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Seasonality, risk and return in daily COMEX gold and silver data 1982–2002

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This study examines seasonality in the conditional and unconditional mean and variance of daily gold and silver contracts over the 1982–2002 periods. Using COMEX cash and futures data, we find that the evidence is weak for the mean but strong for the variance. There appears to be a negative Monday effect in both gold and silver, across cash and futures markets. Within a GARCH framework we find that the Monday seasonal does not disappear, indicating that it is not a risk-related artefact, the Monday dummy in the variance equations being significant also. No evidence of an ARCH-in-Mean effect is found.

I. Introduction and Motivation

Gold and silver have acted as multifaceted metals down through the centuries, possessing similar characteristics to money in that they act as a store of wealth, medium of exchange and a unit of value (Goodman, 1956; Solt and Swanson, 1981). Dooley \textit{et al}. (1995) all report that gold is a borderless asset. Gold and silver have also played closely related roles as precious metals and are considered as substitutes in portfolio diversification (Ciner, 2001). According to Liu and Chou (2003), a close relationship exists between gold and silver, regardless of the issue that their monetary roles have not been significant in recent times and their industrial uses offer little substitutability. There is evidence that these metals can play a useful role in diversifying risk (see Sherman, 1982; Kaufman and Winters, 1989; Chua \textit{et al}.., 1990; Davidson \textit{et al}.., 2003), as well as being an attractive investment in their own right. In addition, the importance of gold in the economy has been shown to persist, with Davidson \textit{et al}. (2003) finding that many world industrial indices still show sensitivity to gold prices. However, there are also economic fundamentals that may act to drive the prices of gold and silver apart. While both are used extensively in industrial processes, there are significant differences between these uses. Silver is extremely reflective, a good conductor of electricity and has extensive use in optics and photography. Gold’s industrial uses are fewer, with the majority of demand coming from the jewellery and dental markets as well as being driven by Central Bank reserve demand (official sector gold). Extensive documentation on gold and silver can be found from the World Gold Council (www.gold.org), the Silver Institute (www.silverinstitute.org) and the International Precious Metal Institute (www.ipmi.org).

With recent equity market volatility, research has also begun to re-examine the relationship between these metals and equities. Thus for example Aggarwal and Soenen (1988), Johnson \textit{et al}. (1997) and Egan and Peters (2001) show the defensive properties of gold in a portfolio, given its high negative correlation

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with equity indices. Brauer and Ravichandran (1986) perform a similar analysis for silver, and Draper et al. (2002) for platinum, gold and silver. As noted, Davidson et al. (2003) find sensitivity of industrial indices to gold prices. Given that much financial research in equity markets involves searching for anomalies, in particular daily seasonal effects in equity markets, it is interesting, therefore, to examine the extent and nature of any such seasonal in the precious metal markets. Moreover, in addition to the evidence from the research noted above, there also exists significant evidence of persistent daily seasonality across a wide variety of assets other than equities. For fixed income securities, Gibbons and Hess (1981), Flannery and Protopapadakis (1988), Jordan and Jordan (1991), Singleton and Wingender (1994), Kohers and Patel (1996) and Adrangi and Ghazanfari (1996) have all detected various degrees of daily seasonality. Gold has previously been analysed by Ball et al. (1982) and Ma (1986), while Chang and Kim (1988), Chamberlain et al. (1990) and Johnston and Kracaw (1991) all investigate futures markets. Finally, Redman (1997), finds evidence of daily and monthly seasonality in real estate investment trusts.

Equally, there is evidence of daily variation in the higher moments of equity markets. Aggarwal and Schatzberg (1997) calculate aggregate skewness and kurtosis firm size classes and weekdays, and examine these directly using ANOVA and Kruskal–Wallis measures. Further evidence is to be found in Cheung et al. (1994), Kramer (1996) and Tang (1997). Evidence in Choudhry (2000) on South-East Asian markets indicates a significant daily seasonal in the conditional variance of a number of equity indices. With the exception of Choudhry (2000) these have focused on the unconditional distribution of these moments.

To broaden the evidence of seasonality in other assets, the existence of seasonal behaviour patterns in commodity markets is examined. A number of authors in the 1980s documented the existence of the negative Monday effect and a January effect in commodity futures prices; see for example Chiang and Tapley (1983), Keim (1983) and Gay and Kim (1987). Milonas and Thomadakis (1997) reported a monthly effect in raw material prices, where over the period 1966 to 1977 the author found that the average daily growth rate in the Dow Jones Spot Commodity Index for the first nine trading days was in excess of the last nine trading days. Girma and Paulson (1998) also find support for the existence of seasonality in petroleum futures spreads.

