A Gold Bubble?

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First draft: October 25, 2012

Abstract

In this paper we use a test developed by Phillips et al. (2011) to identify a bubble in the gold market. We find that the price of gold followed an explosive price process between 2002 and 2012 interrupted only briefly by the subprime crisis in 2008. We also provide a theoretical foundation for such bubble tests based on a behavioural model of heterogeneous agents and demonstrate that periods of explosive price behaviour are consistent with increased chartist activity in the gold market. The identification strategy yields economically intuitive results and is a simple alternative to using more complex estimation techniques commonly used in the heterogenous agents literature.

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JEL classification: C22; C51; G02

Keywords: bubble; gold; investor behaviour; explosive process; heterogeneous agents; chartists
Combating asset price bubbles ... requires us to be successful in both identifying the incipient bubble and in developing and implementing a response that will limit bubble growth and avert a destructive asset price crash.


The ultimate asset bubble is gold.

—George Soros, The World Economic Forum 2010, Davos, Switzerland.¹

Asset price bubbles have presented an important (and difficult) challenge to researchers and policymakers for centuries.² Yet there is still not a widespread understanding of the causes of such price behaviour and some fundamental questions still appear to remain unanswered. One such question, which is the focus of the present paper, is how can we define an asset price bubble in a practical way in order to be able to identify their existence?³

Recent renewed interest in asset price bubbles however, precipitated by the sub-prime crisis or global financial crisis in 2008, has increased our understanding of the possible mechanisms through which bubbles (and their inevitable collapse) are generated. Such insights now allow us to detect early warning signs of potential bubble-like behaviour. More specifically, recent advances in the detection of asset price bubbles from their time-series characteristics, developed in a series of works by Peter C. B. Phillips and co-authors,⁴ means that it is no longer necessary to wait

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¹See http://www.telegraph.co.uk/finance/financetopics/davos/7085504/Davos-2010-George-Soros-warns-gold-is-now-the-ultimate-bubble.html. At this time Soros also massively reduced his stake in gold ETFs before gold recorded annual gains in 2010 and 2011 and rose to a high of $1,920.30 per ounce in September 2011.
²For a detailed history see, for example, Kindleberger (2005).
³We focus here only on the detection of such bubbles, however there are many related questions regarding the appropriate policy response if a bubble is indeed detected. In this regard, the heterogeneous agents foundation for the bubble tests presented in Section 2 may be useful.
⁴See, for example, Phillips et al. (2011), Phillips and Yu (2011) and Phillips et al. (2012). Technically, the method relies on recursive regressions coupled with sequential right-sided unit-root tests.
for a market correction in order to identify bubble-like behaviour.\textsuperscript{5} Such an ability to detect bubbles prior to their collapse is crucial if policies are to be implemented in a timely manner in order to reduce the severity of the inevitable price correction; and the resulting impact on financial stability and the real economy.

In relation to gold, only a cursory inspection of the time series of gold prices over the last 40 years begs the question as to whether or not gold has been experiencing bubble behaviour since the turn of the century—making gold an ideal candidate for the application of these newly developed bubble tests. The aim of this paper, therefore, is to employ the econometric techniques developed by Phillips and co-authors to test if, and indeed when, bubbles have emerged (and collapsed) in the market for gold. The ability to tell whether gold is or is not in a bubble has important implications given that gold is viewed by many as a store of value and a safe haven (see Baur and Lucey, 2010; Baur and McDermott, 2010). If the price of gold is inflated and exhibits bubble-like characteristics the safe haven property can be destroyed and with it the stabilizing effect of the existence of such an asset on the financial system.\textsuperscript{6}

A major advantage of the proposed bubble tests in the context of the gold market is that no assumption is needed regarding the fundamental value of the asset; Phillips and Yu (2011) interpret explosiveness in price as sufficient evidence for the existence of bubbles. Therefore, due to the distinct lack of a believable consensus fundamental value for gold we also adopt this interpretation in the present paper.\textsuperscript{7}

\textsuperscript{5}Gürkaynak (2008) provides a detailed survey of the state of the advances in the econometric detection of asset price bubbles up to 2008 (pre-Phillips).

\textsuperscript{6}Baur and Glover (2012b) study the mechanisms through which investors could potentially destroy the safe-haven property of gold and similar safe-haven assets.

