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# Do Precious and Industrial Metals Act as Hedges and Safe Havens for Currency Portfolios?[*]

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**Abstract**

This study explores whether metals act as hedges and safe havens for currency investing portfolios. Three widely used currency investment strategies: carry, momentum and value are adopted. The empirical results argue that gold and silver do exhibit hedge and safe haven properties for all three strategies. Silver works as a strong hedge during extreme market conditions. However, these hedge and safe haven properties became weaker after the year 2000. We also find that industrial metals do not work as either hedges or safe havens for carry portfolios.

*Keywords*: Metals, Currency, Carry Trade, Hedge, Safe Haven

*JEL Codes*: F31, G10, G11

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## 1. Introduction

Precious metals have often been used to store value against shocks suffered by other assets. In particular, gold showed a good performance during the global financial crisis of 2008. Thus the hedge and safe haven statuses of gold have been investigated in the past. For instance, Baur and Lucey (2010) defined the concepts of hedge and safe haven, and Baur and McDermott (2010) tested whether gold acts as a hedge and a safe haven during stock market turmoil. They found that gold is indeed a safe haven asset in relation to European and U.S. stock markets. Other precious metals also have diversification benefits; Hillier et al. (2006) demonstrate that silver and platinum prices are not correlated with stock market indices, and hence proposed that such precious metals should be included in portfolios. Further, gold acts as a hedge against U.S. dollar depreciation (Reboredo, 2013), while this relation varies over time (Joy, 2011). Although gold works as a hedge tool for currency investors, they may not invest in a single currency rather invest in a currency portfolio.

Recently, a portfolio approach has become widely used in currency investing, and it is considered advantageous to average out any currency specific component. For instance, Lustig et al. (2011) sort currencies based upon interest rate differences from a base country and construct carry portfolios. Carry is the most popular currency investing strategy, while currency momentum and value portfolios have also been investigated (e.g. Kroencke et al. 2014; Barroso and Santa-Clara 2015). Pojarliev and Levich (2010) report that carry, momentum and value strategies have been widely adopted by currency fund managers. The aim of this study is to investigate whether metals provide hedge and safe haven properties for currency portfolio investors.

The first contribution of this study, therefore, is that of extending the hedge and safe haven literature in relation to currency markets and exploring whether precious metals act as hedges and/or safe havens for currency portfolios. This issue is particularly important for carry trades since the high average return of carry trades is compensation for risk, and carry trades entail crash risk as pointed out by Brunnermeier et al. (2009). The second contribution is that here we employ not only precious metals but also industrial metals. Industrial metals may have stronger hedging properties than precious metals. Indeed, Agyei-Ampomah et al. (2014) show that portfolios consisting of bond and industrial metals outperform those of bond and precious metals in the bear market.

The outline of this paper is as follows: Section 2 describes currency portfolio constructions; Section 3 explains the econometric methodology; Section 4 presents the data; Section 5 displays the empirical results; and Section 6 concludes.

## 2. Currency Portfolio

This study computes a currency excess return using spot and forward rates and assuming U.S. investors. The currency excess return $r_{j,t}$ for currency $j$ at time $t$ is defined as:

$$r_{j,t} = \frac{F_{j,t-1} - S_{j,t}}{S_{j,t}} \tag{1}$$

where $F_{j,t-1}$ is the forward price of foreign currency $j$ per unit of U.S. dollar and this price is agreed at $t-1$ and delivered at $t$, and $S_{j,t}$ is the spot price of foreign currency $j$ at $t$. Following Lustig et al. (2011), we take into account transaction costs using bid-ask prices.

This study considers carry, momentum and value strategies at a monthly frequency. At the end of each month, currencies are sorted by a characteristic and the $k$ highest currencies are in the long, and $k$ lowest currencies are in the short positions. This is the same as the approach proposed by Bakshi and Panayotov (2013), and for example, we denote by carry (2, 2), a carry trade portfolio under which two currencies are bought and two currencies are sold.

### 2.1. Carry Strategy

Carry trade portfolios are constructed based upon forward discounts. This strategy exploits deviations from the uncovered interest rate parity. In other words, a high interest rate currency generates a higher return than a low interest rate currency because the interest rate difference is not offset by the change in the spot exchange rate. Following Lustig et al. (2011), a forward discount $FD_{j,t}$ is computed as the difference between forward and spot rates at time $t$:

$$FD_{j,t} = \frac{F_{j,t} - S_{j,t}}{S_{j,t}}. \tag{2}$$

When $FD_{j,t}$ is positive, this means that the interest rate in the foreign country $j$ is higher than that in U.S., since we assume that the covered interest rate parity condition is satisfied (e.g. Akaram et al., 2008). In carry portfolios, investors go long (short) in currencies when there are high (low) forward discounts.

### 2.2. Momentum Strategy

A momentum strategy uses a past return as a characteristic, instead of a forward discount. Here, we employ a past three months cumulative currency excess return. Kroencke et al. (2014) and Barroso and Santa-Clara (2015) also adopted this definition, since Menkhoff et al. (2012) reported that momentum has persistence, but that including longer than the past three months did not provide a higher return. In momentum portfolios, long (short) currencies have high (low) past excess returns.

### 2.3. Value Strategy

A value strategy exploits information of a fundamental value: and if the price of currency $j$ is undervalued compared with what is considered its fundamental value, then investors invest in the currency $j$. The fundamental value is computed as the cumulative five year change of the real exchange rate as in Kroencke et al. (2014) and Barroso and Santa-Clara (2015). The fundamental value $VA_{j,t}$ is computed as:

$$VA_{j,t} = \frac{S_{j,t-3} CPI_{j,t-60} CPI_{US,t-3}}{S_{j,t-60} CPI_{j,t-3} CPI_{US,t-60}} \qquad (3)$$

where $CPI_{j,t-3}$ is the price level of consumer goods in country $j$ at *t-3*, and $CPI_{US,t-3}$ is the price level in the U.S. We follow Kroencke et al. (2014) and employ a three month lag to avoid overlaps between momentum and value strategies. Further, Barroso and Santa-Clara (2015) stated that a lag value is appropriate since there is a time lag involved in the observation of price levels. If $VA_{j,t}$ is higher (lower) than one, then this it indicates that the currency is overvalued (undervalued), and thus is in the short (long) position.

## 3. Econometrics Methodology

In this section, we present an econometrics model which will allow us to explore a hedge and a safe haven. Following Baur and McDermott (2010), a metal excess return $rm_t$ is dependent upon a currency portfolio excess return $rcp_t$ and extreme market conditions for the currency portfolio are taken into account by dummy variables:

$$rm_t = \alpha + \beta_t rcp_t + e_t \quad (4)$$

$$\beta_t = \delta_0 + \delta_1 D10 + \delta_2 D5 + \delta_3 D1 \quad (5)$$

$$h_t = \omega + \theta e_{t-1}^2 + \gamma h_{t-1} \quad (6)$$

where $\alpha$ and $\beta_t$ are estimated parameters, and $e_t$ is an error term. The parameter $\beta_t$ depends upon the dummy variables, $D10$, $D5$ and $D1$, which capture extreme market movements. The dummy variable *Di* is equal to one if the currency portfolio return falls in the lower *i*th percentile. The estimated parameter $\delta_0$ is the hedge coefficient, and if $\delta_0$ is not statistically different from zero then the metal is a weak hedge for the currency portfolio. Further, if $\delta_0$ is significantly negative, this indicates that the metal is a strong hedge.

The nonlinear hedging properties are captured by the parameters, $\delta_1$, $\delta_2$ and $\delta_3$, and if one of these parameters is statistically significant, the metal excess return has a nonlinear relationship with the currency portfolio excess return. A safe haven is captured by the sum of the hedge and the nonlinear parameters. The safe haven parameter is calculated as the sum of the parameters $SH_i = \sum_{p=0}^{i} \delta_p$. If $SH_i$ is not statistically different from zero, this indicates that the metal is a weak safe haven for the currency portfolio. Moreover, if $SH_i$ is significantly negative, this demonstrates that the metal is a strong safe haven.

The error term $e_t$ follows the GARCH (1, 1) process, as described in Baur and McDermott (2010) and Agyei-Ampomah et al. (2014), and takes into account heteroscedasticity in the returns data. Equations (4) $-$ (6) are jointly estimated with Maximum Likelihood.

