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Gold and platinum: Toward solving the price puzzle

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ABSTRACT

Gold and platinum prices are positively correlated over 1985–2006. Yet, over shorter sample periods the correlation changes from positive to negative (1996–2001) and back. The objective of this paper is to determine whether this shift is the result, at least in part, of the rapid increase in forward sales by gold producers, which had the effect of substantially lowering gold prices in the second half of the 1990s (Kearney, A. & Lombra, L. (2008). The non-neutral short run effects of derivatives on gold prices. *Applied Financial Economics, 18*, 985–994). The results show declining gold prices are associated with large net increases in forward sales, while rising gold prices are associated with declining forward sales or producer dehedging.

1. Introduction

Precious metals, such as gold and platinum, have often been considered attractive assets for portfolio investment, especially during times of rising inflation and global economic and political instability. Of the two, gold has received special emphasis given its role during the Gold Standard and its comparative value which rose to a local peak at $676 per ounce in 1980 during the Volcker disinflation. Comparing the 1980s and 1990s, platinum and gold prices declined on average; platinum fell from $477 per ounce to $394 per ounce (17%); gold fell from $416 per ounce to $349 per ounce (16%).[2] While

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[1] Tel.: +1 814 865 9555; fax: +1 814 863 2085.
[2] Taylor (1998) notes gold, platinum and silver prices declined by 2.5% per year from 1988 to 1996. In addition, he provides some evidence that precious metals prices share a positive long-run relation with the price level.

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this suggests gold and platinum prices were related over these two decades, more careful inspection of the paths of these time series uncovers a significant divergence over the mid-to-late 1990s. More specifically, platinum prices recover to $440 per ounce in 1999 from a low of $351 in 1991, while gold prices fall dramatically after 1995 and hit bottom at $261 per ounce in 1999. Given their positive correlation over most of the past two decades, it is natural to ask: what explains the puzzling behavior of gold prices relative to platinum prices from 1996 through 1999?

Kearney and Lombra (2008) investigate the behavior of gold prices over the last 30 years. Their results indicate (1) there was a structural break in the historical relationship between gold prices and real long-term interest rates after 1995 and (2) the use of derivatives, namely forward contracts, by gold producers probably pushed gold prices below what they would have otherwise been over the second half of the 1990s.[3] In addition, the findings of Kearney and Lombra suggest that subsequent producer "dehedging" in the face of rising gold prices over the past 5 years has probably helped boost gold prices toward levels more consistent with the longer run fundamentals.[4]

This paper investigates the robustness of these findings across markets by examining the anomalous behavior of gold prices relative to platinum prices over the second half of the 1990s. While gold and platinum are characterized as precious metals because of their relative scarcity and high economic value, the composition of their demands differs widely. Investment, which includes jewelry, accounts for about 90% of the demand for gold, while industrial use occupies approximately two thirds of the total demand for platinum (O'Connell, 2005). In other words, while gold and platinum are considered gross substitutes in investor portfolios, the other factors influencing their respective demands and prices differ markedly. This degree of orthogonality is convenient from the perspective of our focus on the underlying investment linkages across these markets and the illumination that it in turn can provide in helping to isolate the factors that explain the behavior of gold prices in the 1990s.[5]

The remainder of the paper is organized as follows. Section 2 investigates the behavior of gold and platinum prices over the 1985–2006 period and provides background on how the use of forward contracts by gold producers could have affected the price of gold. Section 3 describes the data and empirical investigation. A cointegrating relationship between the dynamic paths of gold and platinum prices over 1985–1995 is identified and is employed to forecast gold prices over 1996–2006. The equilibrium errors are subsequently calculated and the linkage between the equilibrium errors and changes in forward sales is examined. Section 4 concludes the paper.