\textsuperscript{7}It should be noted that for those assets for which a fundamental value is readily available or estimated, the question of defining a bubble should involve these estimates of the fundamental value. However, for those assets whose fundamental value is opaque such as commodities, and in particular gold, this method removes any errors due to mispecification of the fundamental value.
In addition, similarly to Phillips et al. (2011),\(^8\) who demonstrate that a rational bubble leads to explosive price behaviour, we justify an explosive price process from an alternative heterogenous agents foundation. Therefore, instead of merely detecting bubble behaviour in the gold market, our behavioural foundation for the dynamics estimated in the bubble tests allows us to glean information about the activities of speculative traders in the gold market over time. These results indicate that the number and impact of speculative traders varies through time and that in periods where specific groups of traders are more active the price dynamics change from a mean-reverting process (consistent with the real supply and demand for gold) to an explosive process.

**Related literature**

The precipitous rise in gold prices in recent years has not gone unnoticed by the academic literature. Other recent studies have also attempted to assess whether the gold market is currently exhibiting a price bubble, however these papers use different methodologies and as such reach differing conclusions. Bialkowski et al. (2011) attempt to test for bubble behaviour in the price of gold by estimating the fundamental value of gold using the convenience yield model of Pindyck (1993).\(^9\) While this method produces some interesting results (indicating that a gold bubble does not currently exist) we choose instead to employ a method that needs much

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\(^8\)See also Diba and Grossman (1988).

\(^9\)In a recent update of their paper, Bialkowski et al. (2012) modify their approach by constructing a fundamental value of gold from a multivariate regression of gold returns on proxies for the many various roles that gold plays in the financial markets, such as a dollar hedge, inflation hedge, portfolio diversifier, and safe haven. While this method also produces some interesting results (again indicating no gold bubble) we believe that some of the factors modelled here should not be interpreted as fundamental factors but instead as factors that have induced speculative investors into the gold market, inducing bubble-like behaviour there. Indeed, if enough factors where added to the fundamental value of gold then we would always be able to explain away any bubble-like behaviour of gold prices. This argument demonstrates, once again, that it is a very subjective task to construct a fundamental value of gold, motivating our decisions to avoid the need to do so.
less restrictive assumptions on the knowledge of the fundamental value of gold.

Similar to the present paper, Jarrow et al. (2011) also do not use any notion of the fundamental price of gold in order to test for a bubble in the gold market. These authors reach the conclusion that the recent rise in the gold price was not a bubble, however their methodology is very different to ours and is based on an analysis of the volatility structure of gold prices; the intuition being that speculative trading abnormally increases the asset’s volatility. It must be noted, however, that these authors only employ one week of tick data from August 2011 to test for bubble behaviour.

Evidence in support of a bubble in the gold market includes Homm and Breitung (2012), who also adopt and modify the framework of Phillips et al. (2011). As an application they consider many asset markets, including gold, finding evidence of bubble-like behaviour in the gold price; detecting significant explosive behaviour (at the 1% level) for the period January 1968 to January 1980 but with less significant behaviour (only at the 10% level) for the period January 1985 to November 2010. However, only a very limited analysis of gold is provided in this paper.

An important strand of the extant literature, intimately related to the issue of bubbles in commodity markets such as gold, is the role in which institutional investors have played in driving commodity prices in recent years. Since the turn of the century, commodities markets (including gold) have seen the investment of billions of dollars from institutional investors and, as such, commodities now constitute a considerable proportion of many investors’ portfolios. As a result of this, it is believed by many that a structural change in the commodity markets has occurred, leading to a process known as ‘the financialization of commodities’ (see Tang and Xiong, 2010). The behavioural foundations for the price dynamics proposed in Section 2
are in line with this process and provides an alternative theoretical justification for
the bubble tests employed.

There has also been some recent literature supporting our view that the funda-
mental price of gold is extremely difficult to determine, and so should be avoided
if at all possible in tests for a gold bubble. Most notably, Blose (2010), using data
from 1988-2008, report that changes in expected inflation, a quantity often thought
to be one of the main drivers of a ‘fundamental’ value of gold, does not appear to
significantly affect the price of gold. This result casts doubts on the validity of the
proposed fundamental drivers of the gold price.