## 4. Data

Daily spot and one-month forward rates against the U.S. dollar were obtained from Datastream. Following Kroencke et al. (2014) and Bakshi and Panayotov (2013), we employ the G-10 currencies. They are mostly liquid currencies which are widely used in currency investment strategies. Currency portfolios are rebalanced at the end of every month, and these data cover from January 1984 to April 2017. To compute real exchange rates, the Consumer Price Index was obtained from OECD/Main Economic Indicators.

We also used S&P GSCI commodity price excess return indices and calculated log returns. The S&P GSCI indices have precious and industrial metal sub-indices. Three precious metal sub-indices (gold, silver, platinum) and five industrial metal sub-indices (copper, lead, nickel, zinc, aluminium) are collected. The data for most of the industrial metal sub-indices covers from January 2000 to April 2017, since data for these are not available for the entire period.

## 5. Empirical Results

### 5.1. Movements in currency

Figure 1. Returns for the currency investments. The left (right) panel displays portfolios with two (three) long and two (three) short positions.

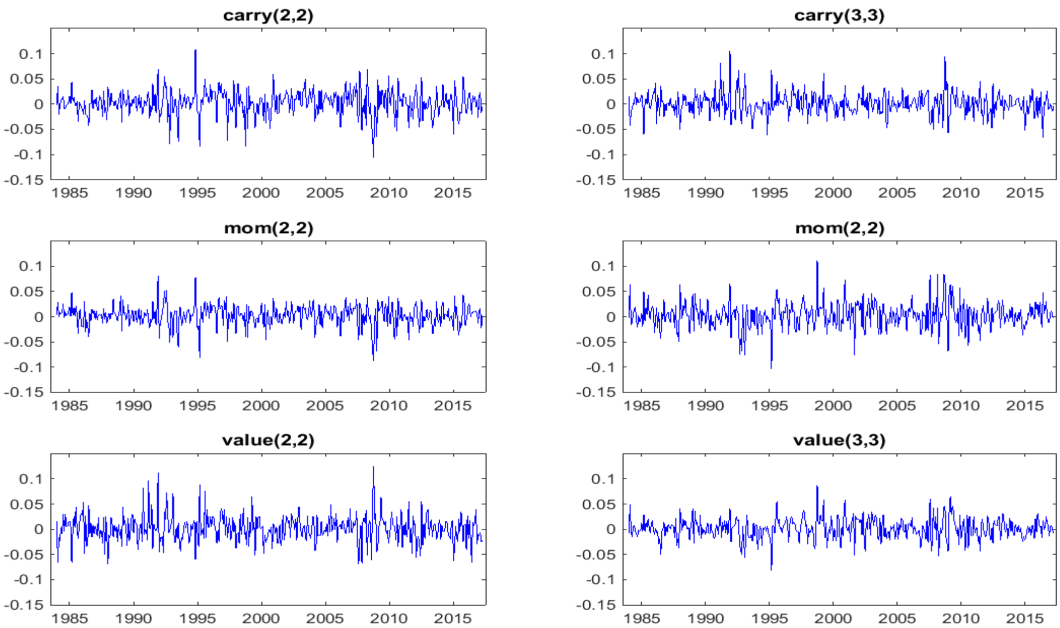
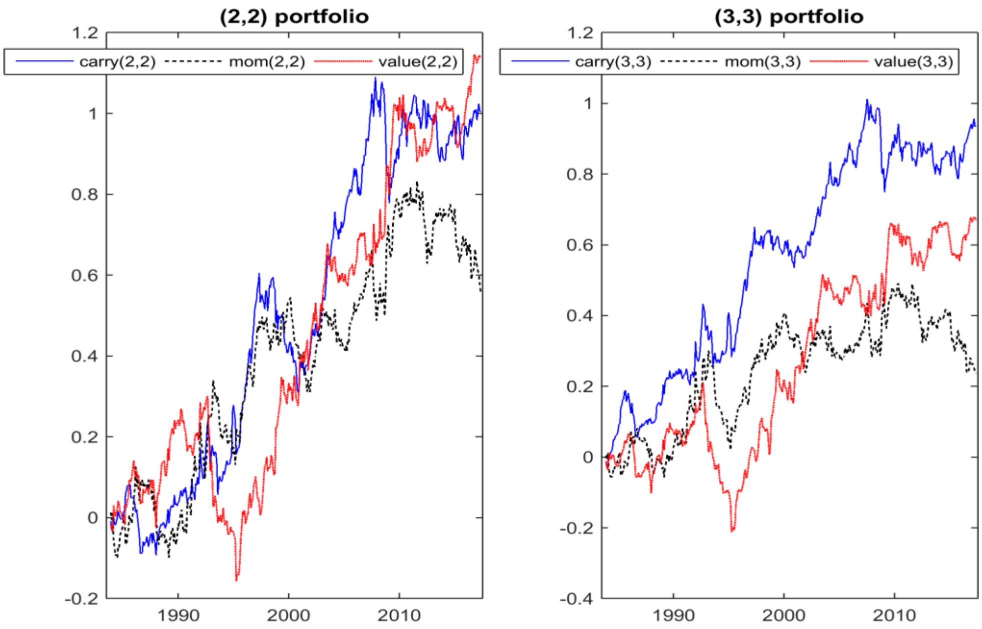


Figure 2. Cumulative returns for the currency investments. The left (right) panel displays portfolios with two (three) long and two (three) short positions.




Returns and cumulative returns for the currency investments are displayed in Figures 1 and 2. All three strategies have different return patterns. Interestingly, carry portfolios suffered a negative return at the time of the financial crisis in 2008, whereas the other two strategies did not. Further, the value (2,2) portfolio showed better performance than the carry (2,2) portfolio.

5.2. Full-period results

We move on to our main results for hedge and safe haven properties. Table 1 presents the estimation results for equations (4) − (6). The estimated parameter $c_0$ indicates whether the metal works as a hedge for currency portfolios. The safe haven parameter $SH_i$ captures extreme market conditions. A statistically significant $SH_i$ presents evidence of a non-linear relationship between metal and currency portfolio returns.

The hedge parameter $c_0$ of gold in Table 1 is negative but not statistically significant for all currency portfolios, indicating that gold acts as a weak hedge for carry, momentum, and value currency portfolios. Gold does not co-move with currency portfolios, therefore investors obtain the diversification benefit including gold in their portfolios. Gold works as a strong safe haven for carry (2,2) and momentum (2,2) in the lower 5th percentile shocks, since the safe haven parameter $SH_2$ is statistically significant at the 5% level. For instance, the lower 5th percentile return of carry (2,2) is $-4.5\%$ and the estimation result indicates that the excess return of gold increases by 1.8%[1]. For the extreme negative shocks in the lower 1st percentile, gold is a strong safe haven for momentum (3,3).

Silver also acts as a weak hedge for all currency portfolios. The safe haven parameter results indicate that silver has a strong safe haven property in extreme market conditions. The statistically significant $SH_3$ for the carry (2,2), momentum (3,3), value (2,2) and value (3,3) portfolios demonstrate the strong non-linear relationship between currency portfolio and silver returns. The safe haven effects of silver are stronger than those of gold. For example, at the lower 5th percentile of carry (2,2), the excess return of silver is 3.2%.

In contrast to monthly stock market results reported by Baur and McDermott (2010), all estimation results of $SH_3$ are negative, suggesting that the diversification benefit of containing silver is large for currency investors. Silver provides higher returns during currency market turmoil and allows to protect the values of the portfolios.

On the other hand, copper does not act as a hedge for carry portfolios. The carry portfolios are strongly correlated to the excess return of copper. These are surprising results since Agyei-Ampomah et al. (2014) show that industrial metals work better as hedge tools than precious metals in bond markets. Furthermore, the copper return has positive

[1] It is calculated by $-4.5\% \times (-0.39)$.

coefficients in some extreme market conditions, implying that copper does not work as a safe haven.

Overall, precious metals such as gold and silver are hedge and safe haven tools for currency portfolios. In particular, silver provides a strong safe haven function. However, copper is not a hedge for carry currency portfolios.

