**Impact of macroeconomic news on metal futures**

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**Abstract**

This paper uses intra-day data for the period 2002 through 2008 to examine the intensity, direction, and speed of impact of U.S. macroeconomic news announcements on the return, volatility and trading volume of three important commodities – gold, silver and copper futures. We find that the response of metal futures to economic news surprises is both swift and significant, with the 8:30 am set of announcements – in particular, nonfarm payrolls and durable goods orders – having the largest impact. Furthermore, announcements that reflect an unexpected improvement in the economy tend to have a negative impact on gold and silver prices; however, they tend to have a positive effect on copper prices. In comparison, realized volatility and volume for all three metals are positively influenced by economic news. Finally, there is evidence that several news announcements exert an asymmetric impact on market activity variables.

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## 1. Introduction

The relationship between information arrival and asset price movements is of central importance to price formation and price discovery in financial markets, and is a topic that has been extensively investigated in the literature. For instance, the mixture of distributions model relies on "news" to explain movements in asset returns (see Tauchen and Pitts, 1983). Among the various sources of information the role of public information is frequently examined because they are easily identifiable, and also carry implications for the canonical model of weakly efficient markets which posits that security prices reflect all available information. Chen, Roll, and Ross (1986) highlight the importance of macroeconomic factors such as industrial production and measures of unanticipated inflation on stock returns. In a related study, Flannery and Protopapadakis (2002) relate equity returns to macroeconomic variables. More recently, research attention has shifted to an examination of intra-day data that provides additional insights into the market microstructure behavior relating to trading and pricing variables. As a case in point, Adams, McQueen, and Wood (2004) show that unanticipated inflationary news has distinguishable effects on intra-day equity returns, and that most of this information is incorporated within minutes of the news release.

This paper explores the price formation process and trading volume activity in the metals futures market around the release of *new* macroeconomic information. Four important questions are addressed. First, what is the impact of macroeconomic news on the return, realized volatility and volume of gold, silver and copper futures? Second, does the release of macroeconomic news affect the three metals in different ways? Third, how long does it take for the impact of macroeconomic news shocks to be fully absorbed by the market? Finally, does the metals market respond asymmetrically to the release of unexpected macroeconomic news?

The answers to these questions are important for several reasons. First, our analysis is based on high-frequency intra-day data, which allows us to detect patterns of market reaction that may not be easily discerned in lower frequency daily data. In this regard, it is important to point out that the empirical literature using daily data finds only mixed or relatively weak evidence of the link between macroeconomic announcements and commodity prices (see Roache and Rossi, 2010; Hess, Huang and Niessen, 2008), thus lending support to the argument that, unlike other assets, commodity prices are predetermined with respect to U.S. macroeconomic aggregates such as real output, consumption and investment variables (Kilian and Vega, 2010). Therefore, an investigation of how an important class of commodities, specifically metals, responds to macroeconomic news at intra-day frequencies provides a meaningful contrast with existing studies. Based on Andersen's (1996) argument that different types of news may have different stochastic arrival processes and therefore convey varying impacts on pricing behavior, we evaluate the impact of 19 different types of macroeconomic news. These announcements are sorted by the time of each news release, with the aim of identifying those announcement times that have the largest impact on the metals market. Furthermore, taking into account evidence from related asset markets such as equities (Koutmos and Booth, 1995), we also examine whether or not metal futures respond asymmetrically to economic news. We contend that a study of how metal futures prices react to positive versus negative economic surprises would be informative not only in terms of market efficiency and information processing, but may also provide an explanation as to why previous studies that do not account for potential asymmetries may have been unsuccessful in documenting a significant relationship between economic news and commodity prices.

Second, compared to financial assets, there is a relative paucity of studies that examine the role of information in the metal futures markets. This is especially noteworthy considering that in recent years there has been a steady increase in the amount of investor attention given to these markets. In general, the popularity of commodities, and in particular metals, stems from the belief that these assets act as a hedge against inflation, offer valuable diversification opportunities to investors, serve as a monetary medium during times of market uncertainty, and have a wide range of manufacturing and industrial applications. It is therefore not entirely surprising that these products are one of the most heavily traded in organized futures exchanges.

Finally, our study is comprehensive in scope in that it evaluates the responsiveness of several market activity variables including return, volatility and trading volume. We construct a realized volatility measure that accounts for intra-day price information within each particular time interval.

Therefore, to summarize, our sample period, research design, and empirical methods allow us to investigate more fully the high-frequency dynamics of three important commodities. The remainder of the paper is organized as follows. In the next two sections we provide a literature review and discuss theoretical considerations, respectively. Section 4 explains the data sources, summary statistics and cleaning procedures. Section 5 provides a brief description of the research design and empirical methods, and discusses the results. Section 6 concludes the paper.

## 2. Literature review

A survey of the literature in the metals commodities markets reveals three major research streams: (a) characterization of the distributional properties of metal prices (Khalifa, Miao and Ramchander, 2011); (b) identification of dynamic relationships between futures and spot prices of various metals (Kocagil, 1997); and (c) examination of metals as a hedge against inflation,

currency rate risk, and market uncertainty (Baur and Lucey, 2010). Our study on how metal futures market responds to macroeconomic news adds a new dimension to the literature and carries implications for market efficiency, risk premia, and the pricing and trade behavior of gold, copper and silver.

Although there is a vast amount of literature that documents the effects of macroeconomic news on stocks (e.g., Boyd, Hu and Jagannathan, 2005), bonds (e.g., Simpson and Ramchander, 2004; Nowak et al., 2011) and currencies (e.g., Simpson, Ramchander and Chaudhry, 2005; Chen and Gau, 2010), the corresponding literature on the reaction of metal prices to economic announcements is relatively scarce. Some notable exceptions exist. Using daily data, in a broader examination of 12 different commodities including gold, silver and copper, Roache and Rossi (2010) find that daily prices are relatively insensitive to macroeconomic news. Hess, Huang and Niessen (2008) provide a state-dependent interpretation of macroeconomic news by showing that daily commodity prices are responsive only during recessionary periods, but not during periods of economic growth.

To our knowledge there are only two studies that use intra-day data to examine gold and/or silver prices. Christie-David, Chaudhry and Koch (2000) use intra-day 15-minute transaction prices between 1992 and 1995 to show that the impact of economic surprises on the return variance of gold and silver futures prices is less pronounced compared to interest rate futures. Cai, Cheung and Wong (2001) provide a detailed characterization of return volatility in gold futures using 5-minute returns between 1994 and 1997. They find that the impact of macroeconomic announcements is much smaller on gold compared to the impact on Treasury bond or currency markets, and only four announcements – jobs report, inflation, GDP and personal income – carry statistically significant effects on gold volatility.

Our study differs from both Christie-David et al. (2000) and Cai et al. (2001) in several regards. First, we use a longer and more recent time frame (2002 through 2008) for the analysis, a period during which metal prices experienced a dramatic increase in price and trading activity. For instance, the futures price of gold increased more than threefold during this period (from about $278 per troy ounce in 2002 to about $1,003 in 2008). There was also a corresponding rise in aggregate trading volume from about 6.8 million contracts in 2001 to more than 38 million in 2008.[1] Second, our study is more comprehensive in scope since we consider the impact of economic news on three important market activity variables – i.e., returns, volatility and trading volume. Third, we differentiate our work from prior studies by constructing a realized volatility measure that has been shown to provide consistent estimates of integrated volatility in the underlying price process (see Barndorff-Nielsen and Shepard, 2002).[2] A final point of distinction is that our study allows for the possibility of return, realized volatility and volume measures to respond asymmetrically to macroeconomic news announcements, and examines the persistence of economic shocks in the metals futures market.

**3. Theoretical considerations**

Physical commodities are different from most financial assets in that they are continuously produced and consumed. The fact that they can be stored implies that production need not be consumed at once. Therefore, mismatches between production and consumption levels can lead to either accumulation or depletion of inventory resulting in price changes. The theory of storage

[1] The price movement in the copper market is even more dramatic. Its price was about $0.66 per pound at the beginning of 2002 and reached a peak in July 2008 when it closed at about $4.04 per pound; only to drop precipitously to about $1.26 at the end of 2008. The aggregated volume in copper futures increased from 2.8 million contracts in 2001 to 4.56 million contracts in 2008. Silver also seem to have followed a similar meteoric rise. It was about $4.53 per troy ounce at the beginning of 2002 and closed at its peak at $20.92 in March 2008. The aggregate volume of silver futures increased from 2.58 million in 2001 to 8.8 million in 2008.

[2] Note that, however, the presence of microstructure noise may bias realized volatility estimates. We account for such potential bias using alternative estimators, as discussed in the 'research design' section of the study.

(see Brennan, 1958) highlights the role of the interest costs of storing the commodity as an important determinant of commodity price changes. In this framework, an unexpected increase in interest rates reduces the demand for inventories (since it raises storage costs) and puts downward pressure on commodity prices.

Unfortunately, given that aggregate inventories are usually not observable and inventory estimates are subject to potential misrepresentation, one may have to explain observed price changes in the context of information arrival. It is in this context that an examination of macroeconomic news, which reveals new information about future economic conditions, becomes pertinent in explaining commodity price movements. However, it must be noted that although news releases are expected to affect commodity prices by altering market beliefs about future economic conditions, the direction of the impact is indeterminate *a priori*. For instance, announcements that cause market participants to revise their expectations of inflation upwards may lead investors to rebalance their portfolios by shifting out of money and into physical assets like commodities. This is likely to result in a positive price change. On the other hand, based on the policy anticipation hypothesis, if market participants anticipate a tighter monetary policy response to curb higher inflation, this may cause real interest rates to rise, and along with slower expected economic growth, drive down commodity prices. In sum, the response of commodity price changes to macroeconomic news is an empirical issue since the price response function is an amalgam of inflation expectations and expected monetary policy response.

Predicting the price response can be further complicated by the fact that there is a wide degree of variation among individual commodity types. This is illustrated by Erb and Harvey (2006) who find a low degree of correlation between different commodity futures products. In the case of metals, it would be reasonable to expect that the price response of precious metals

(gold and silver) which are often seen as an alternative investment vehicle is different from industrial metals such as copper which is viewed a primary input in manufacturing. Therefore, it is possible that a surprise improvement in economic growth may cause gold and silver prices to drop because of portfolio rebalancing effects, but result in higher copper prices due to greater industrial demand.

The pattern of the response of trading volume to anticipated announcements may also take different forms. Theoretical trading models such as Glosten and Milgrom (1985) endow informed traders with private information about impending announcements. Prior to anticipated announcements, these models imply that liquidity declines, as market makers seek to protect themselves from trading with informed traders, while volume may increase as long as the benefits of informed trading exceed the costs of trading. In these models, the public announcement ameliorates the advantage of the informed traders, and volume may be either low or high, depending on whether there is pent up demand from uninformed traders.

In models such as that described by Kim and Verrecchia (1994), the acquisition of private information prior to the announcement is endogenous, and depends on the cost of acquiring private information as well as the expected quality of the announcement. They find that volume after the announcement is directly related to price volatility (measured as the absolute value of the price change), with an increase in the quality of the announcement tending to strengthen the reaction of volume. There is no reason for these characterizations to be mutually exclusive, so an empirical study can offer evidence on which effect tends to dominate.

Finally, in comparison to returns and volume, our expected response of volatility is somewhat more predictable. Ross (1989) argues that in an arbitrage free economy return volatility should be related to information arrival or variation in information frequencies. This

argument is supported by Pasquariello and Vega (2007) who find that, ceteris paribus, price volatility increases in the presence of public information signals. Our research attempts to disentangle these various effects.

## 4. Data characteristics

### *4.1. Futures prices and macroeconomic announcements data*

Our data on metals prices consists of intra-day, tick-by-tick, futures transaction prices for gold, silver and copper for the period January 2002 through December 2008. The data for trading volume is available only for 2007 and 2008. The futures data is obtained from the *Futures Industry Institute*.

Gold, silver and copper metal futures trade on the *Chicago Mercantile Exchange* (CME), which provides both open outcry (pit) and electronic (Globex) trading. Open outcry trading occurs Monday through Friday during the following hours (Eastern Standard Time): 8:20 am – 1:30 pm for gold, 8:25 am – 1:25 pm for silver, and 8:10 am – 1:00 pm for copper. Trading is also offered simultaneously on the Globex electronic trading platform Sunday through Friday from 6:00 pm – 5:15 pm. The raw tick-by-tick futures price data specifies the time, to the nearest second, and the price of the futures transaction. We construct a continuous price series from front month contract, rolling over to the next contract when the daily tick volume of the first back-month contract exceeds the daily tick volume of the current front month contract. This procedure avoids stale prices from the front-month contract that typically occur in the four weeks prior to expiration. The futures prices are then sampled at 1-minute discrete intervals, yielding about 500,000 price observations for each metal. The 1-minute observations are then used to construct 5-minute return and volatility measures.