In regards to the bubble tests employed in the present paper, Phillips et al.
(2011) introduced a recursive regression methodology to investigate the explosive
characteristics of asset prices; identifying periods of significant explosive behaviour
as an asset price bubble. Phillips and Yu (2011) later modified this methodology
to test for bubble migration across different asset markets. They concluded that
a bubble in the real estate market, starting in February 2002, migrated selectively
into both the commodity market\footnote{Note that commodity prices and gold prices do not fit into the theoretical framework of rational
bubbles since they provide no future cash flows, however Phillips and Yu (2011) take explosive prices
as evidence of speculator induced bubble-like behaviour.} and the bond market following the onset of the
subprime crisis in 2007. They suggest that a flight-to-quality or perceived safe haven
phenomena were at play during this time. Notably absent in the analysis of Phillips
and Yu (2011) is the gold market, which appears to be an ideal candidate for such
tests. Our paper fills this gap.

Finally, we note that Arora and Shi (2012) also propose a heterogenous agent
foundation for certain asset price bubble tests. However, these authors refer to
tests developed by van Norden (1996) and Brooks and Katsaris (2005)—based on
differing bubble regimes—rather than the more recent tests, proposed by Phillips
et al. (2011), considered in the present paper.

This paper contributes to the literature in two major ways. First, it presents an empirical application of a recently developed bubble-identification framework to an asset of global importance and second, it provides an alternative foundation for such a test based on the heterogeneous agents literature. This paper also demonstrates that there is a rather simple alternative to the estimation of complex switching mechanisms commonly used in the heterogeneous agents literature for identifying periods of speculative trader activity.

The bubble-identification methodology reveals that gold exhibited bubble-like characteristics and an explosive price behaviour in recent years. Furthermore, our behavioural foundations for the bubble tests allow us to interpret the p-value generated from such tests as a simple (and almost natural) proxy for the weight or the importance of speculative traders relative to investors following more stabilizing strategies or real demand and supply factors.

The remainder of this paper is structured as follows: Section 1 describes the econometric framework to test for explosive price behaviour and bubbles. Section 2 presents the behavioural foundations for the bubble test. Section 3 describes and discusses the estimation results. Finally, Section 4 summarizes the findings and concludes.

1 Econometric Framework

To test for evidence of explosive behaviour in the price of gold we follow Phillips et al. (2011) (henceforth PWY) and recursively estimate right-sided unit-root tests. We use different start dates or initialization dates and can identify periods of statistically significant explosive price behaviour and periods of statistically insignificant
explosive price behaviour.

More formally, we apply the augmented Dickey-Fuller (ADF) test and estimate the following autoregressive specification by recursive least squares

\[
X_t = \mu + \delta X_{t-1} + \sum_{j=1}^{J} \phi_j \Delta X_{t-j} + \epsilon_t
\]  

(1)

where \( \epsilon_t \sim iid(0, \sigma^2) \).

The model is estimated repeatedly using subsets of the sample data incremented by one observation at each iteration. It is a forward recursive estimation strategy since the number of observations increases moving forward in time at each iteration. The lag order \( J \) is determined following the approach by Campbell and Perron (1991). The null hypothesis is \( H_0 : \delta = 1 \) and the right-tailed alternative hypothesis is \( H_1 : \delta > 1 \) which allows for mildly explosive autoregressions.

We use the resulting ADF t-test statistic and the associated p-value calculated for each (recursive) sample up to observation \( t \) to analyze whether there are periods in which the price process is mildly explosive and thus consistent with a bubble. We will show in the next section that an explosive process is consistent with chartists or feedback traders whilst a non-explosive process is consistent with real demand and investors who do not follow chartist strategies. Once more we note that an advantage of this approach is that no assumption is needed regarding the fundamental value of the asset, i.e. the econometric framework to test for bubbles does not depend on a fundamental value as in Bialkowski et al. (2012) among others.

We do not follow the approach of PWY and date stamp the origination and the collapse of any periods of explosive price behaviour since our interest lies in the question of whether or not there exists a bubble in the gold market. The forward recursive estimation technique provides this information but we are happy with a
graphical identification. We do not think that it is important to know the exact origination but rather a period in which it originated or whether there is a bubble at all. Given the conflicting evidence of the existing research on bubbles in the gold market it seems more important to identify the existence of a bubble and its causes rather than to date stamp the origination by the day. Our empirical results provide strong evidence for the existence of a bubble in the gold market but also illustrate that the exact origination varies with the chosen sample period. Interestingly, the empirical results are very similar and thus robust with respect to different sample frequencies.