5.3. Sub-period results

Hedge and the safe haven characteristics may vary over time (e.g. Joy, 2011; Agyei-Ampomah et al., 2014). To investigate this point, we divide the sample period into two sub-periods, January 1984 to December 1999 and January 2000 to April 2017. The latter period includes the global financial crisis in 2008 and the financialization of commodities is widely used within it (e.g. Irwin and Sanders, 2011; Cheng and Xiong, 2014). Sufficient observations are required to estimate equations (4) – (6), since dummy variables $D10$, $D5$ and $D1$ capture only extreme movements. For instance, only two observations in $D1$ are equal to one in sub sample period 2.

Table 2 presents the results for sub sample period 1. We see that the hedging power of gold is stronger than that indicated in the full sample period result. The estimated $c_0$ demonstrates that gold acts as a strong hedge for carry and value portfolios. Interestingly, copper serves as a weak hedge and a safe haven for most currency portfolios in this period. In summary, in the early period, metals had stronger hedge properties.

Table 3 shows the results for sub sample period 2. In addition to the four metals we have investigated above, we include the other four industrial metals, covering a shorter period. None of the precious and industrial metals act as strong hedges in the latter period.

Safe haven functions are weaker after 2000 and this may be related to commodity index investing. The positive and statistically significant results of $SH_1$ demonstrate that including precious metals in carry portfolios does not offer diversification benefits during extreme negative markets.

Moreover, the industrial metals have positive and statistically significant hedge parameters, suggesting that they co-move with the carry portfolios. The safe haven parameters for the industrial metals are also positive and statistically significant for carry portfolios, implying that the industrial metals such as copper, zinc and aluminium do not serve as safe haven tools against extreme market shocks. Overall, industrial metal returns co-move with the returns of carry portfolios in the latter period, and no metals have strong hedge properties for any of the currency portfolios.

## 6. Conclusion

This paper investigates the hedge and safe haven properties of metals for various currency investing strategies. The currency carry trade strategy is widely used, although now, after the global financial crisis, it does not generate a positive excess return; hence it is important to analyse other currency investment strategies.

Precious metals work as hedges and safe havens for currency carry, momentum and value portfolios. In particular, silver exhibits a strong safe haven property for all investment strategies. However, these hedge and safe haven properties are weaker in the more recent period. This might be related to the fact that many investors have started to include precious metals in their portfolios. Further, industrial metals do not exhibit a hedge property for carry portfolios in the more recent period. In contrast to the bond market literature, industrial metals co-move with the carry portfolios during extreme market conditions.

Table1

The hedge and safe haven characteristics of metals for currency portfolios: full sample period

| | Gold | | | | Silver | | | |
|---|---|---|---|---|---|---|---|---|
| | Hedge | $SH_1$ | $SH_2$ | $SH_3$ | Hedge | $SH_1$ | $SH_2$ | $SH_3$ |
| Carry(2,2) | -0.109 | 0.206 | -0.393 * | 0.359 *** | 0.165 | 0.066 | -0.723 ** | -0.445 |
| Carry(3,3) | -0.129 | 0.350 | -0.384 | 0.194 | -0.027 | 0.538 | -0.597 * | -1.175 ** |
| Momentum(2,2) | 0.000 | 0.166 | -0.338 * | 0.149 | 0.026 | 0.165 | -0.229 | -0.193 |
| Momentum(3,3) | -0.108 | 0.099 | 0.104 | -0.851 *** | -0.093 | -0.211 | 0.255 | -1.171 *** |
| Value(2,2) | -0.093 | -0.923 *** | -0.309 | -0.376 | 0.165 | -0.747 | -0.601 | -0.888 *** |
| Value(3,3) | -0.154 | -0.439 | -0.208 | -0.425 | 0.141 | -0.358 | -0.211 | -1.385 *** |
| | Platinum | | | | Copper | | | |
| | Hedge | $SH_1$ | $SH_2$ | $SH_3$ | Hedge | $SH_1$ | $SH_2$ | $SH_3$ |
| Carry(2,2) | 0.098 | 0.205 | 0.009 | -0.142 | 0.532 *** | 0.568 | 0.358 | 0.845 |
| Carry(3,3) | -0.071 | 0.796 | 0.178 | -0.122 | 0.599 ** | 1.659 ** | 0.244 | 0.327 |
| Momentum(2,2) | -0.124 | 0.228 | -0.326 | 0.609 | -0.076 | 0.868 * | 0.106 | 0.956 |
| Momentum(3,3) | -0.214 | -0.184 | 0.044 | -0.103 | 0.056 | 0.164 | 1.065 ** | -0.831 |
| Value(2,2) | -0.125 | -0.430 | 0.098 | -0.271 | 0.098 | 0.671 | 0.034 | 0.307 |
| Value(3,3) | -0.019 | -0.864 | 0.436 | -0.370 | 0.141 | 0.818 ** | 0.690 | 0.090 |

Notes: This table shows the estimation results in equations (4) − (6). Hedge indicates estimation results for $\delta_0$. The safe haven parameter $SH_i = \sum_{p=0}^{i} \delta_p$, and the Wald test is used to investigate the null hypothesis that $SH_i$ is equals to zero. *, **, and *** indicates significance at the 10%, 5% and 1% level respectively. The sample period is from January 1984 to April 2017.

Table2

The hedge and safe haven characteristics of metals for currency portfolios: sub period 1

| | Gold | | | | Silver | | | |
|---|---|---|---|---|---|---|---|---|
| | Hedge | $SH_1$ | $SH_2$ | $SH_3$ | Hedge | $SH_1$ | $SH_2$ | $SH_3$ |
| Carry(2,2) | -0.259 *** | 0.092 | -0.199 | -0.454 | -0.167 | -0.167 | -0.374 | -1.936 |
| Carry(3,3) | -0.144 | -0.213 | -0.338 | -0.497 | -0.215 | 0.146 | -0.766 * | -1.994 |
| Momentum(2,2) | -0.078 | 0.143 | -0.535 *** | 1.021 | -0.056 | -0.029 | -0.443 | 0.334 |
| Momentum(3,3) | -0.183 | 0.136 | -0.277 | 0.091 | -0.162 | -0.230 | -0.531 | 1.022 |
| Value(2,2) | -0.154 | -1.069 *** | -0.070 | -0.388 | 0.269 | -0.949 | -0.327 | -1.625 |
| Value(3,3) | -0.290 *** | -0.299 | 0.147 | -0.480 | 0.329 | -0.199 | 0.016 | -2.017 |
| | Platinum | | | | Copper | | | |
| | Hedge | $SH_1$ | $SH_2$ | $SH_3$ | Hedge | $SH_1$ | $SH_2$ | $SH_3$ |
| Carry(2,2) | -0.211 | -0.400 | -0.385 | -0.877 | 0.271 | 0.406 | 0.085 | -0.403 |
| Carry(3,3) | -0.328 | -0.771 | 0.172 | -0.891 | 0.300 | 0.614 | 0.158 | -0.413 |
| Momentum(2,2) | -0.218 | -0.348 | -0.208 | 1.474 | 0.050 | 0.700 | -0.531 | 4.148 |
| Momentum(3,3) | -0.253 | -0.364 | -0.316 | 0.547 | 0.105 | 0.713 | 0.314 | -1.551 |
| Value(2,2) | -0.447 ** | -0.749 | 0.283 | -0.696 | 0.010 | -1.380 *** | 0.442 | -0.317 |
| Value(3,3) | -0.367 | -1.066 | 0.420 | -0.890 | -0.084 | 0.183 | 0.619 | -0.381 |

Notes: This table shows the estimation results in equations (4) $-$ (6). Hedge indicates estimation results for $\delta_0$. The safe haven parameter $SH_i = \sum_{p=0}^{i} \delta_p$, and the Wald test is used to investigate the null hypothesis that $SH_i$ is equals to zero. *, **, and *** indicates significance at the 10%, 5% and 1% level respectively. The sample period is from January 1984 to December 1999.