2. Background

Fig. 1 plots nominal gold and platinum prices per ounce, as reported by the Commodity Research Bureau. Gold and platinum prices appear to be positively correlated except for most of the 1996 through 2001 period.[6]

As the correlations in Table 1 indicate, while gold and platinum prices are positively correlated over the full sample period, 1985:3–2006:3, the sign and magnitude of the correlations vary over shorter sample periods.[7] More specifically, the correlation drops from 65% over the 1990:1–1995:4 period to

[3] The behavior of gold prices after the mid-1990s has been investigated by Hamilton (2000) who finds platinum prices lead gold prices by 10 months over 1995–2000 but are synchronous with gold prices over 1960–1994. Moreover, his research findings show that while the correlation between platinum futures prices and open interest (i.e., outstanding contracts) over 1974–1994 and 1995–1999, is roughly 50%, the correlation between gold futures prices and open interest drops from 80% to 1%.

[4] The behavior of gold prices during the dehedging period is important in the sense that it reduces the likelihood that the relationship between producer use of derivatives over 1996–1999 and gold prices is purely spurious.

[5] The referee rightly asks, "Why platinum?" Silver, for example, appears to be an attractive alternative to platinum since the price of silver has often, at least roughly followed the price of gold over the last 20–30 years. However, the disruptive effects of the crisis in the silver market brought on by the Hunt brothers' attempt to corner the market in the late 1970s and early 1980s, along with the demand factors noted above, and scant use in coinage, led us to focus on platinum. Other precious metals that might share similar characteristics with platinum, e.g., gold-molybdenum, were considered but not selected because of relative scarcity, thin trading and the resulting lack of reliable data.

[6] Statistical analysis begins in 1985:3 to focus on the last two decades when the price quotes for platinum seem most reliable. According to the Commodity Research Bureau, in the 1970s and early 1980s trading was apparently too thin much of the time to track transactions prices in a reliable manner.

[7] The data are quarterly and henceforth all dates denote year and quarter; e.g., 1985:3 denotes the third quarter of 1985.

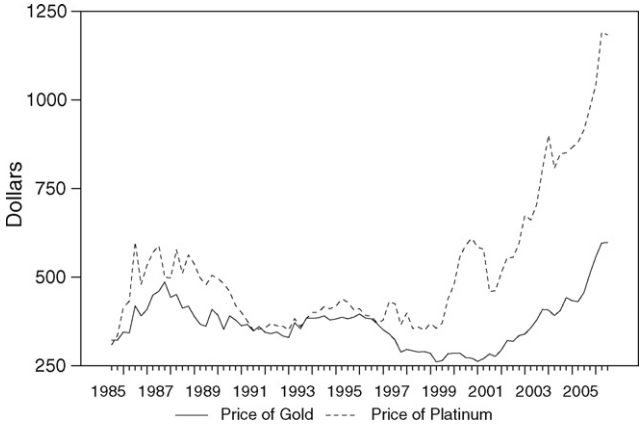

Fig. 1. Gold and platinum prices. *Notes*: Gold and platinum prices per ounce are nominal and were obtained from the Commodity Research Bureau.

Table 1
The correlation between gold and platinum prices.

1985:3–2006:3	0.66
1985:3–1989:4	0.79
1990:1–1995:4	0.65
1996:1–2001:3	−0.36
2001:4–2006:3	0.98

Notes: Data were obtained from the Commodity Research Bureau. Calculations were made using the %CORR procedure in RATS (Estima, 2004).

negative 36% over 1996:1–2001:3, suggesting there may have been a fundamental shift in the forces linking these two markets over the second half of the 1990s. Interestingly, movements in gold and platinum prices return to a nearly perfect correlation from 2001:4 through the rest of the sample period.

As mentioned above, Kearney and Lombra find evidence that the use of forward contracts by gold producers to sell gold on a prespecified future date, either to take advantage of an anticipated decline in price (some would call this speculation) or guard against a possible decline in price (some would call this hedging), appears to have had the effect of substantially lowering gold prices below what they would have been based upon historical relationships.[8] Whatever the motivation or characterization, the front end of forward sales (also referred to as "short sales" or "shorts") involves intermediaries, in this case the so-called bullion banks (i.e., financial firms such as JP Morgan), arranging a forward contract (that locks in the agreed selling price of gold on a prespecified delivery date) with a gold mining company that plans to deliver gold (to the bullion bank) at some future date. The bullion bank subsequently borrows gold from a central bank and typically sells it immediately into the spot market, thereby increasing market supply.

