The Gold Price in Times of Crisis*

Jedrzej Bialkowski†, Martin T. Bohl, Patrick M. Stephan and
Tomasz P. Wisniewski

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Abstract

Motivated by the recent gold price boom, this paper investigates whether rapidly growing investment activities have caused a new asset price bubble. Drawing on gold's role as dollar hedge, inflation hedge, portfolio diversifier, and safe haven, we calculate fundamentally justified returns, approximate gold's fundamental value, and apply a Markov regime-switching Augmented Dickey-Fuller (ADF) test which has substantial power for detecting explosive behavior. Although our results are sensitive to the specification of the fundamental value, we show that a model accounting for the current European sovereign debt crisis accurately tracks the gold price observed in the market.

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†Corresponding author: Department of Economics and Finance, University of Canterbury, New Zealand, Tel.: +64 3 364 3316; Fax: +64 3 364 2635, E-mail: jedrzej.bialkowski@canterbury.ac.nz

1. Introduction and Literature Review

Since 2001, the price of gold has skyrocketed from a level of US$ 250 per troy ounce to an all-time high of US$ 1,900 in August 2011, before falling substantially to around US$ 1,200 at the end of June 2013. At first blush, this price trajectory may bear resemblance to a bubble path. It needs to be mentioned, however, that the considered period witnessed some extreme shifts in the underlying economic fundamentals, which are bound to affect the intrinsic value of gold. The recent world financial crisis was characterized by crashing real estate and stock market valuations as well as bank failures, while the current European sovereign debt crisis substantially increased the default risk of several countries. At the same time, interest rates on bank deposits were pushed to very low levels. Related to this, central banks have carried out a very expansive monetary policy addressing the refinancing problems of banks and governments, but simultaneously increasing inflation expectations.

In circumstances like these, investment in gold became a rather appealing option and financial market participants might have expanded its portfolio weight significantly. Gold is seen as a globally accepted currency which never loses its purchasing power, and maintains its value even in the face of erosion of the monetary or banking systems. Some of these risk-mitigating characteristics have been discussed in prior literature, which evaluated the increasingly important role of gold as dollar hedge (Capie et al., 2005; Tully and Lucey, 2007; Sjaastad, 2008; Zagaglia and Marzo, 2013), inflation hedge (Adrangi et al., 2003; Worthington and Pahlavani, 2007; Blose, 2010) and portfolio diversifier (Jaffe, 1989; Hillier et al., 2006).[1] In addition, gold is regarded as a safe haven in times of turmoil (Baur and Lucey, 2010; Baur and McDermott, 2010; Chan et al., 2011).

On the other hand, gold's growing attractiveness as an investment asset and the gold price boom might indicate a speculative bubble. According to the World Gold

[1] In the same vein, there is also evidence that gold serves as a store of value against other major currencies (Sjaastad and Scacciavillani, 1996; Pukthuanthong and Roll, 2011).

Council (2013), the estimated global bar and coin investments rose from 67 tonnes in the first quarter of 2003 to 378 tonnes in same quarter of 2013. At the same time, the total gold demand from industry and jewelers remained relatively constant during this period (see Figure 1).[2] Phillips and Yu (2010) find evidence for a speculative bubble moving from the equity market (up to 2000) over the US housing market (up to 2007) to the crude oil market (up to mid-2008). Thus, we ask whether the gold market is another victim of such a wandering asset price bubble. If this was indeed the case, gold market participants would run the risk of experiencing huge losses due to potential bubble implosion. Of course, this would question gold's role as safe haven in times of crisis.

So far, to the best of our knowledge, the possibility that the gold price may currently exhibit a speculative bubble has attracted attention in the academic literature, but no final conclusion could be reached yet. The present paper aims to extend the existing evidence by applying an econometric technique which allows for early detection of speculative bubbles. Thus, we are able to offer insights not only for academics, but also for decision makers engaged in fighting speculative bubbles by framing early monetary policy responses or other regulatory interventions. In addition, investors rattled by the recent world financial and the current European sovereign debt crisis might benefit from our results with respect to their portfolio decisions.

[Figure 1 about here]

Until now, econometric testing for speculative bubbles has mainly been focusing on (US) stock markets. Gürkaynak (2008) provides a recent in-depth survey of econometric methods used for detecting asset price bubbles. This survey includes the well-known variance bounds tests, West's two-step method, (co)integration-based tests as well as the concept of intrinsic bubbles and methods treating bubbles as an

[2] For further information on the global gold market see, for instance, Shafiee and Topal (2010).

unobserved variable. By contrast, little effort has been made to date in identifying speculative bubbles in the gold price. Blanchard and Watson (1982) draw on runs and tail tests, but are unable to conclude whether the gold price was unjustifiably high between 1975 and 1981, given the caveats of their methodology. Diba and Grossman (1984) investigate the stationarity properties of the gold price for the time period from 1975 to 1983, and find that it was entirely based on market fundamentals.

As shown by Evans (1991), however, the ordinary unit-root and cointegration tests do not allow for the detection of the important class of periodically bursting bubbles. Due to the bursting nature of such bubbles, these tests have a tendency to reject the null hypothesis of non-stationarity in favor of the stationary alternative all too often. Being aware of this critique, Pindyck (1993) draws on the convenience yield approach, and calculates gold's fundamental value based on the present value model for commodities. Running tests of forecasting power, Granger causality, and restrictions of appropriately specified vector autoregressive (VAR) models, Pindyck (1993) finds evidence in favor of gold price bubbles between 1975 and 1990. In addition, based on a dynamic factor model, Bertus and Stanhouse (2001) focus on the gold futures market, and provide weak support for the bubble hypothesis during notable socioeconomic events in the time period from 1975 to 1998. Finally, Drozdz et al. (2003) make use of a log-periodic power law (LPPL), and detect a gold price bubble, analyzing the interval between 1978 and 1982.

With regard to the recent gold price boom, only few studies provide preliminary empirical evidence. Drawing again on the LPPL approach, Drozdz et al. (2008) support the hypothesis of a gold price bubble from 2003 to 2008. In particular, they are even able to identify a local bubble on top of a long-run bubble, so that the former is called "super-bubble". In addition, following Pindyck (1993), Went et al. (2012) build on the convenience yield model, and run the duration dependence test which indicates gold price bubbles in the time span from 1976 to 2005. Unfortunately, their approach suffers from the fact that they cannot conclude when speculative bubbles affected the gold price exactly. Homm and Breitung (2012) use the Supremum Augmented Dickey-Fuller (SADF) test, and find evidence for gold price bubbles between 1968 and 1980 (at the 1%-level) and between 1984 and 2010 (at the 10%-level). However, their methodology only tests for explosiveness in the price time series itself, and does not take gold's fundamental factors into consideration. As a consequence, Homm and Breitung (2012) are thus unable to conclude whether their findings might result from major economic events such as the recent world financial and the current European sovereign debt crisis rather than speculative excess. In similar spirit, Baur and Glover (2012) also draw on the SADF test, and find evidence of explosiveness in the gold price series without allowing for a fundamental value.

In order to overcome these caveats, we propose to construct gold's fundamental value making use of its role as dollar hedge, inflation hedge, portfolio diversifier, and safe haven. Drawing on the deviations of the actual gold price from its fitted value, we then apply a Markov regime-switching ADF test to identify periods that are characterized by explosive behavior. Based on estimated probabilities of being in the possible bubble and the non-bubble regime, this approach thus also allows for the detection of speculative bubbles during the recent world financial and the current European sovereign debt crisis. While our results are to a certain extent dependent on the choice of the gold fundamentals, the most realistic models provide little evidence of speculative bubbles both for the gold price boom from 1979 to 1982 and the more recent period. In particular, we find that the European sovereign debt crisis can be seen as the main driver for the recent gold price boom.