Table 3

The hedge and safe haven characteristics of metals for currency portfolios: sub period 2

| | Gold | | | | Silver | | | |
|---|---|---|---|---|---|---|---|---|
| | Hedge | $SH_1$ | $SH_2$ | $SH_3$ | Hedge | $SH_1$ | $SH_2$ | $SH_3$ |
| Carry(2,2) | 0.073 | 0.619 * | -0.407 | 1.163 | 0.407 | 0.740 | -0.487 | 0.982 |
| Carry(3,3) | -0.119 | 1.398 *** | -0.645 ** | 1.380 *** | 0.290 | 1.535 * | -0.289 | 0.944 |
| Momentum(2,2) | 0.193 | 0.216 | -0.289 | 0.172 | 0.313 | 0.165 | -0.209 | 0.776 |
| Momentum(3,3) | 0.136 | 0.794 ** | -0.658 ** | -1.085 | 0.295 | 0.651 | -0.449 | -2.257 |
| Value(2,2) | -0.030 | -0.424 | -0.742 ** | -0.765 | 0.083 | -0.018 | -0.937 | -1.554 |
| Value(3,3) | -0.025 | -0.550 | -0.816 ** | -0.472 | 0.040 | -0.035 | -0.447 | -1.618 * |
| | Platinum | | | | Copper | | | |
| | Hedge | $SH_1$ | $SH_2$ | $SH_3$ | Hedge | $SH_1$ | $SH_2$ | $SH_3$ |
| Carry(2,2) | 0.478 | 0.430 | 0.751 * | 0.577 | 0.669 | 1.350 | 0.894 *** | 3.070 *** |
| Carry(3,3) | 0.431 | 1.816 *** | 0.836 ** | 0.527 | 0.821 ** | 2.259 *** | 0.871 ** | 3.559 *** |
| Momentum(2,2) | 0.169 | 0.500 | -0.552 | 0.342 | -0.125 | 0.987 | 0.195 | 1.432 |
| Momentum(3,3) | 0.138 | 0.653 | -0.386 | -0.695 | -0.073 | 0.087 | 1.179 ** | -0.378 |
| Value(2,2) | 0.182 | 0.301 | -0.175 | -0.018 | 0.087 | 2.010 *** | -0.796 | 0.687 |
| Value(3,3) | 0.327 | -0.816 | 0.208 | 0.684 | 0.368 | 0.104 | 0.544 | 0.411 |
| | Lead | | | | Nickel | | | |
| | Hedge | $SH_1$ | $SH_2$ | $SH_3$ | Hedge | $SH_1$ | $SH_2$ | $SH_3$ |
| Carry(2,2) | 0.813 *** | 1.509 | -0.382 | 0.663 | 0.523 | 1.444 | 0.868 | 2.085 |
| Carry(3,3) | 0.887 ** | 1.272 * | 0.692 | 0.586 | 0.777 * | 1.957 | 1.493 | 2.219 |
| Momentum(2,2) | -0.084 | 0.702 | 0.199 | 1.064 | -0.099 | 0.753 | -0.600 | 1.714 |
| Momentum(3,3) | -0.093 | 1.224 | 0.826 | -0.935 | 0.008 | 1.064 | 0.266 | -1.071 |
| Value(2,2) | 0.223 | 0.949 | -0.457 | 0.436 | 0.105 | 0.494 | 0.431 | 1.371 |
| Value(3,3) | 0.587 * | -1.595 * | 0.832 | 0.879 | 0.117 | 0.598 | 0.296 | 1.980 |
| | Zinc | | | | Aluminium | | | |
| | Hedge | $SH_1$ | $SH_2$ | $SH_3$ | Hedge | $SH_1$ | $SH_2$ | $SH_3$ |
| Carry(2,2) | 0.386 | 1.621 | 0.215 | 3.274 *** | 0.471 *** | 1.362 ** | 0.309 | 2.621 *** |
| Carry(3,3) | 0.663 ** | 1.455 | 0.669 | 3.496 *** | 0.573 ** | 1.350 ** | 0.823 * | 1.272 *** |
| Momentum(2,2) | -0.345 | 0.742 | -0.621 | 1.558 | 0.121 | 0.484 | 0.375 | 0.930 |
| Momentum(3,3) | -0.235 | 0.335 | 0.175 | -0.865 | 0.184 | 1.085 | 0.732 * | -0.283 |
| Value(2,2) | -0.053 | 1.373 | -1.165 ** | 0.935 | 0.182 | 0.616 | -0.012 | 1.103 |
| Value(3,3) | 0.023 | -0.290 | 0.642 | 1.321 | 0.271 | -0.210 | 0.837 | 0.882 |

Notes: This table shows the estimation results in equations (4) − (6). Hedge indicates estimation results for $\delta_0$. The safe haven parameter $SH_i = \sum_{p=0}^{i} \delta_p$, and the Wald test is used to investigate the null hypothesis that $SH_i$ is equals to zero. *, **, and *** indicates significance at the 10%, 5% and 1% level respectively. The sample period is from January 2000 to April 2017.

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# Do Precious and Industrial Metals Act as Hedges and Safe Havens for Currency Portfolios?

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Table A1 Parameter Estimates: Full Sample

| Gold | carry(2,2) | | carry(3,3) | | mom(2,2) | | mom(3,3) | | value(2,2) | | value(3,3) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\alpha \times 10^4$ | -4.05 | | -4.56 | | -13.97 | | -12.04 | | -34.62 | | -14.94 | |
| | (24.25) | | (23.73) | | (25.88) | | (25.05) | | (23.15) | | (23.04) | |
| δ0 | -0.11 | | -0.13 | | 0.00 | | -0.11 | | -0.09 | | -0.15 | |
| | (0.12) | | (0.14) | | (0.09) | | (0.11) | | (0.09) | | (0.12) | |
| δ1 | 0.32 | | 0.48 | | 0.17 | | 0.21 | | -0.83 | *** | -0.29 | |
| | (0.31) | | (0.37) | | (0.28) | | (0.35) | | (0.32) | | (0.57) | |
| δ2 | -0.60 | * | -0.73 | * | -0.50 | * | 0.01 | | 0.61 | * | 0.23 | |
| | (0.34) | | (0.42) | | (0.29) | | (0.36) | | (0.33) | | (0.60) | |
| δ3 | 0.75 | *** | 0.58 | * | 0.49 | * | -0.95 | *** | -0.07 | | -0.22 | |
| | (0.25) | | (0.30) | | (0.29) | | (0.33) | | (0.35) | | (0.42) | |
| $\omega \times 10^4$ | 0.30 | | 0.34 | | 1.74 | | 0.34 | | 1.19 | * | 1.21 | |
| | (0.27) | | (0.31) | | (1.08) | | (0.29) | | (0.69) | | (0.88) | |
| θ | 0.03 | * | 0.04 | * | 0.10 | ** | 0.04 | ** | 0.14 | *** | 0.10 | ** |
| | (0.02) | | (0.02) | | (0.04) | | (0.02) | | (0.05) | | (0.04) | |
| γ | 0.95 | *** | 0.95 | *** | 0.81 | *** | 0.95 | *** | 0.81 | *** | 0.84 | *** |
| | (0.03) | | (0.03) | | (0.08) | | (0.03) | | (0.07) | | (0.08) | |
| LLV | 684.30 | | 683.18 | | 681.56 | | 684.20 | | 688.43 | | 683.20 | |
| AIC | -3.38 | | -3.30 | | -3.37 | | -3.38 | | -3.40 | | -3.38 | |