While the short seller incurs an obligation to repay the borrowed gold, the proceeds from the spot sale are invested by the bullion bank on behalf of the short seller in some other relatively safe and liquid instrument such as Treasury bills. When the contract expires it can be renegotiated (in effect rolled over, thus deferring any actual delivery of gold) or closed out. If the contract is closed out, the producer can either deliver gold out of production or purchase it spot (leaving the gold in the ground). If the contract is closed out, the bullion bank purchases the gold, an increase in demand, and repays the gold loan from the central bank. So long as the number of contracts closed out approximately matches

[8] While the data are sketchy, market participants tell us that central bank activity in derivatives markets is extremely limited.

the number newly written, the impact on the price of gold should be neutral (see Appendix A for more detail).

Over the decade of the 1990s, there was a "marked preference" for forwards and spot-deferred forward contracts over other types of derivative products (Cross, 2000, p. 66). Spot-deferred contracts differ from typical forward contracts in that they allow producers to defer delivery indefinitely. When the delivery date approaches, if the price of gold spot is below the spot-deferred price, the producer will close out the contract and reap her profit. On the other hand, if the spot price is above the spot-deferred contract price, the producer will sell gold spot and defer delivery on a previously arranged forward sale, i.e., roll the contract forward.[9] Hence, it is easy to understand the popularity of these spot-deferred contracts which provided producers with a means to earn a positive return regardless of the direction of spot prices. Moreover, since the leased gold remains in the market, the initial impact in the spot market on the price of gold of arranging the short sale is not reversed. Given that the above ground stock of gold far exceeds annual production, why would such activities of gold producers in the forward market matter?

Over the second half of the 1990s, the average annual level of net short sales by producers as reported by Gold Fields Mineral Services (GFMS) Ltd., a precious metals consultant, increased substantially (by 79%) compared to the first half. Since the net increase in the gold sold forward was usually matched by an equal increase in leased gold sold into the market, the increase in short positions together with the ability to spot-defer amounted to a substantial acceleration or increase in the market supply of gold well beyond normal market trading or production and delivery into the market.[10]

Relevant to the research in this study, Adam and Fernando (2006) uncover results showing that gold mining firms that hedged their future production over 1989–1999, gained significantly positive cash flows (forward price exceeded the future spot price), despite periods of rising and falling gold prices over this sample period. Furthermore, their results show that cash flows were "substantially higher" over the months when gold prices were falling within the decade in comparison to when they were rising. The empirical results that follow elucidate these findings. More specifically, the results in Section 3 show that, as the volume of short sales increased over 1996–1999, the acceleration in the increase in the supply of gold placed downward pressure on the spot prices which had the effect of widening the spread between forward and spot prices.

In the empirical investigation that follows, we will extend the existing literature on the behavior of gold prices in the 1990s by using platinum prices as a control variable. Our objective is to determine how gold and platinum prices are related and whether producer short sales help to explain the change in the correlation between these two assets prices—from positive to negative and back—over 1990–2006 as shown in Table 1.

3. Empirical investigation

3.1. The data

The sample period for this study, reflecting data availability discussed in note six and below, is 1985:3 through 2006:3. Gold and platinum prices, obtained from the Commodity Research Bureau, consist of the daily closing price from the 24-h global market. In addition, we employ a unique dataset that contains the hedge books of 93 gold mining companies—thereby accounting for nearly all of the relevant market activity—collected by GFMS Ltd. that begins in 1990:4. Since forward contracts occupy the greatest proportion in the global hedge book: 81% from 1996 to 1999 and 76% from 2000 to 2006:3, we focus on the impact of the use of forward contracts by producers, input as net forward sales (the

[9] A spot-deferred contract is a forward contract that has a flexible delivery/maturity date, with pre-set notice period, and typically has floating interest rates (including gold lease rate). The contract has no set delivery date and therefore allows the user to defer indefinitely or to deliver gold before maturity (i.e., these contracts have a maturity date which can be changed). As Cross (2000, p. 105) points out, spot-deferred contracts, like forward contracts, are private, nonmarketable contracts, agreed upon by the user and creator and therefore the specifics are negotiable, i.e., interest rates may be fixed. Hence, the description of the contract in this paper may appear somewhat vague. For more information see Cross (2000, p. 109).