2 A behavioural foundation for the bubble tests

The aim of this section is to provide an alternative behavioural foundation for the bubble test of PWY. We demonstrate that there exists a theoretical mapping between the ADF test statistic (and the associated p-values) of such bubble tests and the activity and importance of certain chartist groups commonly used in the heterogeneous agents literature.\(^{11}\) We assume the following structural model for the price formation (see, for example, Farmer and Joshi, 2002; He and Westerhoff, 2005)

\[
P_{t+1} = P_t + \theta \left( \sum_h D_t^h - S_t \right) + \epsilon_t
\]

where \(P_t\) denotes the gold price, \(D_t^h\) the demand of agents of ‘type’ \(h\), and \(S_t\) the available supply of the asset. The types of agents active in a given market and their associated asset demands can be wide-ranging and dependent on the particular application. In the present context of the gold market, which is both a real and

\(^{11}\)For a detailed survey of the history and recent advances in heterogeneous agents models see Hommes (2006), Chiarella et al. (2009), or Hommes and Wagener (2009).
a financial asset, there is clearly demand for gold in industrial uses (such as the manufacture of jewelry) and as an investment or speculative asset. We therefore chose to model one agent type to represent real consumer demand, denoted as $D_t^R$. We also explicitly model the demands of two types of so-called ‘chartist’ behaviour, which we call ‘trend followers’ and ‘threshold traders’, denoted by $D_t^{CF}$ and $D_t^{CT}$ respectively. In a departure from the usual heterogeneous agent models, we do not attempt to explicitly model the influence of any gold market ‘fundamentalists’ since, as we alluded to above, we believe that the lack of consensus on a fundamental value of gold, and the resulting dispersion in the agents beliefs, would render such agents aggregate demand tantamount to noise (and so can be incorporated in the noise term $e_t$ above).

Consistent with He and Westerhoff (2005) amongst others, the real demand and supply of gold is modelled in the following stylized and intuitive way

$$D_t^R = a_R - b_R P_t, \quad S_t = a_S + b_S P_t,$$

where $b_R > 0$ and $b_S > 0$, indicating that the demand for gold decreases, and the supply of gold increases, as the gold price rises. The chartists’ demand for gold is dependent on their (heterogenous) beliefs about future price movements and is given by

$$D_t^h = \sum_{j=1}^{N_t^h} a_j^h \left( E_t^{h,j}[P_{t+1}] - P_t \right), \quad h = CF, CT$$

where $a_j^h$ are reaction parameters and $N_t^h$ denotes the (potentially time dependent) number of agents of type $h$ active in the market at time $t$. The expectations are taken with respect to each agent’s subjective belief. Such beliefs are modelled to be consistent with common trading strategies employed by many traders and for our
two groups of chartists they are chosen to be

\[ E_t^{CF,j}[P_{t+1}] = P_t + b_{CF}^j(P_t - P_{t-k_j}), \quad E_t^{CT,j}[P_{t+1}] = P_t + b_{CT}^j(P_t - c^j_t), \]

where the extrapolation parameters \( b_{CF}^j \) and \( b_{CT}^j \), the (possibly time dependent) threshold \( c^j_t \), and the time window over which the trend followers extrapolate past trends \( k_j \), are all allowed to vary across different agents.

At this stage we pause to note that the threshold traders above could also be interpreted as ‘contrarian fundamentalists’ if we identified the threshold \( c^j_t \) as agent \( j \)’s subjective estimate of the fundamental value; their demand function would therefore be consistent with the chartist demand introduced in Day and Huang (1990).\(^{12}\) However, since we recognize the difficulty in estimating such a fundamental value, we allow for a more general interpretation of the threshold level \( c^j_t \). For example, the threshold \( c^j_t \) can also be interpreted in the context of ‘anchoring’, as was described by Tversky and Kahneman (1974). Here, investors base their demand on a certain price level that may function as an anchor. The larger the difference of the current price and the (subjective) anchor, the larger is the demand of these agents, potentially causing explosive price behaviour.

We also comment that this framework is consistent with the idea presented in Brunnermeier (2008) that if a bubble persists, and prices become ‘too’ high, it becomes optimal for fundamental traders to switch to more chartist strategies and \textit{ride} the bubble; they simply cannot afford to trade against the market.\(^{13}\) In our framework this behaviour would correspond to agents changing their parameter \( b_{CT}^j \) from a negative to a positive value in response to a persistent period of increasing prices.