Table 1 reports summary statistics for the *daily* return series for gold, silver and copper. Gold has a daily mean return of 0.065% and standard deviation 1.23%. Copper and silver have daily mean returns of 0.0426% and 0.0511% respectively, and both have a daily standard deviation of about 2%. The distribution of the return series for each metal exhibits negative skewness and excess kurtosis, and for each series the Jarque-Bera test rejects the null hypothesis of normality.

Our data on macroeconomic news releases consists of 19 different announcements and is obtained from *Bloomberg*. For each announcement, we collect both the realized value and the consensus (median) forecast as reported in *Bloomberg*. Each announcement is released monthly on pre-arranged schedule and disseminated immediately on newswires and other data providers.

In order to make meaningful comparison of the estimated news impact across the three asset classes and different news releases, we "standardize" the news measures. Specifically, the unanticipated component, or surprise, in each announcement is computed as the difference between the actual (or realized) value and the consensus forecast, normalized by its standard deviation. Let $A_{i,t}$ denote the realized value of an announcement of type $i$ at time t, and $E_{i,t}$ denote the consensus forecast. The standardized surprise element of the announcement is defined as:

$$SA_{i,t} = \frac{A_{i,t} - E_{i,t}}{\sigma_i}, \qquad (1)$$

where $\sigma_i$ is the sample standard deviation of the surprise component of the type $i$ announcement, $A_{i,t} - E_{i,t}$. Because $\sigma_i$ is constant for each announcement, the standardization procedure should not affect the statistical significance of the estimated response coefficients and fit of the regression model.

We also calibrate each surprise announcement so that a positive value represents stronger-than-expected economic growth, and a negative value represents weaker-than-expected economic growth. Therefore, we switch the sign for the unemployment rate surprise so that positive surprise represents an unemployment rate that is *lower* than expected.

We classify the 19 macroeconomic announcements into three categories depending on the time of each announcement. There are 11 announcements at 8:30 am, 2 announcements at 9:15 am, and 7 announcements at 10:00 am.[3] Table 2 reports the different types of macroeconomic and the associated time of release. A survey of the different economic announcements indicates that there are: (a) 8 real activity economic variables (advance retail sales, capacity utilization, changes in nonfarm payroll, personal income, unemployment rate, housing starts, industrial production, and NAPM); (b) 3 consumption variables (personal consumption expenditure, new home sales, trade balance); (c) 4 investment variables (business inventories, durable goods orders, construction spending, factory orders); (d) 2 price variables (CPI, PPI); and (e) 2 forward looking variables (consumer confidence, leading indicators).

There are a total of 1,584 announcements during the sample period. The distribution of macroeconomic announcements is shown in Figure 1. All announcements are released each month on a prescheduled day at a fixed time. With the exception of the Employment Situation Report, which includes information about nonfarm payrolls and the unemployment rate, and which are usually released on Fridays, most other announcements are evenly distributed through the week. The news releases also appear to be clustered around the middle of the month, with elevated levels during the beginning and end of each month.

[3] Business inventory is a special case. It was released at 8:30 am before June 2003. It was sometimes released at 8:30 am and sometimes at 10:00 am from June 2003 to November 2005. However, since December 2005 it has been always released at 10:00 am. Therefore, there are 10 announcements plus some of the business inventory announcements at 8:30, and there are 6 other announcements plus some of the business inventory announcements at 10:00.

*4.2. Data cleaning and control sample*

We clean the data using the following steps. First, we exclude any weekend announcements. For instance, there are 28 announcements on Saturdays (23 business inventories, 4 capacity utilization and 1 durable goods orders) and 2 announcements on Sundays (1 CPI and 1 for housing starts). Since there is no trading on weekends, we remove these 30 announcements. Second, in order to minimize bias due to stale prices and nonsynchronous trading we eliminate days with relatively low trading activity. There are about 310, 290, and 300 1-minute price intervals per trading day for gold, copper and silver, respectively. We remove those days from the sample where the number of 1-minute price observations is found to be less than 50% of the number of price observations in a normal trading day. Finally, similar to Ederington and Lee (1993), we construct a control sample consisting of trading intervals that are not contaminated by one of our 19 scheduled news announcements. The control sample allows us to make meaningful statistical inferences on the impact of announcements and also accounts for any potential intraday patterns in the data.

We examine price and volume in the study over a 50-minute time period: 10 minutes prior to the new release and 40 minutes after the new release. We compare the study sample response to economic news with a time-matched control sample that is constructed using observations from days when there are no macroeconomic announcements. For example, the 8:30 am study sample includes all days with at least one announcement at 8:30 am, and the corresponding control sample for the 8:30 am announcement is constructed from all remaining days with no macroeconomic announcements. The resulting sample size over each announcement window for gold, silver and copper are reported in Table 3. After deleting days with low trading activity, we have, for the 8:30 announcement interval, 609 days with price information for gold in the study

sample versus 751 days in the control sample. The control sample for copper and silver consists of 605 and 772 days, respectively. In general, we have fewer number of 9:15 announcements compared to the other two announcement times. Also, there are far fewer observations for trading volume (reported in parenthesis) since data for volume is available only for two years, 2007 and 2008.

## 5. Research design and empirical results

### *5.1. Return, volatility and volume measures*

The return (in percent) during the $i^{th}$ interval on day $t$ is calculated as: $R_{t_i} = 100 \times \left(logP_{c,t_i} - logP_{o,t_i}\right)$, where, $P_{c,t_i}$ and $P_{o,t_i}$ represent the closing and opening prices during the $i^{th}$ interval on day $t$. Volume for the $i^{th}$ interval on day $t$, $V_{t_i}$, is the cumulative volume during that interval.

The intra-day volatility in the return series is measured using realized volatility. Realized volatility, also known as the cumulative intra-day squared return measure of volatility, was introduced by Anderson and Bollerslev (1998) for high-frequency data. The realized volatility (in percent) during an interval $(t_{i-1}, t_i]$ is calculated as $\sigma_{t_i} = (\sum_{j=1}^{n} R_j^2)^{1/2}$, where $\sigma_{t_i}$ is the volatility measure and $n$ is the number of (return) observations during that period of time. Note in our study we sample the data at 1-minute frequency; therefore, the realized variance for each five minute interval is the sum of the five 1-minute squared returns.

The popularity of RV in high-frequency studies stems from the fact that it provides a consistent estimator of the daily variation of returns when prices are measured continuously and without measurement error (see Barndorff-Nielsen and Shephard, 2002). However, empirical studies suggest that when prices are sampled at ultra-high intervals (for instance, tick-by-tick data) the presence of market microstructure dynamics can render RV to be a biased and

inconsistent estimator for quadratic variation (see Hansen and Lunde, 2006). Therefore, to lend robustness to our analysis we also estimate the Hansen and Lunde (2006) bias-corrected realized volatility measure and use these estimates in our regressions that examine the impact of macroeconomic news on volatility.[4] These results suggest that microstructure noise has negligible effects on realized volatility, and furthermore the conclusions regarding the impact of news on volatility generally remain unaffected when using the bias-corrected RV measure.[5] Therefore, for the remainder of the paper we provide results that pertain only to the standard RV measure.

*5.2. News impact on return, volatility and volume*

The response of returns, volatility and volume is reported in Table 4 in the form of statistical tests on the equality of means for returns, volatility and volume around the three pre-scheduled announcement times (8:30, 9:15, 10:00). We conduct these tests along two dimensions: (a) the difference between the calculated returns (and realized volatility and volume) over the five-minute interval immediately prior to each set of announcements and the five-minute interval immediately after each set of announcements, for both the control and study samples; and (b) the difference between the returns (and realized volatility and volume) over the five-minute control

[4] The correction incorporates the first-order auto-covariance terms proposed by Zhou (1996) as follows:
$RV_{t_i,AC1} = \sum_{j=1}^{n} R_j^2 + 2\sum_{j=1}^{n-1} R_j R_{j+1}$,
Furthermore, in order to ensure that the bias-corrected RV terms remain positive, Hansen and Lunde (2006) suggest that the RV estimator be adjusted as follows:

$$\mathrm{RV}_{t,ACqb} = \omega_0 \hat{\gamma}_0 + 2\sum_{j=1}^{q} \omega_j \hat{\gamma}_j,$$

$$\hat{\gamma}_j = \sum_{i=1}^{M-j} r_{t,i} r_{t,i+j},$$

in which the weights follow a Bartlett scheme $\omega_j = 1 - \frac{j}{q+1}, j = 0,1,\dots,q$ (also see Maheu and McCurdy, 2011) Based on an autocorrelation analysis our study considers a Bartlett adjustment of q=1.

[5] For the sake of brevity these results are not reported; however, they can be obtained from the authors upon request.

interval and the study interval, both immediately prior to each set of announcements and immediately after each set of announcements.

Panels A, B, and C of Table 4 report the results for gold, copper, and silver, respectively. The results in Panel A suggest that economic announcements do not have a significant effect on gold returns. For the 8:30 announcements, the change in returns before and after the announcement for the study sample is positive, with returns from 0.0107% to 0.0132%, although the difference is not statistically significant (with a t-statistic of 0.2124). Similarly, the difference in returns between the study sample and the control sample is not significant, either before or after the announcement. For the 9:15 announcements, returns after the announcement are greater than returns during the control sample, although the difference is again not significant for either the study or the control samples. Again, the difference in returns between the study sample and the control sample is also not significant, either before or after the announcement. Similar results are obtained for gold returns around the 10:00 announcement.

The results for realized volatility around the announcements contrast sharply with those for returns. For example, around the 8:30 announcement realized volatility for the study sample increases from 0.1070% to 0.1986%, with a t-statistic in excess of 13. This difference is statistically significant at the 1% level. Realized volatility also increases after the 9:15 and 10:00 announcements, with the increase again statistically significant at the 1% level, although the magnitude of the increase is about half that for the 8:30 announcements. Realized volatility after the announcement is also significantly greater than the control sample (at the 1% level) for each announcement, although the difference is again about half as large for the 9:15 and 10:00 announcements, relative to the 8:30 announcements. Our results, therefore, provide strong

evidence that macroeconomic news announcements have a positive and significant impact on realized volatility of the return on metal futures.

We plot the response of realized volatility around the three announcement times (8:30, 9:15, 10:00) for the study sample and the control sample in Figure 2. The time stamp on the horizontal axis indicates the end of the 5-minute interval, e.g., 8:35 covers the period 8:30 to 8:35, and so on. The figure clearly illustrates the tendency of volatility to spike around each of the announcement windows, 8:30, 9:15 and 10:00. Volatility tends to be high for the control sample near the market open for all three metals, but the volatility over the study sample appears to be substantively greater. Visual inspection of the 9:15 and 10:00 announcements indicates that volatility is also unusually high relative to the control sample, although the differences are not as pronounced as for the 8:30 announcements. Finally, there is evidence that the effect of announcements on volatility decays relatively quickly, within about 10 minutes. This may explain why previous studies that rely on daily data are unable to identify a significant relationship between commodity prices and economic announcements.

Finally, the results for volume, reported in the bottom of Panel A, are comparable to realized volatility around the 8:30 and 10:00 announcements. At the 8:30 and 10:00 announcements, volume surges over the study sample, although the magnitude of the increase is much larger for the 8:30 announcement. Interestingly, the change in volume around the 9:15 set of announcements is not found to be statistically significant.

Panels B and C of Table 6 presents the results for copper and silver. In the interest of brevity, the discussion on these two markets is restricted to just a couple of notable observations. First, the announcement effects documented for gold are also generally evident for copper and silver. In other words, announcements tend have a positive and significant impact on volatility and

volume. However, in contrast with gold, the 8:30 and 9:15 announcements have a statistically significant influence on copper returns and the 10:00 announcements have an impact on silver returns. Second, similar to the evidence for gold, the 8:30 set of announcements have the largest impact on volatility and volume for both copper and silver, followed by the 10:00 and 9:15 news releases.

*5.3. Marginal impact of news*

*5.3.1. Response of returns*

Having established the differential impact of aggregate news announcements on returns, volume and volatility between the study and control sample, we now investigate the marginal impact of each macroeconomic news release on returns. In the first step we fit a univariate regression model of the following form:

$$R_{t_{i+1}} = \beta_0 + \beta_j SA_{j,t_i} + \varepsilon_{t_{i+1}}, \quad (2)$$

where, $R_{t_{i+1}}$ is the five-minute return at time $t_{i+1}$, ($t_{i+1}$ could be 8:35, 9:20, or 10:05 on day *t*, whereas $t_i$ takes one of the values at 8:30, 9:15, or 10:00), $SA_{j,t_i}$ is the standardized surprise of the $j^{th}$ announcement at time $t_i$ on day *t*, and $\beta_o$ and $\beta_i$ are parameters to be estimated. The regression estimates correspond to days when there is at least one news announcement.

