Psychological barriers in gold prices?

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Abstract

This paper examines for the first time the existence of psychological barriers in a variety of daily and intra-day gold price series. This paper uses a number of statistical procedures and presents evidence of psychological barriers in gold prices. We document that prices in round numbers act as barriers with important effects on the conditional mean and variance of the gold price series around psychological barriers.
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1. Introduction and motivation

This paper examines if there are detectable barriers at price levels that are perceived to be psychologically important (psychological barriers) in a set of daily and intra-day gold prices. These barriers would manifest themselves by the market finding it ‘difficult’ to break through the barrier to a different level. Such hypothesised barriers have been examined in other asset classes, such as equities (Donaldson & Kim, 1993), bonds (Burke, 2001), and foreign exchange (Mitchell & Izan, in press; Westerhoff, 2003), but not in the gold markets. If gold markets are rational and efficient, as
commentators such as Aggarwal and Soenen (1988) and Wahab, Cohn, and Lashgari (1994) have suggested, we should not expect to see any psychological price barriers. However, significant numbers of commentators attribute particular levels of the gold bullion price as being ‘barriers’ or ‘support levels’ or in some other manner as being intrinsically more ‘important’ than other price levels. In support of such contentions, research on equity (and a few other asset) prices has provided some evidence of the existence of psychological barriers.

It has been argued that gold has a somewhat unique position as an asset that perhaps provides a greater or at least a different scope for such psychological effects than do other asset price series. That market participants perceive such barriers to exist is evident from perusal of reports by many commentators on the gold market. Consider some of the following representative quotations (there are numerous others like these):

Gold is set to test the key $450 barrier in the coming weeks as concerns over the weak US dollar following last week’s re-election of President Bush send investors rushing for the safe-haven metal. Analysts believe the psychological mark is well within reach (Financial Times, November 9, 2004)

Gold breached the key psychological level of US$ 440/oz last week. (Financial Mail (South Africa), November 26, 2004).

Nevertheless, there is no prior academic research on psychological barriers in gold prices. Using a number of statistical procedures (some new) to assess psychological barriers for four different gold price data series covering recent periods of over two decades (including a shorter intra-day series), this paper documents for the first time that there indeed are significant changes in means and variances associated with certain round number gold prices that are perceived as psychological barriers. Given the importance of gold, these results should be of much interest to policy-makers, scholars, and investors.

This paper is structured as follows. The next section briefly reviews the nature of gold prices, followed by a section on why numerical psychological barriers may exist in asset prices, and in particular in gold. The following section outlines strategies for testing psychological barriers followed by a section that outlines the data used and a section that describes the results from a variety of tests.

2. Nature of gold markets and gold prices

Gold is traded 24 h a day and has been an important precious metal for many millennia and almost all of the gold ever mined is still in existence. Demand for gold arises from consumers in the form of jewellery, dental fillings, and other uses; from industry as one of the most ductile metals and as an excellent conductor of heat and electricity; and from central banks, investors, and speculators as a store of value and as an investment. The supply of gold arises from mining, refining of re-cycled gold, and from sales by central banks and investors. Gold also plays an important role as a store of value especially in times of political and economic uncertainty. Gold prices are generally higher than if gold was just another commodity with little or no monetary role.

Unlike the market for other commodities, the gold market and gold prices are also influenced by possible supply related to the vast overhang of all of the gold ever mined and demand related to
political uncertainty and inflationary prospects. Unlike other commodities, a negative relationship between gold prices and mining output of the metal has been documented at least in the short run (Marsh, 1983). In addition, transactions in the gold market by central banks are generally not characterized by profit maximizing behaviour (Aggarwal & Soenen, 1988). Indeed, gold prices can suffer from much uncertainty and over-reaction to certain types of economic and political news. Further, there is some evidence of short-term positive feedback cycles in gold prices (Frank & Stengos, 1989).

In addition to these factors, gold prices may also deviate from efficient market prices because of the special role played by gold as a store of value especially in times of political and economic uncertainty. Further, because of its long and important history in human affairs, ownership of gold is likely to have many psychological dimensions. Gold has been linked to the rise and fall of many empires in history. Gold was even a major factor in a US presidential election when one of the candidates made “bearing the cross of gold” an important issue. Gold is also discussed in many significant religious texts. Thus, because of all of these reasons, gold prices may be particularly subject to the effects of psychological barriers.