There are several reasons why the debt crisis is of great importance to the participants of capital markets in general and gold investors in particular. First, the evidence suggests that the crisis has contagious qualities Arghyrou and Kontonikas (2012), and may spread cross-border with relative ease. Second, the solvency of governments and the fortunes of the financial sector are very closely intertwined. Caruana and Avdjiev (2012) point out that banks have direct portfolio exposures to sovereign risk, while governments often face the need to recapitalize distressed banks. Lane (2012) refers to this vicious circle as diabolic loop. Third, the fiscal trouble at the periphery endangers the very existence of the Euro area. Viewing the situation through the prism of the existing systemic risks, it is easy to understand why investors may have a preference for gold, and why its price has appreciated over time.

The paper proceeds as follows. In Section 2, we discuss the construction of gold's fundamental value. In Section 3, we explain the Markov regime-switching ADF test. In Section 4, we show our empirical results. In Section 5, we briefly conclude.

2. Construction of Gold's Fundamental Value

As outlined above, gold is widely regarded as dollar hedge, inflation hedge, portfolio diversifier, and safe haven. First, if gold is a hedge against the dollar, its price should be inversely related to the strength of the US currency. Second, if gold is a hedge against inflation, its price should comove with the price index of a basket of goods, so that gold's real value is preserved. Third, if gold is a portfolio diversifier (safe haven) against financial assets such as stocks and bonds, its price should be uncorrelated or negatively correlated with them (in times of market turmoil).

Last but not least, we postulate that the gold price is likely to respond to instances of systemic risk, such as the current European sovereign debt crisis. We operationalize the measurement of the severity of the crisis by constructing an empirical gauge based on the difference between the GDP-weighted average 10-year government bond yields of the PIIGS countries (Portugal, Italy, Ireland, Greece, and Spain) and the yield of 10-year German bonds (Bunds). Since the yields are monotonically increasing in the probability of default, this proxy is a barometer of the severity of Euro zone tensions. Recent studies on the European sovereign debt crisis have used a spread between yields offered by bonds of the PIIGS countries and Germany as well. Such spread has thus become a key indicator of the depth of the current European sovereign debt crisis (Mody and Sandri, 2011; De Santis, 2012; Calice et al., 2013). Kalbaska and Gatkowski (2012) point out that the EU core countries such as France, Germany, and the UK hold a significant proportion of PIIGS debt, and are thus heavily exposed. Market professionals are painfully aware of the gravity of the situation, and assign relatively high probabilities to potential partial or complete Euro area disintegration (Brace, 2011).

Based on these possible fundamental factors of the gold price, we explain its rate of return at date t, $r_{Gold,t}$, as follows:

$$\begin{aligned} r_{Gold,t} = & \sum_{i=0}^{2} \gamma_{1,i} \cdot r_{FX,t-i} + \sum_{i=0}^{2} \gamma_{2,i} \cdot r_{Inflation,t-i} + \sum_{i=0}^{2} \gamma_{3,i} \cdot r_{MSCI,t-i} + \\ & \sum_{i=0}^{2} \gamma_{4,i} \cdot r_{T-Bill,t-i} + \sum_{i=0}^{2} \gamma_{5,i} \cdot r_{Spread,t-i} + \nu_t, \end{aligned} \tag{1}$$

where $r_{FX,t}$ is the percentage change of the trade-weighted value of the US Dollar against other major currencies, $r_{Inflation,t}$ is the percentage change of the US all-urban consumer price index, $r_{MSCI,t}$ is the percentage change of the MSCI World index of major stock markets, $r_{T-Bill,t}$ is the 3-month US Treasury bill rate, $r_{Spread,t}$ is the difference between the GDP-weighted average of 10-year government bond yields in PIIGS countries and similar yields in Germany, and ν_t is the error term. $r_{FX,t}$ refers to gold's role as dollar hedge, $r_{Inflation,t}$ should capture its role as inflation hedge, and the selection of $r_{MSCI,t}$, $r_{T-Bill,t}$, and $r_{Spread,t}$ is motivated by gold's role as portfolio diversifier in tranquil periods and as safe haven in times of market turmoil. In particular, $r_{Spread,t}$ represents the widely used indicator of the current European sovereign debt crisis.

All regressors are allowed to have a contemporaneous and a lagged impact of one and two periods. Time series which contain a unit root are adjusted by subtracting the respective variable's mean value of the previous year. All variables are calculated as continuous changes in percent, and refer to the last day of a month, except for the inflation rate which is only available on a monthly frequency anyway. All (adjusted) time series consist of 462 observations (Jan. 1975 – Jun. 2013), except for the spread between the 10-year government bond yields of the PIIGS countries and Germany, which includes 126 observations (Jan. 2003 – Jun. 2013). Thus, the latter variable explicitly captures the possible influence of the current European sovereign debt crisis on the gold return. All time series are taken from THOMSON REUTERS DATASTREAM.

We distinguish between three different models. Model A refers to the shortened sample from Jan. 1975 to Dec. 2007 (396 observations), excluding the spread between the PIIGS countries' and German bond yields in order to calculate gold's fundamental return. It thus covers neither the recent world financial nor the current European sovereign debt crisis.[3] Model B refers to the full sample, again excluding the yield spread. As a consequence, a comparison between Models A and B provides evidence about the impact of the recent world financial crisis on the gold price. Finally, Model C also refers to the full sample, but now includes the yield spread. Therefore, putting Models B and C in relation to each other offers insights in the additional effect of the current European sovereign debt crisis on the gold price.

Since we do not expect gold's role as dollar hedge, inflation hedge, portfolio diversifier, and safe haven to be constant over time, we apply a rolling window approach in order to estimate eq. (1). The first window covers the period from Mar. 1975 to Feb. 1980, and is used to calculate fitted gold returns, $\widehat{r}_{Gold,t}$, for this time span. The window is then rolled forward by one month, so that new parameter estimates and a fitted return can be obtained for Mar. 1980. For Model(s) A (B and C), the procedure is continued until Dec. 2007 (Jun. 2013), resulting in 335 (401) sets of OLS estimates.[4]

[3]Since there can be disagreement about the precise date when the world financial crisis began, we also experiment with alternative end points for the shortened sample such as June 2007 when Bear Stearns suspended redemptions from some of its instruments previously labeled of the high grade variety. However, results (not shown, but available upon request) are qualitatively the same as those presented in SECTION 4.

[4]Alternatively, we add a constant to eq. (1), and repeat the rolling regressions. The fundamentally

Finally, we calculate gold's fundamental value by multiplying its actual price in Feb. 1975 with the fitted gross return of Mar. 1975, ending up with a fitted gold price for the latter month. Afterwards, we multiply this fitted price with the fitted gross return of Apr. 1975, and repeat this exercise until Dec. 2007 in the case of Model A, and until Jun. 2013 in the case of Models B and C, respectively ($\widehat{P}_t = \widehat{P}_{t-1} \cdot (1 + \widehat{r}_{Gold,t})$). Deviations of the actual gold price from its fitted value ($u_t = P_t - \widehat{P}_t$) are interpreted as overvaluation, if positive and as undervaluation if negative, respectively.