Table 5 reports estimated coefficients with corresponding t-statistics, p-values and adjusted R-squares obtained from the individual regression models. The results are discussed first for the 8:30 announcement, followed by the 9:15 and 10:00 announcements. We notice that several 8:30 announcements have a significant impact on gold, copper and silver prices. All three metal prices are sensitive to surprises in durable goods orders, but in different ways. In particular, durable goods order has a negative influence on gold and silver prices, but is positively associated with copper prices. In interpreting the coefficient values it is worth pointing out that the numbers

measure the response of the five-minute post-announcement return to a one standard deviation change in the surprise element of the news. For instance, the $\hat{\beta}_{SDGO} = -0.0644$ coefficient value for gold implies that a one standard deviation unexpected increase (decrease) in durable goods orders causes a decrease (increase) in the price of gold futures by about 0.06% in the five minutes after the announcement. In terms of adjusted R-square values, among the various 8:30 announcements, the nonfarm payroll indicator has the highest degree of explanatory power in the regressions for gold (35%) and silver (23%). The importance of payroll information has been documented in earlier studies such as Andersen and Bollerslev (1998) who refer to the Employment Situation or Jobs Report as the "king" of all announcements because of the significant sensitivity of most asset prices to its public release. We also observe advance retail sales to have a strong influence on gold and silver; whereas, trade balance figures prominently in explaining copper and silver returns. Interestingly, we find silver to be the most responsive to the 8:30 news releases with 4 out of 11 announcements having a significant impact on prices. Finally, housing starts surprises have a positive and significant influence only on copper returns.

An evaluation of the 9:15 announcements indicates that both capacity utilization and industrial production have a negative influence on gold returns. The estimated coefficients of the two announcements are respectively -0.027 (regression adjusted $R^2$ = 3.32%) and -0.0325 (regression adjusted $R^2$ = 5.56%) and are statistically significant at the 10% level or lower. In the case of copper, only industrial production has an influence on copper. Notably, the 9:15 announcements do not have an impact on silver returns.

Among the 10:00 announcements, business inventories have the highest degree of explanatory power for gold and silver returns with adjusted R-square values of 17.5% and 9.17%, respectively. Surprises in business inventories have a negative impact on both gold and

silver returns. In the case of copper, however, returns in this market are positively and significantly influenced by NAPM and new home sales announcements. Again, as in the 8:30 announcements, silver prices are the most sensitive to the 10:00 set of announcements.

The results in Table 5 provide meaningful insights into the nature of the relationship between economic announcements and returns. First, announcements that reflect an unexpected improvement in the economy tend to have a negative impact on gold and silver prices, but a positive effect on copper. For instance, a better than expected economic growth as conveyed by improvements in real activity (e.g., advance retail sales), consumption (e.g., new home sales) and investment (e.g., durable goods orders) has a negative effect on gold and silver prices. One possible explanation for this behavior is that an unexpected improvement in the economy may reduce investors' appetite for precious metals as they seek alternative investments such as stocks and bonds that appear to be relatively more attractive in this environment. On the other hand, copper returns are positively related with economic growth variables (e.g., durable goods orders, housing starts, NAPM). This may be attributed to the fact that copper is an important input good in manufacturing and production related industries (about 70% of the demand for copper comes from electrical and construction industries), and a more sanguine economic climate would be indicative of greater demand for this industrial metal.

In the next step of the empirical analysis we fit a multivariate regression model of the form:

$$R_{t_{i+1}} = c + \sum_{j=1}^{N} \beta_j SA_{j,t_i} + \varepsilon_{t_{i+1}}. \quad (3)$$

To estimate equation (3), we pool together all days with at least one 8:30 (9:15, 10:00) announcement together to form the 8:30 (9:15, 10:00) study sample. In addition to estimating the full model, we also estimate a stepwise regression model that identifies a restricted set of regressors in the joint model with the most influential factors. For the purpose of discussion, only

the stepwise results are reported in the paper.[6] Stepwise regressions allow some or all of the independent variables in a standard linear multivariate regression to be chosen automatically from a set of variables.[7] However, in order to ensure that the stepwise approach does not lead to model over-fitting and result in falsely eliminating influential variables with less significant relationships at the start of the stepwise selection procedure, we check for consistency of the stepwise coefficients both with the univariate model and the full joint regression model containing all economic variables in the system. We also allow for manual additions of selected factors from economic categories that are not represented in the stepwise approach.

The stepwise regression results, which are reported in Table 6, are largely consistent with the univariate regression results discussed earlier. Remarkably, variables that were identified to be influential in the univariate regressions are also found to be significant in the multivariate regressions. We find that the 8:30 set of announcements have the largest impact on gold and silver prices (adjusted R-square values of 23.11% and 14.93%, respectively); whereas, the 9:15 and 10:00 announcements are relatively more influential for copper (adjusted R-squares of 28.33% and 6.21%, respectively). Among the 8:30 announcements, nonfarm payrolls and durable goods orders seem to clearly dominate the price changes on all three metals.

[6] The joint regression model results can be obtained from the authors.

[7] Our stepwise regressions are performed by using the stepwise-forwards method. The stepwise-forwards begins with no additional regressions in the regression, then adds the variable with the lowest p-value. The variable with the next lowest p-value given that the first variable has already been chosen, is then added. Next both of the added variables are checked against the backwards p-value criterion. Any variable whose p-value is higher than the criterion is removed. Once the removal step has been performed, the next variable is added. At this, and each successive addition to the model, all the previously added variables are checked against the backwards criterion and possibly removed. The stepwise-forwards routine ends when the lowest p-value of the variables not yet included is greater than the specified forward stopping criteria. We choose both the forward and backward criteria to be 10%. While such methods are subject to pretest bias, we still view the results as informative in their tendency to highlight variables with the greatest explanatory power.

*5.3.2. Response of volatility and volume*

This section discusses results of the impact of macroeconomic news release on realized volatility and trading volume for the three metals. To examine volatility, we again fit joint regression models along with their stepwise forms for the realized volatility of each metal return series. For the sake of brevity only the reduced stepwise regression results are reported and discussed. In the case of trading volume we are able to estimate only the stepwise regression. This is because the joint regression models face a singularity problem due to a limited number of observations (volume data covers 2007 and 2008) and a relatively large number of regressors. The joint regression model has the following expression:

$$Y_{t_{i+1}} = \beta_0 + \sum_{j=1}^{N} \beta_j ABS(SA_{j,t_i}) + \sum_{s=0}^{3} \gamma_s \; Y_{t_{i-s}} + \varepsilon_{t_{i+1}} \quad (4)$$

where, $Y_{t_{i+1}}$ denotes the realized volatility or volume during the $i+1$ five-minute interval at day $t$ when there is at least one announcement, and $ABS(SA_{j,t_i})$ refers to the absolute value of the surprise of the $j^{th}$ announcement. To control for the persistence in volatility and volume, we include three lags of the left hand side variable as regressors.[8]

The estimated results of the stepwise regression models for the realized volatility are presented in Table 7. Several interesting observations emerge. First, among the 19 different types of announcements, unanticipated news in nonfarm payroll has the greatest impact on the volatility of all three markets. A one standard deviation absolute unexpected shock in nonfarm payroll results in a 0.14%, 0.08% and 0.20% size *increase* in the realized volatilities of gold, copper and silver returns, respectively. Recall that the means of the five-minute realized volatility during the 8:30-8:35 interval in the control samples are only 0.12%, 0.14% and 0.23%

[8] Notice that for returns we do not include the lagged dependent variables since returns do not exhibit persistence. For volume and volatility, however, we find the persistence parameter to be statistically significant in all our regressions. Since the focus of our discussion is on new impact variables these coefficient values are not reported; however, they may be obtained from the authors upon request.

for the gold, copper and silver futures returns. Viewed in this context, *increases* in volatility caused by nonfarm payrolls are about 116%, 57% and 87% of the magnitudes of the corresponding means in the three markets. Second, the announcements explain the largest fraction of variation in gold volatility, with adjusted R-square values about 35% for the 8:30 and 9:15 announcements, and 23% for the 10:00 announcements. Third, economic news announcements are generally associated with elevated levels of volatility, as thirteen of the seventeen reported coefficients are positive.

Using volume data for the two year period 2007 and 2008, the stepwise models identify that, in all instances, the reported announcements have a positive influence on trading volume (Table 8). We interpret these results are most consistent with the model of informed trading depicted by Kim and Verrecchia (1994), in which informed traders tend to have an advantage in processing new information after it is released, rather than in predicting new information. Once again, as in the volatility regression, the twin 8:30 announcements of nonfarm payroll and unemployment rate dominate the announcement shocks. For instance, a one standard deviation shock in nonfarm payroll results in the transaction volume of gold to increase by about 900 contracts in the five minutes following the announcement. Comparatively, the average trading volume during the entire 8:30-8:35 for all the days in the control sample is only about 959 contracts. Similarly, the volume in the silver contract increases by 218 contracts during this interval compared to an average volume of only about 326 contracts in the control sample. We should note, however, that none of the 9:15 announcements are significant in any of the volume regressions.

*5.4. Persistence of announcement shocks on returns, volatility and volume*

The regression results thus far provide evidence on the immediate post-announcement five-minute interval response of gold, silver and copper. In this section, we expand the announcement

window to investigate the persistence of announcement shocks on returns, volatility and volume. Specifically, we run a series of regressions at 5-minute intervals, spanning 10 minutes before the announcement and up to 40 minutes after the announcement, and obtain the adjusted R-square values. The R-square values from the regression are then plotted across time to interpret the persistence of announcement shocks. Figures 3, 4 and 5 report this evidence for returns, volatility and volume.

An overview of Figure 3 suggests that the impact of news announcements on returns dissipates very quickly. Notably, during the 8:30-8:35 minute interval, the highest adjusted R-square values are found for gold and silver. In contrast, copper exhibits a somewhat delayed response to the 8:30 announcement. For the 9:15 announcements, there is about a 30-minute delay before the realization of the highest adjusted R-square for gold and silver. This might explain why we were unable to substantiate a post-announcement effect on returns for these two metals. Copper prices, on the other hand, seem to incorporate the 9:15 announcements quite rapidly. For the 10:00 announcements, the highest adjusted R-squares for gold and copper regressions is realized during the immediate aftermath of the announcement, whereas there is about a 5-10 minute delay in the peak response of silver prices. In all cases, we observe that the metal prices are efficient in incorporating new economic information and the response tends to dissipate in less than an hour after the release of the announcement. Importantly, these results provide an interesting contrast to studies that use low frequency observations and document the sluggish price responsiveness of commodities.

Similar to Figure 3, the evidence from shocks to volatility and volume – Figures 4 and 5, respectively – also paints a picture where both market activity variables are responsive to announcements. However, compared to returns, there tends to be far more persistence in

volatility and volume shocks (particularly with 9:15 and 10:00 announcements) suggesting that these two variables are characterized by different properties. Again, in most cases, shocks seem to dissipate within 60 minutes after the news release.

*5.5. Asymmetric impact of news on returns, volatility and volume*

We have thus far investigated the differential effects, intensity and speed of macroeconomic shocks. The regression results implicate several announcements, chiefly nonfarm payroll and durable goods orders, as having a disproportionate influence in the metals market. The presence of asymmetric response, where the impacts of positive surprises and negative surprises cancel each other, may be one possible reason as to why some announcements are not found to be significant. In this section, we examine the differential or asymmetric response of returns, realized volatility, and volume to positive versus negative positive economic surprises by running a multivariate regression model of the following form:

$$Y_{t_{i+1}} = c + \sum_{j=1}^{N} \beta_j^{+} SA_{j,t_i}^{+} + \sum_{j=1}^{N} \beta_j^{-} SA_{j,t_i}^{-} + \sum_{s=0}^{3} \gamma_s Y_{t_{i-s}} + \varepsilon_{t_{i+1}}, \quad (5)$$

where, $Y_{t_{i+1}}$ denotes the return, realized volatility or volume during the $i+1$ five-minute interval at day $t$ when there is at least one announcement, and $SA_{j,t_i}^{+}$, and $SA_{j,t_i}^{-}$ refer to the positive and negative components of the surprise of the $j^{th}$ announcement. Based on our setup, there are two possible ways in which asymmetries can be observed: (1) both negative and positive surprises have significant impacts, but the magnitudes of their impacts are statistically different from each other, that is, $|\beta_j^{-}| \neq |\beta_j^{+}|$ (a Wald test is conducted to render judgment on the equality of the two coefficients); (2) only either negative or positive surprises are statistically significant, that is, $\beta_j^{-} = 0, \beta_j^{+} \neq 0$, or $\beta_j^{-} \neq 0, \beta_j^{+} = 0$, in which case this would automatically indicate the presence of an asymmetric response. We estimate the full regression model, but report only its stepwise counterpart in Tables 9 through 11.