3. Psychological barriers in asset prices

3.1. Reasons for psychological barriers

Consistent with the existence of limited arbitrage (Shleifer & Vishny, 1997) and psychological aspects of human information processing and decision-making, a number of behavioural biases have been shown to persist in asset price series (Hirshleifer, 2001). For example, the concepts of anchoring and heuristic simplification in behavioural finance are closely related to the issue of psychological barriers. Anchoring (Slovic & Lichtenstein, 1971) is the phenomenon whereby individuals fixate on a recent number or a number which may be held out to be important by informed commentators. Drawing on the heuristics concept of Kahneman, Slovic, and Tversky (1982) and on herding behaviour of Avery and Zemsky (1998) and Welch (2000), Westerhoff (2003) develops formal models of how traders cluster expectations around round numbers. Other researchers (e.g., Sonnemans, 2003) note a number of issues relating to competing hypotheses around why these barriers might a priori be expected, and suggests that in addition to the anchoring approach an element of the phenomenon of odd-ending pricing may be important.

Recent research by Shiller (2000) notes that in the absence of accurate agreement on fundamentals many traders focus on the nearest round number as a reasonable proxy for the fundamental value. Unlike many financial instruments, there is much uncertainty in the price of gold — especially the part above its

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2 “Having behind us the producing masses of this nation and the world, supported by the commercial interests, the laboring interests and the toilers everywhere, we will answer their demand for a gold standard by saying to them: You shall not press down upon the brow of labor this crown of thorns, you shall not crucify mankind upon a cross of gold.” William Jennings Bryant, Speech at the Democratic National Convention, 1896.

3 This concept is well known in marketing, and denotes the phenomenon whereby (due to anchoring and mis-attribution bias) consumers perceive a price such as 99.5 to be significantly different to 100 and not significantly different to 99, even though the percentage difference in both cases is (almost) equal.
commodity value (estimated at around 1/10 of the existing price). Thus, the gold prices we see reflect a large dose of ‘psychological’ value.

Other research (Mitchell & Izan, in press; Mitchell, 2001) draws a distinction between psychological barriers and clustering phenomena and distinguishes clustering, where particular digits and levels appear more often, from psychological barriers, where trades are infrequent at or around a particular cluster of prices. Thus, it is clarified that the two aspects are related but not synonymous. Clustering is necessary, but not a sufficient condition, for a psychological barrier to be present. Tschoegl (1988) shows that while all psychological barriers can be assumed to be round numbers, it is not the case that all round numbers are psychological barriers.

3.2. Testing for psychological barriers

A number of different approaches have been advocated to investigate the potential existence of psychological barriers in asset prices. These break into three broad categories: tests of the distribution of the digits, tests of the behaviour of returns around barriers, and tests of the frequency of digits around presupposed barriers.

Underlying all approaches is the examination of the significant digits of the returns series. Take the two price levels 329.97 and 399.97. If there are no barriers then the probability of any set of trailing digits will be equal to that of any other — the distribution of these will be uniform. It is popularly supposed (see the quotations above) that barriers exist in gold prices around exact hundreds, i.e., at levels such as 300, 400. If this is the case then we should expect to see relatively fewer 00 digit pairs than pairs such as 01, 74, 63 or 98. Thus to test for barriers at this level we examine the pair of digits preceding the decimal point. We refer to these as the “10’s Digits”. For an examination of barriers at levels such as 209.87 or 301.92 we are interested in whether the pair of digits bracketing the decimal point displays a frequency that is different from other pairs of digits. If there exist barriers at levels such as these then we would expect to see relatively fewer xx0.0x digits than otherwise. More formally, the 10’s digits are given as $[P_t \text{mod } 100]$ and the 1’s as $[1000 \times (P_t \text{log}_{10} P_t \text{mod } 1) \text{mod } 100]$, where mod refers to the reduction modulo. These are known formally as $M$-values. Thus, for a series 309.82, 301.09 and 298.87 we would extract 09, 01, 98 and 98, 10, 88 as the 10’s and 1’s digits respectively. Such frequencies would also depend on the execution of stop and limit orders and could well determine different dynamics approaching the barrier from below or from above.