| Silver | carry(2,2) | | carry(3,3) | | mom(2,2) | | mom(3,3) | | value(2,2) | | value(3,3) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\alpha \times 10^4$ | -85.60 | | -65.65 | | -64.23 | | -60.60 | | -113.35 | *** | -93.11 | |
| | (41.10) | | (42.01) | | (45.35) | | (44.51) | | (37.10) | | (37.53) | |
| δ0 | 0.16 | | -0.03 | | 0.03 | | -0.09 | | 0.16 | | 0.14 | |
| | (0.16) | | (0.21) | | (0.13) | | (0.18) | | (0.15) | | (0.19) | |
| δ1 | -0.10 | | 0.57 | | 0.14 | | -0.12 | | -0.91 | | -0.50 | |
| | (0.48) | | (0.66) | | (0.39) | | (0.65) | | (0.56) | | (0.96) | |
| δ2 | -0.79 | | -1.14 | * | -0.39 | | 0.47 | | 0.15 | | 0.15 | |
| | (0.51) | | (0.62) | | (0.45) | | (0.64) | | (0.67) | | (1.09) | |
| δ3 | 0.28 | | -0.58 | | 0.04 | | -1.43 | *** | -0.29 | | -1.17 | * |
| | (0.40) | | (0.56) | | (0.57) | | (0.46) | | (0.48) | | (0.61) | |
| $\omega \times 10^4$ | 5.58 | *** | 5.34 | *** | 5.63 | *** | 5.52 | *** | 4.61 | *** | 5.03 | *** |
| | (1.68) | | (1.60) | | (1.81) | | (1.78) | | (1.49) | | (1.61) | |
| θ | 0.20 | *** | 0.22 | *** | 0.20 | *** | 0.19 | *** | 0.21 | *** | 0.21 | *** |
| | (0.04) | | (0.05) | | (0.05) | | (0.04) | | (0.04) | | (0.05) | |
| γ | 0.72 | *** | 0.71 | *** | 0.72 | *** | 0.73 | *** | 0.72 | *** | 0.72 | *** |
| | (0.05) | | (0.05) | | (0.05) | | (0.05) | | (0.05) | | (0.05) | |
| LLV | 472.74 | | 473.99 | | 470.05 | | 471.93 | | 476.23 | | 475.25 | |
| AIC | -2.32 | | -2.33 | | -2.31 | | -2.32 | | -2.34 | | -2.34 | |

Notes: See the next page.

Table A1 Parameter Estimates: Full Sample (Continue)

| Platinum | carry(2,2) | carry(3,3) | mom(2,2) | mom(3,3) | value(2,2) | value(3,3) |
|---|---|---|---|---|---|---|
| $\alpha \times 10^4$ | 14.67 | 44.68 | 31.02 | 30.43 | 18.59 | 18.85 |
| | (33.99) | (34.30) | (32.82) | (32.28) | (35.54) | (33.87) |
| δ0 | 0.10 | -0.07 | -0.12 | -0.21 | -0.13 | -0.02 |
| | (0.14) | (0.17) | (0.11) | (0.14) | (0.15) | (0.17) |
| δ1 | 0.11 | 0.87 * | 0.35 | 0.03 | -0.30 | -0.84 |
| | (0.27) | (0.49) | (0.34) | (0.45) | (0.50) | (0.65) |
| δ2 | -0.20 | -0.62 | -0.55 | 0.23 | 0.53 | 1.30 ** |
| | (0.31) | (0.51) | (0.44) | (0.51) | (0.49) | (0.63) |
| δ3 | -0.15 | -0.30 | 0.93 | -0.15 | -0.37 | -0.81 * |
| | (0.42) | (0.42) | (0.61) | (0.68) | (0.39) | (0.45) |
| $\omega \times 10^4$ | 12.14 *** | 10.43 *** | 11.51 *** | 11.52 *** | 9.44 *** | 9.31 *** |
| | (3.59) | (3.12) | (3.28) | (3.10) | (2.98) | (2.86) |
| θ | 0.29 *** | 0.27 *** | 0.27 *** | 0.29 *** | 0.26 *** | 0.29 *** |
| | (0.06) | (0.07) | (0.06) | (0.06) | (0.07) | (0.07) |
| γ | 0.43 *** | 0.49 *** | 0.46 *** | 0.45 *** | 0.52 *** | 0.51 *** |
| | (0.12) | (0.11) | (0.11) | (0.11) | (0.11) | (0.11) |
| LLV | 552.43 | 553.57 | 554.07 | 552.99 | 553.37 | 554.98 |
| AIC | -2.72 | -2.73 | -2.73 | -2.72 | -2.73 | -2.73 |

| Copper | carry(2,2) | carry(3,3) | mom(2,2) | mom(3,3) | value(2,2) | value(3,3) |
|---|---|---|---|---|---|---|
| $\alpha \times 10^4$ | 12.63 | 38.73 | 69.04 * | 55.44 | 40.62 | 50.49 |
| | (43.92) | (45.69) | (41.76) | (40.79) | (41.95) | (42.43) |
| δ0 | 0.53 *** | 0.60 ** | -0.08 | 0.06 | 0.10 | 0.14 |
| | (0.19) | (0.25) | (0.16) | (0.20) | (0.15) | (0.19) |
| δ1 | 0.04 | 1.06 | 0.94 * | 0.11 | 0.57 | 0.68 * |
| | (0.79) | (0.80) | (0.53) | (0.73) | (0.45) | (0.37) |
| δ2 | -0.21 | -1.41 * | -0.76 | 0.90 | -0.64 | -0.13 |
| | (0.78) | (0.82) | (0.57) | (0.79) | (0.63) | (0.61) |
| δ3 | 0.49 * | 0.08 | 0.85 | -1.90 | 0.27 | -0.60 |
| | (0.26) | (0.55) | (0.74) | (1.83) | (0.72) | (1.00) |
| $\omega \times 10^4$ | 9.57 *** | 26.06 *** | 24.64 *** | 25.08 *** | 25.99 *** | 25.15 *** |
| | (3.28) | (5.58) | (6.26) | (6.02) | (6.05) | (6.24) |
| θ | 0.16 *** | 0.32 *** | 0.29 *** | 0.28 *** | 0.33 *** | 0.33 *** |
| | (0.05) | (0.06) | (0.06) | (0.06) | (0.06) | (0.06) |
| γ | 0.67 *** | 0.22 * | 0.28 ** | 0.28 *** | 0.24 * | 0.25 * |
| | (0.09) | (0.13) | (0.14) | (0.13) | (0.13) | (0.14) |
| LLV | 494.06 | 495.45 | 489.67 | 489.67 | 486.05 | 487.42 |
| AIC | -2.43 | -2.44 | -2.41 | -2.41 | -2.39 | -2.40 |

Notes: This table shows parameters estimates in equations (4)-(6). The coefficients are estimated with Maximum Likelihood and corresponding standard errors (in parentheses) are reported. Log-Likelihood Value (LLV) and Akaike Information Criterion (AIC) are also reported. The sample period is from January 1984 to April 2017. *,**, and *** indicate significance level at the 10%, 5%, and 1% level, respectively.

Table A2 Parameter estimates: sub period 1

| Gold | carry(2,2) | carry(3,3) | mom(2,2) | mom(3,3) | value(2,2) | value(3,3) |
|---|---|---|---|---|---|---|
| $\alpha \times 10^4$ | -44.23 * | -67.35 *** | -61.63 * | -51.00 | -63.88 | -55.42 ** |
| | (25.66) | (12.84) | (31.71) | (33.87) | (28.71) | (23.85) |
| δ0 | -0.26 *** | -0.14 | -0.08 | -0.11 | -0.15 | -0.29 *** |
| | (0.04) | (0.09) | (0.13) | (0.17) | (0.11) | (0.00) |
| δ1 | 0.35 | -0.07 | 0.22 | 0.21 | -0.91 *** | -0.01 |
| | (0.56) | (0.41) | (0.51) | (0.67) | (0.33) | (0.49) |
| δ2 | -0.29 | -0.12 | -0.68 | 0.01 | 1.00 ** | 0.45 |
| | (0.58) | (0.49) | (0.52) | (0.66) | (0.43) | (0.66) |
| δ3 | -0.26 | -0.16 | 1.56 | -0.95 | -0.32 | -0.63 |
| | - | (98.24) | - | - | - | - |
| $\omega \times 10^4$ | 0.05 | 0.02 | 4.42 | 16.86 ** | 0.98 | 0.09 |
| | (0.11) | (0.10) | (20.25) | (8.28) | (0.65) | (0.08) |
| θ | -0.05 *** | -0.05 *** | -0.02 | 0.13 | 0.17 ** | -0.05 *** |
| | (0.02) | (0.01) | (0.05) | (0.10) | (0.08) | (0.01) |
| γ | 1.05 *** | 1.06 *** | 0.70 | -0.29 | 0.78 *** | 1.05 *** |
| | (0.02) | (0.02) | (1.42) | (0.55) | (0.10) | (0.08) |
| | | | | | | |
| LLV | 370.40 | 370.49 | 358.16 | 356.62 | 359.87 | 370.72 |
| AIC | -3.77 | -3.78 | -3.65 | -3.63 | -3.67 | -3.78 |

