity that is not considered by Phillips and Yu (2011). Under the framework of hypothetical timeline for the spread of crisis in Phillips and Yu (2011), the gold price should be more sensitive to the latent market uncertainties and its price should react to the collapse of property market and the crisis more efficiently than other commodities do. In the meantime, as a risk-hedging tool, the gold price needs not to collapse as other selected commodity markets did in the third hypothetical phase in which the subprime crisis deteriorated rapidly into a global financial crash, draining off the liquidities and suppressing the demands. In any case, both the bleak economic perspective and the speculative incentives contribute to a strong gold price when other commodity markets get shocked by the global imbalance. These arguments will be discussed through some empirical evaluations and analyses.

3.2.1 PSY method

The results obtained through the PSY approach is depicted in Fig. 2. The lower panel in Fig. 2 compares the backward SADF (BSADF) statistic sequence with the 95 % SADF critical value sequence, which are represented by the solid line and the dash line, respectively. This comparison directly locates several significant spikes. If the minimum duration for an explosive period is assumed to be 24 weeks, or about 6 months,

[10] Even though the subprime mortgage crisis emerged in 2006 when there was a dramatic increase in mortgage delinquencies and foreclosures and the housing price fell significantly in the USA, Phillips and Yu (2011) treated August of 2007 as the beginning date of the crisis, when German government officials organized a $5 billion bailout of IKB, a small bank in Germany, at the end of July.

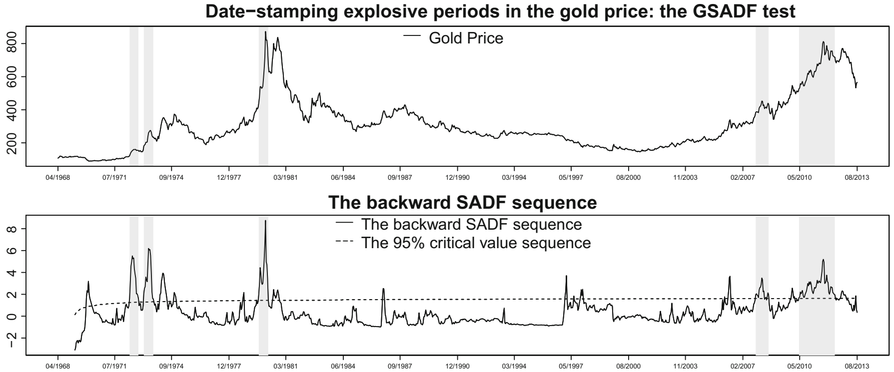

Fig. 2 Detection and real-time date stamping for explosiveness in the gold market using PSY approach (at least 6 months duration). The *upper panel* describes the historical path for the biweekly gold price from 1968 to 2013, adjusted by the 1982–1984 dollars. The *lower panel* compares the backward SADF test statistics sequence with the 95 % critical value sequence. The 95 % critical values are calculated based on Monte Carlo simulation with 2000 replications. Under PSY method, if the minimum duration for an explosive period is assumed to be at least 24 weeks (approximately 6 months), five explosive periods are detected: 05/10/1972–11/08/1972, 02/28/1973–09/12/1973, 09/05/1979–03/19/1980, 11/07/2007–07/30/2008 and 04/21/2010–05/02/2012. These five periods are demonstrated by the *shadow areas*

five explosive periods could be detected and they are demonstrated by the five shadow areas in the upper panel of Fig. 2, which describes the historical path of the biweekly gold price from 1968 to 2013, adjusted by the 1982–1984 dollars.

The first explosive period is from May 1972, 9 months after the Nixon government officially terminated the convertibility between US dollar and gold on August 15, 1971. 1 year later, US devalued dollar to $38 per Troy Ounce from $35 per Troy Ounce. Mills (2004) attributed this first sharp increase in the gold price to “a response to the long period in which it had been artificially held down,” as the developed countries began to print more money for the anticipated fluctuation in currency exchange rates which have been fixed for many years. Mills (2004) complemented that the lack of new mining supply also intensified the demands of gold and thus further promoted the rise of the gold price. The next explosive period came about 3 months later, from February to September in the year of 1973, the eve of the first oil shock. And also during this period, in March 1973, the US devalued dollar again to $42.22 per Troy Ounce. The depreciation in dollar made gold to be more attractive due to its store of value.[11]

The third explosive period is the most significant one of all the five detected episodes. During this period—from September 1979 to March 1980—the gold price rose to its historical high level (measured by 1982–1984 dollars) on January 21, 1980, and dropped sharply after that. The past few years’ recession, which was featured by “stagflation,” undermined the general confidence in currencies, especially in the US dollar. Mingled with the political instability in Iran and Iraq, the second oil crisis aggravated the uncertainty in economic outlook. All these factors led to the inflation of the most famous gold explosiveness.

[11] Mills (2004) has actually combined the two explosive periods as a single one.