However, the assumption of uniformity of digit distribution runs counter to the implications of Benford’s Law. In essence, Benford’s law points out that as the various digits, 1, 2, 3 etc are not increasing at a constant percentage rate, the limit distribution of such digits in a price series need not be uniform. The larger the sample the closer the distribution would be to uniform. Countervailing this, the small sample sizes found in many applications implies that the return generating process, typically in assets involving significant autocorrelations, will have a major impact on the distributions. This point, and the implication that tests of uniformity are useful if the data are confined within relatively small ranges, as are gold prices, are discussed in previous research (De Ceuster, Dhaene, & Schatteman,

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4 This relativity was suggested to the authors by a number of analysts in the London gold market.
5 For details see De Ceuster et al. (1998).
6 We thank Adrian Tschoegl for this point.
1998; Ley & Varian, 1994). As we have a large sample here we do not expect this issue to be problematic.

Generally, two different statistical tests have been used in studies of the uniformity of digits, the chi-square test and a regression test. One paper (Koedijk & Stork, 1994) uses a chi-squared test to reject uniformity in a number of equity indices. Another (Donaldson & Kim, 1993) uses a regression approach. The regression is of the frequency of the DJIA's trailing digits as the dependent variable against a dummy variable, the dummy taking 1 when it is close \(^8\) to the presupposed psychological barrier of 00. This approach was in fact introduced by Ball, Torous, and Tschoegl (1985), in the context of the gold market. Under the null of no barriers, the assumption is that each set of digits, each of the 100 pairs of digits, will be equally likely. Thus, the intercept term is expected to be .01 and the slope coefficient insignificantly different from zero. Generally however (see Donaldson & Kim, 1993; Donaldson, 1990a, 1990b) variety of equity markets (not, however the Nikkei or the Wilshire indices) are shown to deviate from this assumption, with negative coefficients on the intercept indicating fewer than hypothesized occurrences of the digits near the 00 pair. Other research (Burke, 2001) uses chi-squared analyses on US government bond indices, again finding that there is significant evidence for deviation from uniformity.

An earlier study (Koedijk & Stork, 1994) failed to find evidence supporting the significance of 00 barriers in equity returns. However, this finding has been critiqued by Cyree, Domian, Louton, and Yobaccio (1999) for not disaggregating the effects of upward and downward movement. Thus, a third approach uses regression or GARCH analysis to assess the differential impact of being above or below a barrier in the neighbourhood of such a barrier. The initial paper using this approach, Cyree et al. (1999) suggests that volatility effects tend to accompany mean effects, and finds such differential results. A GARCH approach to this problem has also been used by Burke (2001), on the hypothesis that the mean effect depends on whether the series is above, below, or in the barrier zone while variance effects are dependent merely on being in or out of the barrier area. Using this approach for US bonds he finds no barrier effects in a GARCH framework.

3.3. Data used in this paper


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\(^7\) They are able to reject the existence of psychological barriers for S&P 500, the Brussels Stock Exchange, the FAZ General, and the FTSE-100, but not for the Nikkei.

\(^8\) A variety of measures of closeness are used; within 25 of 00, within 5 etc. The results are qualitatively similar.

\(^9\) The London AM Gold Fix is the generally accepted benchmark for gold bullion. Maintained by the London Bullion Market, it has evolved from past practice where the only times at which gold was traded was a morning and afternoon session. The fixing price emerging from the meetings is not the only price at which bullion trades daily — it should be considered as akin to a snapshot price to indicate market conditions at that time and is not a ‘fixed’ or ‘maintained’ price. There are five members of the twice daily London Gold fixing. These members meet morning and afternoon in what is essentially a ceremonial form and indicate the price at which they are willing to trade. It is another striking element of the psychology of gold trading that the ‘price’ from the AM fix in particular is seen as the bellwether price for gold even though in economic terms. The fix should only be considered as an indicative price prevailing at the time (10 am in London), akin to a price at any other given time.
Summary statistics on gold price data series

<table>
<thead>
<tr>
<th></th>
<th>Return series</th>
<th>Level series</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>Gold fix</td>
<td>5478</td>
<td>0.000119</td>
</tr>
<tr>
<td>Gold cash</td>
<td>5255</td>
<td>-0.000041</td>
</tr>
<tr>
<td>Gold Future</td>
<td>5255</td>
<td>-0.000048</td>
</tr>
<tr>
<td>Intraday gold</td>
<td>76,555</td>
<td>0.000020</td>
</tr>
</tbody>
</table>

Fix refers to data relating to the AM London Gold Fix, cash to data from COMEX cash gold trading, future to data from COMEX futures trading, and intraday to data from UBS electronic screen system. Refer to Section 3.3 for details.