The results in Table 9 for gold, copper and silver returns show that several news announcements are influential, and importantly have an asymmetric effect on returns. For gold futures, the Wald test indicates that NAPM has an asymmetric impact with $|\beta_{NAPM}^{-}| = 0.04 \neq |\beta_{NAPM}^{+}| = 0.29$; that is, positive surprises of NAPM have larger impacts than negative ones. There are several other announcements where only either positive or negative surprises are statistically significant, again suggesting the asymmetric nature of the returns response. The influential positive surprises (i.e., better than expected economic growth) include unemployment rate, advance retail sales, business inventories and factory orders. On the other hand, negative economic shocks in trade balance, personal consumption, durable goods orders, industrial production, and consumer confidence are significant.

For copper returns, we observe asymmetric responses to durable goods orders, personal consumption, PPI, housing starts, trade balance, new home sales, industrial production and capacity utilization. For the silver futures, we find asymmetric impacts from trade balance, advance retail sales, personal consumption and NAPM. Finally, both positive and negative nonfarm payroll surprises have a pronounced influence on gold and silver returns; and importantly this impact is not asymmetric.

The asymmetric impact of economic news on realized volatility is reported in Table 10. First, not surprisingly, in all three markets both positive and negative economic surprises exacerbate realized volatility. Second, the results generally supports the notion that "bad" news has a stronger impact than "good" news – i.e., negative economic surprises generally have a larger effect on volatility than positive surprises. The estimated results for gold demonstrate that negative surprises in nonfarm payroll, unemployment rate, trade balance, capacity utilization and consumer confidence increase realized volatility, while only one positive announcement –

nonfarm payrolls– significantly increases volatility. Also, note that the 8:30 announcements again dominate, with only one of the 9:15 announcements containing sufficient information to cause volatility to increase.

The estimated results for copper demonstrate that several announcements – nonfarm payrolls, personal income, personal consumption, PPI, housing starts and NAPM – have an asymmetric impact on realized volatility. In the case of silver, many announcements that were found to have an asymmetric impact on gold volatility also have an asymmetric effect on silver volatility. Furthermore, Wald test for the equality of trade balance coefficients suggest that the magnitude of negative surprises is about 3 times that of positive surprises ($\beta_{TB}^{+} = 0.0405$, $\beta_{TB}^{-} = -1.5636$).

The asymmetric impact on trading volume is presented in Table 11. In general, volume in all three metals is higher in the immediate aftermath of both positive and negative news announcements. Overall, the prominence of unemployment rate and nonfarm payroll surprises is substantiated.

**6. Concluding remarks**

The question of whether commodity prices are influenced by macroeconomic fundamentals or whether they are predetermined with respect to monetary aggregates is a topic that has yet to find consensus. Although there are strong economic reasons to expect commodity prices to be sensitive to macroeconomic fundamentals, prior empirical studies have not been very successful in documenting a strong relationship. We suggest that this might be due to several reasons including measurement of data at low (daily or monthly) frequencies and research methods that do not control for asymmetric impacts.

We undertake a comprehensive examination of the response of return, volatility and trading volume for gold, copper and silver to 19 different types of macroeconomic announcements. Notably, we rely on an improved analytical framework that uses high-frequency data for a sample period spanning 7 years from 2002 to 2008. The announcements are classified by time and direction (i.e., whether the news release signals better-than-expected-economic news or worse-than-expected news) in order to: (a) identify the most important set of announcements; (b) trace the persistence of macroeconomic shocks; and (c) allow for asymmetry in the relationships.

Our analysis reveals that news releases have a strong and instantaneous impact on all three metals. First, the 8:30 set of announcements appear to have the largest impact on prices, realized volatility and trading volume during the immediate post-announcement five minute interval. For instance, univariate regression models show that surprises in nonfarm payroll (released at 8:30 am) explain about 35% and 23% of the returns of gold and silver, respectively during the 8:30 to 8:35 time interval. Copper returns, on the hand, are more sensitive to the 9:15 set of announcements which include capacity utilization and industrial production. The evidence suggests that the behavior of commodity markets is quite similar to other asset markets in terms of their responsiveness to economic information. Our results for volume are most consistent with informed trading models where informed traders tend to have an advantage in processing, rather than predicting, new information.

Second, our results indicate that the metals market respond in an economically predictable manner. Unexpected improvement in economic growth has a negative impact on gold and silver prices, but registers a favorable effect on copper returns. For instance, improvements in real economic activity (e.g., advance retail sales), consumption (e.g., new home sales) and investment (e.g., durable goods orders) are found to negatively influence gold and silver prices. The

performance of copper, on the other hand, is consistent with its status as an important industrial metal that benefits primarily from unexpected growth in the economy.

Finally, our evidence indicates that the effect of macroeconomic news dissipates quickly, within about 60 minutes of the news release, and notably, and that several announcements have an asymmetric impact on market activity variables. These results provide an insightful contrast to previous studies that use daily data to examine the relationship between macroeconomic news and commodity prices.

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**Table 1**
Summary statistics of daily raw returns (percentages) for the period 2002-2008.

| | Gold Futures | Copper Futures | Silver Futures |
|---|---|---|---|
| Mean | 0.0653 | 0.0426 | 0.0511 |
| Median | 0.0897 | 0.0611 | 0.1857 |
| Standard Deviation | 1.2339 | 1.9992 | 2.1158 |
| Skewness | -0.2635 | -0.4042 | -1.0500 |
| Kurtosis | 6.9825 | 7.6518 | 10.3024 |
| Jarque-Bera | 1188.18 | 1635.69 | 4246.01 |
| Probability | 0.0000 | 0.0000 | 0.0000 |
| No. of observations | 1767 | 1761 | 1765 |

**Table 2**
List of U.S. macroeconomic news announcements: 2002-2008.

| Time | Announcements (Abbreviation) | Total | Std. Dev. of Surprise Components |
|---|---|---|---|
| 8:30 | Advance Retail Sales (ARS) | 84 | 0.1582 |
| 8:30 | Business Inventories[2] (BI) | 35 | 2.5123 |
| 8:30 | Change in Nonfarm Payrolls (CNP) | 84 | 108.2439 |
| 8:30 | Consumer Price Index (CPI) | 84 | 78.8039 |
| 8:30 | Durable Goods Orders (DGO) | 84 | 0.7946 |
| 8:30 | Housing Starts (HS) | 84 | 0.2892 |
| 8:30 | Personal Consumption[1] (PC) | 72 | 0.5486 |
| 8:30 | Personal Income (PI) | 84 | 0.5121 |
| 8:30 | Producer Price Index (PPI) | 84 | 55.9627 |
| 8:30 | Trade Balance Goods & Services (TB) | 84 | 0.1434 |
| 8:30 | Unemployment Rate (UR) | 84 | 0.2281 |
| 9:15 | Industrial Production (IP) | 84 | 0.3989 |
| 9:15 | Capacity Utilization (CU) | 84 | 0.3350 |
| 10:00 | Business Inventories[2] (BI) | 49 | 14.3884 |
| 10:00 | Construction Spending (CS) | 84 | 0.5556 |
| 10:00 | Consumer Confidence (CC) | 84 | 0.6866 |
| 10:00 | Factory Orders (FO) | 84 | 8.0338 |
| 10:00 | Leading Indicators (LI) | 84 | 0.1787 |
| 10:00 | NAPM | 84 | 77.2018 |
| 10:00 | New Home Sales (NHS) | 84 | 0.2281 |
| | Total | 1,584 | |

This table lists the 19 different types of macroeconomic announcements along with the standard deviation of the surprise component. The surprise component is measured by: Surprise = Actual – Forecast. (For personal consumption, we only have data from 2003. For business inventories, some of the announcements were at 8:30 and others at 10. )

**Table 3**
Analysis sample.

| Market | Study Sample | | | Control Sample | | |
|---|---|---|---|---|---|---|
| | 8:30 | 9:15 | 10:00 | 8:30 | 9:15 | 10:00 |
| Gold | 609 (169) | 83 (21) | 428 (135) | 751 (197) | 751 (197) | 751 (197) |
| Copper | 475 (101) | 63 (10) | 335 (86) | 605 (139) | 605 (139) | 605 (139) |
| Silver | 630 (177) | 85 (22) | 437 (137) | 772 (220) | 772 (220) | 772 (220) |

This table reports the total number of observations in the study sample and control sample for the 8:30, 9:15, and 10:00 announcements. The numbers in parenthesis are the number of days in the trading volume sample. We have volume data only for 2007 and 2008.

**Table 4**
Test of equality in mean return, realized volatility and volume around announcements.

*Panel A:* Tests of equality in means of returns, realized volatility and volume around macroeconomic announcements for gold futures.

| Gold Futures | Sample | 8:30 Announcement | | Test of Equality in Means | 9:15 Announcement | | Test of Equality in Means | 10:00 Announcement | | Test of Equality in Means |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 8:25-8:30 | 8:30-8:35 | Welch's t-test | 9:10-9:15 | 9:15-9:20 | Welch's t-test | 9:55-10:00 | 10:00-10:05 | Welch's t-test |
| Returns | Control | 0.0096 | 0.0028 | -0.9258 | 0.0001 | 0.0024 | 0.3924 | -0.0108 | -0.0228 | -1.8972[c] |
| | Study | 0.0107 | 0.0132 | 0.2124 | -0.0244 | 0.0026 | 1.3242 | -0.0096 | -0.0235 | -1.5006 |
| | Difference | 0.0011 | | 0.1568 | -0.0245 | | -1.5699 | 0.0012 | | 0.1706 |
| | Difference | | 0.0104 | 0.8743 | | 0.0002 | 0.0181 | | -0.0007 | -0.0782 |
| Realized Volatility | Control | 0.1107 | 0.1156 | 1.1692 | 0.0919 | 0.0970 | 1.5205 | 0.0943 | 0.1051 | 3.1516[a] |
| | Study | 0.1070 | 0.1986 | 13.1942[a] | 0.0974 | 0.1301 | 2.9071[a] | 0.0995 | 0.1356 | 7.0058[a] |
| | Difference | -0.0037 | | -0.8739 | 0.0055 | | 0.7344 | 0.0052 | | 1.2822 |
| | Difference | | 0.083 | 12.0259[a] | | 0.0331 | 3.6890[a] | | 0.0305 | 6.5528[a] |
| Volume | Control | 1054.70 | 959.35 | -1.0237 | 843.61 | 835.23 | -0.1204 | 983.62 | 1135.05 | 1.5731 |
| | Study | 843.25 | 1713.41 | 7.5141[a] | 1134.67 | 1149.91 | 0.0408 | 1015.24 | 1384.46 | 3.2180[a] |
| | Difference | -211.45 | | -2.3911[b] | 291.06 | | 0.9967 | 31.62 | | 0.3342 |
| | Difference | | 754.06 | 6.3135[a] | | 314.68 | 1.2943 | | 249.41 | 2.1719[b] |

This table reports tests of equality in means of returns, realized volatilities, and volume around the announcements intervals at 8:30, 9:15 and 10:00 for gold, copper and silver. The returns, realized volatilities, and volumes are calculated over five minute intervals before and after the announcement time points. Tests for equality in means between the returns, realized volatilities and volumes before and after the announcements are reported for both the control sample and the study sample. We also report tests of equality between the control and study samples, both prior to and after the announcement. The Welch's t-test, sometimes called "Satterthwaite-Welch t-test", allows for unequal cell variances in samples. In our case, the p-values of the Welch's t-test are only slightly higher than the standard t-test. The returns and volatilities are expressed in percentages (i.e., multiplied by 100).