\(^{12}\)Furthermore, threshold traders whose extrapolation parameters \( b_{CT}^j \) is negative could be interpreted as standard fundamentalist in the sense of Day and Huang (1990).

\(^{13}\)Unless you are George Soros, as we noted in our opening quotes.
prices.

Putting the above demands together in (2) yields

\[ P_{t+1} = a + (1 - b)P_t + \sum_{j=1}^{N_{CF}} \alpha_j^{CF}(P_t - P_{t-k_j}) + \sum_{j=1}^{N_{CT}} \alpha_j^{CT}(P_t - c_j^t) + e_t \]  

where \( a := \theta(a_R - a_S), \) \( b := \theta(b_R + b_S), \) and \( \alpha_j^h := \theta a_j^h b_j^h \) denotes the price impact of agent \( j \) of type \( h \). The above can further be manipulated as follows\(^\text{14}\)

\[ P_{t+1} = [a - a_t] + [1 - b + b_t^{CT}] P_t + \sum_{k=0}^{K} \alpha_{t,k}^{CF} \Delta P_{t-k} + e_t \]  

where \( a_t := \sum_{j=1}^{N_{CT}} \alpha_j^{CT} c_j^t \) denotes the impact of the agents thresholds on prices and \( b_t^{CT} := \sum_{j=1}^{N_{CT}} \alpha_j^{CT} \) represents the (time dependent) aggregate price impact of the threshold chartists. Finally, \( \alpha_{t,k}^{CF} = \sum_{i=k+1}^{K} \sum_{j=1}^{N_{CF}} \alpha_j^{CF} I(k_j = i) \), which denotes the aggregate impact of the trend-following chartists on the lagged difference \( \Delta P_{t-k} \), where \( K \) is the maximum lag used by any agent.

In relation to the bubble tests of PWY, we see that the above model specification corresponds exactly to an ADF test (with the appropriate lags) but with time varying parameters that we can map directly onto the variation in the impact and number of the different chartist types as they evolve through time.\(^\text{15}\)

We can see that the chosen real consumer demand and supply functions for gold would result in a stationary gold price in the absence of any speculative trading.\(^\text{16}\)

\(^{14}\)We note that the parameters \( a \) and \( b \) would be much larger in magnitude than \( \alpha_j^h \) since this parameter denotes the price impact on an individual investor on gold prices and in likely very small. The aggregate affect of each group of agent types, however, is clearly dependent on the number of such agents active at that time, an affect that could potentially be very large.

\(^{15}\)An ADF test can be written as follows: \( P_{t+1} = \mu + \delta P_t + \sum_{j=0}^{J} \phi_j \Delta P_{t-j} + \epsilon_{t+1} \). The larger \( \delta \) the larger the role of threshold traders (CTs) and the stronger will be the evidence for this in the test statistics and the p-values.

\(^{16}\)Recall that the price is stationary if \( \delta \) in Eq. (1) or \( (1 - b) \) in Eq. (3) are smaller than one.
In other words, real supply and demand results in gold prices that exhibit mean-reverting behaviour, consistent with standard economic theory. Interestingly, and perhaps counter to one’s initial intuition, we see that pure trend-following chartist activity (CFs) would not result in explosive price behaviour; as defined by $\delta > 1$ in (1).\textsuperscript{17} The reason for this is that such chartist activity increases the future price proportional to the price differences observed in the past—but never by more than that. This implies that the price process does not result in explosive characteristics. Instead, it can be seen that the explosive nature of our linear model above is due entirely to the threshold chartists (CTs) whose demands are price-level dependent. Their behaviour may result in an explosive price process since their demand is not restricted to be based on past price changes as for the trend-following chartists. Such investors buy the asset because the current price is above a certain value, here a threshold $c^j_t$, and if the current price is well above the threshold the effect on the future price will be even higher. This implies that future prices can indeed increase by more than it has increased in the previous period thereby potentially generating an explosive price process. These conclusions are in line with the existing heterogeneous agents literature where the explosive behaviour is often induced by contrarian fundamentalists (e.g. see Day and Huang, 1990) and not by pure trend followers. When chartists are simply trend following, they are usually described as destabilizing, rather than as explosive (e.g. see Hommes and Wagener, 2009).