All data are expressed in US$/Troy Oz. Summary statistics on the series are presented in Table 1 where it is evident that the data are significantly non normal. In order to examine the issues of uniformity and barriers we also calculate the M-values discussed above and derive the frequency of occurrence of each value. As all data are less than 1000 in absolute value only tests of the 10’s and 1’s digits are carried out. Thus we are assessing the existence of barriers around 00 and 0, such as 300 or 330, for example. An interesting feature of the data is that for the high frequency gold the series leaps from 294 to 317 approximately, on September 11 2001, reflecting the impact of the terrorist attacks in New York. However, as the series leaps directly between these two elements there are no 10’s digits around supposed barrier of 300. Thus, we are unable to test this barrier at this data series.

4. Empirical results

4.1. Uniformity tests

Table 2 provides a test of uniformity of the distribution of the frequency of appearance of the 10’s and 1’s digits derived from the data. The data clearly are not drawn from uniform distributions. As Ley and Varian (1994) have shown however such a rejection of uniformity is not in itself sufficient to demonstrate the existence of barriers. In addition, De Ceuster et al. (1998) caution that in series that grow without limit, as the series grows and thus the intervals between the barriers widen, the theoretical distribution of digits and frequencies of occurrence is no longer uniform. While the data examined here

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10 The data are from UBS’s proprietary trading system for their own precious metal customers who operate continually. Thus we have a full series of data 24 h/day.

11 The maxima in particular differ because of the unusual conditions prevailing in the gold markets in the 1980–81 period. This period is covered in the cash data for the London AM fix but not the COMEX data. This period saw the gold market reacting to the attempts to corner the silver market, gold and silver having a distinct long-term relationship. More details on this relationship can be found in Ciner (2001) and Lucey and Tully (2006a).

12 These tables are available on request.

13 An interesting point, for which we thank a referee, is whether the results later are sensitive to the 2001 September 11th data. This is relevant only for one series, the high-frequency data. COMEX, along with other US exchanges, was closed 11–12–13 September 2001, while the London AM Fix data end at 2000. We dropped the data for September 11 2001 from the dataset for the high frequency data, and re-examined. The results for uniformity, barriers and barrier hump results are in essence identical, not surprisingly as we are dropping 288 datapoints, or 0.1% of the data. Results for the data excluding the period are available on request.
are clearly not uniformly distributed and are bounded within reasonably tight limits, the importance of these findings is limited as noted in prior research. Accordingly we examine the frequency of the $M$-values at and near the pre-supposed barriers, as well as the overall shape of the distribution.

### 4.2. Barrier tests

Following Burke (2001), we perform tests designed to measure whether or not observations on or near the barriers occur significantly less frequently than a uniform distribution would predict. In general, these tests examine the shape of the frequency distribution for the various decimal digit combinations. The first test focuses on the frequency of observations in close proximity to the barriers while the second test examines the shape of the frequency distribution. These are referred to as *barrier proximity* and *barrier hump* tests respectively.

We implement the barrier proximity test using Eq. (1) below. The dummy variable takes the value of 1 when the price of the relevant series is at the supposed barrier and 0 elsewhere. The test for barriers then resolves to a test of significance of the coefficient on the dummy variable. Under the null of no barriers $\beta$ will be zero, whereas the presence of barriers will result in a lower frequency of $M$-values at the barrier and thus $\beta$ will be negative and significant. Following Burke (2001) and Donaldson and Kim (1993), a number of specifications of the barrier are examined. The first is a strict barrier at the 0 frequency, the second and third are wider tests where the dummy takes the value 1 in the range 90–02 and 95–05 respectively.

$$f(M) = \alpha + \beta D + \epsilon$$

The *barrier hump* test on the other hand is implemented with Eq. (2) below, where the frequency of occurrence of each $M$–value is regressed on the $M$-value itself and its square.

$$f(M) = \alpha + \phi M + \gamma M^2 + \eta$$

The null of no barriers should result in $\gamma$ being zero, while under the alternative of barriers it will be expected to be negative and significant.

