Is gold a safe haven for investors?

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Abstract

This thesis uses a high-frequency intra-day dataset consisting of gold, S&P500 and U.S. Treasury Bond futures returns, together with precisely timed macroeconomic announcements, to examine the role of gold futures as a safe haven. We test the effects of macroeconomic announcements on the returns and return volatility of gold futures using least squares regressions and a Component-GARCH model. The comovement between gold, S&P500 and U.S. Treasury Bond futures is examined using a Dynamic Conditional Correlation model and copulas, with both methods incorporating the macroeconomic announcements. We find that many of the macroeconomic announcements have a significant effect on the return and volatility of gold futures, and that our univariate analysis supports the role of gold as a safe haven. The results of our multivariate analysis show that many macroeconomic announcements have a significant influence. Moreover, we find that the comovement between gold and S&P500 is very weak, but that there is some proof for the safe haven role of gold following from our copula estimations. For gold and U.S. Treasury Bond futures we find that both futures move in tandem, which supports gold's role as a safe haven as U.S. Treasury Bonds are considered a generally considered as a safe asset.

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1 Introduction

The drivers behind the price and volatility processes of assets are one of the fundamental subjects of research in financial economics. There is a wealth of information that reaches the financial markets each day, and it speaks to reason that this information has a very big influence on both price and volatility. The question remains, however, which information influences both processes, and how. This thesis will look at one source of information, namely macroeconomic announcements, and the effect they have on the price and volatility of gold futures, and on the comovement between gold, S&P500 and U.S. Treasury Bond futures.

The global state of the economy can be considered to be one of the key determinants for the outlook of financial markets and assets. As macroeconomic news and variables are one of the main sources of information available to investors about the global state of the economy, the associated announcement are likely to play a role in the price and volatility process of assets. When we consider the effect of news on the price of assets, our first instinct is that positive news should have a positive effect, and negative news the opposite. Whilst this is true in general for most asset classes, there is one asset for which this relationship certainly is not as straightforward, that asset is gold.

Starting as a means of exchange in the form of coins in the sixth century B.C., gold has played a large role in our economies ever since. It was the gold standard, however, that was the foundation for the importance of gold in our current financial systems. First officially implemented in Great Britain in the 19th century, the gold standard fixed the Pound Sterling to a set mass of gold, a system which many countries later followed. After eventually evolving into the Bretton Woods System, the final convertibility of currency to gold was ended in 1971. Gold has retained a central role in the economic system however, through the holding of gold reserves by central banks.

Four main uses of gold can be distinguished. Firstly, official institutions hold gold as reserves, which accounts for 17% of the aboveground stock of gold. Secondly, private investors hold another 19%. Thirdly, 12% is used for industrial purposes such as consumer electronics and engineering. Finally, the main use of gold is for jewellery which accounts for 50% of the worldwide aboveground stock.[1][2]

Driven by its roles as a store of value, a monetary asset and a safe haven, gold has been used as an investment throughout history. The aforementioned gold reserves held by official institutions are the main example of gold's role as a store of value, which stems from its intrinsic value. While private investors might also consider gold as a store of value, one of the significant disadvantages associated with gold is that it does not generate any income other than its change in value. Gold's role as a monetary asset stems from its use as an inflationary hedge, as the purchasing power of gold remains stable because of its intrinsic value. Next to these two roles, gold is also seen as a safe haven and is often used as a hedge in periods of economic turmoil

[1] Estimates from the World Gold Council, 2010.

[2] The remaining 2% is currently unaccounted for.

and financial distress.

During the current times of financial distress, in which stock and bond markets have endured a severe downturn, the price of gold has risen steadily, even setting an all-time high record of $1,913.50 on August 23, 2011. The gold price has shown this pattern in past crises as well. For example, examining past highs of the gold price we see that the last peak was in 1980, during another period of economic recession. Whilst historically most of the demand for gold came from jewellery, in recent years this has shifted drastically towards investments. This shift in demand gives more rise to the idea that gold can be considered a safe haven during times of economic distress, as investors construct their portfolio to include more gold instead of assets that are considered to be riskier.

It is this last role of gold, the role of a safe haven, which will be the focal point of this thesis. Using high-frequency intra-day prices for futures contracts on gold, stocks, and bonds, together with macroeconomic announcements, we first examine the relationship between macroeconomic announcements and the price and volatility of gold futures. We consider the effect of macroeconomic announcements on the gold futures to examine whether the futures prices do indeed react positively to negative news as the safe haven role of gold suggests. Second, we look at the comovement between gold futures, stock futures, and bond futures, and examine whether macroeconomic news announcements influence this comovement, and whether this influence is dependent on the fact if the news is positive or negative.

This thesis will use several models in order to examine these relationships. To examine the relationship between the price and volatility of gold futures, firstly, we will use least squares regressions. Subsequently, we will look at a Component-GARCH model. We find that many of the macroeconomic announcements have a significant effect on the return and volatility of gold futures, and that our univariate analysis supports the role of gold as a safe haven. Later, when we also include the stock and bond futures in our analysis, we use multivariate GARCH models and copulas in order to examine the comovement between the different assets. Whilst we find that many macroeconomic announcements have a significant influence, our results do not allow for a clear-cut conclusion. Our results show that comovement between gold and S&P500 is very weak, but that there is some proof for the safe haven role of gold following from our copula estimations. For gold and U.S. Treasury Bond futures we find that both futures move in tandem, which supports gold's role as a safe haven as U.S. Treasury Bonds are considered a generally considered as a safe asset.

We examine these models using a dataset consisting of high-frequency gold, S&P500 and U.S. Treasury Bond futures prices and lower-frequency macroeconomic announcements with a sample period from January 2001 to December 2009. The futures prices were supplied to us in 10-second intervals, which we transform to return intervals of different lengths. The macroeconomic announcements we use are all from U.S. macroeconomic indicators and are reported in either weekly, monthly or quarterly intervals.

Whilst previous research has been extensively done on the effect of macroeconomic announcements on asset returns and volatility in general, and for gold specifically, we believe that this thesis can contribute to this field of research in various ways. First, we believe that the use of high-frequency intra-day data of futures prices, paired with precisely timed macroeconomic announcements, will allow us to examine with more precision their relationship than most previous research was able to with lower-frequency data. Secondly, we will examine models that have not been applied previously to this kind of dataset. Finally, little research has yet been done on the effect of macroeconomic announcements on the comovement between different asset classes such as gold, stock and bond futures. Therefore, this thesis should give additional insight into this relationship.

The remaining sections of this thesis are organized as follows. In Section 2 we will discuss prior research in this field. Section 3 will describe the futures and macroeconomic news data and some preliminary statistics. Section 4 describes the methodology and models used for the analysis of the effects of macroeconomic announcements on gold futures prices and the corresponding results. In Section 5 we will describe the methodology and models used to look at the relationship between gold, stock and bond futures and the effects that macroeconomic announcements have on this relation. Section 6 will discuss the findings, describe additional robustness checks and will provide suggestions for further research. Finally, Section 7 will conclude this thesis.

2 Literature review

The effects of macroeconomic announcements, ranging from a single variable to a broad spectrum of macroeconomic announcements, on the return, volatility and comovement of assets have been thoroughly researched in the past, albeit not so extensively for gold. In this section we will consider both the research done on the effects of macroeconomic announcements, and on gold in general.

First, we will discuss past research on the effects of macroeconomic announcements on asset prices and volatility in general. Second, we will focus on research that specifically deals with gold prices and volatility. Finally, we will examine past research pertaining the comovement between different assets and the effects that macroeconomic announcements have on this comovement.

2.1 The effects of macroeconomic news on asset prices and volatility

The interest in the effects of macroeconomic news on asset prices and volatility is a result of the development of the efficient markets hypothesis, of which one of the outcomes was that the arrival of new information should lead to a change in asset prices, and dates back as far as the early 1970s. Early research focussed only on the reaction of stock prices to news about inflation however.[1] In the beginning of the 1980s the focus shifted towards exchange rates, as structural models failed to explain the high volatility in exchange rates at that time.[2]

From the late 1980s and onwards, the research in this field became much more diversified. Frankel and Hardouvelis (1985) study the effect of money supply announcements from the Federal Reserve on the prices of U.S. Treasury bills, five exchange rates and nine commodities, and find that the announcements cause significant reactions for five assets. Hardouvelis (1988) is the first to extend his research to include more than a single macroeconomic variable, and looks at the effects of the unanticipated component in fifteen macroeconomic announcements on exchange and interest rates, and finds significant effects for almost all fifteen variables. Cutler, Poterba, and Summers (1989) look at the effects of seven macroeconomic variables on the volatility of stock returns, and find that they account for one-third of the stock return variance. Barnhart (1989) considers thirteen macroeconomic announcements and their effects on two types of U.S. Treasury bills and fifteen commodities. They find that surprises in almost all variables cause reactions in the Treasury bills, whilst for the commodity prices the set of significant announcements is limited to monetary announcements.

Ghura (1990) examines the reaction of a set of seven macroeconomic indicators on the prices of twenty commodities taking into account the economic cycle. He finds that, in general, macroeconomic variables have only limited effect on commodity prices, but that the effects become significant when the economy is

[1] Works on the reaction of stock prices to inflation announcements include, but are not limited to, Nelson (1976), Bodie (1976), Jaffe and Mandelker (1976), Fama and Schwert (1977) and (Schwert, 1981).

[2] Works on exchange rates include, but are not limited to, Dornbusch (1980), Frenkel (1981), Copeland (1984) and Rose (1984).

transitioning from a recession to an expansion. Ederington and Lee (1993) examine the impact of eighteen macroeconomic news announcements on T-Bond, Euro-Dollar and Deutschmark futures, and find that most of the price adjustment due to a macroeconomic announcement takes place in the 5-minute interval directly following the announcement. They also show that volatility is substantially higher in the 15-minute window following the announcement and that it takes several hours to return to its normal level. In Ederington and Lee (1995), they look at a 10-second interval and find that prices adjust to the release of news within 40 seconds. Balduzzi, Elton, and Green (2001) look at the effect of the surprises in seventeen different public news announcements on various U.S. Treasury Bonds and also find that the release of news is incorporated in the price in under a minute. Fleming and Remolona (1999) look at the effects of four macroeconomic announcements on the U.S. Treasury market. They find that there is a near immediate change in price and volatility after the release of news, together with a drop in trading volume. After two minutes trading volume starts to rise again and volatility has already dropped by two-thirds, it then takes up to 90 minutes for both trade volume and volatility to return to their pre-announcement levels.

Hess, Huang, and Niessen (2008) examine the effects of seventeen U.S. macroeconomic announcements on two commodity futures indices and look at differences between expansions and recessions. They find that during expansions none of the variables have significant influence on the indices, and that during recessions only inflation and real activity have a significant effect. Brenner, Pasquariello, and Subrahmanyam (2009) look specifically at the effects of U.S. macroeconomic announcements on the volatility of, and comovement between, U.S. stocks, Treasury bills and corporate bonds. They find that the surprise component of the announcement significantly influences the volatility and comovement, and that this effect is greater for negative news than for positive news. Andersen, Bollerslev, Diebold, and Vega (2003) look at the effects of macroeconomic variables on the return and volatility of five U.S. dollar spot exchange rates. They specifically consider the asymmetric effects of positive and negative news and conclude that bad news has a more significant impact than good news. In Andersen, Bollerslev, Diebold, and Vega (2007) they expand their research to include U.S., German and British stock, bond and foreign exchange markets. Again, they find significant proof that macroeconomic announcements lead to jumps in the returns. Also, they consider the different reactions depending on the state of the economy and find that for stock markets negative news has a negative effect on returns during expansions and a positive effect during contractions.

Finally, another specific source of news that has been studied are monetary policy decisions of the Federal Open Market Committee (FOMC) and their effect on assets. Bomfim (2003), Bernanke and Kuttner (2005), Gurkaynak, Sack, and Swanson (2005), Zebedee, Bentzen, Hansen, and Lunde (2008), Wongswan (2009) and Hausman and Wongswan (2011) consider their effect on equity markets. Kuttner (2001), Gurkaynak, Sack, and Swanson (2005) and Fatum and Scholnick (2008) look at their effects on various U.S. Treasury bonds. Almost all studies find that the unexpected component of the FOMC announcements influences the return and volatility of assets.

Whilst the above-mentioned works differ in their approach, there are various aspects that they have in common. Firstly, the majority of the studies have used all or a subset of the 24 macroeconomic announcements that are considered in this thesis. Whilst the significance of the various macroeconomic announcements varies between the studies, unemployment and trade balance are found to have a significant effect in almost all of them. Secondly, the studies that examine the difference between the effect of negative and positive announcements almost exclusively find that negative news has a larger effect that positive news. Thirdly, when examining whether the effect of an announcement stems from the absolute announcement or the surprise contained in that announcement, they almost unanimously conclude that it is the surprise component in an announcement that influences asset prices and volatility. Finally, when we consider the methodology of the studies, the majority of the above-mentioned works have in common that they examine the relation between assets and news using regression models. Accordingly, this thesis uses a regression model as a starting point and builds from there.