3. Markov Regime-Switching ADF Test for Bubble Detection

Based on the relationship between the actual gold price and its fitted value, we test for speculative bubbles in the former, extending the conventional ADF equation to a standard two-state first-order Markov regime-switching model. In the literature, this approach has mostly been carried out to analyze directly the stationarity properties of the time series under investigation (Funke et al., 1994; Hall et al., 1999). By contrast, we use the Markov regime-switching ADF test with respect to the deviations of the actual gold price from its fitted value. The main advantage of this approach is that it does not rely on an informal comparison of the switching patterns of different time series, but allows for solid statistical inference instead. If periodically bursting bubbles exist, we should be able to distinguish between a moderately growing regime on the one hand and an explosive and then collapsing regime on the other hand.[5] As shown by a simulation study in Hall et al. (1999), the Markov regime-switching ADF test has substantially more power than the conventional ADF test in order to detect periodically bursting bubbles.

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justified gold return is then defined as the fitted return minus the constant. However, results (not shown, but available upon request) are qualitatively the same as those for the model in eq. (1).

[5]Note that Markov regime-switching models may indicate different regimes even though there are no structural breaks in the data. Thus, we first apply a conventional ADF test to the deviations of the actual gold price from its fitted value, and test the stability of the ADF coefficient making use of the Quandt-Andrews unknown breakpoint tests (the supremum, exponential, and average likelihood ratio test).

The Markov regime-switching ADF equation reads:

$$\Delta u_t = \rho_{0,S_t} + \rho_{1,S_t} \cdot u_{t-1} + \sum_{k=1}^{K} \beta_{k,S_t} \cdot \Delta u_{t-k} + \varepsilon_{S_t}, \tag{2}$$

where Δ stands for the first difference, $S_t = (0,1)$ is the stochastic regime variable, $\psi \equiv (\rho_{0,S_t}, \rho_{1,S_t}, \beta_{k,S_t})'$, with $k = 1, \ldots, K$, are the regime-specific regression coefficients, and $\varepsilon_{S_t} \overset{i.i.d.}{\sim} N(0, \sigma^2_{S_t})$ represents the error term. Judgments on the statistical significance of the regression coefficients are based on critical values obtained by using a parametric bootstrap algorithm (Psaradakis, 1998). If we are able to distinguish between a bubble and a non-bubble regime, we will obtain one $\rho_{1,i}$, $i = (0,1)$, which is statistically significantly larger than zero (so that regime i is explosive and then collapsing), and another $\rho_{1,j}$, $j = (1-i)$, which is not (so that regime j is stationary or contains a unit-root). In order to ensure that the error terms are serially uncorrelated, the optimal lag length, K, is determined by starting with $K_{max} = [T^{(1/3)}]$, where $[\cdot]$ denotes the integer part of its argument, and then reducing the model until the last lagged difference has a statistically significant influence at the 5%-level in at least one regime (general-to-specific approach). Since the probability of S_t being either zero or one depends on the past only through the most recent regime S_{t-1}, the transition probabilities are defined by $p_{00} \equiv \Pr(S_t = 0 | S_{t-1} = 0)$ and $p_{11} \equiv \Pr(S_t = 1 | S_{t-1} = 1)$. Finally, we collect all unknown parameters in the vector $\theta \equiv (\psi, \sigma_{S_t}, p_{00}, p_{11})'$.

In order to estimate θ, we draw on the expectation-maximization (EM) algorithm. The EM algorithm is an iterative procedure that consists of two steps: the expectation step and the maximization step (Hamilton, 1994; Kim and Nelson, 2000). In the expectation step, we estimate the filter probabilities, $\Pr(S_t = i | u_t, \ldots, u_1; \theta)$, and the smoothed probabilities, $\Pr(S_t = i | u_T, \ldots, u_1; \theta)$, of being in the two regimes, using the estimate of θ from the previous iteration step. In the maximization step, we then draw on these probabilities in order to improve the estimate of θ based on the maximum-likelihood (ML) approach. Given the model in eq. (2), however, we need not maximize the log-likelihood function numerically, but are able to obtain a closed-form solution for θ. Furthermore, the EM algorithm is relatively robust with respect to poorly chosen starting values for θ, quickly moving to a reasonable region of the likelihood surface.

4. Empirical Results

4.1. Descriptive Statistics

We start the empirical analysis by calculating descriptive statistics of the univariate time series necessary to estimate eq. (1), based on the samples as described in Section 2. As shown by Panel A of Table 1, the largest positive gold return is more than 25 percent, and occurred during the last gold price boom in Feb. 1980, followed closely by the largest negative return of more than 23 percent in Apr. 1980. In addition, the largest value of the US inflation rate is more than 13 percent, and was measured during the second oil crisis in Mar. 1980 which coincides with the last gold price boom. Apart from this, world stock markets faced their largest decrease of more than 20 percent in Nov. 2008, reflecting the recent world financial crisis. Finally, the spread between the GDP-weighted average of 10-year government bond yields in the PIIGS countries and the 10-year German bonds yield, which had always been positive but skyrocketed over the last couple of years, reached its peak of almost 6.5 percentage points in Jun. 2012, highlighting the current European sovereign debt crisis. The value of the spread started to diminish in the second half of 2012, after the partial write-down of the Greek debt in Mar. 2012, and the announcement of the Outright Monetary Transactions (OMT) program by the European Central Bank in Aug. 2012. The OMT authorizes stabilizing interventions in the European sovereign bond markets with the aim of bringing the long end of the yield curve downwards. It appears that this particular policy objective has to a large extent been reached. Figure 2 gives a visual impression of the (original) time series used for our empirical analysis.

[Figure 2 about here]

More important, as indicated by the conventional ADF test, the gold return, the change of the effective US exchange rate, and the world stock market return are stationary, while the US inflation rate, the 3-month US Treasury bill rate, and the spread between the PIIGS countries' and Germany's bond yields are characterized by a unit-root. Thus, we adjust the latter three time series by subtracting the respective variable's mean value of the previous year in order to make them suitable for use in the regression in eq. (1).

[Table 1 about here]

Based on the rolling window approach, Panel B of Table 1 shows the average correlations among the (stationary) fundamental factors of the gold return. As in the regression analysis (see Sections 4.2 and 4.3), the first window covers the period from Mar. 1975 to Feb. 1980, and is then rolled forward by one month, so that a new correlation matrix can be obtained. In the lower triangular matrix, we report the average correlations among the change of the effective US exchange rate, the adjusted US inflation rate, the world stock market return, and the adjusted 3-month US Treasury bill rate for the window rolling through the sample from Mar. 1975 to Dec. 2007 (335 correlation matrices). In the upper triangular matrix, we add the adjusted spread between the 10-year government bond yields of the PIIGS countries and Germany, and show the average correlations for the window rolling through the sample from Feb. 2003 to Jun. 2013 (66 correlation matrices). Since all average correlations among the five fundamental factors are quite low, we conclude that multicollinearity does not disturb the regression analysis.

Finally, we also apply variance-inflation tests to examine whether the correlations between our independent variables have consequences for the precision of our estimates. Chatterjee and Price (1991) suggest that values for Variance Inflation Factors (VIFs) in the region of 10 indicate a problem. According to the variance-inflation tests for our model with and without the yield spread, none of the regressions suffers from the multicollinearity problem. All VIF factors are lower than 1.21.

4.2. Regression Results

In Panel A of TABLE 2, we show the results of the rolling window approach used to estimate the time-varying impact of the five fundamental factors on the gold return. Instead of reporting the parameter estimates for each window, we focus on the mean values of the contemporaneous and the one- and two-period lagged influence. In addition, we calculate the mean aggregate impact of the contemporaneous and the lagged regressors. As expected, the gold return is negatively affected by the change of the effective US exchange rate and the adjusted 3-month US Treasury bill rate, but has a positive relationship with the adjusted US inflation rate and, in particular, with the adjusted spread between the 10-year government bond yields of the PIIGS countries and Germany. Only the consistently positive influence of the world stock market return does not coincide with gold's role as portfolio diversifier.[6] Finally, we show the number of significant parameters in relation to the total number of windows, which include the respective variable, for the contemporaneous and the lagged influence on the gold return. Overall, the ratios indicate that the regressors selected serve as reasonable proxies in order to reflect gold's role as dollar hedge, inflation hedge, portfolio diversifier, and safe haven.