Results for these *barrier proximity* tests are show in Table 3, from which it is clear that we can reject the no barriers hypothesis for the 10’s digits in all series, but not for the 1’s digits. Barriers in the daily

<table>
<thead>
<tr>
<th></th>
<th>10’s digits</th>
<th>1’s digits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold fix</td>
<td>4.72, 0.00</td>
<td>2.16, 0.00</td>
</tr>
<tr>
<td>Gold cash</td>
<td>4.77, 0.00</td>
<td>2.12, 0.00</td>
</tr>
<tr>
<td>Gold future</td>
<td>4.38, 0.00</td>
<td>3.20, 0.00</td>
</tr>
<tr>
<td>Intraday gold</td>
<td>4.75, 0.00</td>
<td>5.23, 0.00</td>
</tr>
</tbody>
</table>

Fix refers to data relating to the AM London Gold Fix, cash to data from COMEX cash gold trading, future to data from COMEX futures trading, and intraday to data from UBS electronic screen system. Refer to Section 3.3 for details.

Table shows the results of a Kolmogrov–Smirnov $Z$ statistic test for uniformity. The column $z$-stat shows the value of the test statistic, while $p$-value gives the marginal significance of this statistic. H0: uniformity, Ha: non uniformity. The null hypothesis is soundly rejected for all series examined.
The gold price series appear from this test to exist at levels such as 300, 200 etc but not at levels such as 310, 350 etc. Barriers in the high frequency data, however, also seem to exist at the latter digits. There being some evidence of barriers at all forms of specifications (strict and region) we concentrate hereafter on the strictest formulation of barriers. Using this formulation, Table 4 shows the results of the barrier hump test but there is little evidence here of a persistent barrier.

### 4.3. Conditional effects

Psychological barriers are generally taken as offering ‘support’ or ‘resistance’ to series. The statistical interpretation of this is that the dynamics of the returns series around and in the vicinity of these barriers

<table>
<thead>
<tr>
<th>Barrier dummy</th>
<th>Series</th>
<th>10’s digits</th>
<th>1’s digits</th>
<th>10’s digits</th>
<th>1’s digits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold fix</td>
<td>−21.000</td>
<td>0.000</td>
<td>0.865</td>
<td>29.505</td>
<td>0.000</td>
</tr>
<tr>
<td>Gold cash</td>
<td>−18.740</td>
<td>0.000</td>
<td>0.853</td>
<td>15.596</td>
<td>0.000</td>
</tr>
<tr>
<td>Gold future</td>
<td>−8.640</td>
<td>0.000</td>
<td>0.865</td>
<td>1.455</td>
<td>0.030</td>
</tr>
<tr>
<td>Intraday gold</td>
<td>255.162</td>
<td>0.000</td>
<td>0.599</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fix refers to data relating to the AM London Gold Fix, cash to data from COMEX cash gold trading, future to data from COMEX futures trading, and intraday to data from UBS electronic screen system. Refer to Section 3.3 for details.

The table shows the results of a regression of the form $f(M) = \beta_0 + \beta M + \gamma M^2 + \eta$ where $M$ is the frequency of appearance of individual modulo values. $p$-value gives the marginal significance of the coefficients against a null of zero.
should differ from that elsewhere. Unlike Burke (2001) we do not impose exogenous assumptions regarding the impact of being in the barrier region. Instead, what is of interest is the issue of the differential effect on the return from being in the region of the barrier, and whether the barrier is being approached from above (towards a hypothesised support barrier) or below (towards a presumed resistance barrier). We define four regimes around barriers: UB for the 5 d prior to the gold price reaching a barrier from below, but before it breaches the barrier, UA for the 5 d after reaching the barrier from below, DB and DA for the 5 d before and after breaching the barrier in a downwards direction. These take the value 1 for the days noted, and zero otherwise.

Shown in Table 5 are results of a simple autoregression model. We note that in general the sum of the coefficients around upward movements is greater than that of downward movements, providing some evidence of differential effects in returns depending on whether one is moving through a barrier from below or above. It is also clear however that, with the exception of the futures market, there is little statistical significance to these regions. The explanatory power is low, but of a similar magnitude to the results in Cyree et al. (1999). While the residuals are relatively clean with no serial correlation, there is evidence of ARCH, to degree 4, still present.