*Panel B:* Tests of equality in means of returns, realized volatility and volume around macroeconomic announcements for copper futures.

| Copper Futures | Sample | 8:30 Announcement | | Test of Equality in Means | 9:15 Announcement | | Test of Equality in Means | 10:00 Announcement | | Test of Equality in Means |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 8:25-8:30 | 8:30-8:35 | Welch's t-test | 9:10-9:15 | 9:15-9:20 | Welch's t-test | 10:00-10:05 | 10:00-10:05 | Welch's t-test |
| Returns | Control | -0.0033 | -0.0061 | -0.2680 | 0.0058 | -0.0084 | -1.7108[b] | 0.0020 | -0.0100 | -1.4081 |
| | Study | -0.0126 | 0.0101 | 1.7279[c] | 0.0243 | -0.0394 | -2.5287[b] | -0.0102 | -0.0022 | 0.5448 |
| | Difference | -0.0093 | | -0.8581 | 0.0185 | | 1.0417 | -0.0122 | | -1.0472 |
| | Difference | | 0.0162 | 1.2627 | | -0.031 | -1.5679 | | 0.0078 | 0.6372 |
| Realized Volatility | Control | 0.1380 | 0.1407 | 0.4435 | 0.1096 | 0.1065 | -0.5579 | 0.1026 | 0.1137 | 1.8867 |
| | Study | 0.1429 | 0.1893 | 6.5357[a] | 0.0957 | 0.1206 | 1.5389 | 0.1054 | 0.1380 | 3.9413[a] |
| | Difference | 0.0049 | | 0.8211 | -0.0139 | | -1.3359 | 0.0028 | | 0.3817 |
| | Difference | | 0.0486 | 6.7665[a] | | 0.0141 | 1.0390 | | 0.0243 | 3.5036[a] |
| Volume | Control | 114.04 | 124.01 | 0.7042 | 92.97 | 95.04 | 0.2095 | 87.40 | 98.23 | 1.2372 |
| | Study | 88.70 | 129.99 | 3.0905[a] | 83.50 | 92.10 | 0.3947 | 90.22 | 114.93 | 1.7539[c] |
| | Difference | -25.34 | | -2.1245[b] | -9.47 | | -0.5521 | 2.82 | | 0.3089 |
| | Difference | | 5.98 | 0.3881 | | -2.94 | -0.1762 | | 16.70 | 1.2057 |

*Panel C:* Test of equality in means of return, realized volatility and volume around macroeconomic announcements for silver futures.

| Silver Futures | Sample | Means Around 8:30 | | Test of Equality in Means | Means Around 9:15 | | Test of Equality in Means | Means Around 10:00 | | Test of Equality in Means |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 8:25-8:30 | 8:30-8:35 | Welch's t-test | 9:10-9:15 | 9:15-9:20 | Welch's t-test | 10:00-10:05 | 10:00-10:05 | Welch's t-test |
| Return | Control | 0.0052 | 0.0081 | 0.1564 | -0.0070 | -0.0074 | -0.0471 | -0.0222 | -0.0079 | 1.3387 |
| | Study | 0.0137 | 0.0274 | 0.6139 | 0.0106 | -0.0028 | -0.3455 | -0.0020 | -0.0514 | -2.6693[a] |
| | Difference | 0.0085 | | 0.3805 | 0.0176 | | 0.6565 | 0.0202 | | 1.4420 |
| | Difference | | 0.0193 | 1.0210 | | 0.0046 | 0.1601 | | -0.0435 | -2.6951[a] |
| Realized Volatility | Control | 0.3153 | 0.2302 | -7.4237[a] | 0.1727 | 0.1724 | -0.0491 | 0.1673 | 0.1708 | 0.5662 |
| | Study | 0.3115 | 0.3355 | 1.7080 | 0.1702 | 0.2108 | 2.0718[b] | 0.1740 | 0.2138 | 3.3465[a] |
| | Difference | -0.0038 | | -0.2826 | -0.0025 | | -0.1963 | 0.0067 | | 0.8521 |
| | Difference | | 0.1053 | 8.7503[a] | | 0.0384 | 2.3564[b] | | 0.043 | 3.9404[a] |
| Volume | Control | 463.07 | 325.86 | -4.3813[a] | 234.40 | 236.08 | 0.0982 | 266.13 | 287.19 | 0.9199 |
| | Study | 426.57 | 486.19 | 1.9143 | 232.59 | 334.00 | 1.4990 | 284.61 | 346.09 | 1.7686[b] |
| | Difference | -36.50 | | -1.2280 | -1.81 | | -0.0434 | 18.48 | | 0.6261 |
| | Difference | | 160.33 | 4.9078[a] | | 97.92 | 1.7466[c] | | 58.9 | 2.0068[c] |

Notes: Superscripts "a", "b" and "c" indicate significance at the 1%, 5%, and 10% levels, respectively.

**Table 5**
Impact of macroeconomic news releases on returns: Results from univariate regressions.

| Time | Macroeconomic Announcements | Returns of Gold Futures $R_{+5}$ | | | Returns of Copper Futures $R_{+5}$ | | | Returns of Silver Futures $R_{+5}$ | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $\hat{\beta}_j$ | T-Stat | $R^2$ | $\hat{\beta}_j$ | T-Stat | $R^2$ | $\hat{\beta}_j$ | T-Stat | $R^2$ |
| 8:30 | Advance Retail Sales | -0.0783 | -3.6631[a] | 0.1373 | 0.0085 | 0.3247 | -0.0159 | -0.0995 | -2.8318[a] | 0.0807 |
| | Business Inventories | 0.0172 | 0.6730[a] | -0.0255 | -0.0114 | -0.3767 | -0.0406 | -0.0404 | -1.1167 | 0.0106 |
| | Change in Nonfarm Payrolls | -0.3050 | -6.4746[a] | 0.3470 | 0.0541 | 1.5689 | 0.0264 | -0.3866 | -4.8668[a] | 0.2253 |
| | Consumer Price Index | 0.0180 | 0.8470 | -0.0038 | -0.0068 | -0.1939 | -0.0175 | 0.0572 | 1.6972[c] | 0.0241 |
| | Durable Goods Orders | -0.0644 | -3.7821[a] | 0.1457 | 0.0994 | 3.4176[a] | 0.1357 | -0.0733 | -2.1565[b] | 0.0436 |
| | Housing Starts | -0.0068 | -0.3497 | -0.0115 | 0.0611 | 3.0840[a] | 0.1224 | -0.0383 | -1.0705 | 0.0018 |
| | Personal Consumption | -0.0066 | -0.2504 | -0.0144 | -0.0082 | -0.2862 | -0.0176 | -0.0004 | -0.0108 | -0.0145 |
| | Personal Income | -0.0155 | -0.8724 | -0.0032 | -0.0052 | -0.2536 | -0.0158 | -0.0175 | -0.4934 | -0.0095 |
| | Producer Price Index | 0.0056 | 0.2505 | -0.0122 | -0.0285 | -1.0397 | 0.0014 | 0.0453 | 1.1285 | 0.0034 |
| | Trade Balance | 0.0199 | 0.8081 | -0.0045 | 0.0512 | 2.3873[b] | 0.0762 | 0.0931 | 2.6151[b] | 0.0688 |
| | Unemployment Rate | -0.0709 | -1.1981 | 0.0056 | 0.0141 | 0.3919 | 0.0159 | -0.1066 | -1.2183 | 0.0062 |
| 9:15 | Capacity Utilization | -0.0270 | -1.8361[c] | 0.0332 | -0.0417 | -1.6492 | 0.0339 | -0.0400 | -1.2852 | 0.0091 |
| | Industrial Production | -0.0325 | -2.3279[b] | 0.0556 | 0.0697 | 2.8294[a] | 0.1130 | -0.0371 | -1.2511 | 0.0072 |
| 10:00 | Business Inventories | -0.0979 | -2.8246[a] | 0.1745 | -0.0151 | -0.2279 | -0.0473 | -0.0987 | -2.0567[b] | 0.0917 |
| | Consumer Confidence | 0.0259 | 1.4932 | 0.0151 | 0.0131 | 0.5579 | -0.0102 | 0.0126 | 0.5265 | -0.0089 |
| | Construction Spending | 0.0042 | 0.1877 | -0.0169 | 0.0141 | 0.6235 | -0.0155 | -0.0815 | -2.1840[b] | 0.0582 |
| | Factory Orders | -0.0194 | -1.6111 | 0.0203 | 0.0255 | 1.2684 | 0.0108 | -0.0248 | -1.1872 | 0.0052 |
| | Leading Indictors | 0.0102 | 0.5851 | -0.0085 | 0.0002 | 0.0114 | -0.0152 | 0.0175 | 0.3310 | -0.0113 |
| | NAPM | 0.0283 | 1.6586 | 0.0225 | 0.3333 | 3.5752[a] | 0.1764 | 0.0475 | 1.5699 | 0.0184 |
| | New Home Sales | -0.0323 | -1.5689 | 0.0184 | 0.0895 | 2.9232[a] | 0.1055 | -0.0667 | -1.9490[c] | 0.0334 |

This table presents the results from the univariate regressions of the form: $R_{t_{i+1}} = \beta_0 + \beta_j SA_{j,t_i} + \varepsilon_{t_{i+1}}$, where $R_{t_{i+1}}$ is the five-minute post-announcement return.

**Table 6**
Stepwise models of impact of macroeconomic news on returns.

| | Gold $R_{+5}$ | | | Copper $R_{+5}$ | | | Silver $R_{+5}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Optimal Regressors | $\hat{\beta}_j$ | T-Stat | Optimal Regressors | $\hat{\beta}_j$ | T-Stat | Optimal Regressors | $\hat{\beta}_j$ | T-Stat |
| 8:30 | Intercept | 0.0028 | 0.3063 | Intercept | 0.0104 | 1.0313 | Intercept | 0.0131 | 0.8837 |
| | CNP | -0.3087 | -12.819[a] | DGO | 0.0994 | 3.4775[a] | CNP | -0.4035 | -9.8125[a] |
| | UR | -0.1237 | -4.9134[a] | HS | 0.0622 | 2.2294[b] | UR | -0.1611 | -3.9189[a] |
| | ARS | -0.0782 | -3.1249[a] | CNP | 0.0528 | 1.9995[b] | ARS | -0.0989 | -2.3838[b] |
| | DGO | -0.0641 | -2.4553[b] | TB | 0.0426 | 1.7804[c] | TB | 0.0939 | 2.3324[b] |
| | | | | | | | DGO | -0.0715 | -1.7174[c] |
| | Adjusted $R^2$ | 0.2311 | | Adjusted $R^2$ | 0.0412 | | Adjusted $R^2$ | 0.1493 | |
| | F-Statistics | 46.6755[a] | | F-Statistics | 6.0734[a] | | F-Statistics | 23.0766[a] | |
| 9:15 | Intercept | -0.0012 | -0.0866 | Intercept | -0.0454 | -2.743[a] | Intercept | -0.0028 | -0.0976 |
| | IP | -0.0325 | -2.4164[b] | IP | 0.1249 | 4.8263[a] | | | |
| | | | | CU | -0.1140 | -4.069[a] | | | |
| | Adjusted $R^2$ | 0.0557 | | Adjusted $R^2$ | 0.2833 | | Adjusted $R^2$ | 0.0000 | |
| | F-Statistics | 5.8390[a] | | F-Statistics | 13.2520[a] | | F-Statistics | | |
| 10:00 | Intercept | -0.0219 | -2.9451[a] | Intercept | -0.0053 | -0.5134 | Intercept | -0.0493 | -3.4352[a] |
| | BI | -0.0981 | -3.3681[a] | NHS | 0.0950 | 3.9673[a] | CS | -0.0826 | -2.1631[b] |
| | NAPM | 0.0303 | 1.8045[c] | NAPM | 0.3341 | 2.8937[a] | NHS | -0.0642 | -1.8307[c] |
| | NHS | -0.0316 | -1.7402[c] | | | | BI | -0.1011 | -1.6629[c] |
| | Adjusted $R^2$ | 0.0331 | | Adjusted $R^2$ | 0.0621 | | Adjusted $R^2$ | 0.0175 | |
| | F-Statistics | 5.8674[a] | | F-Statistics | 12.0512[a] | | F-Statistics | 3.5945[b] | |

This table reports the estimated stepwise regression models for returns of the three metals. The stepwise regressions pick up only the announcements which have an impact on the returns at the 10% significance level. The stepwise regression models have the form: $R_{t_{i+1}} = c + \sum_{j=1}^{N} \beta_j SA_{j,t_i} + \varepsilon_{t_{i+1}}$. , where $R_{t_{i+1}}$ is the five-minute post-announcement return, $SA_{j,t_i}$ is the standardized surprise of the $j^{th}$ announcement at time $t_i$ on day $t$. Superscripts "a", "b" and "c" indicate significance at the 1%, 5%, and 10% levels, respectively. Refer to Table 2 for abbreviations for the various macroeconomic announcements.