The work on daily variation in the moments of gold and silver is extremely thin. We have been able to find no study that has investigated seasonality in the silver market, and few indeed that have examined gold. Ball et al. (1982) investigate the morning and afternoon fixings of gold in the London metal exchange over the 1975–79 period. They find little evidence of either a daily seasonal or a negative Monday. This is independent of whether Monday returns are measured as Friday am – Monday am or Friday pm – Monday pm. If anything, there appears to be a negative Tuesday return. Ma (1986) provides contradictory results. Ma analyses the afternoon fixings from January 1975. He finds that while both pre- and post-1981 (when significant changes in settlement procedures and institutional arrangements were instituted) there existed daily seasonality, the nature of this seasonality changes. Pre-1981 there was a negative Tuesday return. Ma (1986) provides evidence to support ‘a pattern of below-average returns in the second half, particularly September’ Tschoegl (1987).

Tsehoel (1987) investigates monthly London afternoon fixing mean returns of gold during the period 1975 to December 1984. The author reports that the data does not give support to the null hypothesis of no monthly seasonality. The author examined seasonality under 3 definitions: cyclical patterns; particular months displaying returns that are significantly different; and lastly where no one month is significantly different from the average, taking all months together add explanatory value. Under these conditions the author states that a stable cyclical pattern does not exist and nor does a January effect. However the author did find weak evidence to support ‘a pattern of below-average returns in the second half, particularly September’ Tschoegl (1987).

Herbst and Maberly (1988) issued a reply to Ma (1986) where the authors reported on the validity of the results. Herbst and Maberly (1988) questioned the synchronization of observations for spot and future gold prices. In addition, Wednesday’s spot mean returns was −4.31% compared to Wednesday’s futures mean return of +9.86% for the period, while during this period futures prices declined from $434.20 to $323.90 per troy ounce. Herbst and Maberly (1988) postulate that the conflicting results are due to 4 significant dates in 1982: 8 September; 15 September; 13 October and 20 October, when spot and future gold prices moved in opposite paths. The authors report that if these outliers were deleted

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1 See, for example, the research quoted in Keim (1983).
the reported mean returns for spot and future gold prices on Wednesday over this period would be +2.72% and +4.77% respectively.

In a reply towards Ball et al. (1982) and Ma (1986), Ma et al. (1989) replicate the tests of Herbst and Maberly (1988), where the authors did not report statistics of significant for their results. Ma et al. (1989) report that Wednesday and non Wednesday mean return on both spot and future markets are not significantly different from zero, while the Kruskal–Wallis Chi-squared reports that a significant difference between Wednesday and non Wednesday returns does not exist regardless of the inclusion of the four observations. Therefore, the authors confirm the results of Ma (1986) and conclude that the high Wednesday returns that existed before October 1981 may indeed be due to the next day settlement procedure in foreign exchange.

Coutts and Sheikh (2002) examined the All Gold Index of the Johannesburg Stock Exchange for the existence of weekend, January and pre-holiday effects in gold equity stocks. Over the period 5 January 1987 to 15 May 1999, the authors report that no evidence exists of a weekend, January or holiday effect in this index.

Since these works, the examination of gold and related asset seasonality has lagged. This study thus attempts to fill that gap, using a variety of robust estimators that take account of the dynamics of the series. In particular, we investigate the daily seasonal in the conditional and unconditional first and second moments (mean and variance) of four assets: gold cash prices, silver cash prices, gold futures prices and silver future prices. This study uses an extended dataset of 20 years to investigate seasonality in the cash and future markets of these metals. We thus allow for comparisons between the gold market dynamics as found in earlier studies such as Ma (1986) and now. In addition, this is the first study of its kind to examine seasonality in the silver market. Using sophisticated econometric modelling, with parametric and non-parametric analysis, we provide an appropriate investigation of the cash and futures market of gold and silver.

The importance of daily seasonality lies in the challenge that it may give to standard notions of market efficiency. While there are many definitions of an informational efficient market, the basic element required is that there is no possibility of making persistent trading profits over and above a 'buy-and-hold' strategy from previous information. If there was a discernable pattern evident then prices would adjust to incorporate this and over time, the pattern would disappear.