\textsuperscript{17}An explosive process can be thought of as a process whose absolute price changes are higher the higher the level of the price, therefore in the absence of noise, or other mean-reverting forces, the process would explode.
3 Empirical Results

This section presents the empirical results and is structured in a descriptive part, a presentation and discussion of the estimation results based on monthly data and daily data, and an interpretation of the results with a focus on the heterogeneous agents foundation of the bubble test and its implications.

Figure 1 shows the evolution of the price of gold measured at a monthly frequency and denominated in US dollars from January 1970 to August 2012. The Figure illustrates that the price of gold increased significantly from around US$ 300 around the year 2000 to above US$ 1,900 in 2011. The magnitude of the price increase is consistent with significant speculative demand and suggests the presence of a bubble. We assume that an increasing price of an asset over a relatively long period (10 years) can not be explained with a change in the fundamental value of the asset (if it exists; see Baur and Glover, 2012a). A large change in any fundamental value should be incorporated in the price of the asset within a relatively short time span but not over a period of 10 years. A long sequence of small changes in the fundamental value may be an alternative explanation but is highly unlikely.

*** Insert Figure 1 about here ***

Figures 2-4 constitute the first part of the presentation and discussion of the estimation results. The figures show the test statistic and the associated p-values for monthly data based on the full sample period from 1970 to 2012 (Figure 2) and two shorter sample periods, namely from 1990 to 2012 (Figure 3) and from 2000 to 2012 (Figure 4).\textsuperscript{18}

\textsuperscript{18}The estimates are obtained with the use of the software R. The ADF test results are based on
Figure 2 illustrates that statistically significant bubble characteristics are found for some episodes between 1970 and 1980 and between 2008 and 2012. Figure 3 displays the results for a shorter sample period from 1990 to 2012 and shows significant bubble characteristics between 2006 and 2012. A further shortening of the sample period by 10 years from 2000 to 2012 (see Figure 4) moves the origination of the bubble further back in time to the year 2002 and yields a 10-year episode of significant bubble characteristics only shortly interrupted in 2008.\footnote{We also applied a forward-moving fixed window regression as an alternative to the forward recursive regression. Not surprisingly, a fixed moving window yields more volatile results, i.e. more switching between periods of significant bubble characteristics and periods of insignificant bubble characteristics.}

The results for monthly data illustrate that the sample period has an influence on the identification of bubble characteristics.

The use of daily data potentially increases the power of the bubble test and can also identify differences in the use of daily and monthly data. In other words, is the bubble identification framework more likely to detect bubbles for daily or for monthly data? While this seems to be a statistical question the analysis of both

\begin{itemize}
  \item The functions \texttt{adf.test} and, for robustness checks, the function \texttt{pp.test} (Phillips Perron test).
  \item The lag order is determined similar to the approach by PWY as suggested in Campbell and Perron (1991). The lag order for monthly data is estimated at 7 months and the lag order for daily data is estimated at 22 days for the full sample periods from 1970 to 2012. Shorter sample periods generally decrease the lag order slightly.
\end{itemize}
daily and monthly data also provides a methodology to analyze whether chartist or feedback trader behaviour is more prevalent for daily data or for monthly data.

Figures 5-7 present the estimation results for three different sample periods of decreasing size based on daily data. The results show that daily data identify very similar episodes of significant bubble characteristics compared to the results based on monthly data.

*** Insert Figure 5 about here ***

*** Insert Figure 6 about here ***

*** Insert Figure 7 about here ***

The estimation results imply that the gold price behaved like a bubble for periods in the 1970s and early 1980s, and, depending on the sample period, in the period between 2002 and 2012. We have outlined in Section 2 that a bubble, when defined as an explosive price process, is caused by chartists or contrarian fundamentalists following certain trading strategies. We want to extend the economic foundation for bubbles to a mapping of the p-value with the importance of chartists following strategies that lead to an explosive price process. Since the p-value is always between zero and one, it provides a simple (and almost natural) proxy for the weight or the importance of chartists relative to investors following more stabilizing strategies or real demand and supply factors. Hence, we interpret the p-values close to one as evidence for the dominance of real factors or investors that follow strategies that are consistent with a mean-reverting price behaviour and p-values close to zero as
evidence for the dominance of chartists strategies. Episodes in which the p-value is close to one can be identified in the 1970s especially with the use of daily data and the full sample period. Episodes which imply a large weight of chartists are consistent with low p-values such as the episode between 2002 and 2012 identified with daily data.