2.2 Gold

The strong surge in gold prices during the recent period of financial turmoil has resulted in more and more attention to a commodity on which research was scarce in the past. In this subsection we will discuss two specific focal points when it comes to the research on gold. First, we will discuss in more detail studies that have been done on the effects of macroeconomic announcement on gold. Second, we will discuss papers that have looked into the safe haven, or hedging role of gold, and its comovement with other asset classes.

Of the four previously mentioned articles that look into the effect of macroeconomic announcements on commodities prices, three have included gold in their analysis. We will discuss the findings of these articles with respect to gold, together with research that focuses on gold specifically.

As mentioned before Frankel and Hardouvelis (1985) look at the effect of Federal Reserve money supply announcements on nine commodities on a daily interval. They find that for gold, a positive money growth surprise leads to a significantly negative return during the weekend following the announcement. Barnhart (1989) looks at the response of fifteen daily futures prices to thirteen macroeconomic announcements. They find that only money supply and the Federal Reserve surcharge rate have a significant, and in both cases negative, effect on gold futures returns. Ghura (1990) looks at the effect of seven macroeconomic variables on gold futures prices using ordinary least squares regressions. He finds that only surprises in unemployment announcements result in significant changes in the daily gold futures price, and that a positive surprise results in a positive change in price.

Christie-David, Chaudhry, and Koch (2000) use gold and silver futures prices to examine the effects of 23 macroeconomic announcements, and are the first to consider intra-day data on gold futures prices. Using ordinary least squares regressions they find that announcements concerning inflation, unemployment, GDP, PPI, capacity utilization and federal deficit have significant effects on the 15-minute gold futures returns after the announcement. For all six, a positive surprise results in a positive reaction of the gold futures price. They also consider the variance of gold futures returns and find that this is significantly higher on days on which an announcement takes place. Cai, Cheung, and Wong (2001) examine the effect of 23 U.S. macroeconomic announcements on the volatility of 5-minute gold futures returns. They use a Fractionally Integrated GARCH (FIGARCH) model combined with a flexible Fourier Form and find that employment reports, GDP, CPI and personal income have a significant and positive effect on volatility. Roache and Rossi (2009) compare the reaction of gold futures and eleven other commodities to a set of thirteen macroeconomic announcements from both the U.S. and European Union. Using a GARCH approach they find that daily gold futures prices react significantly to announcements concerning retail sales, inflation and non-farm payrolls, and that the sign of these coefficients suggest a counter-cyclical nature of gold. This last finding is further emphasized when they consider the asymmetric effects of good and bad news. Finally, they conclude that the positive reaction of gold to bad news, together with its reaction to interest rate surprises, supports the role of gold as a safe haven for investors.

Next, we look at research concerning the safe haven or hedging role of gold. Draper, Faff, and Hillier (2006) examine the hedging capabilities of gold, silver and platinum by regressing their returns on the S&P500 index returns and find that all three have significantly negative coefficients, and should therefore be able to reduce systematic risk when used in a portfolio. When they extend their regressions to look at asymmetric effects during periods of high and low volatility they find that this negative relationship, and their hedging capability, is even stronger during periods of high volatility. Finally, they compare the efficiency of financial portfolios that do, and do not include precious metals, and find that the portfolios which include gold perform better. Baur and McDermott (2009) look at the role of gold as a safe haven or hedge for thirteen stock indices from developing and developed countries. They find that gold acts as a safe haven for the stock markets in the U.S., Canada and major European countries, but not for developing countries such as Brazil, India, Russia and China. Baur and Lucey (2010) extend this to study if gold can be considered a hedge or a safe haven for stocks and bonds from the U.S., United Kingdom and Germany. They find that gold is a safe have for stocks in all three countries, but only for a limited window of 15 days after an extreme negative shock. In contrast, gold is not a safe haven for bonds of all three countries. They also find that gold is a hedge for U.S. and U.K. stocks and German bonds. Ciner, Gurdgiev, and Lucey (2010) look at returns on gold, oil, U.S. stocks, U.S. bonds and the dollar, and examine if, and how, these work as safe havens for each other. They find that gold acts as a safe haven for all but oil when examined on a daily interval. Coudert and Raymond-Feingold (2011) examine if gold is a safe haven for monthly stock index returns from the United States, United Kingdom, Germany, France and the G7.[1] They find that gold can be considered a safe haven for all five stock indices in

[1]The G7 consists of Canada, France, Germany, Great Britain, Italy, Japan, and the United States.

bear markets, and note that this might be a result of a decrease in conditional covariance between stocks and gold during periods of economic downturn. Baur (2011) finds that the volatility of gold returns reacts stronger to positive return shocks than negative return shocks. Dicle, Levendis, and Alqotob (2011) examine the role of gold and U.S. treasuries as safe haven for the S&P500, NASDAQ Composite Index, CAC40, DAX, Nikkei Index and FTSE 100 stock indices. They find that an increase in the volatility of the stock markets leads to an increase in the gold price, which reinforces the role of gold as a safe haven.

Considering the above-mentioned research on gold, we see that the number of macroeconomic announcements that have been found to have a significant effect on gold prices and volatility is much smaller than for the assets considered in the research in the previous subsection. Furthermore, we see that the majority of the works find that there is proof for either the hedging or safe haven role of gold.

2.3 The comovement of assets and the effect of macroeconomic news

As discussed in the previous subsection, quite some research on gold has examined the relation and comovement between gold and other assets. None of these have incorporated macroeconomic announcements into their analysis however. As far as we have been able to determine no published work has attempted to examine this relationship until now.

When we expand our investigation to include research on the effects of macroeconomic announcements on the comovement between asset classes that do not include gold, the results are still few.

Christiansen and Ranaldo (2007) examine the influence of macroeconomic announcements on the correlation between stock and bond returns on an intra-day level. They find that announcements have significant effects on the realized correlation between the S&P500 and U.S. Treasury notes. It should be noted that the effect comes mostly from the fact that there is an announcement and not so much from the surprise in the announcement.

Chulia, Martens, and van Dijk (2010) extend this line of research and study the effect of federal funds target rate decisions of the Federal Open Markets Committee (FOMC) on the returns and volatility of, and correlation between, individual stocks from the S&P100. They find that surprises in the announcements lead to significant changes in correlation. When considering the asymmetric effects of positive and negative announcements, they conclude that negative surprises decrease the correlation, whilst for positive announcements it is not the surprise, but the mere fact that an announcement is made that influences correlations.

3 Data

This section discusses the dataset used for this thesis. We will give more insight into the time series of futures data and the macroeconomic announcements. We will also discuss some preliminary findings.

3.1 Futures time series

3.1.1 Description

For this thesis we use a high-frequency intra-day dataset of transaction prices of gold, S&P500 and U.S. Treasury Bond futures contracts.

There are several reasons why we look at gold futures data and not at the spot market. Firstly, data for gold futures is available at a higher frequency than spot market data and gold futures have longer trading hours. Secondly, the futures market provides more liquidity than the spot markets and carries less transaction costs due to its nature. Thirdly, the spot market for gold is concentrated in London, and the resulting time difference causes some macroeconomic announcements to always be announced outside of trading hours. Ultimately, the use of gold futures data instead of spot data comes down to very subtle differences, most parties in the market actually consider the end-of-day price of the most actively traded contract month of that future to be the spot price. Considering that we use futures data for gold, in order to ensure consistency, we have chosen to also use futures data for the S&P500 and U.S. Treasury Bond series.

We consider a sample period from January 1, 2001 to December 31, 2009. During this period the contracts were traded on the Chicago Board of Trade (CBOT) until 2007. The CBOT then merged with the Chicago Mercantile Exchange (CME) where the trading of the contracts continued thereafter.

The trading in gold futures contracts is done both through open outcry on the trading floor, and through the electronic trading system of the CME, called CME Globex. The open outcry trading takes place in a pit on the CME trading floor from Monday to Friday, from 8:20 a.m. until 1:30 p.m. Eastern Time (ET). The electronic trading through Globex takes place from Sunday 6:00 p.m. until Friday 5:15 p.m. ET with a 45-minute break each day between 5:15 and 6:00 p.m.. The S&P500 futures contracts are traded through open outcry from 8.30 a.m. until 3:15 p.m. (ET) from Monday to Friday, and through Globex from 3:30 p.m. until 8:15 a.m. (ET) the next day from Monday to Thursday, and from 5:00 p.m. on Sunday until 8:15 a.m. (ET) the next Monday. The U.S. Treasury Bond futures contracts are traded through open outcry on Monday to Friday from 7.20 a.m. until 2:00 p.m. (ET), and through Globex from 5:00 p.m. until 4:00 p.m. (ET) the next day from Sunday to Friday.

We consider only trading that takes place from 8:00 a.m. to 18:00 p.m., or what we consider to be day trading, as this is where the majority of trading takes place and because the macroeconomic announcements are only released during the day.

Gold futures contracts are traded for the first three consecutive calendar months beginning at the current month at any time; in February, April, August and October within a 23-month period beginning with the current month, and any June and December falling within a 72-month period beginning with the current month. The S&P500 contracts are traded for the first, and first eight, contracts on the quarterly cycle consisting of March, June, September and December for Globex and open outcry respectively. The U.S. Treasury Bond futures contracts are traded for the first three contracts in the March quarterly cycle.

From these different contracts three time series of futures transaction prices are constructed by taking the nearest contract traded at that point in time. The transaction price is rolled over to the next month when the traded volume for the next month exceeds the volume of the nearest contract. We then construct the log returns for each interval with

$$r_t = \log(P_{t+1}) - \log(P_t)$$

where r_t is the return for the interval starting at time t and P_t is the futures price at time t. These are then multiplied by 100×100 so that all returns are shown in basis points.

The data is originally obtained at ten-second intervals, which are then aggregated to 5-minute intervals.

3.1.2 Preliminary findings

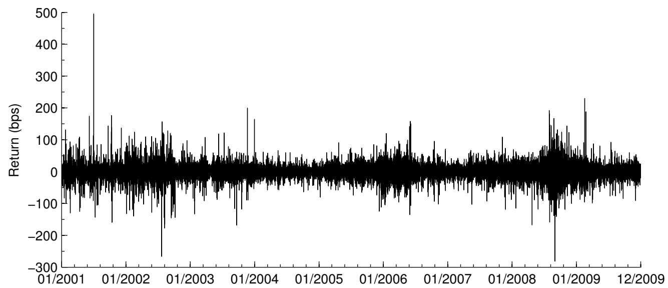
The summary statistics for the 5-minute futures returns are shown below in Table 1 on page 10.

	Gold	S&P500	Treasury Bond
Mean	0.0303	-0.0246	0.0044
Maximum	494.801	386.638	344.235
Minimum	-280.942	-578.940	-522.100
Standard deviation	10.092	11.839	5.995
Skewness	0.255	0.266	-6.296
Kurtosis	54.421	86.185	561.063

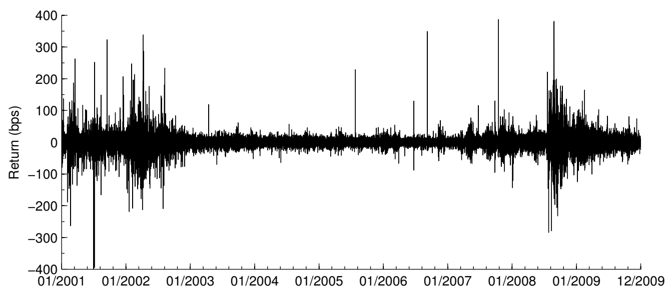
Table 1 – Summary statistics for 5-minute futures returns, January 1, 2001 - December 31, 2009. This table shows the summary statistics for the 5-minute returns of the gold, S&P500 and U.S. Treasury Bond futures from January 1, 2001 until December 31, 2009. All returns are reported in basis points.

As can be seen from the summary statistics, the average 5-minute futures returns are very close to zero for all three series. There are clearly some extreme returns, however, as the maxima and minima show. For gold, the most extreme observation is a positive return of 495 basis points on the 17th of September 2011, this extreme jump is because this was the first day of trading after the September 11th attacks in the U.S.. The largest negative return occurred in the morning of the 16th of October 2008, the same day that stock markets around the world recorded record losses. When we consider the skewness of the returns, we see that the returns for gold and S&P500 futures are positively skewed, indicating that large positive returns occur more frequently than large negative returns. The U.S. Treasury Bond futures show the opposite effect as they are negatively skewed.

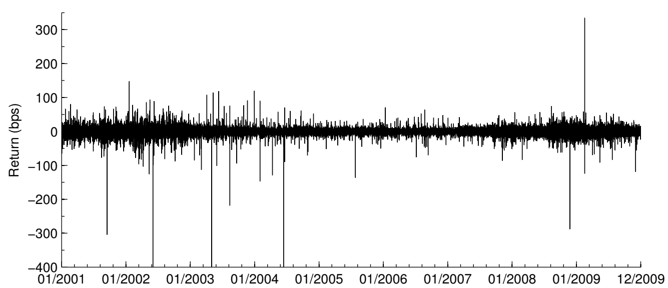
Figure 1 on page 11 shows plots of the 5-minute returns for the three futures series over the whole sample.



(a) Gold futures.



(b) S&P500 futures.



(c) U.S. Treasury Bond futures.

Figure 1 – Futures returns series (basis points), January 1, 2001 - December 31, 2009.