II. Gold and Silver Markets: An Introduction

Gold and silver prices float freely in accordance with supply and demand, responding quickly to political and economic events. A large range of companies from mining companies to fabricators of finished products, users of silver and gold content industrial materials and investors, draw on COMEX futures and options and the London Bullion Market primarily. LBM trades essentially physical gold and silver while COMEX trades in the derivatives of these metals. Gold is quoted in dollars and cents per troy ounce, while silver is quoted in cents per troy ounce.

Gold and to a lesser extent silver are highly liquid. Gold can be readily bought or sold 24 hours a day, in large denominations and at narrow spreads. This cannot necessarily be said of most other investments. This is highlighted by Draper et al. (2002) who state that total annual production of gold (2300 tons) is cleared by the LBMA every 2.5 days. According to Ong and Izan (1999) gold is a homogenous commodity, traded continuously across the globe. Silver is traded in London, Hong Kong, Chicago, Zurich and New York. In London, silver is traded on a physical basis for spot and futures prices. According to the Silver Institute, London remains the true centre of the physical silver trade for most of the world; however, significant study contracts trading market for silver occurs in COMEX. Clearly, looking at the above, no more than in equity markets, we see neither systemic force that act at the daily frequency to alter the dynamics of these markets nor would we expect to see such daily seasonality persist in these markets given the high degree of liquidity.

London and New York are two of the most important markets for trading gold and silver. The London Bullion Market (LBM) trades essentially physical metals while COMEX trades in the derivatives of the metals. The COMEX Exchange or the LBM do not set prices of commodities. Rather, the exchange provides a platform where buyers and sellers can come together and publishes the prices that result from those transactions. There are five members of the twice daily London Gold fixing, while three members of the LBMA meet each working day at 12 noon for the daily silver fixing. Clients place orders with the dealing rooms of the fixing members. The price is adjusted to reflect whether there are more buyers or sellers at a given price. The price that emerges from trading is determined by supply and demand. It is important to note that 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 dynamics at that time than to a ‘fixed’ or ‘maintained’ price.

The main factors of demand for gold are industrial use, Central Bank demand and jewellery demand. A sale of official gold reserves has a large influence on the price of gold. A large component of jewellery demand emanates from India and China. In addition, private demand includes the physical hoarding of gold bars and investment in options and futures. Therefore, a change in the attitudes of private investors can have significant alterations for the price of gold. Gold supply is composed of mine production with Indonesia having the largest producing mine; official sector sale, gold scrap with discarded jewellery the biggest component of scrap and net disinvestment (see Radetski, 1989). Investment holdings account for 16 percent of the total stock of gold. Gold’s status as an investment asset has been examined by a number of authors including Aggarwal and Soenen (1988), Johnson and Soenen (1997), Ciner (2001) and Egan and Peters (2001). Sherman (1982) recommended holding 10–20% of portfolios in gold. Jaffe (1989) reports that gold has a low correlation with most assets over the period of 1971–1987, suggesting that gold may reduce portfolio risk. He finds that gold has virtually no relationship with stocks and bonds. Davidson et al. (2003) commented that gold has renewed its diversification status in the aftermath of the Asian crisis as it is once again being used as a hedging device by investors. According to Draper et al. (2002) portfolios that contain gold, silver or platinum perform significantly better than standard equity portfolios. Therefore, the astute investor, using this financial shelter, can minimize risk while maximizing returns.

The price of silver is determined by the interaction of the supply and demand components of the market, the global economy, consumer tastes and images, inflation, fluctuations in deficits, performance of the electronics industry, etc. Silver is produced as a by-product of gold primarily and to a lesser extent lead, zinc and other metals. It is common practice for silver to follow the market movements of gold. The demand for silver as a private investment is not as strong as for gold as industry consumes silver while silver use in industry is much greater. Supply of silver is dominated by mine production, scrap recycling, disinvestment, government sales and producer hedging.

Gold and silver share a lot of similar properties as both are used as industrial components and investment assets. The quantity of gold and silver required is determined by the quantity demanded for industrial, investment and jewellery use. Therefore an increase in the quantity demanded by the industry will lead to an increase in the price of these metals (Radetski, 1989; Draper et al., 2002). Price changes can also be the result of a change in the Central Bank’s holding of these precious metals. In addition, changes in the rate of inflation, currency markets, political harmony, equity markets, producer and supplier hedging all affect the price equilibrium of these metals.