| Silver | carry(2,2) | carry(3,3) | mom(2,2) | mom(3,3) | value(2,2) | value(3,3) |
|---|---|---|---|---|---|---|
| $\alpha \times 10^4$ | -114.47 ** | -112.61 ** | -107.51 * | -100.79 | -169.68 *** | -140.03 *** |
| | (49.45) | (52.13) | (61.91) | (61.91) | (47.52) | (47.94) |
| δ0 | -0.17 | -0.21 | -0.06 | -0.16 | 0.27 | 0.33 |
| | (0.24) | (0.29) | (0.15) | (0.22) | (0.20) | (0.29) |
| δ1 | 0.00 | 0.36 | 0.03 | -0.07 | -1.22 | -0.53 |
| | (0.76) | (1.19) | (0.75) | (1.22) | (0.85) | (1.70) |
| δ2 | -0.21 | -0.91 | -0.41 | -0.30 | 0.62 | 0.21 |
| | (0.79) | (1.19) | (0.81) | (1.22) | (1.00) | (1.87) |
| δ3 | -1.56 | -1.23 | 0.78 | 1.55 | -1.30 | -2.03 |
| | - | - | - | - | - | - |
| $\omega \times 10^4$ | 9.14 ** | 9.13 *** | 10.88 ** | 11.85 ** | 7.70 ** | 9.58 ** |
| | (3.60) | (3.42) | (4.68) | (4.73) | (3.16) | (4.05) |
| θ | 0.24 *** | 0.25 *** | 0.23 *** | 0.25 *** | 0.24 *** | 0.23 *** |
| | (0.07) | (0.07) | (0.07) | (0.08) | (0.06) | (0.06) |
| γ | 0.56 *** | 0.54 *** | 0.54 *** | 0.50 *** | 0.59 *** | 0.56 *** |
| | (0.12) | (0.11) | (0.13) | (0.14) | (0.10) | (0.12) |
| | | | | | | |
| LLV | 259.09 | 260.21 | 254.2168 | 255.03 | 260.155 | 258.65 |
| AIC | -2.62 | -2.63 | -2.56 | -2.57 | -2.63 | -2.61 |

Notes: See the next page.

Table A2 Parameter estimates: sub period 1 (Continue)

| Platinum | carry(2,2) | carry(3,3) | mom(2,2) | mom(3,3) | value(2,2) | value(3,3) |
|---|---|---|---|---|---|---|
| $\alpha \times 10^4$ | -23.77 | -12.67 | -13.67 | -16.93 | -6.89 | -15.83 |
| | (52.09) | (48.94) | (48.51) | (45.77) | (47.08) | (44.00) |
| δ0 | -0.21 | -0.33 | 0.22 | -0.25 | -0.45 | -0.37 |
| | (0.22) | (0.25) | (0.14) | (0.17) | (0.19) | (0.17) |
| δ1 | -0.19 | -0.44 | -0.13 | -0.11 | -0.30 | -0.70 |
| | (0.85) | (0.91) | (0.59) | (0.75) | (0.59) | (0.65) |
| δ2 | 0.02 | 0.94 | 0.14 | 0.05 | 1.03 | 1.49 |
| | (0.80) | (0.90) | (0.69) | (0.79) | (0.58) | (0.63) |
| δ3 | -0.49 | -1.06 | 1.68 | 0.86 | -0.98 | -1.31 |
| | - | - | - | - | - | - |
| $\omega \times 10^4$ | 0.86 | 11.57 *** | 14.34 *** | 1.28 | 8.24 *** | 1.02 |
| | (0.56) | (3.71) | (4.12) | (0.89) | (2.97) | (2.86) |
| θ | 0.09 ** | 0.47 *** | 0.38 *** | 0.09 * | 0.45 *** | 0.10 ** |
| | (0.04) | (0.15) | (0.12) | (0.05) | (0.15) | (0.07) |
| γ | 0.89 *** | 0.30 ** | 0.27 ** | 0.88 *** | 0.40 *** | 0.88 *** |
| | (0.04) | (0.13) | (0.12) | (0.06) | (0.14) | (0.11) |
| LLV | 278.83 | 275.82 | 274.68 | 276.39 | 279.17 | 280.40 |
| AIC | -2.82 | -2.79 | -2.78 | -2.80 | -2.82 | -2.84 |

| Copper | carry(2,2) | carry(3,3) | mom(2,2) | mom(3,3) | value(2,2) | value(3,3) |
|---|---|---|---|---|---|---|
| $\alpha \times 10^4$ | -18.67 | -16.76 | 4.69 | -3.21 | -7.65 | 8.18 |
| | (61.21) | (62.78) | (60.16) | (58.93) | (58.54) | (59.33) |
| δ0 | 0.27 | 0.30 | 0.05 | 0.11 | 0.01 | -0.08 |
| | (0.28) | (0.33) | (0.22) | (0.23) | (0.25) | (0.25) |
| δ1 | 0.13 | 0.31 | 0.65 | 0.61 | -1.39 ** | 0.27 |
| | (1.13) | (1.15) | (0.78) | (1.32) | (0.55) | (0.89) |
| δ2 | -0.32 | -0.46 | -1.23 | -0.40 | 1.82 * | 0.44 |
| | (1.21) | (1.29) | (1.13) | (1.28) | (0.88) | (1.85) |
| δ3 | -0.49 | -0.57 | 4.68 | -1.87 | -0.76 | -1.00 |
| | - | - | - | - | - | - |
| $\omega \times 10^4$ | 6.45 ** | 6.21 ** | 5.72 | 6.25 ** | 6.18 * | 6.58 ** |
| | (3.04) | (2.97) | (3.54) | (3.09) | (3.61) | (3.29) |
| θ | 0.14 * | 0.15 * | 0.11 | 0.15 * | 0.14 ** | 0.14 * |
| | (0.07) | (0.08) | (0.07) | (0.08) | (0.07) | (0.08) |
| γ | 0.74 *** | 0.74 *** | 0.78 *** | 0.73 *** | 0.74 *** | 0.74 *** |
| | (0.11) | (0.11) | (0.13) | (0.12) | (0.12) | (0.12) |
| LLV | 240.99 | 241.26 | 243.32 | 242.06 | 242.68 | 240.86 |
| AIC | -2.43 | -2.43 | -2.45 | -2.44 | -2.44 | -2.43 |

Notes: This table shows parameters estimates in equations (4)-(6). The coefficients are estimated with Maximum Likelihood and corresponding standard errors (in parentheses) are reported. – indicates that standard errors are not obtained. Log-Likelihood Value (LLV) and Akaike Information Criterion (AIC) are also reported. The sample period is from January 1984 to December 1999. *,**, and *** indicate significance level at the 10%, 5%, and 1% level, respectively.

Table A3 Parameter estimates: sub period 2

| Gold | carry(2,2) | carry(3,3) | mom(2,2) | mom(3,3) | value(2,2) | value(3,3) |
|---|---|---|---|---|---|---|
| $\alpha \times 10^4$ | 51.60 | 54.57 | 37.17 | 37.77 | 19.75 | 22.54 |
| | (38.88) | (39.57) | (41.09) | (39.55) | (39.09) | (38.41) |
| δ0 | 0.07 | -0.12 | 0.19 | 0.14 | -0.03 | -0.02 |
| | (0.17) | (0.21) | (0.15) | (0.20) | (0.14) | (0.18) |
| δ1 | 0.55 | 1.52 *** | 0.02 | 0.66 | -0.39 | -0.52 |
| | (0.38) | (0.11) | (0.37) | (0.40) | (0.50) | (0.63) |
| δ2 | -1.03 ** | -2.04 *** | -0.50 | -1.45 *** | -0.32 | -0.27 |
| | (0.43) | (0.01) | (0.38) | (0.49) | (0.53) | (0.71) |
| δ3 | 1.57 *** | 2.02 *** | 0.46 | -0.43 | -0.02 | 0.34 |
| | (0.40) | (0.43) | (1.83) | (4.82) | (9.96) | (0.64) |
| $\omega \times 10^4$ | 5.96 | 0.06 | 4.09 | 2.64 | 3.52 | 4.25 |
| | (6.74) | (0.33) | (3.47) | (2.24) | (3.39) | (4.01) |
| θ | 0.12 | -0.05 | 0.15 | 0.11 * | 0.14 | 0.14 |
| | (0.09) | (0.03) | (0.09) | (0.07) | (0.09) | (0.09) |
| γ | 0.63 * | 1.05 *** | 0.70 *** | 0.79 | 0.72 *** | 0.69 *** |
| | (0.33) | (0.04) | (0.18) | (0.12) | (0.19) | (0.22) |
| | | | | | | |
| LLV | 338.04 | 345.88 | 332.80 | 335.96 | 335.34 | 334.48 |
| AIC | -3.17 | -3.25 | -3.12 | -3.15 | -3.15 | -3.14 |