When we look at these figures, we can see that there is quite some variation in the returns over the span of our sample. The previously mentioned maximum and minimum returns are clearly visible, together with some other extreme returns. The graph also shows that there are periods in which large returns seem to cluster. This suggests that heteroskedasticity is present in our futures returns, and that we might need to take this into account for our further analysis.

It is also interesting to examine the intra-day patterns of the futures return series. The mean absolute return of the futures series for each of the 120 5-minute intervals of the day are shown in Figure 2 on page 12.

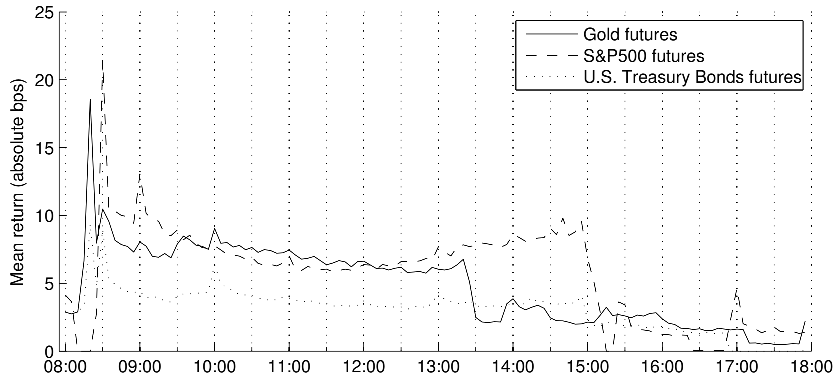


Figure 2 – Mean absolute returns for the 120 5-minute intervals of the day for gold, S&P500 and U.S. Treasury Bond futures.

When we look at the mean returns between 08:00 a.m. and 18:00 p.m., which we consider to be the part of the day in which day trading takes place, we can see a clear pattern. The mean absolute returns shoot up at the start of open outcry trading at 8:20 a.m., but immediately halve in the next 5-minute interval. For both the gold and U.S. Treasury Bond futures they then slowly decline until the end of open outcry trading at 1:30 p.m. The S&P500 futures show a different pattern however, they also start with a slow decline but start rising again around noon until open outcry trading stops at 3.00 p.m., resulting in a U-shape.

To get a first impression whether macroeconomic announcements have an influence on gold futures returns, we look at the times at which the majority of macroeconomic news announcements are released, which is at 8:30 a.m. and at 10:00 a.m.. At 8:30 a.m. we can see a clear spike where the mean absolute return rises sharply again after a drop following the start of the open outcry trading. We can also see a small spike at 10:00 a.m..

The variance of the futures returns series in the 120 5-minute intervals of the day are shown in Figure 3 on page 13. These show the same patterns as for the mean absolute returns. Both provide a first indication that macroeconomic announcements influence the gold futures returns.

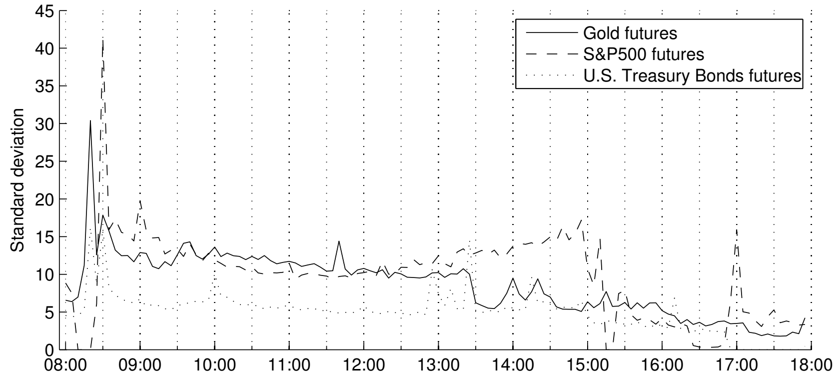
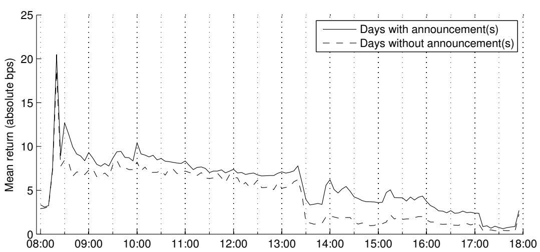
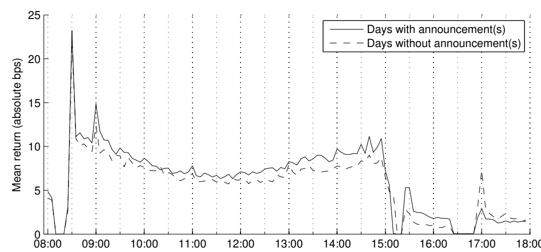


Figure 3 – Standard deviation for the 120 5-minute intervals of the day for gold, S&P500 and U.S. Treasury Bond futures.

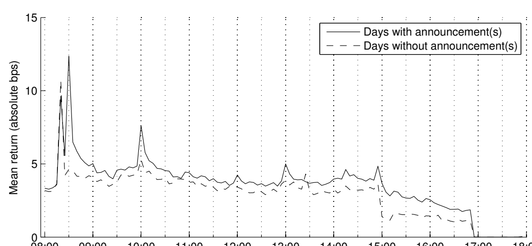
Finally, we look at the difference in the patterns of the mean absolute returns between days with and days without an announcement.



(a) Gold futures



(b) S&P500 futures



(c) U.S. Treasury futures

Figure 4 – Mean absolute returns for the 120 5-minute intervals of the day for days with and without an announcement.

When we look at the mean absolute returns for the gold and U.S. Treasury futures, we can see that days with an announcement show a spike in mean absolute returns compared to days without an announcement at 8:30 a.m. and 10:00 a.m.. This is another indication that macroeconomic news announcements influence the returns and return volatility of these assets. For the S&P500 futures this effect is less pronounced at 8:30

a.m., this is due to the fact that this coincides with the start of open outcry trading. At 10:00 a.m. the effect is similar to that for the other two assets.

We also see that the mean absolute returns are higher on days on which announcements are made than on days without announcements, which suggests that the futures returns are more volatile for the days with announcements.

3.2 Macroeconomic news announcements

We use real-time data obtained from Econoday[1] on the expectations and realizations of 24 U.S. macroeconomic announcements. The data on the realized announcements originates from Haver Analytics.[2] The expectations for the announcements are constructed by Market News International and Thompson Financial from surveys held amongst professional analysts who give their expectations on approaching announcements. The median of these forecasts is then used as the expected market consensus for the macroeconomic announcement.

Table 2 on page 15 shows the 24 U.S. macroeconomic announcements used in this thesis.

[1]More information on Econoday can be found on www.econoday.com.
[2]More information on Haver Analytics can be found on www.haver.com.

Announcement	Observations	Measure		Dates	Announcement time
Quarterly announcements					
1 – GDP advance	32	Q/Q[a] change (SAAR)[b]	%	01/00 - 12/09	8:30 a.m. ET
2 – GDP preliminary	34	Q/Q change (SAAR)	%	01/00 - 12/09	8:30 a.m. ET
3 – GDP final	34	Q/Q change (SAAR)	%	01/00 - 12/09	8:30 a.m. ET
Monthly announcements					
Real activity					
4 – Nonfarm payroll employment	107	M/M[c] change		01/00 - 12/09	8:30 a.m. ET
5 – Retail sales	107	M/M change	%	01/00 - 12/09	8:30 a.m. ET
6 – Industrial production	106	M/M change	%	01/00 - 12/09	8:30 a.m. ET
7 – Capacity utilization	106	Level	%	01/00 - 12/09	9:15 a.m. ET
8 – Personal income	108	M/M change	%	01/00 - 12/09	9:15 a.m. ET
9 – Consumer credit	103	M/M change	$B[d]	01/00 - 12/09	8:30 a.m. ET
Consumption					
10 – Personal consumption expenditures	108	M/M change	%	01/00 - 12/09	3.00 p.m. ET
11 – New home sales investment	107	Level (SAAR)	%	01/00 - 12/09	8:30 a.m. ET
Investment					
12 – Durable goods orders	108	M/M change	%	01/00 - 12/09	10:00 a.m. ET
13 – Construction spending	108	M/M change	%	01/00 - 12/09	8:30 a.m. ET
14 – Factory orders	107	M/M change	%	01/00 - 12/09	10:00 a.m. ET
15 – Business inventories	105	M/M change	%	01/00 - 12/09	10:00 a.m. ET
Government purchases					
16 - Government budget deficit	102	Level	$B	01/00 - 12/09	2:00 p.m. ET
Net exports					
17 – Trade balance	108	Level	$B	01/00 - 12/09	8:30 a.m. ET
Prices					
18 – Producer price index	105	M/M change	%	01/00 - 12/09	8:30 a.m. ET
19 – Consumer price index	107	M/M change	%	01/00 - 12/09	8:30 a.m. ET
Forward-looking					
20 – Consumer confidence index	107	Level		01/00 - 12/09	10:00 a.m. ET
21 – NAPM index	108	Level	%	01/00 - 12/09	10:00 a.m. ET
22 – Housing starts	108	Level (SAAR)	M[e]	01/00 - 12/09	8:30 a.m. ET
23 – Index of leading indicators	106	M/M change	%	01/00 - 12/09	8:30 a.m. ET
Weekly announcements					
24 – Initial unemployment claims	460	Level	K[f]	01/00 - 12/09	8:30 a.m. ET

Table 2 – U.S. macroeconomic announcements.

The table shows the 24 macroeconomic announcements used in this thesis. The number of announcements made of each type during our sample is shown, together with the time and measure.
[a] Quarter over quarter; [b] Seasonally adjusted annual return; [c] Month over month; [d] Billion United States Dollars; [e] Million; [f] Thousand.

Although the total number of announcements released during our sample is 2,734, some observations were removed to due missing expectations or realized data for the announcements, or because the announcement was made on a day on which no trading in the gold futures occurred. As a result, we remain with 2,691 observations.

As can be seen from the table, the majority of the announcements are made on a monthly basis, with four exceptions however. Firstly, the three announcements on U.S. GDP are made on a quarterly basis. Secondly, the number of initial claims for unemployment insurance is released on a weekly basis.

We define the news of a macroeconomic announcement as the surprise contained in that announcement. Considering that the variables have different units of measurement we follow Balduzzi, Elton, and Green

(2001) and Andersen, Bollerslev, Diebold, and Vega (2003), and standardize these surprises so that the results can be interpreted and compared more clearly. The standardized surprise for variable k at time t is given by

$$S_{k,t} = \frac{A_{k,t} - E_{k,t}}{\sigma_k} \tag{1}$$

where $A_{k,t}$ is the announced, or realized value of the announcement, $E_{k,t}$ was the expected value, or the median analyst forecast, for the announcement, and σ_k is the standard deviation of the surprises $A_{k,t} - E_{k,t}$.

When we look at the nature of the different macroeconomic announcements, we can see that almost all of them are procyclical. That is, positive surprises are considered to be a positive indication for the future state of the economy. There are two variables for which this relation does not hold however, the budget deficit and the initial unemployment claims, which are both countercyclical. In general, we would expect the procyclical announcements to have a negative influence on gold returns and vice-versa for countercyclical announcements due to role of gold as a safe haven.

There are a few announcements however, which require more analysis because cyclical reasoning is oversimplified. First, both the consumer and producer price index are also considered to be indicators for inflation. As gold is also a hedge against inflation, the effect of both CPI and PPI depends on which role of gold, safe haven or inflationary hedge, is stronger for these two announcements. In this light, a small note also has to be made concerning employment numbers, as the theory of the Phillips curve suggests that a rise in the unemployment rate leads to a rise of the rate of inflation. There is little proof substantiating the Phillips curve however, and we expect that the cyclical nature of employment numbers to be of more importance accordingly.

4 Macroeconomic announcements and gold futures

This section will describe the methodology for our analysis of the effects of macroeconomic announcement on gold futures prices and volatility. We start with ordinary least squares regressions to examine the effects of macroeconomic announcements on the futures returns. We continue by looking at the contemporaneous effects of individual announcements on the futures returns. Then, we extend our initial linear regression model by proposing several models which also take into account the effects of macroeconomic announcements on the volatility of the returns. Finally, we look at the contemporaneous effects of the announcements on the volatility of the gold futures.

4.1 Gold futures returns

We follow Andersen, Bollerslev, Diebold, and Vega (2003, 2007) and start with a linear regression model for the 5-minute returns of the gold futures that includes I lagged returns and J lags of the surprises in the macroeconomic announcements for all K types of announcements. This results in the following model

$$r_t = \beta_o + \sum_{i=1}^{I} \beta_i r_{t-i} + \sum_{k=1}^{K}\sum_{j=0}^{J} \beta_{k,j} S_{k,t-j} + \varepsilon_t \tag{2}$$

for $t = 1, \ldots, T$, where r_t is the 5-minute log-return for the gold futures at time t, $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k as given by (1).