The residual ARCH tests indicate that variance is impacted by the barrier regions. This would tend to indicate that a GARCH type model is appropriate. Such models have been used before in the modelling of gold returns (see for example Marshall and Stengos, 1994). Shown in Table 6 are the results of Levene tests for the equality of variance of returns in the regions of the barriers. Testing for seasonality in the unconditional variance is by means of Levene’s test is an alternative to the well-known Bartlett test for equality of variance that is robust to non-normality.

Table 5
Regression (OLS) analysis for barriers: gold price data series

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Gold fix</th>
<th>Gold cash</th>
<th>Gold future</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>p-value</td>
<td>Coefficient</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.0001</td>
<td>0.46</td>
<td>-0.0001</td>
</tr>
<tr>
<td>BD</td>
<td>-0.0006</td>
<td>0.45</td>
<td>0.0010</td>
</tr>
<tr>
<td>AD</td>
<td>0.0004</td>
<td>0.59</td>
<td>-0.0009</td>
</tr>
<tr>
<td>BU</td>
<td>0.0003</td>
<td>0.72</td>
<td>0.0004</td>
</tr>
<tr>
<td>AU</td>
<td>-0.0002</td>
<td>0.81</td>
<td>0.0008</td>
</tr>
<tr>
<td>AR(1)</td>
<td>-0.1047</td>
<td>0.00</td>
<td>-0.0604</td>
</tr>
<tr>
<td>Q(2)</td>
<td>0.69</td>
<td>0.42</td>
<td>4.55</td>
</tr>
<tr>
<td>Q(4)</td>
<td>2.91</td>
<td>0.51</td>
<td>6.44</td>
</tr>
<tr>
<td>Q(6)</td>
<td>11.73</td>
<td>0.30</td>
<td>10.62</td>
</tr>
<tr>
<td>ARCH(1)</td>
<td>0.16</td>
<td>0.03</td>
<td>0.13</td>
</tr>
<tr>
<td>ARCH(4)</td>
<td>0.01</td>
<td>0.07</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Fix refers to data relating to the AM London Gold Fix, cash to data from COMEX cash gold trading, future to data from COMEX futures trading, and intraday to data from UBS electronic screen system. Refer to Section 3.3 for details.

UA, UB, BA and BD are dummy variables. UB is for the 5 d prior to the gold price reaching a barrier from below, but before it breaches the barrier, UA for the 5 d after the barrier from below, DB and DA for the 5 d before and after breaching the barrier in a downwards direction. Thus these take the value 1 for the days noted, and zero otherwise Q(i) is the Portmanteau Q test for serial correlation of order i. ARCH(i) shows the coefficient of the i-th lag in an ARCH LM Test. The dependent variables are the gold fix, cash and future series. p-value gives the marginal significance of the coefficients against a null of zero.
The Levene test tests $H_0: \sigma_i = \sigma_j \forall i,j$, $H_a: \sigma_i \neq \sigma_j \forall i,j$.

Let

$$W = \frac{(N - k) \sum_{i=1}^{k} N_i (Z_i - \bar{Z})^2}{(k - 1) \sum_{i=1}^{k} \sum_{j=1}^{N_i} (Z_{ij} - \bar{Z}_i)^2}$$

(3)

The Levene test rejects the hypothesis that the variances are homogeneous if $W > F_{(1-z,k-1,N-1)}$ where $F_{(1-z,k-1,N-1)}$ is the upper critical value of the $F$ distribution with $k-1$ and $N-1$ degrees of freedom at a significance level of $z$.

It is clear that we can reject the null of equality of variances across the barrier regions in all three cases. Thus, a full analysis of the effect of barriers requires an analysis of the variance and the mean. Shown in Table 7 are the results of a GARCH(1,1) analysis of the returns shown in Eq. (3). We do not include an ARCH-in-Mean term or AR/MA terms in the gold data based on recent research (Lucey & Tully, 2006b). Again, we expect that in the absence of barriers the coefficients on the indicator variables in the mean equation would be insignificantly different from zero. As there is an absence of prior research in this area for the gold market, we have no a priori expectation on the sign of the indicator variables in these variance tests.

$$R_t = \beta_1 + \beta_2 BD_t + \beta_3 AD_t + \beta_4 BU_t + \beta_5 AU_t + \epsilon_t$$

$$\epsilon_t \sim N(0, V_t)$$

$$V_t = \alpha_1 + \alpha_2 BD_t + \alpha_3 AD_t + \alpha_4 BU_t + \alpha_5 AU_t + \alpha_6 V_{t-1} + \alpha_7 \epsilon_{t-1}^2 + \eta_t$$