The last two explosive periods are more recent episodes. The one surged from November 2007 to July 2008 was driven by the subprime mortgage crisis, which negatively affected almost all the developed countries. The dim perspective for the future of those economies as well as the foreseeable more stringent regulations on financial institutions made gold, which has been credited as the safe haven of wealth when economy crashes, to be attractive to both individual and institutional investors. This result is consistent with our early argument: The gold price dramatically rose up soon after August of 2007 when the crisis became more apparently perceived. Also, our result indicates that the explosive behavior in the gold market came earlier than those detected in the crude oil/heating oil markets and the bonds by Phillips and Yu (2011).[12] This explosiveness in the gold price ended before the official announcement of the bailout plan from the US government. The most recent explosiveness began from the end of April 2010. This is at the mid of the first round quantitative easing and just 1 month before the Federal Reserve had expanded its balance sheet to the peak of 2.1 trillion dollars since it began to purchase mortgage-backed securities from the late November 2008. The next two rounds of quantitative easing, introduced in November 2010 and September 2012, respectively, further helped the Federal Reserve to lower the long-term interest rate. Speculation on the long-lasting low interest rates and concerns of inflation brought by the quantitative easing, as well as the downgraded credit rating of the US government for the first time in the country's history due to the debt-ceiling crisis in the mid of 2011, had promoted the gold price to the historical \$1895 per Troy Ounce (in nominal dollar) on September 5, 2011. Figure 2 indicates that this explosive period had the longest duration compared with the previously detected ones and had not terminated until the middle of 2012, 4 months before the announcement of the third round of quantitative easing. Even though there was one more sharp increase almost 6 months later, that rising trend lasted only 2 months. From then on, the gold price had never gone back to its historical high and began to go down from early 2013. One important reason for this downward trend, according to Roubini (2013), is the slow but steady recovery of developed economies and the foreseeable "exit from quantitative easing and zero policy rate."[13]

If the requirement for the minimum duration of an explosiveness is loosened to 3 months, four more similar periods could be located and the results are demonstrated in Fig. 3. The first explosive period observed now is between November of 1969 and March of 1970. Noticed that during this period, there is an obvious downward trend in the gold price, and it happened a year and a half later after the collapse of the London Gold Pool in March of 1968 due to the fact that the overvalued dollar drained out US gold reserves. This fact also indicates that the date-stamping strategy associated with PSY method is also able to locate collapsing subperiods.[14] The other three newly identified explosive periods just followed or expanded the three main exuberant periods identified in Fig. 2. It can be seen that in an obvious rising phase such like the one in 1972 and the one in 1980, temporary adjustment in the gold price

[12] Phillips and Yu (2011) detected that the crude oil and heating oil price bubbles appear in March of 2008 while the bond spread bubbles appear in September of 2008. See (Phillips and Yu 2011, P. 482).

[13] *The Shine Is Off*, Slate, by Nouriel Roubini.

[14] See p. 28, Phillips et al. (2012).

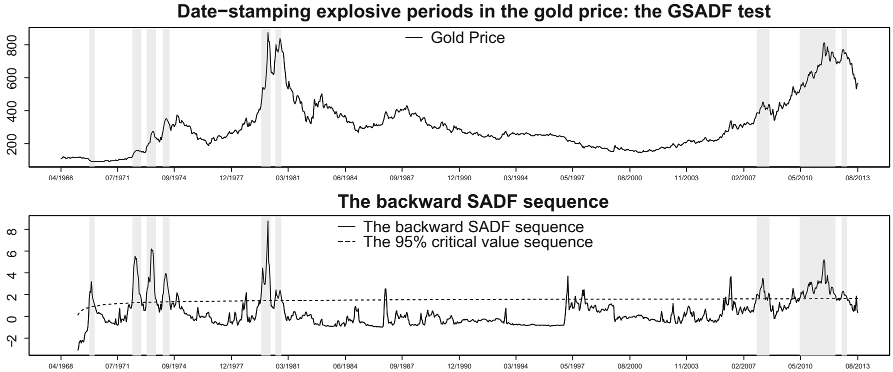

Fig. 3 Detection and real-time date stamping for explosiveness in the gold market using PSY approach (at least 3 months duration). The *upper panel* describes the historical path for the biweekly gold price from 1968 to 2013, adjusted by the 1982–1984 dollars. The *lower panel* compares the backward SADF test statistics sequence with the 95 % critical value sequence. The 95 % critical values are calculated based on Monte Carlo simulation with 2000 replications. Under PSY method, if the minimum duration for an explosive period is assumed to be at least 12 weeks (approximately 3 months), nine explosive periods are detected: 11/26/1969–03/18/1970, 05/10/1972–11/08/1972, 02/28/1973–09/12/1973, 01/30/1974–06/19/1974, 09/05/1979–03/19/1980, 06/25/1980–10/29/1980, 11/07/2007–07/30/2008, 04/21/2010–05/02/2012 and 09/05/2012–12/26/2012. These nine periods are demonstrated by the *shadow areas*

would not disturb the main increasing trend. In those episodes, if the adjustment in the price is not deep and thorough, the gold price tends to bounce back or even rise to a higher level. According to Fig. 3, the recent explosiveness in the gold market ended in the late 2012, just 4 months before the sudden drop of the gold price in April of 2013.