As was noted in Section 3, there are clear indications that heteroskedasticity is present in our data. When we look at the disturbance terms as shown in Figure 5 on page 19, we can clearly see that heteroskedasticity is present in the residuals. Whilst the coefficient estimates will not be efficient, they still remain unbiased and consistent estimates for the parameters in (2). We will later specify a model for the conditional volatility, but for now we estimate (2) using Heteroskedasticity- and Autocorrelation Consistent (HAC) Newey-West standard errors to take the effects of heteroskedasticity into account. The estimates for the coefficients of this model, together with their HAC Newey-West standard errors are shown in Table 3 on page 18.

Dependent variable	β_k	Standard error
GDP		
1 – GDP advance	-13.013***	3.689
2 – GDP preliminary	-8.396***	2.949
3 – GDP final	-0.037	2.873
Real activity		
4 – Nonfarm payroll employment	-13.836***	4.638
5 – Retail sales	-5.508**	2.689
6 – Industrial production	-0.684	1.557
7 – Capacity utilization	-1.242	1.807
8 – Personal income	-1.079	1.015
9 – Consumer credit	-0.026	0.354
Consumption		
10 – Personal consumption expenditures	-0.451	1.147
11 – New home sales investment	-3.831***	1.087
Investment		
12 – Durable goods orders	-3.389**	1.694
13 – Construction spending	0.226	1.385
14 – Factory orders	-2.780**	1.218
15 – Business inventories	-0.498	1.736
Government purchases		
16 - Government budget deficit	1.734**	0.764
Net exports		
17 – Trade balance	-7.576***	2.884
Prices		
18 – Producer price index	1.811	1.302
19 – Consumer price index	1.508	1.383
Forward-looking		
20 – Consumer confidence index	-3.163**	1.603
21 – NAPM index	-5.594***	1.303
22 – Housing starts	-1.164	1.152
23 – Index of leading indicators	1.717	2.016
24 – Initial unemployment claims	3.182***	0.814

Statistics	
R_2	0.003

Table 3 – Effect of macroeconomic news on gold futures returns.

This table shows the results for the estimation of

$$r_t = \beta_o + \sum_{i=1}^{I} \beta_i r_{t-i} + \sum_{k=1}^{K} \sum_{j=0}^{J} \beta_{k,j} S_{k,t-j} + \varepsilon_t$$

for $t = 1, \ldots, T$, where r_t is the 5-minute log-return for the gold futures on interval t and $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k. The model is estimated using $I = 2$ lagged returns and $J = 0$ lagged surprises. The estimates for all the parameters and their Heteroskedasticity- and Autocorrelation Consistent (HAC) Newey-West standard errors are shown in the table above. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

We select the number of lagged returns and announcements which are included in our model based on the Schwarz Information Criterion (SIC), which suggest $I = 2$ lagged returns, and $J = 0$ lagged macroeconomic surprises. We also test a variation of (2) that adds a dummy for days on which an announcement is made as a robustness check, we find that the addition of the dummy does not improve our model.

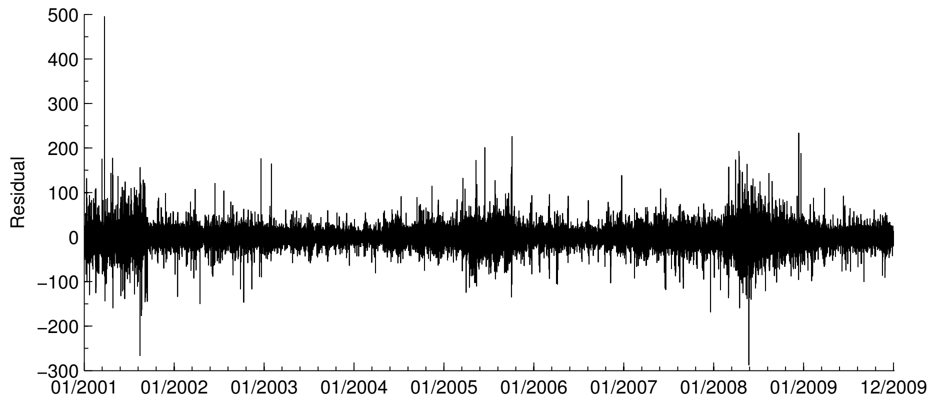


Figure 5 – Disturbance terms of linear regression as given by (2).

Of the 24 announcements, twelve have a significant effect on the gold futures returns. When we look at the signs of the coefficients, we see that two announcements concerning GDP, nonfarm payroll employment, retail sales, new home sales investment, durable goods orders, factory orders, trade balance, consumer confidence index, NAPM index and initial unemployment claims have the negative effect that we expected, and that government budget deficit and initial unemployment claims have the positive effect that we expected.

When we look at the consumer and producer price index, we see that these have a positive effect on the gold futures returns. This suggests that gold is possibly used as an inflationary hedge, and that the consumer and producer price index are not so much procyclical indicators for the safe haven role of gold.

The results for (2) show that most of the explanatory power in our model comes from the lagged returns and the immediate effect of the macroeconomic announcements. Lagged macroeconomic surprises add no additional explanatory power directly, although they do so indirectly through the lagged returns. As our dataset includes 262,893 return observations but only 2,691 macroeconomic announcements, the direct effect of the macroeconomic announcement on returns is limited to only 1.02% of the observations in our dataset. Therefore, we continue by focussing specifically on the effect of a macroeconomic announcement on the 5-minute return directly following the announcement.

We examine the contemporaneous effects of the different types of announcement individually and model the returns with

$$r_t = \alpha_k + \beta_{k,j} S_{k,t} + \varepsilon_t \quad (3)$$

where r_t is the 5-minute return for the gold futures directly following a macroeconomic announcement, and

$S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k as given by (1). The estimation results are shown in Table 4 on page 20.

	α_k		β_k		
Dependent variable	α_k	SE	β_k	SE	adj. R^2
1 – GDP advance	10.710***	3.237	-12.045***	3.196	0.299
2 – GDP preliminary	2.708	2.770	-9.059**	2.638	0.246
3 – GDP final	-4.569	2.844	-0.137	2.760	-0.031
Real activity					
4 – Nonfarm payroll employment	-0.280	4.251	-13.833***	4.032	0.094
5 – Retail sales	-2.687	1.841	-5.051***	1.803	0.061
6 – Industrial production	-0.917	1.374	-1.892	1.315	0.010
7 – Capacity utilization	-0.857	1.365	-1.908	1.292	0.011
8 – Personal income	1.226	1.447	-1.069	1.384	-0.004
9 – Consumer credit	0.419	0.353	0.040	0.355	-0.010
Consumption					
10 – Personal consumption expenditures	0.966	1.439	-0.423	1.441	-0.009
11 – New home sales investment	-1.250	1.717	-3.938**	1.681	0.041
Investment					
12 – Durable goods orders	0.916	1.558	-3.087**	1.509	0.029
13 – Construction spending	-2.907	1.672	0.407	1.725	-0.009
14 – Factory orders	-4.417***	1.060	-3.173***	1.042	0.072
15 – Business inventories	-0.809	1.852	-0.614	1.833	-0.009
Government purchases					
16 - Government budget deficit	0.111	1.180	1.794	1.173	0.013
Net exports					
17 – Trade balance	2.741	1.915	-7.747***	1.945	0.122
Prices					
18 – Producer price index	1.179	1.839	1.390	1.770	-0.004
19 – Consumer price index	0.533	1.699	1.840	1.630	0.003
Forward-looking					
20 – Consumer confidence index	-1.273	1.386	-3.557**	1.399	0.049
21 – NAPM index	-1.161	1.442	-5.285***	1.393	0.111
22 – Housing starts	-1.424	1.429	-0.731	1.363	-0.007
23 – Index of leading indicators	-2.794*	1.635	1.741	1.645	0.001
24 – Initial unemployment claims	-0.067	0.828	3.164***	0.820	0.029

Table 4 – Contemporaneous effect of macroeconomic news on gold futures returns.
This table shows the results for the contemporaneous regressions as given by

$$r_t = \alpha_k + \beta_{k,j} S_{k,t} + \varepsilon_t$$

where r_t is the 5-minute return for the gold futures directly following a macroeconomic announcement, and $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

The general finding from these results is that it is not the fact that an announcement is made that influences the gold futures price, but the surprise component in the announcements.

More specifically, these results show that for three variables the mere fact that an announcement is made has a significant effect. For GDP advance the effect is positive, and for factory orders and index of leading indicators the effect is negative. When we look at the surprise in the announcements, we see that this is significant for eleven of the 24 announcements. When we compare the significance of the coefficients to those for (2), we see that government budget deficit has lost its significance whilst the other eleven variables have remained significant. It should also be noted that all eleven significant coefficients have the sign that substantiates our hypothesis that gold is a safe haven. The influence of a surprise varies between these significant announcements. For GDP advance and nonfarm payrolls this influence is the largest as a positive surprise of one standard deviation results in a negative gold futures return of 12 to 14 basis points, whilst for the initial unemployment claims a positive surprise of one standard deviation results in a increase of the gold futures of about 3 basis points.

When we consider the R^2 for the various variables, we see that these vary greatly between different variables, indicating different levels of explanatory power.

We are also interested in investigating whether the macroeconomic announcements have asymmetric effects on the gold futures returns depending on the fact whether the news can be considered to be negative or positive. In order to account for these asymmetric properties we extend our model to include interactive dummy terms, which results in

$$r_t = \left(\alpha_{1,k} + \beta_{1,k} S_{k,t}\right) D\left(S_{k,t} < 0\right) + \left(\alpha_{2,k} + \beta_{2,k} S_{k,t}\right) D\left(S_{k,t} \geq 0\right) + \varepsilon_t \tag{4}$$

where $D(\cdot)$is a dummy variable which takes the value 1 if the condition $(\cdot)$ is met. The estimation results for (4) are shown in Table 5 on page 22.

Dependent variable	Negative α_1	Negative β_1	Positive α_2	Positive β_2	adj.R^2	Wald test H_0: $\alpha_1 = \alpha_2$	Wald test H_0: $\beta_1 = \beta_2$
1 – GDP advance	5.953	-17.428**	7.832	-8.172	0.266	0.026	0.659
2 – GDP preliminary	-10.333	-21.278**	4.616	-9.563**	0.270	2.555	1.664
3 – GDP final	-1.519	1.784	-5.384	0.513	-0.095	0.139	0.020
Real activity							
4 – Nonfarm payroll employment	1.017	-14.223**	-13.729	-0.598	0.092	1.207	1.085
5 – Retail sales	1.231	-0.962	-4.305	-4.380	0.053	1.024	0.325
6 – Industrial production	-3.043	-3.105	1.708	-4.580	0.004	1.384	0.107
7 – Capacity utilization	-5.026	-4.226*	2.619	-5.375	0.028	3.663*	0.079
8 – Personal income	2.998	2.109	1.615	-1.502	-0.020	0.076	0.330
9 – Consumer credit	0.419	0.194	1.286	-0.878	-0.018	0.555	0.827
Consumption							
10 – Personal consumption expenditures	5.582	2.661	-0.325	-0.131	-0.006	2.038	0.439
11 – New home sales investment	-4.758	-7.646*	-0.927	-3.535	0.031	0.538	0.623
Investment							
12 – Durable goods orders	-0.639	-5.534	-1.569	-0.294	0.024	0.040	1.327
13 – Construction spending	-0.394	0.763	-9.403***	7.486**	0.020	2.849*	1.537
14 – Factory orders	-0.310	0.050	-4.131**	-4.902*	0.088	1.404	2.304
15 – Business inventories	3.406	2.739	-1.649	-0.398	-0.021	0.640	0.265
Government purchases							
16 - Government budget deficit	-0.327	1.898	1.429	0.191	-0.001	0.409	0.298
Net exports							
17 – Trade balance	-10.234**	-24.275***	-3.670	1.083	0.241	1.300	18.545***
Prices							
18 – Producer price index	-2.765	-2.286	3.006	0.503	-0.012	0.999	0.244
19 – Consumer price index	14.066**	9.254**	-6.418**	10.062***	0.105	9.694***	0.021
Forward-looking							
20 – Consumer confidence index	3.267	0.446	-4.119	-1.820	0.059	2.821*	0.260
21 – NAPM index	3.175	-2.578	-6.653**	-0.572	0.133	4.192	0.185
22 – Housing starts	1.374	1.771	-3.116	0.317	-0.016	0.902	0.102
23 – Index of leading indicators	-3.734	1.971	-1.062	-0.001	-0.011	0.186	0.102
24 – Initial unemployment claims	-2.281	1.232	0.849	2.900	0.030	1.609	0.461

Table 5 – Contemporaneous asymmetric effects of macroeconomic news on gold futures returns.
This table shows the results for the contemporaneous regressions taking into account possible asymmetric effects as given by

$$r_t = (\alpha_{1,k} + \beta_{1,k} S_{k,t})\, D\,(S_{k,t} < 0) + (\alpha_{2,k} + \beta_{2,k} S_{k,t})\, D\,(S_{k,t} \geq 0) + \varepsilon_t$$

where r_t is the 5-minute return for the gold futures directly following a macroeconomic announcement, $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k, and $D\,(\cdot)$ is a dummy variable which takes the value 1 if the condition $(\cdot)$ is met. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

In general, these results show that for negative surprises it is still the surprise component of the announcement that has more influence on the stock returns than the mere fact that there is a negative surprise. When we consider the positive surprises, our first finding is that these have less influence on the gold returns, and that the significance here is split equally between the surprise in the announcements and the fact that there is a positive surprise.