| Silver | carry(2,2) | carry(3,3) | mom(2,2) | mom(3,3) | value(2,2) | value(3,3) |
|---|---|---|---|---|---|---|
| $\alpha \times 10^4$ | -49.53 | -31.69 | -50.97 | -50.60 | -84.90 | -75.89 |
| | (62.74) | (66.88) | (61.45) | (59.21) | (55.64) | (54.77) |
| δ0 | 0.41 | 0.29 | 0.31 | 0.30 | 0.08 | 0.04 |
| | (0.27) | (0.37) | (0.23) | (0.30) | (0.21) | (0.26) |
| δ1 | 0.33 | 1.24 | -0.15 | 0.36 | -0.10 | -0.07 |
| | (0.62) | (0.99) | (0.49) | (0.76) | (0.73) | (1.52) |
| δ2 | -1.23 * | -1.82 ** | -0.37 | -1.10 | -0.92 | -0.41 |
| | (0.64) | (0.90) | (0.60) | (0.92) | (1.08) | (1.66) |
| δ3 | 1.47 * | 1.23 | 0.99 | -1.81 | -0.62 | -1.17 |
| | (0.86) | (0.80) | (3.30) | (12.52) | (5.12) | (1.09) |
| $\omega \times 10^4$ | 2.88 | 2.33 | 2.11 | 1.69 | 1.58 | 1.74 |
| | (1.88) | (1.45) | (1.38) | (1.06) | (1.04) | (1.23) |
| θ | 0.15 ** | 0.13 ** | 0.15 ** | 0.11 ** | 0.14 *** | 0.16 *** |
| | (0.06) | (0.06) | (0.06) | (0.05) | (0.05) | (0.06) |
| γ | 0.82 *** | 0.85 *** | 0.84 *** | 0.88 *** | 0.86 *** | 0.56 *** |
| | (0.06) | (0.06) | (0.06) | (0.05) | (0.05) | (0.05) |
| | | | | | | |
| LLV | 226.18 | 225.77 | 223.55 | 226.08 | 225.89 | 224.83 |
| AIC | -2.10 | -2.09 | -2.07 | -2.10 | -2.10 | -2.08 |

Notes: See the next page.

Table A3 Parameter estimates: sub period 2 (continue)

| Platinum | carry(2,2) | carry(3,3) | mom(2,2) | mom(3,3) | value(2,2) | value(3,3) |
|---|---|---|---|---|---|---|
| $\alpha \times 10^4$ | 49.84 | 88.68 | 72.46 | 76.64 | 61.2 | 50.58 |
| | (46.47) | (45.90) | (44.39) | (48.03) | (52.02) | (49.95) |
| δ0 | 0.48 ** | 0.43 * | 0.17 | 0.14 | 0.18 | 0.33 |
| | (0.19) | (0.24) | (0.26) | (0.30) | (0.22) | (0.24) |
| δ1 | -0.05 | 1.39 ** | 0.33 | 0.51 | 0.12 | -1.14 |
| | (0.44) | (0.63) | (0.45) | (0.50) | (0.79) | (0.88) |
| δ2 | 0.32 | -0.98 * | -1.05 | -1.04 | -0.48 | 1.02 |
| | (0.52) | (0.59) | (0.69) | (0.76) | (0.80) | (0.91) |
| δ3 | -0.17 | -0.31 | 0.89 | -0.31 | 0.16 | 0.48 |
| | (1.53) | (1.61) | (2.49) | (6.57) | (2.12) | (7.62) |
| $\omega \times 10^4$ | 9.66 ** | 8.56 *** | 11.58 *** | 11.23 *** | 12.45 *** | 11.85 ** |
| | (3.79) | (3.12) | (4.04) | (4.14) | (4.22) | (5.61) |
| θ | 0.29 *** | 0.29 *** | 0.29 *** | 0.27 *** | 0.32 *** | 0.35 ** |
| | (0.09) | (0.09) | (0.08) | (0.08) | (0.09) | (0.09) |
| γ | 0.50 *** | 0.52 *** | 0.45 *** | 0.48 *** | 0.41 *** | 0.41 *** |
| | (0.14) | (0.12) | (0.13) | (0.13) | (0.14) | (0.19) |
| LLV | 286.56 | 288.50 | 283.58 | 283.04 | 282.63 | 283.64 |
| AIC | -2.68 | -2.70 | -2.65 | -2.64 | -2.64 | -2.65 |

| Copper | carry(2,2) | carry(3,3) | mom(2,2) | mom(3,3) | value(2,2) | value(3,3) |
|---|---|---|---|---|---|---|
| $\alpha \times 10^4$ | 56.81 | 75.85 | 111.33 ** | 97.02 * | 96.90 | 69.68 |
| | (57.95) | (59.20) | (54.87) | (53.48) | (53.43) | (57.39) |
| δ0 | 0.67 *** | 0.82 ** | -0.12 | -0.07 | 0.09 | 0.37 |
| | (0.25) | (0.35) | (0.25) | (0.34) | (0.19) | (0.25) |
| δ1 | 0.68 | 1.44 | 1.11 | 0.16 | 1.92 ** | -0.26 |
| | (0.84) | (0.91) | (0.73) | (0.95) | (0.81) | (0.75) |
| δ2 | -0.46 | -1.39 * | -0.79 | 1.09 | -2.81 *** | 0.44 |
| | (0.80) | (0.82) | (0.75) | (1.09) | (0.98) | (0.86) |
| δ3 | 2.18 *** | 2.69 *** | 1.24 | -1.59 | 1.48 | -0.13 |
| | (0.51) | (0.56) | (2.57) | (24.49) | (3.65) | (1.56) |
| $\omega \times 10^4$ | 22.62 * | 26.94 ** | 33.17 *** | 35.68 *** | 32.14 *** | 34.37 *** |
| | (13.46) | (12.44) | (9.95) | (9.10) | (6.59) | (9.63) |
| θ | 0.24 ** | 0.30 *** | 0.42 *** | 0.39 *** | 0.50 *** | 0.41 *** |
| | (0.10) | (0.10) | (0.09) | (0.09) | (0.10) | (0.08) |
| γ | 0.30 | 0.16 | 0.04 | 0.02 | 0.00 | 0.04 |
| | (0.32) | (0.29) | (0.19) | (0.17) | (0.12) | (0.18) |
| LLV | 265.32 | 265.51 | 253.98 | 252.22 | 257.11 | 251.69 |
| AIC | -2.47 | -2.48 | -2.37 | -2.35 | -2.40 | -2.34 |

Notes: See the next page.