(4)

A number of points are evident from the results presented in the two tables, Tables 6 and 7. For a number of the barrier regions, the mean coefficients have changed in sign, magnitude, and significance. Few of the mean coefficients are now significant. While there is evidence of limited mean effects around barriers, there are clear, consistent, and strong indicators of significant variance effects around barriers. This is particularly evident in the cash gold series, where all values are significant. The variance indicator after a downward movement through a barrier is in all cases negative, indicating that the market ‘calms’ having fallen through a barrier. Consistent with this is the fact that in all cases the indicator before
a downward movement is positive, indicating increased market volatility. This, in all cases at the 10% level, is the only variance indicator that is significant across all series.

Table 8
Barrier hypothesis tests: gold price series

<table>
<thead>
<tr>
<th></th>
<th>Gold fix</th>
<th></th>
<th>Gold cash</th>
<th></th>
<th>Gold future</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>p-value</td>
<td>Coefficient</td>
<td>p-value</td>
<td>Coefficient</td>
<td>p-value</td>
</tr>
<tr>
<td>H1o: no difference in conditional mean return before and after an upwards crossing of a barrier</td>
<td>5.05</td>
<td>0.02</td>
<td>3.63</td>
<td>0.06</td>
<td>0.51</td>
<td>0.47</td>
</tr>
<tr>
<td>H2o: no difference in conditional mean return before and after a downwards crossing of a barrier</td>
<td>0.11</td>
<td>0.74</td>
<td>2.19</td>
<td>0.14</td>
<td>0.33</td>
<td>0.57</td>
</tr>
<tr>
<td>H3o: no difference in conditional mean variance before and after an upwards crossing of a barrier</td>
<td>0.01</td>
<td>0.94</td>
<td>9.62</td>
<td>0.00</td>
<td>0.61</td>
<td>0.44</td>
</tr>
<tr>
<td>H4o: no difference in conditional mean variance before and after a downwards crossing of a barrier</td>
<td>52.13</td>
<td>0.00</td>
<td>40.14</td>
<td>0.00</td>
<td>6.39</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Fix refers to data relating to the AM London Gold Fix, cash to data from COMEX cash gold trading, future to data from COMEX futures trading, and intraday to data from UBS electronic screen system. Refer to Section 3.3 for details.

Table 7
GARCH analysis: barriers in gold price series

<table>
<thead>
<tr>
<th></th>
<th>Gold fix</th>
<th></th>
<th>Gold cash</th>
<th></th>
<th>Gold future</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>p-value</td>
<td>Coefficient</td>
<td>p-value</td>
<td>Coefficient</td>
<td>p-value</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>-0.000218</td>
<td>0.06</td>
<td>-0.000156</td>
<td>0.14</td>
<td>-0.000164</td>
<td>0.12</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>-0.000049</td>
<td>0.96</td>
<td>-0.000098</td>
<td>0.90</td>
<td>-0.006524</td>
<td>0.50</td>
</tr>
<tr>
<td>$\beta_3$</td>
<td>-0.000582</td>
<td>0.54</td>
<td>-0.001758</td>
<td>0.03</td>
<td>-0.000951</td>
<td>0.26</td>
</tr>
<tr>
<td>$\alpha_1$</td>
<td>0.001322</td>
<td>0.09</td>
<td>0.002316</td>
<td>0.00</td>
<td>0.007653</td>
<td>0.43</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>-0.001068</td>
<td>0.26</td>
<td>0.000328</td>
<td>0.62</td>
<td>0.000660</td>
<td>0.22</td>
</tr>
<tr>
<td>$\alpha_3$</td>
<td>0.000001</td>
<td>0.00</td>
<td>0.000000</td>
<td>0.00</td>
<td>0.000000</td>
<td>0.00</td>
</tr>
<tr>
<td>$\alpha_4$</td>
<td>0.000018</td>
<td>0.06</td>
<td>0.000014</td>
<td>0.00</td>
<td>0.000033</td>
<td>0.06</td>
</tr>
<tr>
<td>$\alpha_5$</td>
<td>-0.000012</td>
<td>0.18</td>
<td>-0.000010</td>
<td>0.00</td>
<td>-0.000011</td>
<td>0.00</td>
</tr>
<tr>
<td>$\alpha_6$</td>
<td>0.000000</td>
<td>0.90</td>
<td>0.000006</td>
<td>0.00</td>
<td>-0.000015</td>
<td>0.37</td>
</tr>
<tr>
<td>$\alpha_7$</td>
<td>0.102124</td>
<td>0.00</td>
<td>0.047729</td>
<td>0.00</td>
<td>0.037251</td>
<td>0.00</td>
</tr>
<tr>
<td>$\beta_4$</td>
<td>0.898121</td>
<td>0.00</td>
<td>0.948333</td>
<td>0.00</td>
<td>0.959675</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Fix refers to data relating to the AM London Gold Fix, cash to data from COMEX cash gold trading, future to data from COMEX futures trading, and intraday to data from UBS electronic screen system. Refer to Section 3.3 for details.