Traditionally gold has played a significant role during times of political and economic crises and during equity market crashes; whereby gold has responded with higher prices. According to Smith, in times of economic uncertainty attention turns to investing in gold as a safe haven (2002, p. 1). Similarly, Faff and Chan (1998) report that gold stocks play an important role as a hedge against other stocks. The authors report that and investment in gold provides an effective hedge against inflation and political instability (1998, p. 22). Taylor (1998) states that both gold and silver along with platinum have provided a short and long run hedge against inflation.

III. Methodology

We test both the conditional and unconditional means and variances of the series. Testing the unconditional means is achieved by a series of regressions of the form

\[ R_t = \sum_{i=1}^{5} \alpha_i + \varepsilon_t \]  

a simple dummy variable regression. The two sets of statistics that emerge are of course the regression \( t \)-statistics, which test the difference from zero of each coefficient, and the regression \( F \)-statistic, which is a joint test of the equality of each coefficient to zero, simultaneously. To ensure robustness of the results from outliers we also apply a robust method, a trimmed least squares regression model. This uses the iterative re-sampling model of Rousseeuw and Leroy (2003).\(^2\) We also report results with Whites correction for disturbances in the error terms to control for heteroskedasticity and autocorrelation. Testing for seasonality in the unconditional variance is by means of Levene’s test, an alternative to the

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\(^2\) Previous versions of this study used a simple trim of the top and bottom 2.5% of data. The results are not significantly different.
well-known Bartlett test for equality of variance that is robust to non-normality. 

The Levene test tests \( H_0: \sigma_i = \sigma_j \forall i,j, \) Ha.: Let 

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

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

GARCH models by now are well known as representations simultaneously of the conditional mean and variance of a series. Thus, we do not propose here to give a detailed recapitulation. In general we can write the GARCH-M models with exogenous variables in both the mean and variance of a series. Thus, we do not represent representations simultaneously of the conditional estimates. Recall that the examinations earlier are of the unconditional mean and variance.

By including dummy variables for days of the week, we are in a position to examine the effect that these have both on the mean and the variance.

There is no agreement in the literature as to which dummy variables should be included. Clare et al. (1998) and Lucey (2000) include daily dummies in the mean and variance for those days that have been shown, from a standard OLS regression, to have significant coefficients in mean returns. Glosten et al. (1993) include dummies for January and October, on similar justification. Beller and Nofsinger (1998) test all calendar variables. Another issue is the mode of propagation of calendar effects. As Beller and Nofsinger (1998) points out, there are of course three places where such dummies can go. The equations above make the implicit assumption that the effect on the conditional variance of calendar effects is through the intercept terms, in effect assuming that there is a different form of conditional variance for each day of the week, etc. Alternatively, it could be the case that the relationship is propagated through the variance itself or through the unexpected returns (residuals).

As there have been very few if any studies published of the conditional variance of these metal contracts, we confine ourselves here with the simplest interpretation. Where there is evidence that there are daily mean seasonals, we include relevant dummies. We also are interested in the potential effect that each day may have on the variance. Thus, we include four dummy variables in the conditional variance equations. We exclude Friday in each of the four contracts studied. The constant term in the variance equation can then be taken as either the mean variance and/or the effect on the variance of the excluded day. The daily dummies for the variance are then properly the differential effects on the variance of the relevant day.

We can interpret the dummy variables as follows: If any daily dummies included in the mean equation remain significant then we may conclude that seasonality is not due to daily variation in risk. If the dummies become insignificant in the mean equation but are significant in the variance equation, we can conclude that there is seasonality in market risk, whether this is priced or not. The extent, if any, of the degree of a relationship from risk to return can also be seen from the magnitude and significance of the ARCH-in-Mean term. In all cases a GARCH(1,1) model is applied in Leveraged form.

**Data**

We examine four series: daily prices for gold and silver cash and futures traded on COMEX, denoted...
as Cash Gold, Cash Silver, Future Gold and Future Silver. We analyse, as normal, percentage changes. The futures contract data are linked to form a continual series using the methodology proposed by Spurgin (1999). The method used is described in more detail therein, but in essence, it involves a continual roll strategy. Each day a percentage of the front contract is sold and rolled into the next-out contract. The roll strategy is linear, with the percentage $P_t$ held in the near contract being

$$\frac{\text{# days until first day of nearby contract expiry month}}{\text{# days from last expiration to nearby expiration}}$$

Each day ($P_{t-1} - P_t$) is rolled. If NB is the nearby contract and NX the next-out then the spot index of any day is given by $S_t = NB \times P_t + NX \times (1 - P_t)$. The total data set extends over the period January 1982 – November 2002. In total, we have 5256 data points available. Given the fact that the above roll mechanism will lose data at the end, the total adjusted future index gives us 5225 data points.