**Table 7**
Stepwise model of impact of macroeconomic news on realized volatility.

| | Gold $RV_{+5}$ | | | Copper $RV_{+5}$ | | | Silver $RV_{+5}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Optimal Regressors | $\hat{\beta}_j$ | T-Stat | Optimal Regressors | $\hat{\beta}_j$ | T-Stat | Optimal Regressors | $\hat{\beta}_j$ | T-Stat |
| 8:30 | Intercept | 0.0952 | 9.9618[a] | Intercept | 0.0852 | 7.4360[a] | Intercept | 0.1949 | 13.6505[a] |
| | ABS_CNP | 0.1442 | 9.5281[a] | ABS_CNP | 0.0767 | 5.7166[a] | ABS_CNP | 0.1995 | 7.2280[a] |
| | ABS_UR | 0.0800 | 5.0778[a] | ABS_PI | -0.0358 | -2.7338[a] | ABS_UR | 0.1061 | 3.8416[a] |
| | ABS_BI | -0.0518 | -2.0028[b] | | | | ABS_TB | 0.0420 | 1.7645[c] |
| | ABS_ARS | 0.0241 | 1.6755[c] | | | | | | |
| | Adjusted $R^2$ | 0.3576 | | Adjusted $R^2$ | 0.2345 | | Adjusted $R^2$ | 0.2631 | |
| | F-Statistics | 55.8418[a] | | F-Statistics | 23.845[a] | | F-Statistics | 55.7665[a] | |
| 9:15 | Intercept | 0.0407 | 2.2928[b] | Intercept | 0.0789 | 3.0725[a] | Intercept | 0.0912 | 3.0409[a] |
| | ABS_CU | 0.0364 | 3.2618[a] | ABS_CU | -0.0638 | -2.1556[b] | | | |
| | | | | ABS_IP | 0.0504 | 1.8018[c] | | | |
| | Adjusted $R^2$ | 0.3483 | | Adjusted $R^2$ | 0.2184 | | Adjusted $R^2$ | 0.2990 | |
| | F-Statistics | 8.2315[a] | | F-Statistics | 2.6084[b] | | F-Statistics | 8.5312[a] | |
| 10:00 | Intercept | 0.0729 | 9.8303[a] | Intercept | 0.0663 | 7.7184[a] | Intercept | 0.0624 | 3.5262[a] |
| | ABS_CC | 0.0377 | 4.7421[a] | ABS_NAPM | 0.1325 | 2.2288[b] | | | |
| | ABS_NAPM | 0.0236 | 2.9555[a] | ABS_CS | -0.0339 | -2.1008[b] | | | |
| | ABS_BI | 0.0269 | 1.8931[c] | | | | | | |
| | Adjusted $R^2$ | 0.2343 | | Adjusted $R^2$ | 0.2702 | | Adjusted $R^2$ | 0.1937 | |
| | F-Statistics | 18.3579[a] | | F-Statistics | 20.2395[a] | | F-Statistics | 25.9522[a] | |

This table reports the estimated stepwise regression models for the realized volatility (RV) five minutes after each announcement. The stepwise regressions pick up only the announcements which have impacts on the five-minute realized volatility at the 10% significance level. The stepwise regression models have the form: $RV_{t_{i+1}} = \beta_0 + \sum_{j=1}^{N} \beta_j ABS(SA_{j,t_i}) + \sum_{s=0}^{3} \gamma_s \ RV_{t_{i-s}} + \varepsilon_{t_{i+1}}$. $RV_{t_{i+1}}$ is the post-announcement five-minute realized volatility, $ABS(SA_{j,t_i})$ is the absolute value of the surprise of the $j^{th}$ announcement, and $\gamma$ is the volume persistence parameter that accounts for dependent variable lags (not reported). Superscripts "a", "b" and "c" indicate significance at the 1%, 5% and 10% levels, respectively. Refer to Table 2 for abbreviations for the various macroeconomic announcements.

**Table 8**
Stepwise model of impact of macroeconomic news on trading volume (2007-2008).

| | Gold $V_{+5}$ | | | Copper $V_{+5}$ | | | Silver $V_{+5}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Optimal Regressors | $\hat{\beta}_j$ | T-Stat | Optimal Regressors | $\hat{\beta}_j$ | T-Stat | Optimal Regressors | $\hat{\beta}_j$ | T-Stat |
| 8:30 | Intercept | 818.79 | 6.4871[a] | Intercept | 30.33 | 2.4878[b] | Intercept | 256.17 | 6.3106[a] |
| | ABS_UR | 822.61 | 3.7171[a] | ABS_UR | 87.43 | 3.7744[a] | ABS_UR | 235.51 | 3.8686[a] |
| | ABS_CNP | 902.08 | 2.9492[a] | ABS_ARS | 86.40 | 2.9954[a] | ABS_CNP | 217.68 | 1.9704[c] |
| | | | | | | | ABS_ARS | 132.12 | 1.9095[c] |
| | Adjusted $R^2$ | 0.3525 | | Adjusted $R^2$ | 0.5586 | | Adjusted $R^2$ | 0.2659 | |
| | F-Statistics | 23.2685[a] | | F-Statistics | 19.8271[a] | | F-Statistics | 15.5715[a] | |
| 9:15 | Intercept | 174.19 | 0.8291 | Intercept | 79.86 | 1.6478 | Intercept | 62.17 | 1.2393 |
| | Adjusted $R^2$ | 0.7826 | | Adjusted $R^2$ | 0.6460 | | Adjusted $R^2$ | 0.8325 | |
| | F-Statistics | 15.2966[a] | | F-Statistics | 2.2809 | | F-Statistics | 21.1300[a] | |
| 10:00 | Intercept | 415.08 | 2.9698[a] | Intercept | 4.63 | 0.2490 | Intercept | 85.53 | 2.1109[b] |
| | ABS_NAPM | 308.16 | 2.1120[b] | ABS_CC | 230.24 | 3.8882[a] | ABS_BI | 130.43 | 1.9295[c] |
| | Adjusted $R^2$ | 0.3567 | | Adjusted $R^2$ | 0.4290 | | Adjusted $R^2$ | 0.3188 | |
| | F-Statistics | 14.7500[a] | | F-Statistics | 12.0211[a] | | F-Statistics | 12.2604[a] | |

This table reports the estimated stepwise regression models for trading volume five minutes after each announcement. The stepwise regressions pick up only the announcements which have impact on the five-minute volume at the 10% significance level. The stepwise regression models have the form: $V_{t_{i+1}} = \beta_0 + \sum_{j=1}^{N} \beta_j ABS(SA_{j,t_i}) + \sum_{s=0}^{3} \gamma_s \, V_{t_{i-s}} + \varepsilon_{t_{i+1}}$. $V_{t_{i+1}}$ is the five-minute post-announcement volume, $ABS(SA_{j,t_i})$ is the absolute value of the surprise of the $j^{th}$ announcement, and $\gamma$ is the volume persistence parameter that accounts for dependent variable lags (not reported). Superscripts "a", "b" and "c" indicate significance at the 1%, 5% and 10% levels, respectively. Refer to Table 2 for abbreviations for the various macroeconomic announcements.

**Table 9**
Asymmetric impact of macroeconomic news on returns.

*Panel A:* Model estimation results.

| | Gold $R_{+5}$ | | | Copper $R_{+5}$ | | | Silver $R_{+5}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Optimal Regressors | $\hat{\beta}_j^+(\hat{\beta}_j^-)$ | T-stats | Optimal Regressors | $\hat{\beta}_j^+(\hat{\beta}_j^-)$ | T-stats | Optimal Regressors | $\hat{\beta}_j^+(\hat{\beta}_j^-)$ | T-stats |
| 8:30 | Intercept | -0.0028 | -0.2762 | Intercept | 0.0200 | 1.7575[c] | Intercept | 0.0010 | 0.0592 |
| | P_CNP | -0.2849 | -5.9318[a] | P_DGO | 0.0668 | 1.6906[c] | P_CNP | -0.3773 | -4.5888 |
| | N_CNP | -0.3285 | -11.017[a] | N_DGO | 0.1379 | 3.2042[a] | N_CNP | -0.4115 | -7.8327 |
| | P_UR | -0.1727 | -4.8659[a] | N_PC | -0.2664 | -2.7227[a] | P_UR | -0.1322 | -2.2098 |
| | N_TB | -2.5442 | -4.1276[a] | N_CNP | 0.0698 | 2.2564[b] | N_UR | -0.2023 | -3.1038 |
| | N_PC | -0.2919 | -3.0733[a] | P_PPI | -0.0790 | -1.8519[c] | P_TB | 0.1003 | 2.5038 |
| | P_ARS | -0.0902 | -2.7570[a] | N_HS | 0.0755 | 1.7495[c] | N_TB | -3.1764 | -3.0343 |
| | N_DGO | -0.0721 | -2.0741[b] | P_TB | 0.0409 | 1.7227[c] | P_ARS | -0.1232 | -2.1966 |
| | | | | | | | N_PC | -0.3052 | -1.9769 |
| | Adjusted $R^2$ | 0.2575 | | Adjusted $R^2$ | 0.0574 | | Adjusted $R^2$ | 0.1600 | |
| | F-Statistics | 31.1178[a] | | F-Statistics | 5.1229[a] | | F-Statistics | 15.9774[a] | |
| 9:15 | Intercept | -0.0156 | -1.0234 | Intercept | -0.0137 | -0.4654 | Intercept | -0.0028 | -0.0976 |
| | N_IP | -0.0452 | -2.4610[b] | P_IP | 0.0784 | 2.0098[b] | | | |
| | | | | N_IP | 0.1844 | 4.0836[a] | | | |
| | | | | P_CU | -0.1329 | -2.2391[b] | | | |
| | | | | N_CU | -0.1181 | -2.9596[a] | | | |
| | Adjusted $R^2$ | 0.0581 | | Adjusted $R^2$ | 0.2914 | | Adjusted $R^2$ | 0.0000 | |
| | F-Statistics | 6.0563[a] | | F-Statistics | 7.3740[a] | | F-Statistics | | |
| 10:00 | Intercept | -0.0079 | -0.9897 | Intercept | -0.0206 | -1.9049[c] | Intercept | -0.0487 | -3.3564[a] |
| | P_BI | -0.1184 | -3.1044[a] | P_NHS | 0.1471 | 4.7293[a] | N_NAPM | 0.0602 | 1.7907[c] |
| | P_NAPM | -0.2854 | -3.0905[a] | P_NAPM | 0.4060 | 2.6445[a] | | | |
| | N_NAPM | 0.0435 | 2.5631[b] | | | | | | |
| | P_FO | -0.0509 | -2.0509[b] | | | | | | |
| | N_CC | 0.0299 | 1.7586[c] | | | | | | |
| | Adjusted $R^2$ | 0.0547 | | Adjusted $R^2$ | 0.0724 | | Adjusted $R^2$ | 0.0050 | |
| | F-Statistics | 5.9385[a] | | F-Statistics | 14.0280[a] | | F-Statistics | 3.2067[c] | |

*Panel B:* Wald test of equality of coefficients.

| Null Hypothesis | Chi-square | P-Value | Chi-square | P-Value | Chi-square | P-Value |
|---|---|---|---|---|---|---|
| $\lvert\beta_{CNP}^+\rvert = \lvert\beta_{SCNP}^-\rvert$ | 0.5352 | 0.4644 | | | 0.1091 | 0.7412 |
| $\lvert\beta_{DGO}^+\rvert = \lvert\beta_{SDGO}^-\rvert$ | | | 1.4107 | 0.2349 | | |
| $\lvert\beta_{TB}^+\rvert = \lvert\beta_{TB}^-\rvert$ | | | | | 8.6300 | 0.0033 |
| $\lvert\beta_{UR}^+\rvert = \lvert\beta_{UR}^-\rvert$ | | | | | 0.5601 | 0.4542 |
| $\lvert\beta_{CU}^+\rvert = \lvert\beta_{CU}^-\rvert$ | | | 0.0341 | 0.8536 | | |
| $\lvert\beta_{IP}^+\rvert = \lvert\beta_{IP}^-\rvert$ | | | 2.5483 | 0.1104 | | |
| $\lvert\beta_{NAPM}^+\rvert = \lvert\beta_{NAPM}^-\rvert$ | 6.6986 | 0.0096 | | | | |

This table reports the estimated stepwise regression models for the returns five minutes after each announcement. The stepwise regressions pick up only the announcements which have an impact on the five-minute returns at the 10% significance level. The stepwise regression models have the form: $R_{t_{i+1}} = c + \sum_{j=1}^{N} \beta_j^+ SA_{j,t_i}^+ + \sum_{j=1}^{N} \beta_j^- SA_{j,t_i}^- + \varepsilon_{t_{i+1}}$. $R_{t_{i+1}}$ is the post-announcement five-minute return, $SA_{j,t_i}^+$ and $SA_{j,t_i}^-$ are the positive (P) and negative (N) components of the surprise of the $j^{th}$ announcement. Panel A presents the model estimation results and panel B tests the equality of the parameters of the negative and positive surprises if both of their impacts are significant at the 10% significance level (picked up by the stepwise regression). Superscripts "a", "b" and "c" indicate significance at the 1%, 5% and 10% levels, respectively. Refer to Table 2 for abbreviations for the various macroeconomic announcements.

**Table 10**

Asymmetric impact of macroeconomic news on realized volatility.