When we consider the findings in more detail, we see that for the negative surprises the fact that there is a negative surprise concerning trade balance or consumer price index, has a negative and positive significant effect respectively. Furthermore, the magnitude of the surprise component for the negative surprise is significant for seven variables, namely, GDP advance, GDP preliminary, nonfarm payroll employment, capacity utilization, new home sales investments, trade balance and consumer price index. Of these, all but consumer price index have the expected negative sign indicating that a negative surprise has a positive effect on the gold price, supporting gold's role as a safe haven. Also, the positive sign for the consumer price index indicates that it has a stronger effect for gold's role as an inflationary hedge than its role as a safe haven.

Looking at the positive surprises, we see that for four announcements the fact that there is a positive surprise is significant, and that for four the magnitude of the surprise is significant. For GDP preliminary the magnitude of the positive surprise is significant. For construction spending, factory orders and consumer price index both the fact that there is a positive surprise and the magnitude of those surprises are significant. Finally, for NAPM only the fact that a positive surprise is announced is significant. The coefficient for the magnitude of the positive surprise in construction spending announcements is positive surprisingly. Furthermore, the coefficient for consumer price index again indicates that it is a better indicator for the role of gold as an inflationary hedge than as a safe haven. The remaining significant coefficients all have the expected sign supporting that gold acts as a safe haven.

We conduct Wald tests to examine whether the coefficients differ between negative and positive surprises. We test the null hypotheses $H_0 : \alpha_1 = \alpha_2$ and $H_0 : \beta_1 = \beta_2$ to examine whether the effect of the fact that there is a surprise and the magnitude of that surprise, respectively, differ significantly for positive and negative surprises. For capacity utilization, construction spending, consumer price index and consumer confidence index we can significantly reject the null-hypothesis for the event of a surprise. Considering the magnitude of the surprises, we can only reject the null-hypothesis for trade balance.

Whilst the difference between the effects of positive and negative surprises might not be statistically significant, from an economic point of view there certainly are significant differences. For GDP advance and preliminary for example, the effect of a negative surprise is more than twice as large as the effect a positive surprise of the same magnitude. This difference is even more significant for nonfarm payroll employment and trade balance, where a positive surprise of one standard deviation results in almost no change in the gold futures returns whilst a negative surprise of one standard deviations results in a positive return of the gold futures of almost 15 and 25 basis points respectively.

Finally, when we examine the difference between the adjusted R^2 for the symmetric and asymmetric estimations, we see that the adjusted R^2 of the symmetric contemporaneous estimations is higher for 14 of the 24 macroeconomic announcements. This indicates that the use of the asymmetric model has limited use with regards to explanatory power.

4.2 Gold futures return volatility

After having modelled the effect of the macroeconomic announcements on the returns of the gold futures, we continue with their effect on the volatility of the gold futures returns. As mentioned before we proceed by extending (2) by specifying a model for the conditional volatility ε_t. We follow Andersen, Bollerslev, Diebold, and Vega (2003) by using a linear model that includes I lagged values of the absolute returns, J lags of the macroeconomic announcements and a flexible Fourier form to account for the pattern of volatility over a day. This results in the following model

$$\mid \hat{\varepsilon}_t \mid = \gamma_o + \sum_{i=1}^{I} \gamma_i \mid \hat{\varepsilon}_{t-i} \mid + \sum_{k=1}^{K} \sum_{j=0}^{J} \gamma_{k,j} \mid S_{k,t-j} \mid + \sum_{q=1}^{Q} \left(\delta_q \cos\left(\frac{q2\pi t}{288}\right) + \phi_q \sin\left(\frac{q2\pi t}{288}\right)\right) + \nu_t \qquad (5)$$

where $\mid \hat{\varepsilon}_t \mid$ is the absolute value of the residual of (2) at time t, and $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k as given by (1). The final part of this equation, containing the sine and cosine, is the flexible Fourier form which allows for a smooth intra-day pattern of volatility.

In order to estimate this model we use a two-step weighted least squares approach. First, we estimate (2) using ordinary least squares. We then use the residuals to estimate (5) using ordinary least squares once again. The inverse of the estimated values of this equation are then used as weights to reestimate (2), this time using weighted least squares.

There are however some issues that might arise with this process. The specification for the conditional volatility, as given by (5), in no way assures that the fitted values will be negative. Even though in our case this does not occur, it is still clearly a very important flaw. Also, values fitted very closely to zero will be given a very large weight which is out of proportion.

The results of this two-step feasible weighted least squares model as given by (2) and (5) are shown in Table 6 on page 25.

Dependent variable	Cond. Mean $\beta_{k,0}$	Cond. Volatility $\gamma_{k,0}$
1 – GDP advance	-11.945**	6.467***
2 – GDP preliminary	-7.581**	1.893
3 – GDP final	-0.319	1.398
Real activity		
4 – Nonfarm payroll employment	-16.561***	16.945***
5 – Retail sales	-10.823***	4.686***
6 – Industrial production	-1.022	-0.468
7 – Capacity utilization	-0.680	1.174
8 – Personal income	2.060***	-0.004
9 – Consumer credit	0.033	-0.672
Consumption		
10 – Personal consumption expenditures	1.807***	-1.432
11 – New home sales investment	-3.358**	0.798
Investment		
12 – Durable goods orders	-4.723**	2.856***
13 – Construction spending	0.493	1.111
14 – Factory orders	-2.714*	0.540
15 – Business inventories	-1.038	2.101***
Government purchases		
16 - Government budget deficit	0.268	0.225
Net exports		
17 – Trade balance	-7.984***	4.910***
Prices		
18 – Producer price index	3.304**	0.103
19 – Consumer price index	0.583	1.234*
Forward-looking		
20 – Consumer confidence index	-4.218**	2.367***
21 – NAPM index	-5.405***	1.854**
22 – Housing starts	-1.723	-0.258
23 – Index of leading indicators	0.347	3.121***
24 – Initial unemployment claims	3.376***	1.826***

Table 6 – Effect of macroeconomic news on gold futures returns and volatility.
This table shows the results for two-step feasible weighted least squares regression, given by

$$r_t = \beta_o + \sum_{i=1}^{I} \beta_i r_{t-i} + \sum_{k=1}^{K}\sum_{j=0}^{J} \beta_{k,j} S_{k,t-j} + \varepsilon_t$$

and

$$\mid \hat{\varepsilon}_t \mid = \gamma_o + \sum_{i=1}^{I} \gamma_i \mid \hat{\varepsilon}_{t-i} \mid + \sum_{k=1}^{K}\sum_{j=0}^{J} \gamma_{k,j} \mid S_{k,t-j} \mid + \sum_{q=1}^{Q} \left(\delta_q \cos\left(\frac{q2\pi t}{288}\right) + \phi_q \sin\left(\frac{q2\pi t}{288}\right)\right) + \nu_t$$

for $t = 1, \ldots, T$, where r_t is the 5-minute log-return for the gold futures at time t, $\mid \hat{\varepsilon}_t \mid$ is the absolute value of the residual of (2) at time t, and $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k. It also includes a flexible Fourier form for the intra-day volatility patterns, as given by the part with cosine and sine. The model is estimated using $I = 2$ lagged returns and $J = 0$ lagged surprises in the return equation and with $I = 2$ lagged residual, 0 lagged surprises and $Q = 3$ flexible Fourier form terms. The estimates for all the parameters are shown in the table above. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

Once again, we need to stress the fact that this method of estimation is flawed by design. Nevertheless, the results are included to give a first insight into the effects of the macroeconomic announcements on gold futures return volatility. Based on the Schwarz Information Criterion we select $I = 2$ lagged returns and $J = 0$ lagged surprises in the return equation and $I = 2$ lagged residuals, $J = 0$ lagged surprises and $Q = 3$ flexible Fourier form terms for the volatility equation. We see that this method changes very little for the estimation of the return equation when we compare it to (2) with HAC standard errors, only government budget deficit has lost its significant effect whilst consumer credit and producer price index have become significant. Looking at the coefficients for (5), we find that eleven announcements have a significant influence on volatility directly, and that in all eleven cases the announcement results in an increase in volatility.

As our preliminary analysis indicates that days with an announcement have more volatile returns than days without announcements, we also consider a variant of (5) that includes a dummy variable which takes the value 1 if an announcement is released on that day. To our surprise however, this did not result in an improvement of the Schwarz and Akaike Information Criterion. The results for (5) with the dummy variable are shown in the Appendix in Table A.1 on page 69.

To overcome the issues associated with the two-step feasible least squares estimation we venture onto another class of models, those of the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) class, specifically we propose a variation of a Component-GARCH model. The Component-GARCH model as suggested by Lee and Engle (1993) and Engle and Lee (1999) allows us to decompose the volatility into two components, a long-run component q_t, and a short-run component s_t. This approach allows us to take into account the intra-day pattern of volatility in the form of a flexible Fourier Form, and the immediate effect of macroeconomic announcements on short-run volatility.

For the traditional GARCH model, the conditional variance is given by

$$h_t = \omega + \alpha\left(\varepsilon_{t-1}^2 - \omega\right) + \beta\left(h_{t-1} - \omega\right)$$

which results in a conditional variance that mean reverts to a constant ω. The Component-GARCH allows us to decompose the conditional variance in time varying long-run volatility component q_t and a short-run volatility component $h_t - q_t$ as follows

$$\begin{aligned} q_t &= \omega + \rho\left(q_{t-1} - \omega\right) + \phi\left(\varepsilon_{t-1}^2 - h_{t-1}\right) \\ h_t - q_t &= \omega + \alpha\left(\varepsilon_{t-1}^2 - q_{t-1}\right) + \beta\left(h_{t-1} - q_{t-1}\right) \end{aligned}$$

The long-term component of the Component-GARCH model reverts to ω with powers of ρ. The persistence of the short-run component is given by powers of $(\alpha + \beta)$.

We use this Component-GARCH model and incorporate aspects of (2) and (5), which results in

$$\begin{aligned} r_t &= \beta_o + \sum_{i=1}^{I} \beta_i r_{t-i} + \sum_{k=1}^{K}\sum_{j=0}^{J} \beta_{k,j} S_{k,t-j} + \varepsilon_t \\ q_t &= \omega + \rho\left(q_{t-1} - \omega\right) + \phi\left(\varepsilon_{t-1}^2 - h_{t-1}\right) \\ h_t - q_t &= \omega + \alpha\left(\varepsilon_{t-1}^2 - q_{t-1}\right) + \beta\left(h_{t-1} - q_{t-1}\right) + \sum_{k=1}^{K}\sum_{j=0}^{J} \gamma_{k,j} \mid S_{k,t-j} \mid + \sum_{q=1}^{Q}\left(\delta_q \cos\left(\frac{q2\pi t}{288}\right) + \phi_q \sin\left(\frac{q2\pi t}{288}\right)\right) \\ \varepsilon_t &\sim i.i.d.\ (0, h_t) \end{aligned} \qquad (6)$$

The conditional mean equation is the same as (2), which includes J lags of the 5-minute log-returns r_t and where $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k. The short-run component $h_t - q_t$ includes the flexible Fourier form for the intra-day pattern of volatility and the macroeconomic surprises $S_{k,t}$.

The parameters of the Component-GARCH model, as given by (6), are estimated using quasi-maximum likelihood, for which the estimation results are shown in Table 7 on page 28.

	Cond. Mean	Cond.Variance
Dependent variable	β_k	$\gamma_{k,0}$
1 – GDP advance	-9.147***	45.227**
2 – GDP preliminary	-6.993***	22.829*
3 – GDP final	-0.808	40.070*
Real activity		
4 – Nonfarm payroll employment	-11.121***	-2.835***
5 – Retail sales	-6.972***	29.088***
6 – Industrial production	-0.832	-4.740
7 – Capacity utilization	-1.167	7.012
8 – Personal income	-1.053	8.046
9 – Consumer credit	-0.123	-17.439***
Consumption		
10 – Personal consumption expenditures	0.152	-13.353
11 – New home sales investment	-3.438***	-1.465
Investment		
12 – Durable goods orders	-5.968***	45.886**
13 – Construction spending	0.494	6.457
14 – Factory orders	-3.098***	-0.286
15 – Business inventories	-0.016	23.375**
Government purchases		
16 - Government budget deficit	4.535***	53.955***
Net exports		
17 – Trade balance	-8.943***	16.555***
Prices		
18 – Producer price index	2.153**	2.072
19 – Consumer price index	0.810	11.181
Forward-looking		
20 – Consumer confidence index	-5.725***	41.986***
21 – NAPM index	-5.040***	11.075*
22 – Housing starts	-0.533	22.409**
23 – Index of leading indicators	-0.784	10.277
24 – Initial unemployment claims	2.954***	20.543***
Component-Garch parameters		
α		0.056
β		0.044
ρ		0.597
ϕ		0.060

Table 7 – Effect of macroeconomic news on gold futures returns and volatility using the Component-GARCH model.