4 Conclusions

This paper applied a recently developed test to the price of gold to answer the question whether gold features bubble-like characteristics. The answer is yes. We find strong evidence of explosive price behaviour based on different sample periods and different sample frequencies, i.e. daily and monthly data. The results show that both daily and monthly sampling frequencies provide similar results and detect a bubble period extending from 2002 to 2012 only shortly interrupted in 2008 and 2009 possibly due to the effects of the subprime crisis. We also propose a behavioural foundation for the bubble test and show that chartists, more precisely agents using certain price thresholds, dominate the gold market today which means that the real demand has indeed declined in relative importance. This interpretation is backed by data on the demand components of gold which show that real demand has indeed significantly declined relative to investment demand (e.g. see World Gold Council, 2012).

The estimation results imply that the role of gold as a store of value and a safe haven is under threat. Bubbles often pose a risk to financial stability but the consequences may be more severe if the asset is viewed as a stable and safe asset. If the price of gold continues to display characteristics of a bubble policy makers should be aware of the potential implications for financial stability.
Finally, it should be noted that the mere existence of bubble-like behaviour in the gold market need not, in itself, be cause for concern. If the bubble were to ‘burst’ slowly, i.e. over a one-year or two-year period, the implications for financial stability may be less severe than an abrupt and extreme fall in the price of gold. Therefore, one essential component in determining policy implications, and an avenue for future research in this area, is to assess the likelihood of an abrupt bursting of the gold bubble.

References


Figure 1: Price of gold. The graph shows the evolution of the price of gold measured at a monthly frequency (15th of each month) in US dollars from 1970 to 2012.
Figure 2: **Bubble test statistic and p-value - sample: monthly prices 1972 - 2012.** The figure shows two plots. The top graph plots the bubble test statistic of a unit-root test with a mildly explosive process as an alternative. The bottom graph plots the associated p-value and can be used as an estimate of the amount of chartist activity in the gold market. A p-value close to zero implies that the null hypothesis of an explosive price process and the dominance of chartists cannot be rejected at a significance level of $(1 - p)\%$.
Figure 3: Bubble test statistic and p-value - sample: monthly prices 1990 - 2012. The figure shows two plots. The top graph plots the bubble test statistic of a unit-root test with a mildly explosive process as an alternative. The bottom graph plots the associated p-value and can be used as an estimate of the amount of chartist activity in the gold market. A p-value close to zero implies that the null hypothesis of an explosive price process and the dominance of chartists cannot be rejected at a significance level of $(1 - p)\%$.
Figure 4: **Bubble test statistic and p-value - sample: monthly prices 2000 - 2012.** The figure shows two plots. The top graph plots the bubble test statistic of a unit-root test with a mildly explosive process as an alternative. The bottom graph plots the associated p-value and can be used as an estimate of the amount of chartist activity in the gold market. A p-value close to zero implies that the null hypothesis of an explosive price process and the dominance of chartists cannot be rejected at a significance level of $(1 - p)$%.
Figure 5: **Bubble test statistic and p-value - sample: daily prices 1971 - 2012.** The figure shows two plots. The top graph plots the bubble test statistic of a unit-root test with a mildly explosive process as an alternative. The bottom graph plots the associated p-value and can be used as an estimate of the amount of chartist activity in the gold market. A p-value close to zero implies that the null hypothesis of an explosive price process and the dominance of chartists cannot be rejected at a significance level of \((1 - p)\%\).
Figure 6: **Bubble test statistic and p-value - sample: daily prices 1990 - 2012.** The figure shows two plots. The top graph plots the bubble test statistic of a unit-root test with a mildly explosive process as an alternative. The bottom graph plots the associated p-value and can be used as an estimate of the amount of chartist activity in the gold market. A p-value close to zero implies that the null hypothesis of an explosive price process and the dominance of chartists cannot be rejected at a significance level of \((1 - p)\%\).
Figure 7: Bubble test statistic and p-value - sample: daily prices 2000 - 2012. The figure shows two plots. The top graph plots the bubble test statistic of a unit-root test with a mildly explosive process as an alternative. The bottom graph plots the associated p-value and can be used as an estimate of the amount of chartist activity in the gold market. A p-value close to zero implies that the null hypothesis of an explosive price process and the dominance of chartists cannot be rejected at a significance level of \((1 - p)\%\).