Shown in Table 1 are the average daily volumes of trade on the four contracts over the period – in all cases the markets have shown growth, on this measure, over the period of analysis. Although gold has been freely traded since 1974, we have concentrated on the post 1982 period for a number of reasons including the attempted cornering of the silver market by the Hunt brothers, and the change in settlement procedures in London in late 1981. Shown in Figs 1 and 2 are the price levels over this period. All data are analysed in log-percentage return terms. Table 2 shows detail of the first four moments of gold and silver, by days of the week over the entire dataset.

As cited earlier, there is significant evidence from the equity markets of the tendency of stock markets to decline on a Monday and peak on a Friday. Evidence from Fields (1931), Kelly (1930), French (1980), Lakonishok and Levi (1982), Kohers and Kohers (1995) and Maberly (1995) all document a peak in returns on a Friday and a trough on Mondays.

Shown in Table 2 are some basic statistics. The above results correlate to the findings of this study, that Monday returns are consistently negative and the lowest for all days of the week.

Kohers (1995) and Maberly (1995) all document a peak in returns on a Friday and a trough on Mondays.

Shown in Table 2 are some basic statistics. The above results correlate to the findings of this study, that Monday returns are consistently negative and the lowest for all days of the week. As evidenced in the equity markets, Monday’s standard deviation in both cash and futures gold and future silver is also the highest of all days of the week. Lakonishok and Levi (1982), Lakonishok and Smidt (1988) and Kohers and Kohers (1995) have reinforced the pattern of Monday having the lowest often negative return of the week despite having the highest, or at least the higher than average, risk as proxied by the standard deviation. Thus, the pattern found stereotypically in equity markets follows here. This reflects evidence from previous studies on seasonality in equity markets and is in line with the results of Ma (1986).

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3 We also analysed a continual series constructed by simply rolling to the nearest month when the contract expired. The results from this were qualitatively similar to the results presented here.

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Table 1. Average daily volume/open interest, 2002

<table>
<thead>
<tr>
<th></th>
<th>Cash silver</th>
<th>Cash gold</th>
<th>Future silver</th>
<th>Future gold</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>$6.05</td>
<td>$25.83</td>
<td>$15.26</td>
<td>$70.50</td>
</tr>
<tr>
<td>1987</td>
<td>$12.90</td>
<td>$26.11</td>
<td>$57.49</td>
<td>$95.81</td>
</tr>
<tr>
<td>1992</td>
<td>$9.51</td>
<td>$18.95</td>
<td>$67.04</td>
<td>$84.18</td>
</tr>
<tr>
<td>1997</td>
<td>$17.69</td>
<td>$34.52</td>
<td>$85.01</td>
<td>$171.81</td>
</tr>
<tr>
<td>2002</td>
<td>$12.69</td>
<td>$35.93</td>
<td>$81.53</td>
<td>$158.32</td>
</tr>
</tbody>
</table>

---

Fig. 1. Gold prices 1982–2002

Fig. 2. Silver prices 1982–2002
In examination of higher moments in the equity markets, Scott and Horvath (1980) show that investors have a preference for kurtosis and are adverse to skewness. Aggarwal and Schatzberg (1997) find a negative Monday return. Skewness patterns follow those of the first two moments for the first period they examine, but ‘flip’ in the second, with the Monday skewness going from lowest to highest. This result contrasts with the results here where Monday’s skewness statistics, with the exception of silver cash, are consistently the highest and negative. Kurtosis does not follow mean returns as reported in Aggarwal and Schatzberg (1997), Monday’s kurtosis are positive and the largest in gold cash and silver futures. These results on higher moments of the precious metals show greater similarity with evidence from Asian equity markets as reported in Ho and Cheung (1994) and Tang (1997), both of whom reported that higher moments do not follow a pattern similar to that of lower moments.

From the above results, it appears that seasonality in the first moment may exist. Monday returns are low with no obvious explanation from risk. Similarly, the maximum returns, which occur not on Friday as in equity markets except for Cash gold, the remainder occurring on Thursday, have low standard deviations. However, risk premia in futures and cash markets differ in their derivation, with both however ultimately being a reward for the potential for loss arising from the tails of the distribution. What is interesting here is that the cash and futures markets are in broad agreement, indicating perhaps that the lack of payoff to potential risk is generalized.