[TABLE 2 about here]

Based on the fitted gold returns, we then calculate gold's fundamental value as outlined in SECTION 2, and put it in relation to the actual gold price. Both time series and the deviations of the actual gold price from its fitted value are shown in the upper part of FIGURE 3. The figure in the left column refers to Model B which

[6] Note that BAUR (2013) also finds that the price of gold is positively related to stock market movements in emerging markets and on a global level but slightly negatively correlated with the S&P500 supporting the property of gold as a hedge at least for mature stock markets.

excludes the adjusted spread between the PIIGS countries' and Germany's bond yields in order to calculate gold's fundamental return, while the figure in the right column refers to Model C which includes the yield spread.[7] Interestingly, both figures indicate a persistent overvaluation of the gold price in the first half of the 1980s, but differ sharply with respect to most recent times. While Model B suggests a substantial overvaluation over the last few years, Model C leads to a close co-movement of the actual gold price and its fitted value. As a consequence, we argue that the current European sovereign debt crisis might be seen as the main driver for the recent gold price boom.

[Figure 3 about here]

In order to validate this visual evidence empirically, we turn to the econometric analysis of the deviations of the actual gold price from its fitted value. Using these deviations, we first estimate the conventional ADF equation, and test the stability of the ADF coefficient by making use of the Quandt-Andrews unknown breakpoint tests. Results for Models A to C are reported in Panel A of Table 3. Interestingly, they indicate that only in the case of Model B do the deviations of the actual gold price from its fitted value appear to show different adjustment dynamics over time. By contrast, no such instability of the ADF coefficient can be detected for Models A and C. Since the conventional ADF test does not display explosive behavior for the full sample of any model, we conclude that only Model B may lead to (relatively short) periods of emerging and then collapsing speculative bubbles.

[Table 3 about here]

As a consequence of the stability tests, we further conclude that analyzing the deviations of the actual gold price from its fitted value in the case of Model B requires the

[7] Since Model A is nested into Model B, we do not show graphical illustrations for the former separately.

Markov regime-switching ADF test from eq. (2). For reasons of comparison, we also run this bubble test for Models A and C. Results for all three models are reported in TABLE 4. Interestingly, they have some characteristics in common. First, the constant is positive in regime 0, negative in regime 1, and nearly always statistically significant. Second, starting with $p_{max} = [T^{(1/3)}] = 7$, we end up with two lagged differences for each model in order to ensure that the error terms are serially uncorrelated. Third, regime 0 is always more volatile, but less persistent than regime 1 ($\sigma_0 > \sigma_1$, $p_{00} < p_{11}$), so that we expect the former to indicate periods that are possibly affected by speculative bubbles.

[TABLE 4 about here]

More important, in all three models, the ADF coefficient ρ_{1,S_t} is not statistically significantly smaller or bigger than zero in both regimes.[8] The only exception is regime 0 of Model B, which shows explosive behavior. Thus, once we focus on the shortened sample from Jan. 1975 to Dec. 2007 (Model A), we do not find evidence of speculative bubbles in the gold price. Instead, we interpret the gold price boom from 1979 to 1982 as a response to skyrocketing inflation and geopolitical turmoil. Our results thus challenge the findings of DIBA AND GROSSMAN (1984), PINDYCK (1993), BERTUS AND STANHOUSE (2001), and DROZDZ ET AL. (2003). By contrast, extending the sample up to Jun. 2013 but excluding the adjusted spread between the PIIGS countries' and Germany's bond yields in order to calculate gold's fundamental return (Model B) leads to explosive deviations of the actual gold price from its fitted value. The corresponding smoothed and filter probabilities are shown in the lower part of the left column in FIGURE 3, and indicate a speculative bubble in the gold price since the beginning of 2008. As a consequence, the recent world financial crisis does not seem to suffice as an explanation for the recent gold price boom. However, once we use the full

[8]Note that, as in the case of the conventional ADF equation, ρ_{1,S_t} follows a different distribution than the other coefficients so that critical values are not the same.

sample, and include the yield spread, as shown in eq. (1), in order to calculate gold's fundamental return (Model C), we again do not find evidence of speculative bubbles in the gold price. The corresponding smoothed and filter probabilities are shown in the lower part of the right column in Figure 3. Our results are thus in contrast to those of Drozdz et al. (2008), Went et al. (2012), Homm and Breitung (2012), and Baur and Glover (2012). In short, the outcome of the Markov regime-switching ADF tests corresponds to the results of the stability tests, using the conventional ADF equation. In addition, we conclude that the current European sovereign debt crisis, reflected by the skyrocketing spread between the PIIGS countries' and Germany's bond yields, can be seen as the main driver for the recent gold price boom.

4.3. Robustness Checks

In order to check the robustness of our results, we repeat the econometric analysis as outlined in Section 4.2, but now use a recursive window approach in order to calculate gold's fundamental returns. This approach works as follows: The first window again covers a period of five years. In contrast to the rolling window approach, however, we then continuously extend the subsample by one month, so that the last window is equal to the full sample. Put differently, while the rolling approach is characterized by a constant window length, the recursive approach does not neglect the data from the beginning of the sample.

In Panel B of Table 2, we show the results of the recursive window approach used to estimate the time-varying impact of the five fundamental factors on the gold return. As in the case of the rolling window approach, the gold return is negatively affected by the change of the effective US exchange rate and the adjusted 3-month US Treasury bill rate, but has a positive relationship with the adjusted US inflation rate, the world stock market return, and, in particular, the adjusted spread between the 10-year government bond yields of the PIIGS countries and Germany. In addition, the regressors selected again serve as reasonable proxies in order to reflect gold's role as dollar hedge, inflation hedge, portfolio diversifier, and safe haven.

Based on the fitted gold returns from the recursive regression, we then calculate gold's fundamental value as outlined in Section 2, and put it in relation to the actual gold price. Afterwards, we again measure the stability of the ADF coefficient in the conventional ADF equation, using the deviations of the actual gold price from its fitted value. Results for Models B and C are reported in Panel B of Table 3. As in the case of the rolling window approach, we find that different adjustment dynamics are present over the full sample only if gold's fundamental return is calculated without considering the adjusted yield spread.

Finally, we re-run the Markov regime-switching ADF test from eq. (2), still using the deviations of the actual gold price from its fitted value. Results for Models B and C are reported in Panel A of Table 5. As in the case of the rolling window approach, we see that the general-to-specific approach leads to model specifications with two lagged differences. In addition, regime 0 is again more volatile, but less persistent than regime 1. However, also in line with the results from Section 4.1, only Model B leads to explosive deviations of the actual gold price from its fitted value, while Model C does not indicate speculative bubbles. In short, we thus again conclude that the current European sovereign debt crisis can be seen as the main driver for the recent gold price boom.

[Table 5 about here]

Apart from this check of the methodological robustness, we are also interested in whether our results depend on the construction of our proxy for the current European sovereign debt crisis. Thus, we repeat the rolling window regression as outlined in Section 4.2, but now use the (adjusted) spread between the population-weighted average of 10-year government bond yields in the PIIGS countries and Germany in order to calculate gold's fundamental returns. Descriptive statistics of the (adjusted) population-weighted spread are reported in the last two rows of Panel A in Table 1. As in the case of the GDP-weighted spread, the population-weighted spread had always been positive but skyrocketed over the last couple of years, reaching its peak of more than 7 percentage points in Jun. 2012.