*Panel A:* Model estimation results.

| | Gold $RV_{+5}$ | | | Copper $RV_{+5}$ | | | Silver $RV_{+5}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Optimal Regressors | $\hat{\beta}_j^+(\hat{\beta}_j^-)$ | T-stats | Optimal Regressors | $\hat{\beta}_j^+(\hat{\beta}_j^-)$ | T-stats | Optimal Regressors | $\hat{\beta}_j^+(\hat{\beta}_j^-)$ | T-stats |
| 8:30 | Intercept | 0.0930 | 9.8742[a] | Intercept | 0.0842 | 7.3466[a] | Intercept | 0.1912 | 13.544[a] |
| | N_CNP | -0.1388 | -8.3500[a] | N_CNP | -0.0855 | -5.6067[a] | N_CNP | -0.2138 | -7.5570[a] |
| | P_CNP | 0.1988 | 7.2547[a] | N_PI | 0.0886 | 2.7214[a] | P_CNP | 0.2622 | 5.6257[a] |
| | N_UR | -0.1253 | -5.6442[a] | P_CNP | 0.0608 | 2.3458[b] | N_UR | -0.2000 | -5.2859[a] |
| | N_TB | -0.9083 | -2.6720[a] | P_PPI | 0.0466 | 2.2201[b] | N_TB | -1.5636 | -2.5583[b] |
| | N_UR | 0.0410 | 2.0719[b] | N_PC | -0.0952 | -1.9676[b] | P_TB | 0.0405 | 1.7241[c] |
| | | | | P_PI | -0.0240 | -1.7097[c] | | | |
| | Adjusted $R^2$ | 0.3726 | | Adjusted $R^2$ | 0.0963 | | Adjusted $R^2$ | 0.2868 | |
| | F-Statistics | 59.9809[a] | | F-Statistics | 8.2984[a] | | F-Statistics | 41.7464[a] | |
| 9:15 | Intercept | 0.0523 | 3.0436[a] | Intercept | 0.0678 | 2.8965[a] | Intercept | 0.0912 | 3.0409[a] |
| | N_CU | -0.0424 | -3.9270[a] | | | | | | |
| | Adjusted $R^2$ | 0.3820 | | Adjusted $R^2$ | 0.1160 | | Adjusted $R^2$ | 0.2990 | |
| | F-Statistics | 9.5211[a] | | F-Statistics | 1.9024 | | F-Statistics | 8.5312[a] | |
| 10:00 | Intercept | 0.0726 | 9.7450[a] | Intercept | 0.0617 | 7.1818[a] | Intercept | 0.0624 | 3.5262[a] |
| | N_CC | -0.0366 | -4.5107[a] | P_NHS | 0.0313 | 2.1258[b] | | | |
| | P_NAPM | -0.0209 | -2.5768[b] | N_NAPM | -0.1594 | -1.8185[c] | | | |
| | N_CS | -0.0279 | -1.9051[b] | | | | | | |
| | Adjusted $R^2$ | 0.2286 | | Adjusted $R^2$ | 0.2701 | | Adjusted $R^2$ | 0.1937 | |
| | F-Statistics | 17.7804[a] | | F-Statistics | 20.2290[a] | | F-Statistics | 25.9522[a] | |

Panel B: Wald Test of Equality of Coefficients

| Null Hypothesis | Chi-square | P-Value | Chi-square | P-Value | Chi-square | P-Value |
|---|---|---|---|---|---|---|
| $\lvert\beta_{CNP}^+\rvert = \lvert\beta_{CNP}^-\rvert$ | 4.0682 | 0.0437 | 0.6935 | 0.4050 | 0.8261 | 0.3634 |
| $\lvert\beta_{TB}^+\rvert = \lvert\beta_{TB}^-\rvert$ | | | | | 6.2067 | 0.0127 |
| $\lvert\beta_{UR}^+\rvert = \lvert\beta_{UR}^-\rvert$ | 9.1547 | 0.0025 | | | | |
| $\lvert\beta_{PI}^+\rvert = \lvert\beta_{PI}^-\rvert$ | | | 3.3834 | 0.0659 | | |

This table reports the estimated stepwise regression models for the realized volatility (RV) five minutes after each announcement. The stepwise regressions pick up only the announcements which have an impact on the five-minute realized volatility at the 10% significance level. The stepwise regression models have the form: $RV_{t_{i+1}} = c + \sum_{j=1}^{N} \beta_j^+ SA_{j,t_i}^+ + \sum_{j=1}^{N} \beta_j^- SA_{j,t_i}^- + \sum_{s=0}^{3} \gamma_s \ RV_{t_{i-s}} + \varepsilon_{t_{i+1}}$. $RV_{t_{i+1}}$ is the post-announcement five-minute realized volatility, $SA_{j,t_i}^+$ and $SA_{j,t_i}^-$ are the positive (P) and negative (N) components of the surprise of the $j^{th}$ announcement, and $\gamma$ is the volume persistence parameter that accounts for dependent variable lags (not reported). Panel A presents the model estimation results and panel B reports the result of tests of equality of the coefficients of the negative and positive surprises if both of their impacts are significant at the 10% significance level (picked up by the stepwise regression). Superscripts "a", "b" and "c" indicate significance at the 1%, 5% and 10% levels, respectively. Refer to Table 2 for abbreviations for the various macroeconomic announcements.

**Table 11**
Asymmetric impact of macroeconomic news on trading volume (2007-2008).

*Panel A:* Model estimation results.

| | Gold $V_{+5}$ | | | Copper $V_{+5}$ | | | Silver $V_{+5}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Optimal Regressors | $\hat{\beta}_j^+(\hat{\beta}_j^-)$ | T-stats | Optimal Regressors | $\hat{\beta}_j^+(\hat{\beta}_j^-)$ | T-stats | Optimal Regressors | $\hat{\beta}_j^+(\hat{\beta}_j^-)$ | T-stats |
| 8:30 | Intercept | 1558.58 | 16.806[a] | Intercept | 114.71 | 10.280[a] | Intercept | 443.54 | 18.326[a] |
| | P_CNP | 3127.12 | 3.4060[a] | N_UR | -78.10 | -2.5501[b] | N_UR | -177.82 | -2.6439[a] |
| | P_UR | 1866.06 | 3.6232[a] | P_ARS | 124.50 | 2.7668[c] | P_CNP | 488.88 | 2.5404[b] |
| | N_UR | -557.73 | -2.2020[b] | N_PI | 88.02 | 1.9963[b] | N_CNP | -336.52 | -2.5754[b] |
| | | | | P_CNP | 188.84 | 2.0511[b] | P_ARS | 209.08 | 1.6878[c] |
| | | | | P_DGO | 67.37 | 1.7328[c] | | | |
| | Adjusted $R^2$ | 0.1880 | | Adjusted $R^2$ | 0.1664 | | Adjusted $R^2$ | 0.1115 | |
| | F-Statistics | 13.9615[a] | | F-Statistics | 4.9912[a] | | F-Statistics | 6.5235[a] | |
| 9:15 | Intercept | 1149.91 | 4.8298[a] | Intercept | 92.10 | 14.880[a] | Intercept | 334.00 | 6.1187[a] |
| | Adjusted $R^2$ | 0.0000 | | Adjusted $R^2$ | 0.0000 | | Adjusted $R^2$ | 0.1144 | |
| | F-Statistics | | | F-Statistics | | | F-Statistics | 5.5475[a] | |
| 10:00 | Intercept | 1338.07 | 14.771[a] | Intercept | 101.95 | 8.8496[a] | Intercept | 334.76 | 13.293[a] |
| | N_NAPM | -478.46 | -2.8662[a] | N_CC | -355.26 | -4.3254[a] | N_CS | -215.73 | -2.0066[b] |
| | P_BI | -552.19 | -1.7511[c] | | | | | | |
| | N_BI | -977.48 | -2.5659[b] | | | | | | |
| | Adjusted $R^2$ | 0.1011 | | Adjusted $R^2$ | 0.1724 | | Adjusted $R^2$ | 0.0218 | |
| | F-Statistics | 6.0244[a] | | F-Statistics | 18.7093[a] | | F-Statistics | 4.0264[b] | |

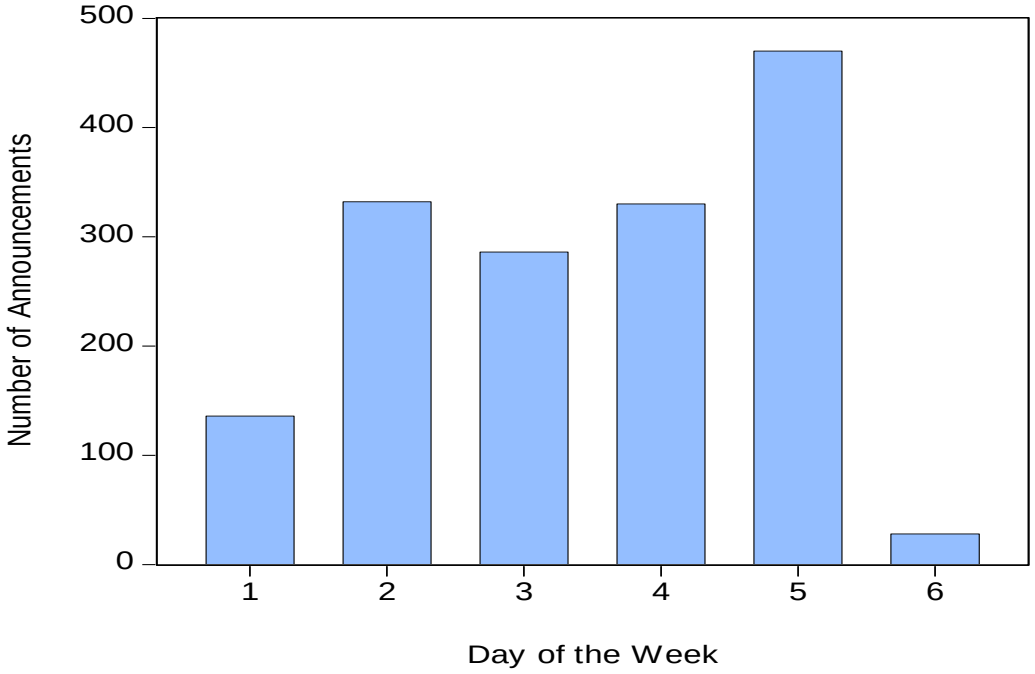
*Panel B:* Wald test of equality of coefficients.

| Null Hypothesis | Chi-square | P-Value | Chi-square | P-Value | Chi-square | P-Value |
|---|---|---|---|---|---|---|
| $\lvert\beta_{CNP}^+\rvert = \lvert\beta_{CNP}^-\rvert$ | | | | | 0.4507 | 0.5020 |
| $\lvert\beta_{UR}^+\rvert = \lvert\beta_{UR}^-\rvert$ | 5.4552 | 0.0195 | | | | |
| $\lvert\beta_{BI}^+\rvert = \lvert\beta_{BI}^-\rvert$ | 0.7145 | 0.3980 | | | | |

This table reports the estimated stepwise regression models for trading volume five minutes after each announcement. The stepwise regressions pick up only the announcements which have an impact on the five-minute volumes at the 10% significance level. The stepwise regression models have the form: $V_{t_{i+1}} = c + \sum_{j=1}^{N} \beta_j^+ SA_{j,t_i}^+ + \sum_{j=1}^{N} \beta_j^- SA_{j,t_i}^- + \sum_{s=0}^{3} \gamma_s \, V_{t_{i-s}} + \varepsilon_{t_{i+1}}$. $V_{t_{i+1}}$ is to the five-minute post-announcement volume, $SA_{j,t_i}^+$ and $SA_{j,t_i}^-$ are the positive (P) and negative (N) components of the surprise of the $j^{th}$ announcement, and $\gamma$ is the volume persistence parameter that accounts for dependent variable lags (not reported). Panel A presents the model estimation results and panel B reports the result of tests of equality of the coefficients of the negative and positive surprises if both of their impacts are significant at the 10% significance level (picked up by the stepwise regression). Superscripts "a", "b" and "c" indicate significance at the 1%, 5% and 10% levels, respectively. Refer to Table 2 for abbreviations for the various macroeconomic announcements.