[10] For more information on the impact of derivatives on the gold market, see Neuberger (2001).

difference between short and long positions in millions of ounces of the major producers in the market for gold) by GFMS.[11] In order to match the periodicity of forward sales (quarterly), the data for gold and platinum prices for the third month of each quarter are employed to construct quarterly series; daily data are averaged over the month in converting to monthly.

3.2. Are gold and platinum prices cointegrated?

Economic and financial theory suggest that if gold and platinum are, in normal circumstances, substitutes for one another as investment assets, we would expect the prices of these two assets to be positively related, ceteris paribus. In order to test this hypothesis, gold and platinum prices (in logs) are first examined for stationarity using the augmented Dickey–Fuller unit root test. The results, reported in Appendix B, indicate both of these time series are I(1), i.e., they are stationary in first differences.

The Johansen (1991, 1995) methodology was next employed to determine if gold and platinum prices (nominal) are cointegrated over the full sample period as well as the subsample ending in 1995—the structural breakpoint identified previously by Kearney and Lombra.[12] Starting with a maximum lag length of four, a lag length of two was selected.[13] The results, shown in Appendix B, do not reject the null of no cointegration over the full sample period; however, a single cointegrating vector was identified over the 1985:3 through 1995:4 sample period which, after normalization, can be expressed as follows (t-statistics in parentheses):

$$\ln goldpr_t = \underset{(4.72)}{2.70} + \underset{(5.89)}{0.53} \ln platpr_t \tag{1}$$

Consistent with Fig. 1 and Table 1, the above results indicate the relationship between gold and platinum prices is positive. Using Eq. (1), the forecasted price of gold is calculated to determine what gold prices would have been after 1995 if the cointegrating relationship had held throughout the rest of the sample period. As Fig. 2 shows, the actual price of gold and the forecasted price (antilog $\ln goldpr_t$), tend to move in opposite directions until late 2001; moreover, the actual price of gold is below forecast throughout most of sample period (1996:1–2006:3).

3.3. Do forward sales help to explain the puzzling behavior of gold prices relative to platinum prices?

Fig. 3 plots net forward sales (in millions of ounces) by gold producers against equilibrium errors (in dollars), which are calculated by subtracting the forecasted price from the actual price of gold over the 1996–2006:3 period.

As the plot indicates, while producer short sales (dotted line) increased from a low of 56 million ounces (1731 tons) in 1996:3 to a high of 82 million ounces (2551 tons) in 1999:3 or 46%, errors became larger and more negative, falling from $25 in 1996:1 to −$186 in 2000:4. Conversely, after the peak in short sales in 1999:3, producer dehedging is associated with a decline in short sales from 82 million ounces (2551 tons) to 31 million ounces (964 tons) in 2006:3 or 62%, and errors shrink by 70%, as they move from −$186 to −$55.

In order to quantify the relationship between equilibrium errors and short sales, ceteris paribus, $Errors_t$, are regressed on one lag, $Errors_{t-1}$, the log of net short sales, $\ln SS_t$, and $Other_t$ variables men-

[11] As the referee points out, the volume of forward contracts traded would be useful. However, forward contracts are private agreements and are not traded on an organized exchange. The GFMS data are "forwards and loans" from the global hedge book. The use of forwards and loans by mining companies generally resulted in the immediate (or deferred) sale of gold in the spot market. Gold loans were used to finance future production; their popularity has diminished with the introduction of more sophisticated hedging instruments: the proportion of loans to total forwards and loans dropped from 12% in 1992:4 to 2% in 1999:4 and 3% by 2006:3.

[12] The Andrews–Quandt and Andrews–Ploberger tests for structural break at an unknown point uncover a breakpoint in the neighborhood of 1996. Also the Chow test with breakpoint at the end of 1995 overturns the null of parameter stability at the one percent level of significance (p-value = 0.007).