In Panel C of Table 2, we show the results of the rolling window approach employed to calculate fitted gold returns. While the effects of the other fundamental factors are similar to the results reported in Panels A and B of Table 2, the adjusted population-weighted spread has the expected positive influence on the gold return. Based on the fitted gold returns, we again calculate gold's fundamental value as outlined in Section 2, and put it in relation to the actual gold price. Using the deviations of the actual gold price from its fitted value, we then measure the stability of the ADF coefficient in the conventional ADF equation. Results for Model C, with the GDP-weighted yield spread replaced by the population-weighted spread, are reported in Panel C of Table 3. As before, however, we do not find different adjustment dynamics once we use the full sample and the proxy for the current European sovereign debt crisis.

Finally, we again run the Markov regime-switching ADF test from eq. (2), still using the deviations of the actual gold price from its fitted value. Results are reported in Panel B of Table 5. As in the case of the GDP-weighted yield spread, using the population-weighted spread in Model C does not allow for finding speculative bubbles in the gold price. In short, we thus again conclude that the current European sovereign debt crisis can be seen as the main driver for the recent gold price boom.

5. Conclusion

Motivated by the recent gold price boom, this paper investigates whether rapidly growing investment activities have caused a new asset price bubble. Drawing on gold's role as dollar hedge, inflation hedge, portfolio diversifier, and safe haven, we calculate fundamentally justified returns, and approximate gold's fundamental value. Based on the deviations of the actual gold price from its fitted value, we then apply a Markov regime-switching ADF test which has substantial power to detect explosive behavior. Even though the particular results from our empirical testing are dependent on the definition of gold fundamentals, we find that the most realistic models which consider the impact of the current European sovereign debt crisis are able to capture the actual behavior of the gold price quite closely. Consequently, we conclude that one does not need to resort to the irrational bubble explanation in order to account for the considerable swings observed in the gold market. To a large extent, these results are in contrast to much of the existing literature.

The most likely explanation for the gold price boom from 1979 to 1982 is that skyrocketing inflation (caused by the second oil crisis and amplified by a very expansive monetary and fiscal policy) and geopolitical turmoil (due to the beginning of the Iran-Iraq war and the Soviet invasion of Afghanistan) caused financial market participants to look for stable investments in unstable times. Similarly, many investors might have returned to gold as a safe haven in times of the recent world financial and, in particular, the current European sovereign debt crisis, thereby creating excess demand and the corresponding price surge. In presence of serious questions regarding the viability of the banking sector and the international monetary system, the acquisition of gold represents a perfectly rational reaction on this part of investors. It is important to stress at this stage that our proxy for the severity of the debt crisis, which is derived from the sovereign bond yields of the PIIGS countries, is absolutely crucial to explaining the recent evolution of gold prices.

A key question that arises as a by-product of our research is how to define the relevant fundamental drivers of commodity prices. A large number of standardized valuation models are available for securities that provide periodic cash flows, such as bonds and stocks. Most of these valuation techniques, however, are not directly applicable in the context of commodities. While some approaches, such as the convenience yield model (Pindyck, 1993), may provide guidance to investors, we feel that our knowledge in this field is still inchoate. Future research should focus on how to provide a robust pricing framework for commodities in general and gold in particular. Our contribution to the pricing debate is related to the observation that episodes of severe crisis have non-negligible ramifications for market valuations.

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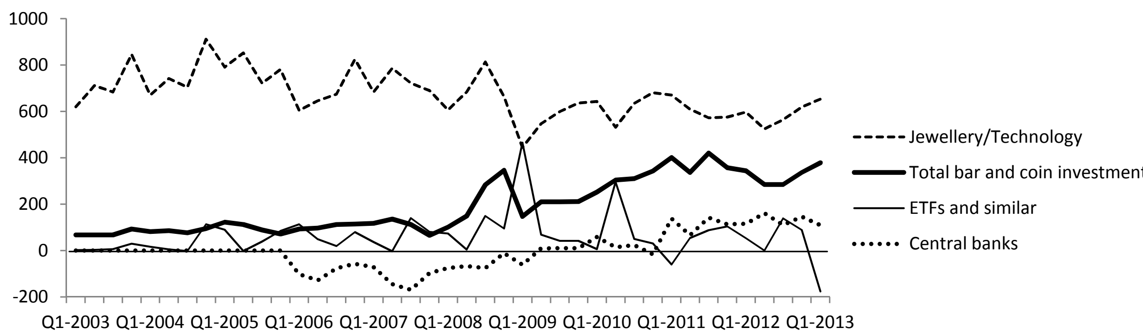
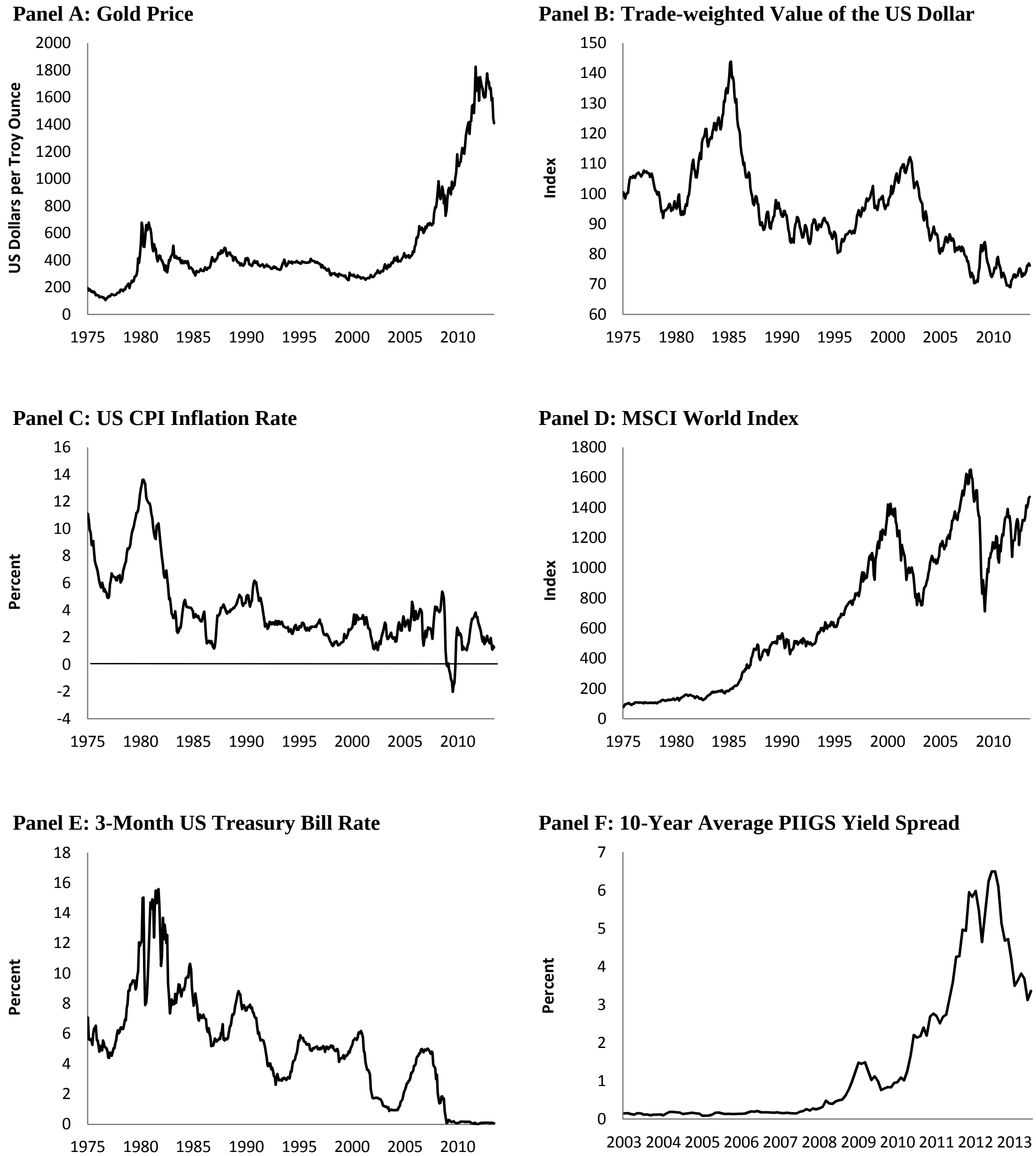
Figure 1: Gold Demand