This table shows the results for the Component-GARCH model, as given by

$$\begin{aligned} r_t &= \beta_o + \sum_{i=1}^{I}\beta_i r_{t-i} + \sum_{k=1}^{K}\sum_{j=0}^{J}\beta_{k,j}S_{k,t-j} + \varepsilon_t \\ q_t &= \omega + \rho\left(q_{t-1} - \omega\right) + \phi\left(\varepsilon_{t-1}^2 - h_{t-1}\right) \\ h_t - q_t &= \omega + \alpha\left(\varepsilon_{t-1}^2 - q_{t-1}\right) + \beta\left(h_{t-1} - q_{t-1}\right) + \sum_{k=1}^{K}\sum_{j=0}^{J}\gamma_{k,j} \mid S_{k,t-j} \mid + \sum_{q=1}^{Q}\left(\delta_q \cos\left(\frac{q2\pi t}{288}\right) + \phi_q \sin\left(\frac{q2\pi t}{288}\right)\right) \\ \varepsilon_t &\sim i.i.d.\ (0, h_t) \end{aligned}$$

The conditional mean equation is the same as (2), which includes J lags of the 5-minute log-returns r_t and where $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k. The short-run component $h_t - q_t$ includes the flexible Fourier form for the intra-day pattern of volatility and the macroeconomic surprises $S_{k,t}$. The model is estimated using $I = 2$ lagged returns and $J = 0$ lagged surprises in the return equation and with $J = 0$ lagged surprises and $Q = 3$ flexible Fourier form terms in the short run volatility equation. The estimates for all the parameters are shown in the table above. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

We select the number of lagged returns and announcements which are included in our model based on the Schwarz Information Criterion (SIC), which suggests $I = 2$ lagged returns and $J = 0$ lagged surprises in the return equation and with $J = 0$ lagged surprises and $Q = 3$ flexible Fourier form terms in the short term volatility equation.

When we consider the conditional mean equation of the Component-GARCH model, we see that our parameters estimates are very similar to the results for (2). The same twelve variables are significant, although the level of significance has changed somewhat, and producer price index is now also significant whilst it was not for our earlier model. When we look at the size of the coefficients, we see that nonfarm payroll have the largest effect, closely followed by GDP advance and trade balance. However, the effect of a surprise of one standard deviation in an announcement does not result in a change of more than 12 basis points of the gold futures returns for any of the announcements. For the majority of the announcement the effect of a surprise of one standard deviation on the returns is limited between 0 and -1 basis point.

For the conditional volatility equation of our Component-GARCH model, we find that fourteen macroeconomic announcements have a significant effect on the volatility of the gold futures returns. All but two of these, being consumer credit and nonfarm payroll employment, have a significant positive effect. Four announcements have an especially large and positive effect on the volatility when we consider the size of the coefficient, these are GDP advance, durable goods orders, government budget deficit and consumer confidence index for which an absolute surprise of one standard deviation results in an increase of conditional variance between 40 and 50. When we compare this to our findings for (5), we find that the announcements that have a significant effect have almost all remained the same, although surprisingly the sign for nonfarm payroll employment has become negative.

To examine whether the Component-GARCH specification of our model is able to model the intra-day volatility pattern of our high-frequency data correctly, we plot the conditional volatility estimates for the 120 5-minute intervals of the day together with the mean realized standard deviations for those same intervals in Figure 6 on page 29.

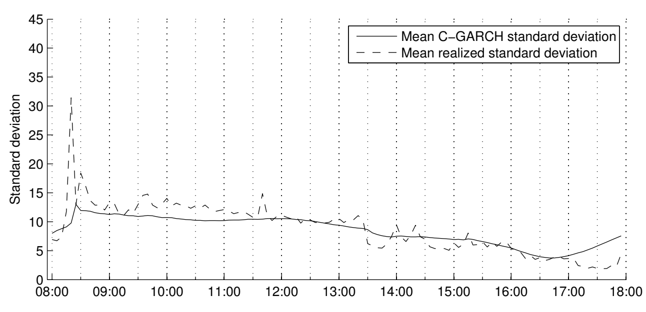


Figure 6 – Daily pattern of conditional volatility estimates of Component-GARCH model and mean realized standard deviation.

We can see that the mean estimated conditional standard deviations are very close to the mean realized standard deviations, with the exception that the model is unable to replicate the spike in volatility when open outcry trading starts at 08:20 a.m.. We do, however, feel that our specification for the conditional volatility is adequate as it is able to properly model the decline in volatility during the day.

Finally, we will examine the contemporaneous effects of the macroeconomic announcements on the volatility of gold futures returns in a similar fashion as we did for the returns themselves. We will use two measures for the volatility and regress those on the surprises of individual announcement types. First, we follow Chulia, Martens, and van Dijk (2010) and consider the realized volatility (RV) for asset i, as given by

$$RV_t = \sqrt{\sum_{i=k,k\neq 0}^{l} (r_{t+i})^2} \tag{7}$$

where r_t is the 5-minute return for the gold futures on interval t. Past research has shown that the effects of announcements on volatility generally last for at least an hour. Therefore, we set $k = -2$ and $l = 11$ so that we use a window that starts 10 minutes before an announcement and includes a full hour after the announcement. We exclude the 5-minute interval directly following the announcement, $i = 0$, to exclude the possible effect of a return-jump caused by an announcement. Subsequently, we follow Chulia, Martens, and van Dijk (2010) and use bipower variation (BPV) as a second measure for volatility, as this is not affected by possible return jumps. The bipower variation is given by

$$BPV_t = \sqrt{\frac{1}{2}\pi \sum_{i=k}^{l-1} \mid r_{t+i} \mid\mid r_{t+i+1} \mid} \tag{8}$$

where r_t is the 5-minute return for the gold futures on interval t. Again, we set $k = -2$ and $l = 11$ so that we use a window that starts 10 minutes before an announcement and includes a full hour after the announcement. We then take the difference of the realized volatility and bipower variation around the window of an announcement and the same window one day earlier to measure the change in volatility. Subsequently, we examine the contemporaneous effects of the macroeconomic announcements on our volatility measures with the regressions

$$\Delta RV_t = \alpha_k + \beta_{k,j} \mid S_{k,t} \mid + \varepsilon_t \tag{9}$$

and

$$\Delta BPV_t = \alpha_k + \beta_{k,j} \mid S_{k,t} \mid + \varepsilon_t \tag{10}$$

to obtain the parameter estimates for the contemporaneous effects of macroeconomic announcements on gold futures return volatility. The results for bipower variation are given in Table 8 on page 31.

Dependent variable	α_k	β_k	R^2
1 – GDP advance	0.128	10.370	0.046
2 – GDP preliminary	14.056***	-13.038	0.082
3 – GDP final	9.976	-0.381	0.000
Real activity			
4 – Nonfarm payroll employment	30.262***	16.329**	0.039
5 – Retail sales	6.813	6.251	0.016
6 – Industrial production	-19.952***	32.671***	0.249
7 – Capacity utilization	-19.306***	31.375***	0.233
8 – Personal income	12.064***	-5.846	0.024
9 – Consumer credit	-8.103*	3.104	0.004
Consumption			
10 – Personal consumption expenditures	7.827*	0.966	0.000
11 – New home sales investment	2.287	2.022	0.001
Investment			
12 – Durable goods orders	3.252	4.025	0.010
13 – Construction spending	11.017*	4.914	0.006
14 – Factory orders	6.283	-8.231	0.018
15 – Business inventories	2.389	2.275	0.002
Government purchases			
16 - Government budget deficit	-2.357	12.822***	0.094
Net exports			
17 – Trade balance	15.725**	-0.965	0.000
Prices			
18 – Producer price index	-3.149	2.914	0.003
19 – Consumer price index	14.740***	-6.126	0.019
Forward-looking			
20 – Consumer confidence index	8.485*	0.136	0.000
21 – NAPM index	4.900	1.019	0.000
22 – Housing starts	4.157	-1.071	0.001
23 – Index of leading indicators	1.580	-5.446	0.013
24 – Initial unemployment claims	10.298***	-0.764	0.000

Table 8 – Contemporaneous effect of macroeconomic news on bipower variation.

This table shows the results for the contemporaneous regressions as given by

$$\Delta BPV_t = \alpha_k + \beta_{k,j} \mid S_{k,t} \mid + \varepsilon_t$$

where ΔBPV_t is the difference between the bipower variation around a macroeconomic announcement minus the bipower variation of the same window one day earlier, and $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

In general, we see that the fact that there is an announcement has more influence on the bipower variation than the magnitude of the surprise in the announcements. Specifically, we see that the event of an announcement has a significant, and positive effect on the gold futures bipower variation for nine of the 24 announcement types. For three variables, the event of an announcement has a negative effect.

When we consider the magnitude of the surprise component in the announcements, we find that the absolute surprise has a significant, and positive effect on bipower variation for nonfarm payroll employment, industrial production, capacity utilization and government budget deficit.

The results for realized volatility show very similar findings and are shown in the Appendix in Table A.2 on page 70.

Subsequently, we estimate models that allow us to examine the asymmetric effects of announcements on gold futures return volatility as given by

$$\Delta RV_t = (\alpha_{1,k} + \beta_{1,k} S_{k,t}) \, D(S_{k,t} < 0) + (\alpha_{2,k} + \beta_{2,k} S_{k,t}) \, D(S_{k,t} > 0) + \varepsilon_t \tag{11}$$

and

$$\Delta BPV_t = (\alpha_{1,k} + \beta_{1,k} S_{k,t}) \, D(S_{k,t} < 0) + (\alpha_{2,k} + \beta_{2,k} S_{k,t}) \, D(S_{k,t} > 0) + \varepsilon_t \tag{12}$$

The results for the asymmetric contemporaneous effects of macroeconomic announcements on the bipower variation of gold futures returns as given by (12) are shown in Table 9 on page 33.

Dependent variable	Negative α_1	Negative β_1	Positive α_2	Positive β_2	R^2	Wald test H_0 : $\alpha_1 = \alpha_2$	Wald test H_0 : $\beta_1 = \beta_2$
1 – GDP advance	25.873**	13.755	-26.218**	33.667***	0.337	11.898***	1.790
2 – GDP preliminary	23.570	10.950	8.996	-14.429	0.156	0.646	2.077
3 – GDP final	2.002	-2.876	11.666	0.983	0.012	0.222	0.048
Real activity							
4 – Nonfarm payroll employment	35.300***	-5.142	14.803	45.886***	0.096	1.259	8.375***
5 – Retail sales	9.462	-4.442	5.063	6.768	0.018	0.163	0.883
6 – Industrial production	-27.707***	-41.888***	-2.693	1.003	0.314	4.469**	10.500***
7 – Capacity utilization	-47.303***	-52.782***	6.159	-4.948	0.407	23.557***	18.059***
8 – Personal income	5.681	-4.717	12.428***	-6.757*	0.031	0.380	0.022
9 – Consumer credit	-7.778	-3.661	-8.405	2.272	0.006	0.004	0.381
Consumption							
10 – Personal consumption expenditures	10.887	2.200	5.494	6.014	0.008	0.346	0.167
11 – New home sales investment	2.329	-3.575	1.937	1.162	0.003	0.001	0.176
Investment							
12 – Durable goods orders	0.421	-9.506	4.772	-0.074	0.028	0.299	1.486
13 – Construction spending	28.028***	3.345	0.825	8.711	0.069	5.268**	0.197
14 – Factory orders	0.499	4.453	10.448	-12.726	0.023	0.587	1.716
15 – Business inventories	12.029	0.808	-1.501	1.062	0.043	2.036	0.001
Government purchases							
16 - Government budget deficit	-3.876	-15.844***	2.554	2.258	0.113	0.570	3.479**
Net exports							
17 – Trade balance	26.044**	10.468	10.087	3.715	0.016	1.587	0.272
Prices							
18 – Producer price index	0.838	1.158	-6.220	5.617	0.009	0.461	0.192
19 – Consumer price index	28.166**	13.835	12.487**	-6.476	0.037	1.626	3.856*
Forward-looking							
20 – Consumer confidence index	7.309	-2.813	9.731	-2.852	0.005	0.070	0.000
21 – NAPM index	3.453	-3.781	5.966	-0.869	0.003	0.061	0.087
22 – Housing starts	8.317	5.154	0.056	2.527	0.009	0.838	0.091
23 – Index of leading indicators	-1.701	6.335	3.292	-3.967	0.023	0.164	0.708
24 – Initial unemployment claims	5.538	-3.741	15.112***	-5.779	0.009	3.703*	0.169

Table 9 – Contemporaneous asymmetric effects of macroeconomic news on bipower variation.
This table shows the results for the contemporaneous regressions taking into account possible asymmetric effects as given by

$$\Delta BPV_t = (\alpha_{1,k} + \beta_{1,k} S_{k,t}) D(S_{k,t} < 0) + (\alpha_{2,k} + \beta_{2,k} S_{k,t}) D(S_{k,t} > 0) + \varepsilon_t$$

where ΔBPV_t is the difference between the bipower variation around a macroeconomic announcement minus the bipower variation of the same window one day earlier, $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k, and $D(\cdot)$is a dummy variable which takes the value 1 if the condition $(\cdot)$ is met. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

These results show, in general, for both negative and positive surprises, that the largest influence of an announcement on the bipower variation comes from the actual occurrence of the announcement and not so much from the magnitude of the absolute surprise in the announcement, this matches our findings from the symmetric analysis. Also, we see that the coefficients for the negative surprises are significant in more cases than for the positive surprises, which coincides with our intuition that bad news has a larger effect on volatility than good news.