Table 3 displays the results of the Kolmogorov Smirnov Z test and the Jarque–Bera statistics for the equality of distributions. The results for all variables reject the equality of the distribution at the 5% level, thus confirming that the data is non-normal. Also shown as in Figs 3, 4 and 5 are histograms of the data in terms of log percentage change, with a normal curve superimposed. All data sets are very peaked due to the high kurtosis factor. The distributions do not display any obvious degree of skewness. Accordingly, we do not carry out tests for seasonality in the higher moments.

### IV. Results

**Unconditional mean and variance results**

Beginning the formal analysis, Table 4 shows the results of a regression analysis of the first moments.
Fig. 3. Data in percentage change

Evolution over 4/1/82 - 28/11/02

Fig. 4. Data relative changes
There does not appear to be an issue of daily seasonality in the first moment as none of the regressions show a significant $F$-statistic, indicating that overall seasonality is not evident. However, Monday has significant $t$-statistics for Cash Gold and Cash Silver, while there are no significant coefficients for the futures series. The results for the robust regression, where the $t$-statistics are calculated according to whites procedure, are qualitatively the same as for the trimmed OLS, with the evidence being if anything weaker again. The trimmed least squares approach, TLS, shows no days as being significantly different from zero.

We have, however, evidence that the data are non-normally distributed, which would warn against an over-reliance on parametric evidence alone. Therefore, the Kruskal–Wallis test, a non-parametric alternative to ANOVA, is used to supplement the results above. The results are shown in Table 5. While we cannot reject the null that the cash series are drawn from a distribution where the daily returns are the same this is not the case for the futures data. This result is inconsistent with the regression results. Testing for a day of the week effect in equity markets, using both the regression $F$ and Kruskal–Wallis test, Elyasiani et al. (1996), Arsad and Coutts (1997) and Steeley (2001) all found agreement between the two sets of tests. Our finding here is thus perhaps evidence that the seasonality in the mean, if present, is weak and not statistically robust.

Table 6 shows the results for the presence of seasonality in the second moment. In all cases, we can reject the null of homogeneity of variance across days of the week, indicating that there may well exist, a daily seasonality in the variances of these assets. The question remains open, given our dataset, as to whether this daily seasonal in variance is a weekend or Monday issue. According to Cross (1973) and French (1980) the Monday effect is Friday close to Monday close data. However, Rogalski (1984) and Harris (1986) state that a weekend effect if evident is returns examined from Friday close to Monday opening. The consensus evidence for equities is for a weekend effect.

\[\text{Fig. 5. Histograms of data plus normal curve}\]
and variances that the evidence is stronger for seasonality, at the daily frequency, for the variance of the data than for the means.

Conditional mean and variance results

Table 7 shows the results of GARCH models. Shown are the coefficients and beside them their \( P \)-values. Both specifications provide a good fit to the data: the diagnostic statistics (available on request) indicate no significant residual serial correlation or significant residual ARCH effects, the constant of variance is positive and significant for gold series, and the variance is non-explosive. The likelihood ratio test in Table 8 indicates that the Leveraged GARCH model does not fit the data any better than the simple GARCH model, a typical finding. In general therefore we concentrate on the GARCH(1,1) results.

For cash gold the constant in the mean, the payoff for non risk factors, is positive. However, it is negative for all other series, but is in all cases insignificant. Thus, in no case can we assert that there is a significant payoff to gold or silver for factors related other than risk. Indeed, given that the ARCH-in-Mean terms are also statistically insignificant, indicating no payoff for risk it appears that the precious metals are being priced by states outside the standard pricing model. This result is in line with that found in Faff and Hillier (2004) in relation to the risk-return trade-off for gold industry stocks.

For cash gold and silver, we note that the Monday dummy in the mean remains significant and negative even with the addition of the dummy variables in the variance equation. Overall, therefore, the Monday effect in the cash gold and silver prices is not driven by variations in risk on Monday. We should note that the dummies in the variance