Notes: The figure shows gold demand by category (in tonnes). Source: World Gold Council (2013)

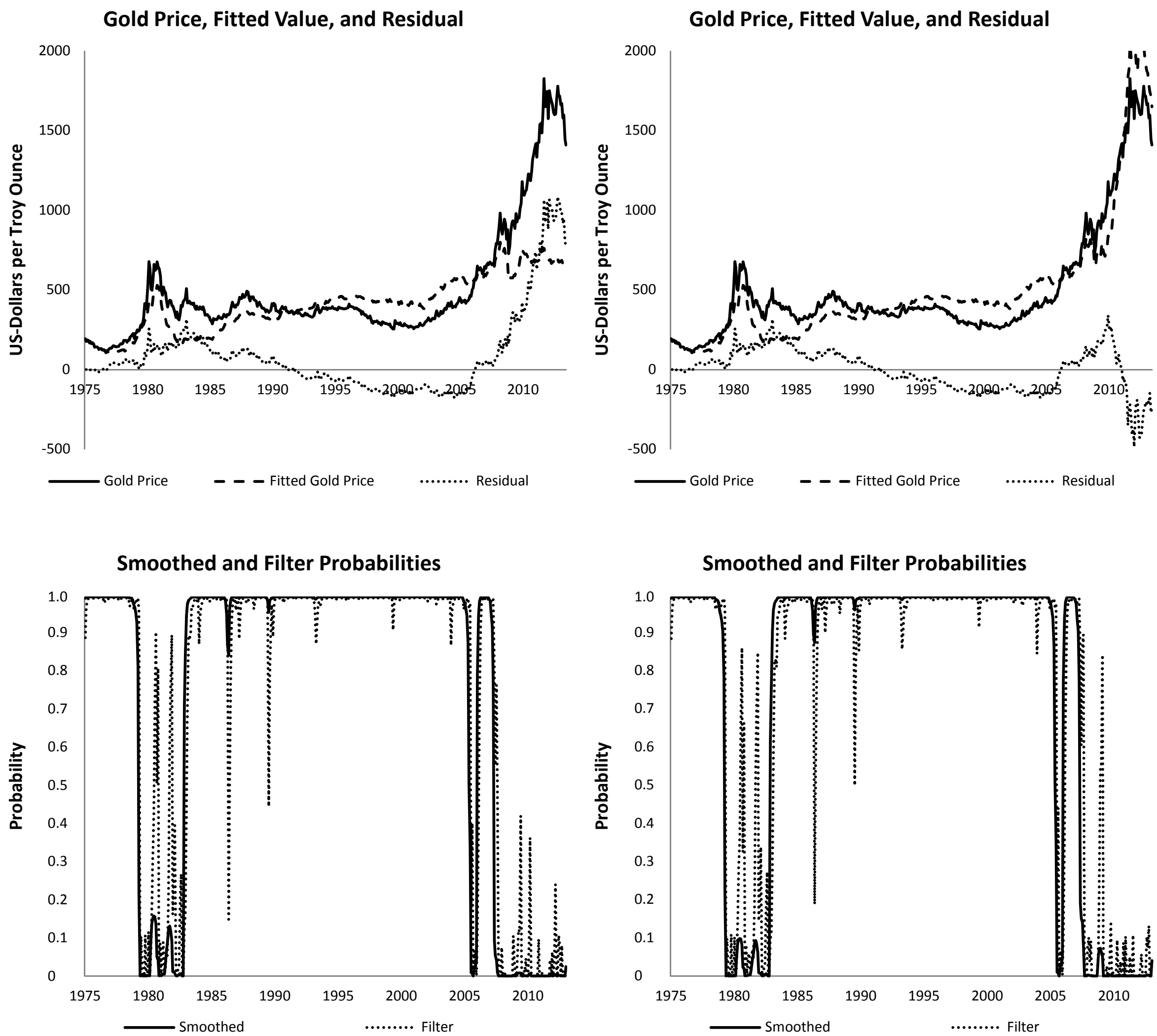
Figure 2: Gold Price and Fundamental Factors



Notes: Panel A shows the gold price (in US Dollars per troy ounce), Panel B the trade-weighted value of the US Dollar against other major currencies, Panel C the change of the US all-urban consumer price index (in percent), Panel D the MSCI World Index of major stock markets, Panel E the 3-month US Treasury bill rate (in percent), and Panel F the spread of the GDP-weighted average PIIGS countries' and Germany's 10-year government bond yield. All time series are given on a monthly frequency. Panels A to E cover the full sample (Jan. 1975 – Jun. 2013). Panel F covers the shortened sample (Jan. 2003 – Jun. 2013).

Figure 3: Gold Price, Fitted Value, and Residual – Smoothed and Filter Probabilities

Model B: Excluding Adj. Average PIIGS Yield Spread **Model C: Including Adj. Average PIIGS Yield Spread**



Notes: The left column refers to Model B which excludes the adjusted average PIIGS yield spread in order to calculate gold's fundamental return. The right column refers to Model C which includes the adjusted average PIIGS yield spread. Both models cover the full sample (Jan. 1975 – Jun. 2013). In both columns, the upper figure shows the actual gold price (solid line), its fitted value (dashed line), and the difference between both time series (dotted line). The fitted value is calculated as described in Section 2. All time series are denoted in US Dollars per troy ounce. The lower figure of each column shows the smoothed (solid line) and the filter probabilities (dotted line) of being in regime 1, using the Markov regime-switching ADF test in eq. (2), which is based on the difference between the actual gold price and its fitted value.

Table 1: Descriptive Statistics

Panel A: Univariate Time Series

	Mean	Max	Min	Std	Skew	Kurt	ADF
Gold	0.44	25.22	-23.70	5.57	0.20	2.90	I(0)
Exchange Rate	-0.06	6.47	-5.39	1.71	-0.07	0.41	I(0)
Inflation	4.02	13.62	-2.01	2.76	1.45	2.05	I(1)
Adj. Inflation	-0.13	3.27	-4.12	1.16	-0.40	0.60	I(0)
MSCI World	0.63	13.57	-20.84	4.47	-0.68	2.18	I(0)
T-Bill	5.14	15.59	0.01	3.40	0.60	0.48	I(1)
Adj. T-Bill	-0.11	4.66	-4.58	1.13	-0.04	2.32	I(0)
PIIGS GDP	1.48	6.49	0.09	1.87	1.29	0.35	I(1)
Adj. PIIGS GDP	0.19	2.51	-1.98	0.71	0.21	1.96	I(0)
PIIGS Pop	1.57	7.10	0.09	2.04	1.33	0.46	I(1)
Adj. PIIGS Pop	0.20	2.59	-2.25	0.79	0.10	1.97	I(0)