The coefficients for the occurrence of a negative surprise are significant and positive for five announcements, and significant and negative for industrial production and capacity utilization. For the magnitude of the surprise in the announcement, we see that negative surprises is significant and raises the volatility for these last two variables together with government budget deficit.

The positive surprises are much less influential than the negative surprises as mentioned earlier. The occurrence of an announcement is significant for four variables and their signs are all positive for all but GDP advance. The coefficients for the surprise component of the announcement are significant for GDP advance, nonfarm payroll employment and personal income.

The use of realized volatility as the regressor results in very similiar estimates, which are shown in the Appendix in Table A.3 on page 71.

5 Multivariate analysis

This section will describe the analysis of the effects of macroeconomic announcements on the comovement of gold, stock and bond futures. We start by looking at the correlation between the different series. Subsequently, we analyse the contemporaneous effects of macroeconomic news on realized correlation. We then continue with a multivariate GARCH model. Finally, we consider a copula approach.

5.1 Correlation

We start our analysis of the comovement between the different futures contracts by examining the Pearson's correlation of the three different contracts in our sample. The correlation for 5-minute, 60-minute and daily return intervals are shown in Table 10 on page 35.

$$\begin{bmatrix} 1.000 & 0.0011 & 0.0617 \\ 0.0011 & 1.000 & -0.0029 \\ 0.0617 & -0.0029 & 1.000 \end{bmatrix}$$

(a) 5-minute return intervals.

$$\begin{bmatrix} 1.000 & -0.0046 & 0.1129 \\ -0.0046 & 1.000 & -0.0369 \\ 0.1129 & -0.0369 & 1.000 \end{bmatrix}$$

(b) 60-minute return intervals.

$$\begin{bmatrix} 1.000 & -0.0210 & 0.1145 \\ -0.0210 & 1.000 & -0.2425 \\ 0.1145 & -0.2425 & 1.000 \end{bmatrix}$$

(c) Daily returns.

Table 10 – Pearson's correlation matrix for gold, S&P500 and U.S. Treasury Bond futures.

The principal conclusion from these matrices is that the correlation between the different series is very weak overall, even though it becomes slightly stronger as the length of the return interval increases. We also see that the correlation between gold and S&P500 futures is positive and very close to zero for the 5-minute return intervals, while it is negative and less close to zero for the 60-minute and daily intervals.

We continue our analysis by examining the contemporaneous effects of macroeconomic announcements on the correlation between gold, S&P500 and U.S. Treasury Bond futures in a similar fashion as was done for the realized volatility and bipower variation before. We define the realized correlation between futures i and j as

$$RC^{*}_{ij,t} = \sum_{k=l,l\neq 0}^{u} \frac{r_{i,t+k} r_{j,t+k}}{RV_{i,t} RV_{j,t}} \quad (13)$$

where $RV_{i,t}$ is the realized variance as defined earlier by (7). We set $k = -2$ and $l = 11$ so that we use a window that starts 10 minutes before an announcement and includes a full hour after the announcement. Just as for the realized variance earlier, we exclude the interval $k = 0$ in the numerator in order to exclude the possible effect of a return-jump caused by an announcement. For this same reason, we follow Barndorff-Nielsen and Shephard (2004) and Chulia, Martens, and van Dijk (2010) and also consider the bipower correlation as given by

$$BPC^{*}_{ij,t} = \frac{\pi}{8} \sum_{k=l}^{u-1} \frac{(\mid r_{i,t+k} + r_{j,t+k} \mid\mid r_{i,t+k+1} + r_{j,t+k+1} \mid - \mid r_{i,t+k} - r_{j,t+k} \mid\mid r_{i,t+k+1} - r_{j,t+k+1} \mid)}{BPV_{i,t} BPV_{j,t}} \quad (14)$$

where $BPV_{i,t}$ is the bipower variation as given earlier by (8). Again, we set $k = -2$ and $l = 11$ so that we use a window that starts 10 minutes before an announcement and includes a full hour after the announcement. In order to ensure that the correlation measures lie on [-1,1] we follow Christiansen and Ranaldo (2007) and Chulia, Martens, and van Dijk (2010), and apply a Fisher transformation on $RC^{*}_{ij,t}$ and $BPC^{*}_{ij,t}$ given by

$$F(x) = \frac{exp(2x^{*}) - 1}{exp(2x^{*}) + 1} \quad (15)$$

We then take the difference between the realized and bipower correlation around the window of an announcement and the same window one day earlier to measure the change in correlation. Subsequently, we examine the contemporaneous effects of the macroeconomic announcement on our correlation measures with the regressions

$$\Delta RC_{ij,t} = \alpha_k + \beta_{k,j} \mid S_{k,t} \mid + \varepsilon_t \quad (16)$$

and

$$\Delta BPC_{ij,t} = \alpha_k + \beta_{k,j} \mid S_{k,t} \mid + \varepsilon_t \quad (17)$$

The results for the bipower correlation of gold and S&P500 futures, and of gold and U.S. Treasury Bond futures are shown in Table 11 on page 37.

Dependent variable	Gold – S&P500 α_k	Gold – S&P500 β_k	Gold – S&P500 R^2	Gold – U.S. Treasury Bonds α_k	Gold – U.S. Treasury Bonds β_k	Gold – U.S. Treasury Bonds R^2
1 – GDP advance	-0.007	-0.010	0.000	-0.060	0.072	0.031
2 – GDP preliminary	-0.029	0.055	0.018	-0.026	-0.049	0.012
3 – GDP final	0.079	-0.036	0.011	0.021	-0.058	0.021
Real activity						
4 – Nonfarm payroll employment	0.001	-0.043	0.010	0.098*	-0.110*	0.050
5 – Retail sales	-0.069	0.047	0.012	0.041	-0.037	0.012
6 – Industrial production	-0.036	0.022	0.001	-0.024	0.042	0.004
7 – Capacity utilization	-0.017	-0.011	0.000	-0.103*	0.168**	0.066
8 – Personal income	-0.010	0.008	0.000	-0.010	0.004	0.000
9 – Consumer credit	-0.039	0.012	0.001	0.069	-0.092	0.038
Consumption						
10 – Personal consumption expenditures	0.022	-0.040	0.011	0.020	-0.039	0.010
11 – New home sales investment	0.015	0.028	0.005	-0.071	0.027	0.004
Investment						
12 – Durable goods orders	-0.021	0.018	0.002	-0.024	-0.011	0.001
13 – Construction spending	-0.010	0.009	0.000	-0.024	0.055	0.013
14 – Factory orders	-0.019	-0.002	0.000	-0.020	0.058	0.013
15 – Business inventories	-0.063	0.024	0.002	0.033	-0.031	0.005
Government purchases						
16 - Government budget deficit	0.047	-0.135	0.040	0.012	-0.082	0.007
Net exports						
17 – Trade balance	-0.019	-0.036	0.003	-0.026	-0.007	0.000
Prices						
18 – Producer price index	0.057	-0.089	0.027	-0.025	0.004	0.000
19 – Consumer price index	-0.142**	0.102	0.030	-0.010	0.010	0.000
Forward-looking						
20 – Consumer confidence index	-0.007	0.013	0.001	0.024	-0.060	0.012
21 – NAPM index	0.001	-0.033	0.005	0.004	-0.043	0.008
22 – Housing starts	-0.152**	0.109*	0.047	0.001	-0.013	0.001
23 – Index of leading indicators	-0.110*	0.196***	0.105	0.079	-0.154**	0.074
24 – Initial unemployment claims	-0.030	0.035	0.006	-0.008	0.001	0.000

Table 11 – Contemporaneous effect of macroeconomic news on bipower correlations for gold and S&P500 futures, and gold and U.S. Treasury Bond futures.

This table shows the results for the contemporaneous regressions as given by

$$\Delta BPC_{ij,t} = \alpha_k + \beta_{k,j} \mid S_{k,t} \mid + \varepsilon_t$$

where $\Delta BPC_{ij,t}$ is the difference between the bipower correlation around a macroeconomic announcement minus the bipower correlation of the same window one day earlier between futures i and j, and $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

For the bipower correlation between gold and S&P500 futures we see that very few macroeconomic announcements have a significant effect. We find that the occurrence of an announcement concerning consumer price index, housing starts or index of leading indicators has a significant negative effect. The magnitude of the absolute surprise in the announcements is only significant for housing starts and index of leading indicators, and is in both cases positive.

When we consider the bipower correlation between gold and U.S. Treasury Bond futures, we see again that very few variables have a significant effect. For nonfarm payroll employment and capacity utilization both the occurrence and the magnitude of an announcement have a significant effect, whilst for index of leading indicators only the magnitude of the surprise is significant.

The results for the analysis with realized correlation as regressor are shown in the Appendix in Table A.4 on page 72, and lead to similar findings.

In order to gain more insight into the effect of good and bad news, subsequently, we estimate models that allow us to examine the asymmetric effects of announcement on the correlation between the three futures contracts as given by

$$\Delta RC_{ij,t} = (\alpha_{1,k} + \beta_{1,k} S_{k,t})\, D\,(S_{k,t} < 0) + (\alpha_{2,k} + \beta_{2,k} S_{k,t})\, D\,(S_{k,t} > 0) + \varepsilon_t \tag{18}$$

and

$$\Delta BPC_t = (\alpha_{1,k} + \beta_{1,k} S_{k,t})\, D\,(S_{k,t} < 0) + (\alpha_{2,k} + \beta_{2,k} S_{k,t})\, D\,(S_{k,t} > 0) + \varepsilon_t \tag{19}$$

The results for the asymmetric contemporaneous effects of macroeconomic announcements on the bipower correlation as given by (19) are shown in Table 12 on page 39 for the correlation between gold and S&P500 futures, and in Table 13 on page 40 for the bipower correlation between gold and U.S. Treasury Bond futures.

Dependent variable	Negative α_1	Negative β_1	Positive α_2	Positive β_2	R^2	Wald test H_0: $\alpha_1 = \alpha_2$	Wald test H_0: $\beta_1 = \beta_2$
1 – GDP advance	-0.038	0.010	0.035	-0.007	0.011	0.077	0.004
2 – GDP preliminary	-0.054	-0.060	-0.019	0.058	0.022	0.027	0.367
3 – GDP final	0.151	0.100	0.061	0.017	0.031	0.178	0.242
Real activity							
4 – Nonfarm payroll employment	-0.088	-0.032	0.143*	-0.180**	0.087	5.623**	1.965
5 – Retail sales	-0.031	-0.022	-0.090	0.052	0.016	0.233	0.262
6 – Industrial production	-0.106	-0.053	-0.010	0.048	0.017	0.397	0.237
7 – Capacity utilization	-0.034	0.079	-0.022	0.087	0.039	0.006	0.001
8 – Personal income	-0.088	-0.139	-0.004	-0.004	0.008	0.368	0.463
9 – Consumer credit	-0.013	-0.003	-0.069	0.021	0.006	0.248	0.042
Consumption							
10 – Personal consumption expenditures	0.104	0.065	-0.004	-0.069	0.041	1.130	1.706
11 – New home sales investment	0.053	-0.055	-0.021	0.021	0.035	0.408	0.465
Investment							
12 – Durable goods orders	-0.023	-0.081	-0.038	-0.026	0.041	0.021	0.313
13 – Construction spending	-0.024	-0.022	-0.001	-0.003	0.001	0.056	0.035
14 – Factory orders	0.046	0.048	-0.058	0.043	0.014	0.996	0.002
15 – Business inventories	-0.200*	-0.098	-0.008	-0.009	0.031	1.791	0.395
Government purchases							
16 - Government budget deficit	-0.004	0.052	0.104	-0.180*	0.057	1.089	1.640
Net exports							
17 – Trade balance	-0.116	-0.081	0.025	-0.108	0.019	0.809	0.023
Prices							
18 – Producer price index	0.102	0.132	0.034	-0.071	0.030	0.240	2.058
19 – Consumer price index	-0.170	-0.056	-0.168**	0.283***	0.107	0.000	4.183**
Forward-looking							
20 – Consumer confidence index	0.043	0.043	-0.053	0.070	0.017	0.905	0.058
21 – NAPM index	-0.022	0.013	0.011	-0.042	0.007	0.072	0.217
22 – Housing starts	-0.199**	-0.110	-0.099	0.092	0.062	0.593	2.806*
23 – Index of leading indicators	-0.030	-0.065	-0.114*	0.239***	0.119	0.262	2.536
24 – Initial unemployment claims	-0.044	-0.053	-0.016	0.016	0.007	0.290	1.663

Table 12 – Contemporaneous asymmetric effect of macroeconomic news on bipower correlation.
This table shows the results for the contemporaneous regressions taking into account possible asymmetric effects as given by

$$\Delta BPC_t = (\alpha_{1,k} + \beta_{1,k} S_{k,t}) \, D\left(S_{k,t} < 0\right) + (\alpha_{2,k} + \beta_{2,k} S_{k,t}) \, D\left(S_{k,t} > 0\right) + \varepsilon_t$$

where $\Delta BPC_{ij,t}$ is the difference between the bipower correlation around a macroeconomic announcement minus the bipower correlation of the same window one day earlier between futures i and j, $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k, and $D(\cdot)$is a dummy variable which takes the value 1 if the condition $(\cdot)$ is met. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

First, we consider the bipower correlation between gold and S&P500 futures. When we consider negative surprises, we find that the only significant variables are the occurrence of a negative surprise concerning business inventories or housing starts. For the positive announcements nonfarm payroll employment, consumer price index and index of leading indicator have a significant effect for both the intercept and the slope coefficient. For consumer price index and index of leading indicators the occurrence and magnitude of a positive announcement decrease the bipower variation, whilst this effect is reversed for nonfarm payroll employment.