[13] One lag was specified by the Akaike, Schwarz and Hannan–Quinn information criteria; however, the Breusch–Godfrey Lagrange Multiplier (LM) test indicated serial correlation disappears at lag length two.

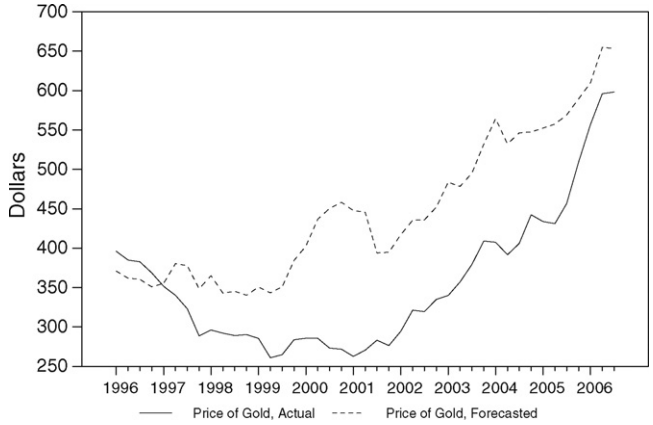

Fig. 2. Gold prices, actual versus forecast. *Notes*: Forecasted gold prices (antilog) were calculated using the cointegrating vector (Eq. (1)) and actual platinum prices (log) over 1996:1–2006:3; actual gold and platinum prices were obtained from the Commodity Research Bureau.

tioned in the literature that might also explain the deviation of actual gold prices from forecast:

$$Errors_t = \beta_o + \beta_1 Errors_{t-1} + \beta_3 \ln SS_t + \beta_4 Other_t + \mu_t \quad (2)$$

where $Errors_t$ equals the log of the actual price of gold minus $\ln goldpr_t$ (calculated using Eq. (1)), and $Other_t$ variables tested for inclusion consisted of:

1. the official holdings of monetary gold (million ounces), obtained from the IMF, *International Financial Statistics* web site, since central bank sales of gold are often linked to lower gold prices during the late 1990s (Haubrich, 1998);
2. credit risk, to pick up the increase in the demand for gold in periods of financial crisis (Levin & Wright, 2006). This variable reflects the change in the gap between Moody's Seasoned Aaa and Baa corporate bond yields as a ratio: Baa/Aaa, obtained from the Federal Reserve Bank of St. Louis web site, FRED. The greater the gap, the higher the default risk;
3. a dummy variable equal to one over 1997:3–2002:1 to pick up the increase in the demand for gold during the Asian crisis that began in July 1997 and spread to Russia, July 1998; the Brazilian crisis

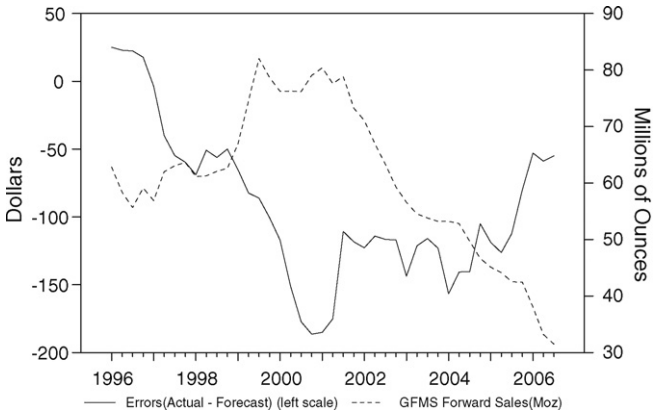

Fig. 3. Forecast errors and net forward sales. *Notes*: Forecast errors are calculated by subtracting forecasted gold prices (antilog) from actual. Forecasted gold prices were calculated using the cointegrating vector, Eq. (1), and actual platinum prices (log) over 1996:1–2006:3. Actual gold and platinum prices were obtained from the Commodity Research Bureau; net forward sales were obtained from GFMS Ltd.