Panel B: Correlation Analysis

	Exchange Rate	Adj. Inflation	MSCI World	Adj. T-Bill	Adj. PIIGS GDP
Exchange Rate	1.00	0.04	-0.40	-0.05	0.14
Adj. Inflation	-0.08	1.00	0.03	0.09	-0.15
MSCI World	-0.15	-0.048	1.00	0.28	-0.31
Adj. T-Bill	0.08	0.46	-0.11	1.00	-0.21
Adj. PIIGS GDP	–	–	–	–	1.00

Notes: Panel A reports the arithmetic mean (Mean), the maximum (Max), the minimum (Min), the standard deviation (Std), the skewness (Skew), the excess kurtosis (Kurt), and the degree of integration based on the Augmented Dickey-Fuller test (ADF) for the change of the gold price per troy ounce (Gold), the change of the trade-weighted value of the US Dollar against other major currencies (Exchange Rate), the (adjusted) change of the US all-urban consumer price index ((Adj.) Inflation), the change of the MSCI index of major stock markets (MSCI World), the (adjusted) 3-month US Treasury bill rate ((Adj.) T-Bill), and the (adjusted) spread between the PIIGS countries' and Germany's 10-year government bond yield, where the average PIIGS yield is weighted by GDP ((Adj.) PIIGS GDP) and the size of population ((Adj.) PIIGS Pop), respectively. I(0) indicates stationarity, and I(1) indicates a unit-root. Time series which contain a unit-root are adjusted by subtracting the respective variable's mean of the previous year. All variables are calculated as continuous changes in percent, and refer to the last day of a month, except for the (adjusted) US inflation rate which is only available on a monthly frequency anyway. All time series consist of 462 observations (Jan. 1975 – Jun. 2013), except for the (adjusted) yield spread which includes only 126 observations (Jan. 2003 – Jun. 2013). In Panel B, the lower triangular matrix reports the average correlations among the change of the effective US exchange rate, the adjusted US inflation rate, the world stock market return, and the adjusted 3-month US Treasury bill rate for the sample from Mar. 1975 to Dec. 2007 (335 correlation matrices). The upper triangular matrix also includes the adjusted GDP-weighted average spread between the 10-year government bond yield of the PIIGS countries and Germany, and shows the average correlations for the sample from Feb. 2003 to Jun. 2013 (66 correlation matrices). All correlation matrices are calculated based on the method of Bravais-Pearson.

Table 2: Regression Results

Panel A: GDP-weighted PIIGS Yield Spread, Rolling Regression

	$\bar{\gamma}_t$	$\bar{\gamma}_{t-1}$	$\bar{\gamma}_{t-2}$	Sum	$S(\bar{\gamma}_t)$	$S(\bar{\gamma}_{t-1})$	$S(\bar{\gamma}_{t-2})$
Exchange Rate	-0.4850	-0.3208	0.3198	-0.4860	0.3616	0.1047	0.0698
Adj. Inflation	0.0558	2.6695	-2.1429	0.5824	0.1421	0.1646	0.1397
MSCI World	0.2189	0.0772	0.1183	0.4144	0.2170	0.0299	0.2020
Adj. T-Bill	-1.4308	1.5987	-0.5705	-0.4026	0.0698	0.0599	0.0175
Adj. PIIGS GDP	1.9685	-0.7940	-0.3303	0.8442	0.6716	0.0896	0.0149

Panel B: GDP-weighted PIIGS Yield Spread, Recursive Regression

	$\bar{\gamma}_t$	$\bar{\gamma}_{t-1}$	$\bar{\gamma}_{t-2}$	Sum	$S(\bar{\gamma}_t)$	$S(\bar{\gamma}_{t-1})$	$S(\bar{\gamma}_{t-2})$
Exchange Rate	-0.5321	-0.4062	0.4028	-0.5355	0.6658	0.0748	0.0224
Adj. Inflation	-0.5341	4.0474	-2.3173	1.1960	0.1397	0.8105	0.6633
MSCI World	0.3052	0.1305	0.0516	0.4873	0.8454	0.0050	0.0698
Adj. T-Bill	-0.5762	0.0575	-0.0120	-0.5307	0.0549	0.0050	0.0000
Adj. PIIGS GDP	1.5315	-0.4682	-0.4413	0.6220	0.6986	0.1233	0.0137

Panel C: Population-weighted PIIGS Yield Spread, Rolling Regression

	$\bar{\gamma}_t$	$\bar{\gamma}_{t-1}$	$\bar{\gamma}_{t-2}$	Sum	$S(\bar{\gamma}_t)$	$S(\bar{\gamma}_{t-1})$	$S(\bar{\gamma}_{t-2})$
Exchange Rate	-0.4844	-0.3231	0.3175	-0.4900	0.3616	0.1047	0.0648
Adj. Inflation	0.0520	2.6647	-2.1377	0.5790	0.1421	0.1646	0.1397
MSCI World	0.2181	0.0763	0.1172	0.4116	0.2170	0.0299	0.1995
Adj. T-Bill	-1.4286	1.5990	-0.5755	-0.4051	0.0698	0.0599	0.0175
Adj. PIIGS Pop	1.9590	-0.8344	-0.2958	0.8288	0.6567	0.0896	0.0000

Notes: In Panels A and B, results are shown for the rolling and the recursive regression, respectively, in eq. (1) of the change of the gold price per troy ounce on the change of the trade-weighted value of the US Dollar against other major currencies (Exchange Rate), the adjusted change of the US all-urban consumer price index (Adj. Inflation), the change of the MSCI index of major stock markets (MSCI World), the adjusted 3-month US Treasury bill rate (Adj. T-Bill) and the adjusted GDP-weighted average spread between the 10-year government bond yield of the PIIGS countries and Germany (Adj. PIIGS GDP). In Panel C, results are shown for the rolling regression in eq. (1) with the adjusted Population-weighted (instead of GDP-weighted) average PIIGS spread (Adj. PIIGS Pop). $\bar{\gamma}_t$, $\bar{\gamma}_{t-1}$, and $\bar{\gamma}_{t-2}$ are the mean values of the contemporaneous (t) and the one- ($t-1$) and two-period lagged ($t-2$) influence, respectively, of the variables in the first column on the gold return based on the rolling regression (Panels A and C) and the recursive regression (Panel B), respectively. Sum is the mean aggregate impact of the contemporaneous and the one- and two-period lagged regressors, respectively, on the gold return ($\bar{\gamma}_t + \bar{\gamma}_{t-1} + \bar{\gamma}_{t-2}$). $S(\bar{\gamma}_t)$, $S(\bar{\gamma}_{t-1})$, and $S(\bar{\gamma}_{t-2})$ are the number of significant parameters (at the 10%-level) in relation to the total number of sample windows, which include the respective variable, for the contemporaneous and the one- and two-period lagged influence, respectively, on the gold return.