Table 4. Regression analysis of daily seasonality

<table>
<thead>
<tr>
<th>Variable</th>
<th>OLS</th>
<th>Robust OLS</th>
<th>TLS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>( P )</td>
<td>Coefficient</td>
</tr>
<tr>
<td>Cash gold</td>
<td>Monday</td>
<td>-0.0007</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Tuesday</td>
<td>0.0002</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>Wednesday</td>
<td>-0.0002</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Thursday</td>
<td>0.0002</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>Friday</td>
<td>0.0003</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>( R(5256) )</td>
<td>1.3628</td>
<td>0.23</td>
</tr>
<tr>
<td>Cash silver</td>
<td>Monday</td>
<td>-0.0011</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Tuesday</td>
<td>0.0001</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>Wednesday</td>
<td>-0.0002</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>Thursday</td>
<td>0.0004</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>Friday</td>
<td>0.0001</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>( R(5256) )</td>
<td>1.024</td>
<td>0.40</td>
</tr>
<tr>
<td>Futures gold</td>
<td>Monday</td>
<td>-0.0002</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>Tuesday</td>
<td>-0.0001</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td>Wednesday</td>
<td>0</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>Thursday</td>
<td>0.0001</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>Friday</td>
<td>0</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>( R(5256) )</td>
<td>0.1678</td>
<td>0.95</td>
</tr>
<tr>
<td>Futures silver</td>
<td>Monday</td>
<td>-0.0005</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>Tuesday</td>
<td>-0.0001</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>Wednesday</td>
<td>0.0002</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>Thursday</td>
<td>0.0007</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>Friday</td>
<td>-0.0005</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>( R(5256) )</td>
<td>1.2845</td>
<td>0.29</td>
</tr>
</tbody>
</table>

Table 5. Non-parametric analysis of daily seasonality

<table>
<thead>
<tr>
<th></th>
<th>KW statistic</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash gold</td>
<td>4.029</td>
<td>0.40</td>
</tr>
<tr>
<td>Cash silver</td>
<td>5.908</td>
<td>0.20</td>
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<tr>
<td>Futures gold</td>
<td>0.750</td>
<td>0.00</td>
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<tr>
<td>Futures silver</td>
<td>2.824</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Table 6. Levene’s test for homogeneity of variance

<table>
<thead>
<tr>
<th></th>
<th>Levene statistic</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash gold</td>
<td>7.879</td>
<td>0</td>
</tr>
<tr>
<td>Cash silver</td>
<td>3.524</td>
<td>0.01</td>
</tr>
<tr>
<td>Futures gold</td>
<td>4.865</td>
<td>0</td>
</tr>
<tr>
<td>Futures silver</td>
<td>3.251</td>
<td>0.01</td>
</tr>
</tbody>
</table>
term properly refer to the differential impact that these days have on the variance versus Friday, which influence is subsumed in the constant of variance.

The daily dummies are significant in the variance equations for cash and futures gold, whereas for cash silver we note that only Monday appears to have a systemic effect, increasing variance. For futures silver we find that only Wednesday is significant, with the effect of decreasing variance. However, the magnitude of these effects is extremely small.

Switching to the LGARCH model, we note that the leverage term is negative and significant in all cases, indicating that the effect of a negative innovation in the mean this period acts to reduce the variance next period. The leverage terms are also, in absolute terms, quite large. However, as noted,
the LGARCH model is rejected as an improved fit for the data.

The statistical significance notwithstanding, the small size of the variance coefficients is indicative of low economic significance. In all cases, compared to either the absolute value or the deviation between the absolute value and Friday value of the unconditional variance, the conditional variance coefficients are between 20 and 200 times smaller than the unconditional. Thus, while statistically significant, there is little likelihood of economic significance. By comparison, the conditional mean dummy values for Monday are greater than the unconditional, but again, small in absolute terms. At levels of 0.05%, the Monday return is well below any feasible trading cost, and thus makes the possibility of a trading mechanism based on exploitation of same unlikely to be successful. This finding is not new in the literature on seasonality (see, for example, Cooper, 1982; Ho and Cheung, 1991; Alexakis and Xanthakis 1995; Athannasakos, 1997; Chow et al., 1997; Anon., 1998; Lucey, 2004 and Steeley, 2004), and thus the usual implication can be drawn; while seasonality may exist, it perhaps provides market timing rather than market trading strategies.

V. Conclusion and Discussion

Ma (1986) et seq. found significant negative Monday effects in the gold market. We confirm this finding for cash gold but not for the futures market, perhaps indicating a greater degree of efficiency in that series. In general, it is the case that futures markets are found to be more efficient, being more liquid. The Monday effect in cash gold appears to be weak and statistically not robust. We also provide the first evidence of daily seasonality in silver prices. These are similar to the gold findings. The evidence from a GARCH model, using a leveraged GARCH specification, is that the seasonality in the mean may not result from seasonality in the variance. We also note that there is no evidence of a return-risk relationship as indicated by the ARCH-in-Mean being insignificant and negative.