Table A3 Parameter estimates: sub period 2 (continue)

| Lead | carry(2,2) | carry(3,3) | mom(2,2) | mom(3,3) | value(2,2) | value(3,3) |
|---|---|---|---|---|---|---|
| $\alpha\times10^4$ | -11.01 | 9.20 | 34.81 | 39.87 | 4.20 | -24.38 |
| | (63.63) | (65.73) | (61.92) | (60.50) | (58.91) | (57.61) |
| δ0 | 0.81 *** | 0.89 ** | -0.08 | -0.09 | 0.22 | 0.59 |
| | (0.31) | (0.36) | (0.28) | (0.36) | (0.27) | (0.30) |
| δ1 | 0.70 | 0.38 | 0.79 | 1.32 | 0.73 | -2.18 * |
| | (1.14) | (0.85) | (0.74) | (1.03) | (1.14) | (0.92) |
| δ2 | -1.89 | -0.58 | -0.50 | -0.40 | -1.41 | 2.43 ** |
| | (1.27) | (2.07) | (1.19) | (1.38) | (1.25) | (1.30) |
| δ3 | 1.05 | -0.11 | 0.86 | -1.76 | 0.89 | 0.05 |
| | (1.35) | (2.28) | (1.40) | (4.07) | (2.33) | (17.25) |
| $\omega\times10^4$ | 2.07 | 2.29 | 2.16 | 1.94 | 2.10 | 2.14 |
| | (1.63) | (1.81) | (1.61) | (1.54) | (1.65) | (1.73) |
| θ | 0.09 ** | 0.08 *** | 0.09 *** | 0.09 *** | 0.10 ** | 0.10 ** |
| | (0.04) | (0.03) | (0.03) | (0.03) | (0.04) | (0.04) |
| γ | 0.89 *** | 0.89 *** | 0.89 *** | 0.89 *** | 0.88 *** | 0.88 *** |
| | (0.04) | (0.04) | (0.03) | (0.03) | (0.04) | (0.04) |
| LLV | 231.40 | 228.83 | 224.68 | 226.04 | 225.15 | 227.77 |
| AIC | -2.15 | -2.12 | -2.08 | -2.10 | -2.09 | -2.11 |

| Nickel | carry(2,2) | carry(3,3) | mom(2,2) | mom(3,3) | value(2,2) | value(3,3) |
|---|---|---|---|---|---|---|
| $\alpha\times10^4$ | 16.24 | 22.00 | 5.62 | 8.50 | 8.80 | 9.24 |
| | (72.09) | (72.61) | (72.63) | (71.95) | (73.62) | (76.96) |
| δ0 | 0.52 | 0.78 * | -0.10 | 0.01 | 0.11 | 0.12 |
| | (0.33) | (0.44) | (0.31) | (0.38) | (0.30) | (0.40) |
| δ1 | 0.92 | 1.18 | 0.85 | 1.06 | 0.39 | 0.48 |
| | (1.65) | (1.33) | (1.06) | (1.08) | (1.36) | (1.17) |
| δ2 | -0.58 | -0.46 | -1.35 | -0.80 | -0.06 | -0.30 |
| | (1.81) | (1.52) | (1.38) | (1.43) | (1.55) | (1.30) |
| δ3 | 1.22 | 0.73 | 2.31 | -1.34 | 0.94 | 1.68 |
| | (1.99) | (1.64) | (2.53) | (2.42) | (4.18) | (3.19) |
| $\omega\times10^4$ | 4.76 | 5.04 | 4.38 | 4.05 | 4.52 | 4.74 |
| | (5.52) | (6.03) | (5.23) | (5.21) | (5.27) | (5.90) |
| θ | 0.05 | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 |
| | (0.04) | (0.05) | (0.04) | (0.04) | (0.04) | (0.04) |
| γ | 0.90 *** | 0.90 *** | 0.91 *** | 0.90 *** | 0.90 *** | 0.89 *** |
| | (0.08) | (0.09) | (0.07) | (0.07) | (0.07) | (0.08) |
| LLV | 188.44 | 190.12 | 184.17 | 183.46 | 183.50 | 183.37 |
| AIC | -1.73 | -1.75 | -1.69 | -1.69 | -1.69 | -1.69 |

Notes: See the next page.

Table A3 Parameter estimates: sub period 2 (continue)

| Zinc | carry(2,2) | | carry(3,3) | | mom(2,2) | | mom(3,3) | | value(2,2) | | value(3,3) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\alpha\times10^4$ | -21.73 | | -31.75 | | -34.95 | | -33.93 | | -29.48 | | -31.68 | |
| | (51.77) | | (54.51) | | (54.95) | | (55.21) | | (52.38) | | (55.29) | |
| δ0 | 0.39 | | 0.66 | ** | -0.35 | | -0.24 | | -0.05 | | 0.02 | |
| | (0.26) | | (0.31) | | (0.23) | | (0.31) | | (0.22) | | (0.30) | |
| δ1 | 1.23 | | 0.79 | | 1.09 | | 0.57 | | 1.43 | | -0.31 | |
| | (1.18) | | (1.16) | | (1.30) | | (1.23) | | (1.63) | | (0.80) | |
| δ2 | -1.41 | | -0.79 | | -1.36 | | -0.16 | | -2.54 | | 0.93 | |
| | (1.36) | | (1.33) | | (1.39) | | (1.70) | | (1.75) | | (1.06) | |
| δ3 | 3.06 | *** | 2.83 | *** | 2.18 | | -1.04 | | 2.10 | | 0.68 | |
| | (0.90) | | (0.90) | | (4.63) | | (1.70) | | (5.61) | | (6.69) | |
| $\omega\times10^4$ | 1.28 | | 1.20 | | 0.60 | | 0.63 | | 0.51 | | 0.55 | |
| | (1.58) | | (1.53) | | (0.85) | | (0.84) | | (0.65) | | (0.84) | |
| θ | 0.10 | * | 0.11 | * | 0.09 | ** | 0.08 | ** | 0.10 | ** | 0.09 | ** |
| | (0.05) | | (0.06) | | (0.04) | | (0.04) | | (0.04) | | (0.04) | |
| γ | 0.88 | *** | 0.87 | *** | 0.91 | *** | 0.91 | *** | 0.90 | *** | 0.91 | *** |
| | (0.07) | | (0.07) | | (0.04) | | (0.03) | | (0.03) | | (0.03) | |
| LLV | 263.32 | | 262.26 | | 249.05 | | 246.59 | | 250.28 | | 247.32 | |
| AIC | -2.45 | | -2.44 | | -2.32 | | -2.29 | | -2.33 | | -2.30 | |

| Aluminium | carry(2,2) | | carry(3,3) | | mom(2,2) | | mom(3,3) | | value(2,2) | | value(3,3) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\alpha\times10^4$ | -7.16 | | -3.03 | | 30.50 | | 29.51 | | 10.22 | | 11.00 | |
| | (38.53) | | (40.06) | | (35.81) | | (34.04) | | (39.53) | | (39.92) | |
| δ0 | 0.47 | *** | 0.57 | ** | 0.12 | | 0.18 | | 0.18 | | 0.27 | |
| | (0.17) | | (0.23) | | (0.17) | | (0.21) | | (0.16) | | (0.19) | |
| δ1 | 0.89 | | 0.78 | | 0.36 | | 0.90 | | 0.43 | | -0.48 | |
| | (0.62) | | (0.70) | | (0.56) | | (0.74) | | (0.68) | | (0.68) | |
| δ2 | -1.05 | ** | -0.53 | | -0.11 | | -0.35 | | -0.63 | | 1.05 | |
| | (0.60) | | (0.74) | | (0.67) | | (0.82) | | (0.72) | | (0.82) | |
| δ3 | 2.31 | *** | 0.45 | | 0.56 | | -1.02 | | 1.12 | | 0.04 | |
| | (0.52) | | (0.50) | | (0.76) | | (1.03) | | (1.00) | | (2.50) | |
| $\omega\times10^4$ | 17.98 | ** | 22.05 | ** | 20.68 | *** | 22.23 | *** | 23.26 | *** | 22.64 | *** |
| | (9.19) | | (10.84) | | (7.30) | | (7.29) | | (7.92) | | (8.18) | |
| θ | 0.30 | * | 0.30 | ** | 0.42 | *** | 0.44 | *** | 0.35 | *** | 0.35 | *** |
| | (0.15) | | (0.14) | | (0.16) | | (0.15) | | (0.13) | | (0.13) | |
| γ | 0.08 | | -0.06 | | -0.04 | | -0.11 | | -0.08 | | -0.06 | |
| | (0.31) | | (0.34) | | (0.22) | | (0.20) | | (0.22) | | (0.23) | |
| LLV | 319.49 | | 318.92 | | 311.18 | | 313.02 | | 311.37 | | 311.78 | |
| AIC | -3.00 | | -2.99 | | -2.92 | | -2.93 | | -2.92 | | -2.92 | |

Notes: This table shows parameters estimates in equations (4)-(6). The coefficients are estimated with Maximum Likelihood and corresponding standard errors (in parentheses) are reported. Log-Likelihood Value (LLV) and Akaike Information Criterion (AIC) are also reported. The sample period is from January 2000 to April 2017. *,**, and *** indicate significance level at the 10%, 5%, and 1% level, respectively.