that was the fallout of the Russian crisis, 1999:1; the Turkish crisis 2000:4–2001:1; Argentina's crisis: 2001:4–2002:1 (Pugel, 2007, pp. 494–500); the dot.com crash in early 2000 and the terrorist attack on September 11, 2001; a separate dummy equal to one over 1997:3–1999:1 was also tested;
4. motor vehicle sales, obtained from the Federal Reserve Bank of St. Louis web site, FRED, which, given the use of platinum in catalytic converters, might influence the demand for platinum and platinum prices;
5. the G5 trade-weighted dollar, obtained from the Federal Reserve Bank of St. Louis web site, FRED, to reflect the impact of fluctuations in the dollar on the price of gold which is valued in dollars. That is, if the dollar depreciates, gold becomes less expensive to foreigners and the demand for gold rises (Levin & Wright, 2006, p. 37);
6. alternative assets: the S&P 500 index, obtained from finance.yahoo.com, and the 10-year Treasury bond rate, obtained from the Federal Reserve Bank of St. Louis web site, FRED, to reflect the possible influence of fluctuations in stock prices and bond rates on gold and platinum prices.

After testing each of these *Other* variables, the inclusion of the log of the S&P500, lagged, resulted in the "best" estimation in terms of the strength of the $\overline{R^2}$, stationarity of μ_t, and significance of coefficients (t-statistics in parentheses) over the 1996:1–2006:3 sample period:[14]

$$Errors_t = \underset{(2.58)}{0.86} - \underset{(11.81)}{0.77}\, Errors_{t-1} - \underset{(3.08)}{0.10} \ln SS_t - \underset{(1.74)}{0.07} \ln SP500_{t-1}$$

$\overline{R^2} = 0.91$, $SEE = 0.04$, Durbin-$h = 1.05$

According to the above, a one percent increase in short sales lowers the actual price of gold below the price that would have otherwise prevailed by 10% (p-value = 0.004).[15] These results support the maintained hypothesis: forward sales by gold producers are negatively related to gold prices. Over the second half of the 1990s, the amount of short sales increased by 46% and this accelerated market supply, which placed downward pressure on actual gold prices, and $Errors_t$ become increasingly more negative. After late 1999 when producer dehedging results in a 62% decline in forward sales, gold prices rise, $Errors_t$ become less negative, and the positive correspondence between the prices of these two assets re-emerges.

4. Conclusion

The objective of this paper is to determine whether the observed negative correlation between gold and platinum prices over 1996–2001 is the result, at least in part, of the increase in forward sales by gold producers. Using the cointegrating relation between gold and platinum prices over 1985–1995 and a unique dataset covering the hedge books of 93 gold mining companies, we uncover results showing forward sales are negatively related to gold prices and equilibrium errors (the actual price of gold minus forecast) over 1996–2006. Hence, the increase in forward sales in the 1990s adversely affected gold prices and therefore altered the return on gold, its relationship with platinum prices and, by extension, other assets considered to be close substitutes in investor portfolios.

Acknowledgement

We would like to thank the two anonymous referees for their helpful comments, Bruce Alway, GFMS Ltd., for his insights and assistance with the Global Hedge Book data, and Ed Coulson, Pennsylvania

[14] The Granger causality test was performed to test whether errors Granger-cause changes in short sales (instead of the other way around). The results do not reject the null: lagged errors are not incrementally predictive for changes in short sales. Also each time series in this estimation is I(1), while μ_t is I(0). See Appendix B. In addition, Stambaugh bias, which is introduced when a return is regressed on a lagged stochastic regressor (Stambaugh, 1999) does not pertain in this case since stationary errors imply OLS test statistics are applicable (Gujarati, 2003, p. 822) and inferences still hold when lagged terms are excluded.

[15] This estimation was tested for serial correlation and heteroskedasticty. The Durbin $h = 1.05$, suggests one cannot reject the null of no serial correlation in the errors (p-value = 0.29). White's test for heteroskedasticity yielded $TR^2 = 5.25$ compared to the critical value of $\chi^2(9) = 16.9$ at the $\alpha = 0.05$ (p-value = 0.81). Hence, the null of homoskedasticity cannot be rejected.