Results are for a $\chi^2$ test of the null hypothesis as shown.
variance are relaxed after the asset breaches the barrier. As in Cyree et al. (1999), the four possible hypotheses are:

**H1o.** There is no difference in the conditional mean return before and after an *upwards* crossing of a barrier;

**H2o.** There is no difference in the difference in conditional mean return before and after a *downwards* crossing of a barrier;

**H3o.** There is no difference in the difference in conditional variance before and after an *upwards* crossing of a barrier;

**H4o.** There is no difference in the difference in conditional variance before and after a *downwards* crossing of a barrier.

With the exception of the two return series for cash gold, we find that in general there is no significant change in the conditional mean returns associated with breaching a barrier. However, we find that in all cases there is strong evidence that the conditional volatility of gold returns changes significantly after crossing barriers in a downward direction. The implications of this are potentially very important. Changes in variance should of course be associated, as a proxy for risk, with changes in expected returns. Although there is some evidence that in the gold market there is no strong relationship between risk and returns (Lucey & Tully, 2006b), the evidence presented here shows that the expected risk–return relationship does exist in the gold market. In addition, this evidence is consistent with the widespread contention that many gold producers and those who are major users of the metal actively use derivative products to hedge their risks (see for example Bailey, 1987; Beelders, 2003, Cai, Cheung, & Wong, 2001; Callahan, 2002; Dionne & Garand, 2003; Tufano, 1996). Accordingly, changes in the variance of the underlying asset in the vicinity of barriers will impact their hedging operations. Finally, Johansen and Sornette (2001) have drawn attention to the need for a non-symmetric model of risk in the gold market, a model that would be consistent with the presence of the barriers we have identified here.

This paper considers the gold market *in isolo* as to how psychological barriers affect it. It is of course the case that gold, as any asset, is affected by its relative returns versus other investment alternatives. In the case of gold, much research (see for example Cai et al., 2001; Ciner, 2001; Davidson, Faff, & Hillier, 2003; Escribano & Granger, 1998; Faff & Hillier, 2004) has identified factors that influence the market, notably silver returns, inflation and inflation expectations, the dollar exchange rate, and bond yields. Conceivably the presence or absence of barriers in gold returns could be a reflection of their reaction to changes in these markets. Also, we have modelled the transition process as a GARCH process. Markov switching models, threshold autoregressive models or other diffusion/jump models may well provide additional insight, especially if combined with the influences on gold noted earlier. Nonetheless, we believe our findings are of interest, demonstrating the importance of dealing with variance as well as mean specifications in the consideration of barriers and demonstrating the existence of barriers in another asset class.

**5. Conclusions**

Gold is an important and unusual asset and the market for gold is important. Prior literature documents psychological barriers, support and resistance levels, and importance of round numbers, in
equity and foreign exchange markets. Despite the importance of psychological elements in the gold market, there is no prior research on these phenomena in the gold market. Using a number of statistical procedures (many new), this paper examines for the first time mean and variance effects around psychological barriers in the gold market.

The findings presented here document that psychological barriers at the 100’s digits (price levels such as $200, $300 etc) do exist in daily gold prices. For high frequency gold prices the evidence is weaker, but this is perhaps a function of the time period under investigation. While we find some evidence of changes in conditional means around psychological barriers, we document strong evidence of changes in the variances of returns in the vicinity of and when crossing (especially from above) psychological price barriers in gold markets.

Acknowledgment

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References