3.2.2 PWY method

For comparing purposes, the PWY approach is employed to the same data since Table 1 has also confirmed that explosive periods do exist during 1968–2013 period under PWY. The results are demonstrated in Fig. 4. Unlike those observed under PSY, now only three obvious explosive periods could be found, and it seems that PWY approach tends to omit the small market adjustment periods for the 1972 and 1980 sharp increasing phases. The first detected explosiveness originated from December 1969 and ended in August 1970, which is similar to the results obtained through the PSY approach. This is consistent with the argument of Phillips et al. (2012), which stated that PWY could still consistently estimate the first one when multiple explosiveness exist during a specific period. However, for the subsequent explosiveness, PWY's estimations of the origination and termination dates tend to be rough and inaccurate. The second substantial rising phase surged from May 1972 and lasted for more than 3 years, to August 1975. The last one detected under PWY is from November 1978 to November 1980. The main difference between Figs. 3 and 4 is that, according to the lower panel of Fig. 4, after the 1980 explosiveness, the backward ADF sequence is quite flat and persistently below the 95 % critical value sequence for almost 30 years until 2011. This indicates that there is no rapid expansion in the gold price over such

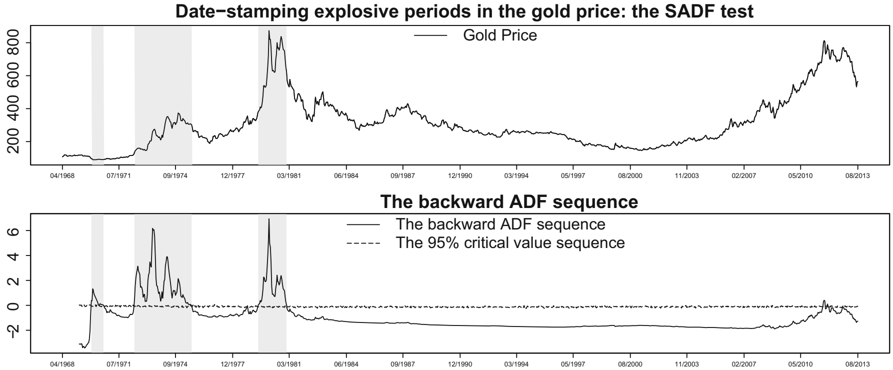

Fig. 4 Detection and real-time date stamping for explosiveness in the gold market using PWY approach (at least 6 months duration). The *upper panel* describes the historical path for the biweekly gold price from 1968 to 2013, adjusted by the 1982–1984 dollars. The *lower panel* compares the backward ADF test statistics sequence with the 95 % critical value sequence. The 95 % critical values are calculated based on Monte Carlo simulation with 2000 replications. Under PWY method, if the minimum duration for an explosive period is assumed to be at least 24 weeks (approximately 6 months), three explosive periods are detected: 12/10/1969–08/19/1970, 05/24/1972–08/27/1975 and 06/13/1979–01/21/1981. These three periods are demonstrated by the *shadow areas*

a long period. Even though the backward ADF statistic sequence surpasses the 95 % critical value sequence twice in 2011, the durations of the two spikes—one is from the end of August to September of 2011 and the other is from the mid-November to December of 2011—are too short to be recognized as explosive periods. The comparison thus provides another example that the PWY approach lacks of consistency when multiple explosiveness exists and is more conservative compared with the PSY approach.

4 Conclusion

In this paper, we employ both Phillips et al. (2011) and Phillips et al. (2012) approaches to detect the explosive behaviors ever existed in the gold market since 1968. Even though both methods confirm the existence of explosive period in the gold price during this time interval, in general PSY method is able to locate explosiveness more accurately and detect the recent rising trend in the gold price during the financial crisis period, while the PWY method finds only three explosiveness and fails to detect the existence of the two explosive periods in the gold price during 2011. This supports the argument that Phillips et al. (2012) is more suitable for detecting pricing explosiveness when multiple explosive periods exist. In addition, this paper once again confirms that gold is the safe haven for risky assets—the backgrounds for all the detected explosive periods are associated with political turmoil, economic recession and concerns about inflation which are erosive to investors' holdings. The recent explosiveness in the gold price emerged soon after the beginning of the subprime mortgage crisis as panic investors transferred assets from property market to the gold market and the gold price reacted to economic turmoil more rapidly than prices of other commodities. For regulators and market participants, an early identification of explosiveness in the gold market might provide an anticipatory warning for irregular behaviors in other markets and relating economic indices. We would like to emphasize that this paper just concentrates on the detection of explosiveness in the gold market; to confirm which explosiveness is a bubble, some thorough discussions are needed.

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