This set of results indicates a number of unusual features. First, although the four assets are correlated positively and significantly with one another, there appears to be a different set of dynamics across the markets. The authors do not wish to imply that the cash and futures markets are not integrated. See, for example, Ciner (2001) where the author finds that the long run stable relationship between the futures prices of gold and silver has broken down during the 1990s. This is also supported by Escribano and Granger (1998) who found that since the 1990s the co-integration relationship between gold and silver has died. However, this is inconsistent with the results of Ma (1985), Ma and Sorensen (1988) and Wahab et al. (1994). Second, in some ways gold in particular can be seen as the ultimate risk-less asset, despite its having volatility. The finding that these markets appear to be driven almost entirely by their own lagged values, the autoregressive and moving average terms being significant, with neither risk (ARCH-in-Mean) nor non-risk (constant in the mean) variables having any significant impact indicates that returns to these assets are perhaps separate from other influences. Fuller investigation of the conditional mean responses of gold and silver to the equity market for example would require a multivariate GARCH modelling. Third, the finding that the leverage term is in many ways the most important element of the variance indicates that while the daily seasonal in the variance is important it is not as significant, again, as the markets response to its own dynamics. Overall, the results indicate that there are fruitful questions of investigation in these markets, and that an understanding of them requires at the least an understanding of the daily seasonal dynamics.

If we accept that there are daily seasonal influences, the question arises as to the source of these. As has been noted the equity markets are significant contributors to this literature. Drawing from this we find that there are three main theories regarding why markets would indicate a daily seasonal. The most relevant can be broadly summed up as the market settlement system (e.g. Bell and Levin, 1998), arrivals of news to the market (e.g. Steeley, 2001) and dissemination of news in the market (e.g. Pettengill and Buser, 1994) hypotheses. At first glance, none of these would seem clear contenders for the causal mechanism. According to Steeley (2001), news announcements occur on Tuesday, Wednesday and Thursday in the UK. The author states that this allows investors to assimilate and consider information over the weekend, in the absence of additional news, and this perhaps favours Monday selling which could ‘depress prices and so produce a significantly negative return over the weekend’ (2001, p. 1942).

Much of the discussion on the causes of seasonal factors in gold has concentrated on longer-term cycles. Thus, Ma (1986) postulated that as Wednesday’s mean returns for the post October 1981 period changed from being negative to positive, therefore the mean returns for Wednesday were
affected by the existence of same-day foreign exchange market settlement. However, Herbst and Maberly (1988) comment that if the four outliers, that are discussed previously, are deleted then the same-day settlement in foreign exchange does not affect Wednesday’s spot mean returns. Tschoegl (1987) reports that gold should not be affected by tax year effects, which has been reported in Roll (1983) as a potential source of seasonal behaviour in stocks. Tschoegl argues that as (at that stage) gold has a market capitalization greater than that of the largest company on the NYSE, and that in addition as gold is traded in many countries throughout the world it is subjected to carrying tax regimes and tax years (1987: 251). The author also postulates that production cycles should bear no influence on gold returns as significant above ground stocks of the metal exist. The author cites interest rates seasonal behaviour as grounds for seasonal behaviour in the gold market also. Milonas (1991) states that seasonal behaviour in commodities may be due to the cyclic nature of their production. The author notes that crop cycle related seasonality’s have been unearthed by various authors including Roll (1983), Anderson (1985) and Fama and French (1988).

According to Coutts and Sheikh (2002), the non existence of seasonal effects in the All Gold Index on the Johannesburg Stock Exchange may be due to the market microstructure of the exchange or indeed the composition of the index. The authors report that this is in contrast to the many studies, which have discovered international evidence of seasonal behaviour in stock markets. Many practitioners in these markets believe that evidence of seasonality is attributed to the tax payment and accounting cycles. In addition, seasonal buying behaviour in the jewellery market, especially in Asia and the Middle East where gold and silver are purchased as a form of savings, during wedding and festival seasons can induce seasonal effects. As silver is more of an industrial metal than gold, it may share some seasonality with base metals which is related to annual auto production and consumption cycles.

In the case of the settlement system we have in gold a rolling settlement, and the prices of both cash and future gold include the cost of carry (explicitly so in the case of the futures and via the gold lease rate in the case of cash gold) in the price. News generated internally in the market is difficult to extract from general news – the mechanism used by Pettengill and Buster (1994) involves data, rise/fall ratios, that have no analogy in the precious metal markets. Thus, we are left with the potential that it is as a consequence of news arriving to the market, or an as yet unspecified mechanism, that induces daily seasonality, especially in the variance.

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References