Table 3: Stability Tests

Panel A: GDP-weighted PIIGS Yield Spread, Rolling Regression

	SupLR	Prob.	ExpLR	Prob.	AveLR	Prob.
Model A	8.7632	0.0466	0.6745	0.3266	0.8642	0.4046
Model B	19.4473	0.0003	8.1028	0.0000	13.0593	0.0000
Model C	3.2157	0.5105	0.3520	0.5804	0.6499	0.5317

Panel B: GDP-weighted PIIGS Yield Spread, Recursive Regression

	SupLR	Prob.	ExpLR	Prob.	AveLR	Prob.
Model B	9.8708	0.0280	3.2438	0.0110	4.5945	0.0112
Model C	2.8966	0.5757	0.3014	0.6415	0.5328	0.6189

Panel C: Population-weighted PIIGS Yield Spread, Rolling Regression

	SupLR	Prob.	ExpLR	Prob.	AveLR	Prob.
Model C	2.9683	0.5606	0.2259	0.7512	0.4260	0.7108

Notes: Results are shown for Quandt-Andrews unknown breakpoint tests measuring the stability of the ADF coefficient in the conventional ADF equation. The time series used represents the deviations of the actual gold price from its fitted value. The fitted value is calculated as described in Section 2. Model A refers to the shortened sample (Jan. 1975 – Dec. 2007), excluding the adjusted average PIIGS yield spread in order to calculate gold's fundamental return. Model B refers to the full sample (Jan. 1975 – Jun. 2013), again excluding the adjusted average PIIGS yield spread. Model C refers to the full sample, including the adjusted average PIIGS yield spread weighted by GDP (Panels A and B) and the size of population (Panel C), respectively. SupLR, ExpLR, and AveLR are the values of the supremum, the exponential, and the average likelihood ratio test, respectively, and Prob. is the corresponding p-value. The optimal lag length of the conventional ADF equation is determined by using the Schwartz information criterion.

Table 4: Markov regime-switching ADF test (1)

GDP-weighted PIIGS Yield Spread, Rolling Regression

	Coef.	**t-value**	**Coef.**	**t-value**
Model A	$S_t = 0$		$S_t = 1$	
ρ_{0,S_t}	0.2339	3.6081***	-0.0186	-2.9499***
ρ_{1,S_t}	-0.1234	-2.8328	-0.0175	-2.8594
β_{1,S_t}	0.0140	0.1171	-0.1958	-3.8432***
β_{2,S_t}	-0.2380	-1.9490*	-0.1891	-3.8080***
σ_{S_t}	0.3033		0.1111	
p_{00}, p_{11}	0.9318		0.9863	
Model B	$S_t = 0$		$S_t = 1$	
ρ_{0,S_t}	0.1789	2.5656**	-0.0161	-2.5382**
ρ_{1,S_t}	0.0049	0.3266***	-0.0158	-2.6737
β_{1,S_t}	-0.3348	-3.5880***	-0.1803	-3.6167***
β_{2,S_t}	-0.2532	-2.6960***	-0.1686	-3.5195***
σ_{S_t}	0.5036		0.1143	
p_{00}, p_{11}	0.9729		0.9899	
Model C	$S_t = 0$		$S_t = 1$	
ρ_{0,S_t}	0.0183	0.3722	-0.0156	-2.4355**
ρ_{1,S_t}	-0.0246	-0.9283	-0.0161	-2.6101
β_{1,S_t}	-0.0355	-0.3782	-0.1759	-3.4905***
β_{2,S_t}	-0.0501	-0.5229	-0.1707	-3.4842***
σ_{S_t}	0.5252		0.1147	
p_{00}, p_{11}	0.9758		0.9903	

Notes: Results are shown for the Markov regime-switching ADF test in eq. (2). The time series used represent the deviations of the actual gold price from its fitted value. The fitted value is calculated as described in SECTION 2. Model A refers to the shortened sample (Jan. 1975 – Dec. 2007), excluding the adjusted average PIIGS yield spread in order to calculate gold's fundamental return. Model B refers to the full sample (Jan. 1975 – Jun. 2013), again excluding the adjusted average PIIGS yield spread. Model C refers to the full sample, including the adjusted GDP-weighted average PIIGS yield spread. $S_t = (0, 1)$ is the stochastic regime variable. ρ_{0,S_t}, ρ_{1,S_t}, and β_{k,S_t}, with $k = 1, \ldots, K$, are the regression coefficients. The optimal lag length, K, is determined by starting with $K_{max} = [T^{(1/3)}]$, where $[\cdot]$ denotes the integer part of its argument, and then reducing the model until the last lagged residual difference has a statistically significant influence at the 5%-level in at least one regime. ***, **, and * denote statistical significance at the 1%-, 5%-, and 10%-level, respectively. All tests are two-sided except for ρ_{1,S_t}, which is left-tailed (right-tailed) for the smaller (bigger) coefficient. Critical values are obtained by using a parametric bootstrap algorithm (PSARADAKIS, 1998). σ_{S_t} denotes the variance of the error term. p_{00} and p_{11} denote the transition probabilities.

Table 5: Markov regime-switching ADF test (2)

Panel A: GDP-weighted PIIGS Yield Spread, Recursive Regression

	Coef.	***t*-value**	**Coef.**	***t*-value**
Model B	$S_t = 0$		$S_t = 1$	
ρ_{0,S_t}	0.2081	2.6407***	-0.0222	-2.8647***
ρ_{1,S_t}	-0.0008	-0.0379***	-0.0101	-2.3170
β_{1,S_t}	-0.2889	-2.8945***	-0.1249	-2.6386***
β_{2,S_t}	-0.2475	-2.4001**	-0.1358	-3.2153***
σ_{S_t}	0.5710		0.1360	
p_{00}, p_{11}	0.9537		0.9858	
Model C	$S_t = 0$		$S_t = 1$	
ρ_{0,S_t}	0.0016	0.0300	-0.0203	-2.4657**
ρ_{1,S_t}	-0.0204	-0.8993	-0.0096	-1.8272
β_{1,S_t}	0.0741	0.7833	-0.0801	-1.5774
β_{2,S_t}	-0.0749	-0.7752	-0.1584	-3.2108***
σ_{S_t}	0.5582		0.1348	
p_{00}, p_{11}	0.9745		0.9903	

Panel B: Population-weighted PIIGS Yield Spread, Rolling Regression

	Coef.	***t*-value**	**Coef.**	***t*-value**
Model C	$S_t = 0$		$S_t = 1$	
ρ_{0,S_t}	0.0106	0.2151	-0.0155	-2.4238**
ρ_{1,S_t}	-0.0177	-0.7097	-0.0161	-2.6068
β_{1,S_t}	-0.0704	-0.7484	-0.1752	-3.4762***
β_{2,S_t}	-0.0473	-0.4936	-0.1702	-3.4746***
σ_{S_t}	0.5288		0.1147	
p_{00}, p_{11}	0.9758		0.9903	

Notes: Results are shown for the Markov regime-switching ADF test in eq. (2). The time series used represent the deviations of the actual gold price from its fitted value. The fitted value is calculated as described in SECTION 2, based on gold's fundamental returns from the recursive window regression with the adjusted GDP-weighted average PIIGS yield spread (Panel A), and from the rolling window regression with the adjusted Population-weighted average PIIGS yield spread (Panel B), respectively. Model B refers to the full sample (Jan. 1975 – Jun. 2013), excluding the adjusted average PIIGS yield spread in order to calculate gold's fundamental return. Model C refers to the full sample, including the respective adjusted average PIIGS yield spread. $S_t = (0, 1)$ is the stochastic regime variable. ρ_{0,S_t}, ρ_{1,S_t}, and β_{k,S_t}, with $k = 1, \ldots, K$, are the regression coefficients. The optimal lag length, K, is determined by starting with $K_{max} = [T^{(1/3)}]$, where $[\cdot]$ denotes the integer part of its argument, and then reducing the model until the last lagged residual difference has a statistically significant influence at the 5%-level in at least one regime. ***, **, and * denote statistical significance at the 1%-, 5%-, and 10%-level, respectively. All tests are two-sided except for ρ_{1,S_t}, which is left-tailed (right-tailed) for the smaller (bigger) coefficient. Critical values are obtained by using a parametric bootstrap algorithm (PSARADAKIS, 1998). σ_{S_t} denotes the variance of the error term. p_{00} and p_{11} denote the transition probabilities.