**Figure 1: Distribution of Macroeconomic Announcements**

Number of Announcements vs. Day of the Week




Number of Announcements vs. Day of the Month

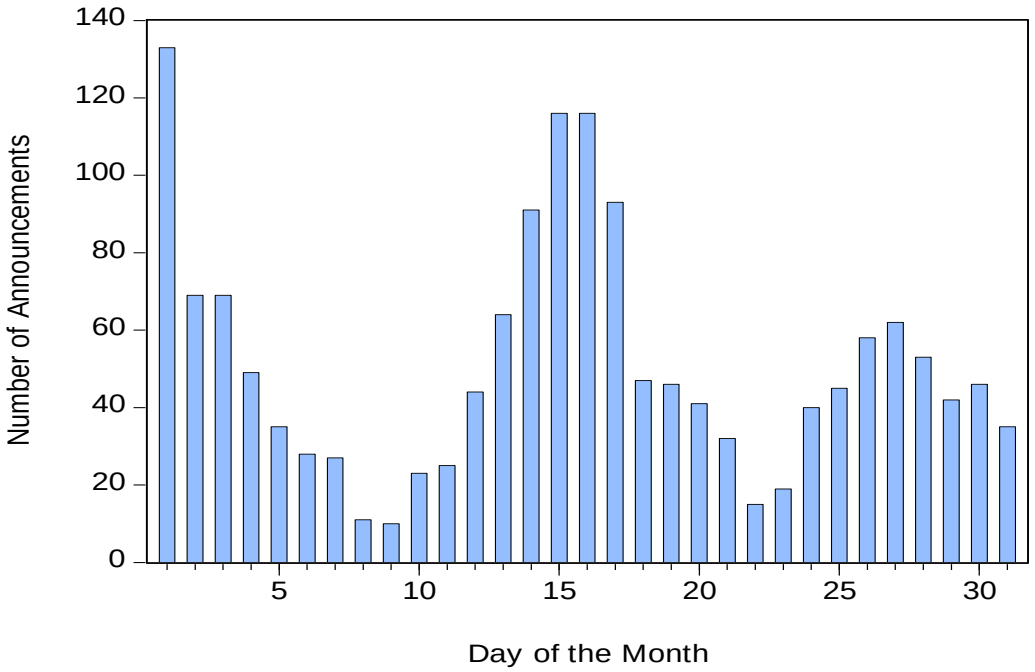


**Figure 2: Means of Realized Volatility in the Study Sample versus Control Sample**

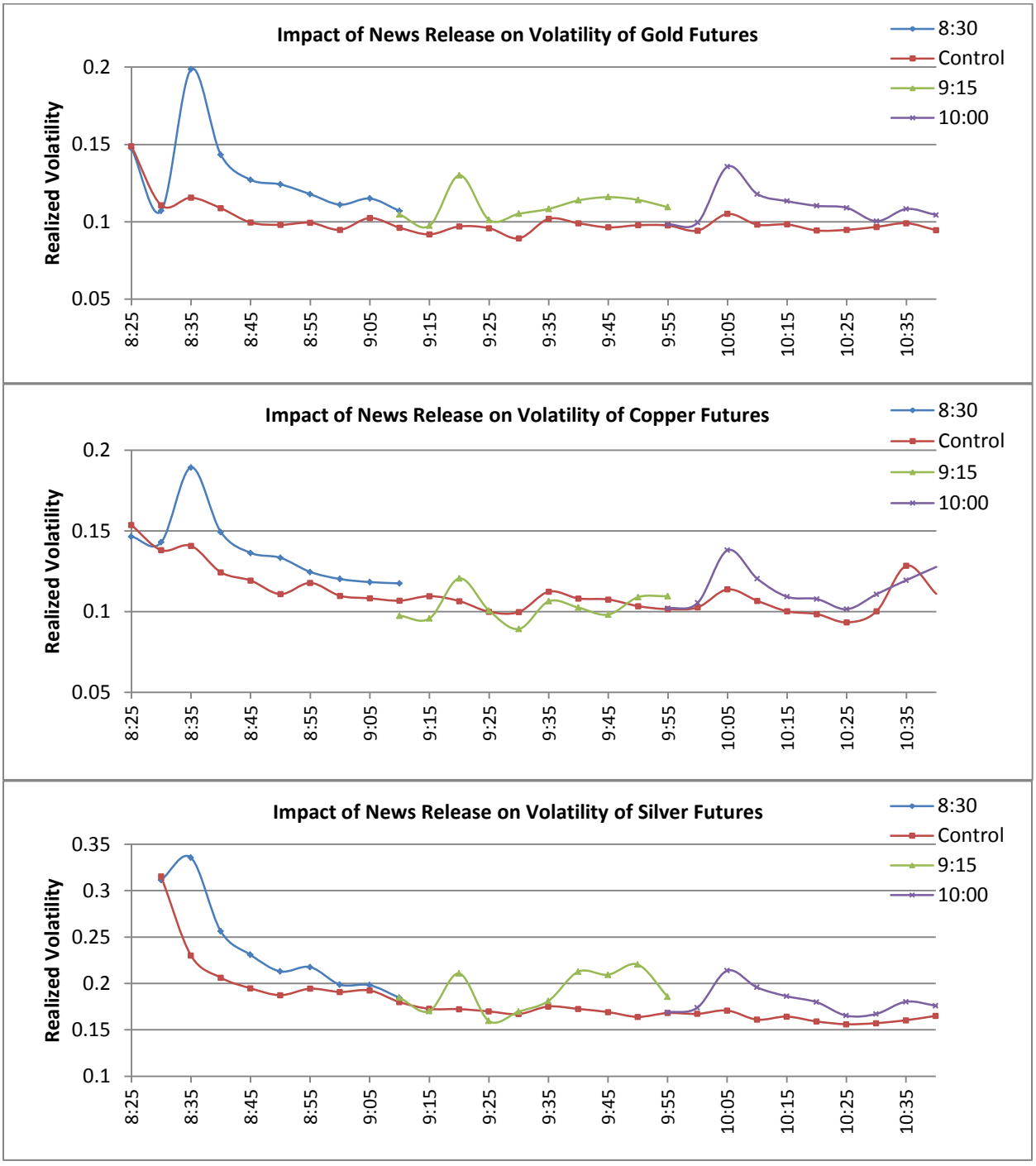


**Figure 3: Persistence of Return Shocks**

This figure presents the values of the adjusted R-square of stepwise regressions in 10 five-minute intervals around the announcement time points.

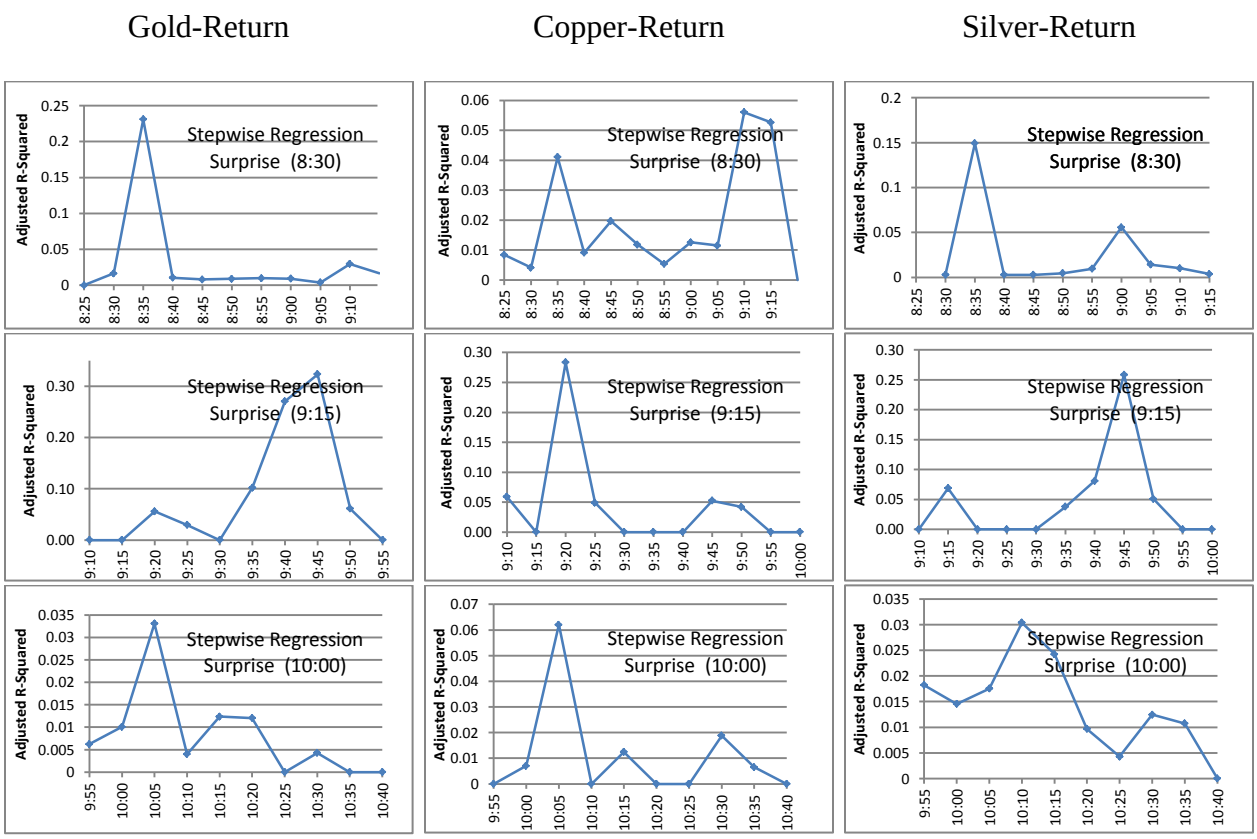


**Figure 4: Persistence of Volatility Shocks**

This figure presents the values of the adjusted R-square of stepwise regressions in 10 five-minute intervals around the announcement time points.

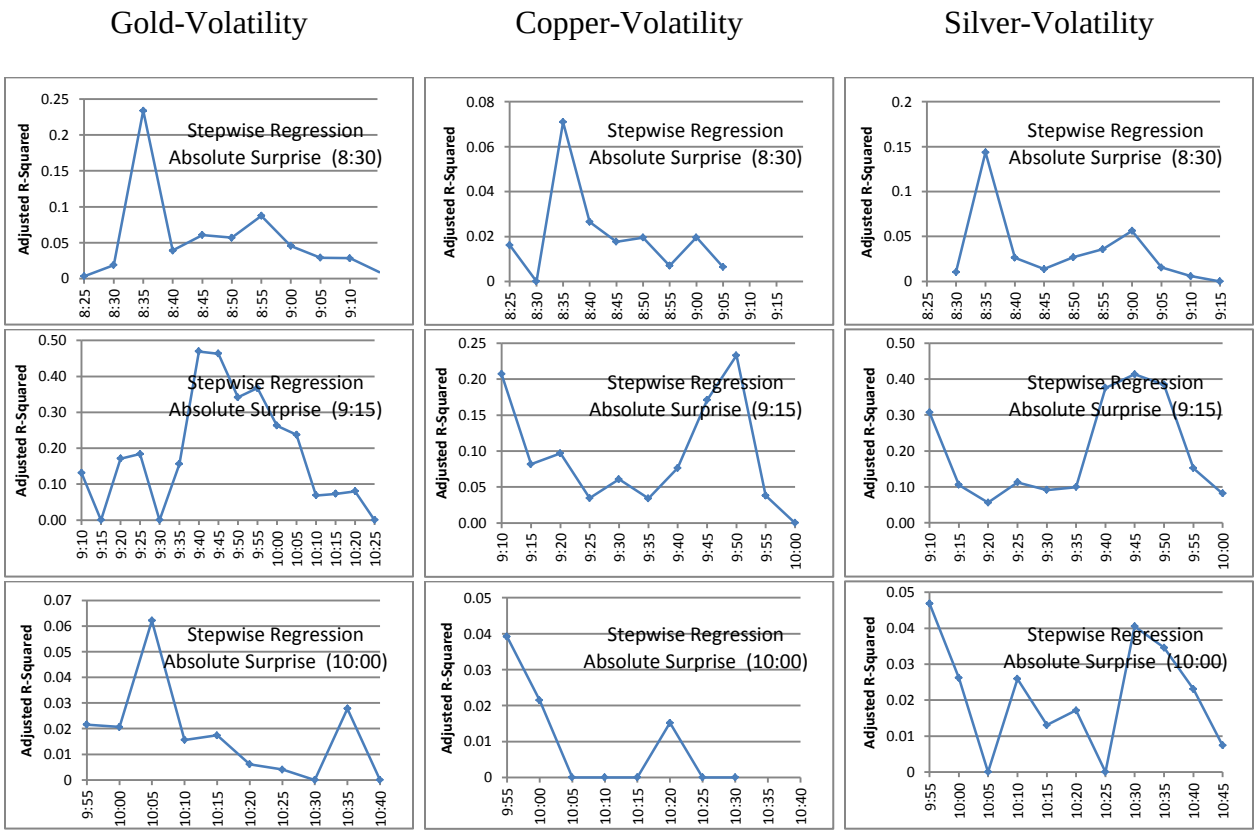


**Figure 5: Persistence of Volume Shocks**

This figure presents the values of the adjusted R-square of stepwise regressions in 10 five-minute intervals around the announcement time points.