State University, who generously provided insightful comments and suggestions that greatly improved the quality of this effort.

Appendix A

Mathematically, the link between gold prices and forward sales can be shown by focusing on a comparison of the forward contract price of gold and the spot price at the maturity of the contract. Assume a mining company signs a forward contract at time t which promises delivery of gold in $t+i$. The bullion bank finances the purchase of gold from the mining company in $t+i$ by borrowing gold from a central bank in time t, selling it spot, and investing the proceeds in a series of Treasury bills which mature in $t+i$. According to the expectations hypothesis of the term structure of interest rates, the expected yield from time t to $t+i$ is the weighted average, r, of the bill rates expected to prevail over this period. At time t, the expected real price of gold upon delivery in $t+i$, $E_t P_{g,t+i}$, equals the preset price established by the forward contract:

$$E_t P_{g,t+i} = P_{g,t} E_t \left(1 + \frac{r - r_{LR}}{100}\right)$$

where $P_{g,t}$ represents the current spot price which is multiplied by the difference between the expected real rate and the central bank's lease rate. When the contract matures in $t+i$, gold producers compare the spot price, $P_{g,t+i}$, with the pre-agreed price:

$$\Delta P_{g,t+i} = (E_t P_{g,t+i} - P_{g,t+i})$$

If the spot price at time $t+i$ is less than or equal to the contract price, gold is delivered to the bullion bank and the loan from the central bank is repaid.[16] Hence, the real price of gold increases at the rate: $E_t(r - r_{\mathrm{LR}})$ and $\Delta P_{g,t+i} > 0$, ceteris paribus. If, however, the spot price is above the contract price, the obvious incentive is to defer delivery.[17] In this case, the producer sells gold into the spot market (the bullion bank rolls over its loan from the central bank), which further increases the supply of gold and places downward pressure on spot prices, $\Delta P_{g,t+i} < 0$.

Appendix B

B.1. Augmented Dickey–Fuller unit root tests

Null: Unit Root

Variable	No. of lags	ADF statistic	p-value
ln *goldpr*	0	−0.16	0.9382
Δln *goldpr*	0	−9.44	0.0000
ln *platpr*	0	−1.21	0.9023
Δln *platpr*	0	−9.85	0.0000
Errors	0	−0.54	0.4766
Δ*Errors*	0	−4.93	0.0000
ln *SS*	1	−1.24	0.1939
Δln *SS*	0	−4.13	0.0001
ln *SP500*	0	−2.32	0.1695
Δln *SP500*	0	−6.67	0.0000
μ	0	−5.46	0.0000

In the above, gold prices and platinum prices (in logs) are represented as, ln *goldpr* and ln *platpr*, respectively; Δ denotes first difference; *Errors* are equal to the log of the actual price of gold minus

[16] For ease of exposition, the analysis above assumes producers deliver newly mined gold to close out the forward contract. However, if the spot price is less than the cost per ounce of mining the gold, a producer may leave her gold in the ground and instead deliver gold purchased in the spot market.

[17] If the producer does not have a spot deferred contract, delivery can be deferred, for example, by negating the forward contract (Neuberger, 2001, p. 34). How delivery is deferred is beyond the scope of this paper.

the forecasted price; the log of forward sales (short sales), ln *SS*; the log of the S&P 500, ln *SP500*; and μ represents the error term in the estimation of Eq. (2) in Section 3.

B.2. Johansen cointegration tests

Null: No cointegration

Trace tests				Maximum eigenvalue			
Null	Alternative	λ_{trace}	*p*-value	Null	Alternative	λ_{max}	*p*-value
Sample period: 1985:3–2006:3							
$r = 0$	$r > 0$	10.31	0.61	$r = 0$	$r = 1$	8.85	0.45
$r \leq 1$	$r > 1$	1.47	0.88	$r = 1$	$r = 2$	1.47	0.88
Sample period: 1985:3–1995:4							
$r = 0$	$r > 0$	20.69	0.04	$r = 0$	$r = 1$	17.47	0.03
$r \leq 1$	$r > 1$	3.22	0.54	$r = 1$	$r = 2$	3.22	0.54

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