Dependent variable	Negative α_1	Negative β_1	Positive α_2	Positive β_2	R^2	Wald test H_0 : $\alpha_1 = \alpha_2$	Wald test H_0 : $\beta_1 = \beta_2$
1 – GDP advance	-0.144	-0.149	0.068	-0.027	0.092	1.038	0.392
2 – GDP preliminary	-0.139	-0.027	0.016	-0.075	0.034	0.438	0.051
3 – GDP final	0.213	0.262*	-0.040	0.148	0.244	1.422	0.448
Real activity							
4 – Nonfarm payroll employment	0.110	0.128*	0.078	-0.070	0.054	0.079	2.564
5 – Retail sales	0.019	0.022	0.053	-0.040	0.013	0.108	0.257
6 – Industrial production	-0.020	-0.059	-0.018	0.002	0.008	0.000	0.113
7 – Capacity utilization	-0.069	-0.134	-0.115	0.182	0.068	0.113	3.445*
8 – Personal income	-0.117	-0.047	0.027	0.010	0.036	1.050	0.080
9 – Consumer credit	0.018	0.022	0.120	-0.167**	0.062	0.889	2.757*
Consumption							
10 – Personal consumption expenditures	0.004	0.013	0.041	-0.104	0.022	0.115	1.204
11 – New home sales investment	-0.068	-0.016	-0.070	0.030	0.004	0.000	0.150
Investment							
12 – Durable goods orders	0.006	0.029	-0.052	0.002	0.004	0.245	0.066
13 – Construction spending	-0.066	-0.103	0.005	0.006	0.024	0.411	0.907
14 – Factory orders	-0.091	-0.108	0.022	0.008	0.026	0.905	0.769
15 – Business inventories	0.107	0.078	-0.004	0.003	0.018	0.851	0.405
Government purchases							
16 - Government budget deficit	-0.040	-0.017	0.102	-0.317	0.041	1.823	1.316
Net exports							
17 – Trade balance	0.013	-0.034	-0.034	-0.068	0.037	0.109	0.047
Prices							
18 – Producer price index	-0.020	-0.023	-0.032	-0.005	0.003	0.009	0.018
19 – Consumer price index	0.072	0.050	-0.028	0.028	0.006	0.369	0.020
Forward-looking							
20 – Consumer confidence index	0.064	0.024	-0.011	-0.119	0.067	0.404	1.213
21 – NAPM index	0.191*	0.211**	-0.082	0.031	0.067	4.067**	2.010
22 – Housing starts	0.029	0.016	-0.032	-0.001	0.006	0.224	0.020
23 – Index of leading indicators	-0.229*	-0.212	0.125**	-0.223***	0.158	5.586**	0.003
24 – Initial unemployment claims	0.002	0.029	-0.019	0.036	0.006	0.171	0.018

Table 13 – Contemporaneous asymmetric effect of macroeconomic news on bipower correlation.
This table shows the results for the contemporaneous regressions taking into account possible asymmetric effects as given by

$$\Delta BPC_t = (\alpha_{1,k} + \beta_{1,k} S_{k,t})\, D\,(S_{k,t} < 0) + (\alpha_{2,k} + \beta_{2,k} S_{k,t})\, D\,(S_{k,t} > 0) + \varepsilon_t$$

where $\Delta BPC_{ij,t}$ is the difference between the bipower correlation around a macroeconomic announcement minus the bipower correlation of the same window one day earlier between futures i and j, $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k, and $D\,(\cdot)$is a dummy variable which takes the value 1 if the condition $(\cdot)$ is met. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

When we examine the results for the bipower correlation between gold and U.S. Treasury Bond futures, we find again that not many announcements have a significant contemporaneous effect. For the announcements with a negative surprise we find that the fact that there is a negative announcement concerning the NAPM index or index of leading indicators, and the negative surprise in GDP final, nonfarm payroll employment and NAPM index have a significant effect.

For the positive announcements, only consumer credit and index of leading indicators have a significant effect.

The regressions for realized correlation show similar results and can be found in the Appendix in Table A.5 on page 73 and Table A.6 on page 74.

Ultimately, when we consider the correlation between the different assets, we find that macroeconomic announcements have only little influence. Also, we find very little proof for the safe haven role of gold.

5.2 Multivariate GARCH

We continue our analysis on the comovement of gold, S&P500 and U.S. Treasury Bond futures with multivariate GARCH models. Specifically, we consider the Dynamic Conditional Correlation (DCC) class of models, which allow us to decompose the conditional covariance of assets into their individual variances and their correlations.

Concretely, the decomposition of the conditional covariance matrix H_t is given by

$$H_t = D_t R_t D_t \tag{20}$$

where D_t is a matrix with the conditional standard deviations, $\sqrt{h_{ii,t}}$ on the diagonal, and R_t is the conditional correlation matrix. For the bivariate case, the conditional covariance matrix H_t can be expressed as

$$H_t = \begin{pmatrix} \sqrt{h_{11,t}} & 0 \\ 0 & \sqrt{h_{22,t}} \end{pmatrix} \begin{pmatrix} 1 & \rho_{12,t} \\ \rho_{12,t} & 1 \end{pmatrix} \begin{pmatrix} \sqrt{h_{11,t}} & 0 \\ 0 & \sqrt{h_{22,t}} \end{pmatrix} \tag{21}$$

A difficulty with the DCC class of models is that we need to ensure that the conditional correlation matrix is positive definite. Engle (2002), Tse and Tsui (2002), and Christodoulakis and Satchell (2002) have proposed different models and methods to ensure this positive definiteness. The model of Engle (2002), for instance, is given by

$$\begin{aligned} Q_t &= \begin{pmatrix} q_{11,t} & q_{12,t} \\ q_{21,t} & q_{22,t} \end{pmatrix} \\ Q_t^* &= \begin{pmatrix} \sqrt{q_{11,t}} & 0 \\ 0 & \sqrt{q_{22,t}} \end{pmatrix} \\ R_t &= \left(Q_t^*\right)^{-1} Q_t \left(Q_t^*\right)^{-1} \end{aligned} \tag{22}$$

where the positive definite matrix Q_t is given by

$$Q_t = (1 - \gamma - \delta)\, \overline{Q} + \gamma \mathbf{u}_{t-1} \mathbf{u}_{t-1}^{'} + \delta Q_{t-1} \tag{23}$$

where $\overline{Q}$ is the unconditional correlation matrix of $\hat{u}_{i,t} = \frac{\varepsilon_{i,t}}{\sqrt{h_{ii,t}}}$.

As our analysis reduces to two bivariate cases, being the relationship between gold and S&P500 futures, and the relationship between gold and U.S. Treasury Bond futures, it is more convenient to use the approach of Christodoulakis and Satchell (2002). While only applicable to the bivariate case, the positive definiteness of the correlation matrix is ensured by applying the same Fisher transformation as before as given by (15). This allows us to express the process of the conditional correlation as a GARCH model given by

$$r^*_{12,t} = \omega_{12} + \gamma u_{1,t-1} u_{2,t-1} + \delta r^*_{12,t-1} \tag{24}$$

where $u_{i,t} = \frac{\varepsilon_{i,t}}{\sqrt{h_{ii,t}}}$. As we are interested in the effects of macroeconomic announcements on the relationship between the different assets we include these as exogenous variables which results in

$$r^*_{12,t} = \omega_{12} + \gamma u_{1,t-1} u_{2,t-1} + \delta r^*_{12,t-1} + \sum_{k=1}^{K} \beta_k \mid S_{k,t} \mid \tag{25}$$

where $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k as given by (1). We then apply the Fisher transformation to force the correlation to lie on $[-1, 1]$ as given by

$$r_{12,t} = \frac{exp\left(2r^*_{12,t}\right) - 1}{exp\left(2r^*_{12,t}\right) + 1} \tag{26}$$

Finally, the conditional covariance is then calculated with

$$h_{12,t} = r_{12,t}\sqrt{h_{11,t} h_{22,t}} \tag{27}$$

where the conditional variances are estimated using the Component-GARCH model as given by (6).

We estimate the parameters of the model using a two-step quasi-maximum likelihood procedure as suggested in Engle (2002). This procedure allows us to decompose the maximum likelihood, just like the conditional covariance matrix, in a part for the conditional variances and a part that concerns the correlation. We estimate the model for returns aggregated to 5-minute, 60-minute and daily intervals using Bollerslev-Woolridge robust standard errors, for which the results are shown in Table 14 on page 43 and Table 15 on page 45.

Dependent variable	5-minute – β_k	60-minute – β_k	Daily – β_k
1 – GDP advance	0.122	-0.109	-0.400***
2 – GDP preliminary	-0.119	0.860	-1.116***
3 – GDP final	0.000	-0.086	-0.389**
Real activity			
4 – Nonfarm payroll employment	0.022	-0.016	-0.879***
5 – Retail sales	-0.014	-0.232	0.822***
6 – Industrial production	-0.128	0.148	-0.078
7 – Capacity utilization	0.384	-0.184	0.345
8 – Personal income	-0.126	0.110	-0.134
9 – Consumer credit	-0.532	0.263	0.448**
Consumption			
10 – Personal consumption expenditures	-0.003	-0.277	0.089
11 – New home sales investment	-0.128	-0.348	0.766***
Investment			
12 – Durable goods orders	0.060	0.172	0.161
13 – Construction spending	0.205	-0.127	0.043
14 – Factory orders	-0.090	0.063	0.484
15 – Business inventories	-0.006	0.051	-0.206
Government purchases			
16 - Government budget deficit	0.030	0.045	-1.128***
Net exports			
17 – Trade balance	-0.020	-0.144	-0.100
Prices			
18 – Producer price index	0.053	0.119	-0.869**
19 – Consumer price index	-0.008	0.082	-0.565**
Forward-looking			
20 – Consumer confidence index	-0.003	0.262	-0.248
21 – NAPM index	0.032	0.011	-0.149
22 – Housing starts	-0.026	0.234	-1.239***
23 – Index of leading indicators	-0.076	-0.085	0.333*
24 – Initial unemployment claims	-0.004	0.077	0.429**

Table 14 – Parameter estimates for Dynamic Conditional Correlation model with exogenous variables for gold and S&P500 futures.

This table shows the results for Dynamic Conditional Correlation model for gold and S&P500 futures as given by

$$r^*_{12,t} = \omega_{12} + \gamma u_{1,t-1}u_{2,t-1} + \delta r_{12,t-1} + \sum_{k=1}^{K}\beta_k \mid S_{k,t} \mid$$

and

$$r_{12,t} = \frac{exp\left(2r^*_{12,t}\right) - 1}{exp\left(2r^*_{12,t}\right) + 1}$$

where $u_{i,t} = \frac{\varepsilon_{i,t}}{\sqrt{h_{ii,t}}}$, $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k, and the last equation is the Fisher transformation to ensure that $r_{12,t}$ lies on $[-1, 1]$. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

When we examine the results for the gold and S&P500 futures, we see that for 5-minute and hourly return intervals none of the 24 macroeconomic announcements have a significant effect. When we consider the daily returns, we see that thirteen macroeconomic announcements have significant effect, of which eight have a negative effect and thus decrease the correlation, and five have a positive effect thus increasing the correlation. The difference in the number of significant variables between the 5-minute and daily returns is most likely due to the fact that the correlation between the assets is higher for the longer interval.

Dependent variable	5-minute – β_k	60-minute – β_k	Daily – β_k
1 – GDP advance	-0.035	0.075	0.751***
2 – GDP preliminary	0.060	0.011	1.246***
3 – GDP final	0.014	0.037	0.943***
Real activity			
4 – Nonfarm payroll employment	0.112	0.077	0.782***
5 – Retail sales	0.173*	0.044	-1.387***
6 – Industrial production	0.018	-0.014	-0.236**
7 – Capacity utilization	0.031***	-0.081**	-0.674*
8 – Personal income	0.028	0.066*	-0.021
9 – Consumer credit	-0.013	-0.101	-0.878***
Consumption			
10 – Personal consumption expenditures	0.096	0.080	0.015
11 – New home sales investment	0.089	0.091	-0.264
Investment			
12 – Durable goods orders	0.134	-0.126***	-0.274
13 – Construction spending	-0.048	0.015	0.599***
14 – Factory orders	0.003	0.080**	-0.686**
15 – Business inventories	0.136	0.020	-0.165
Government purchases			
16 - Government budget deficit	0.015*	0.041	0.963***
Net exports			
17 – Trade balance	0.058	0.104*	0.277
Prices			
18 – Producer price index	0.023	-0.131*	1.875***
19 – Consumer price index	0.208*	-0.004	-0.224
Forward-looking			
20 – Consumer confidence index	0.017	-0.125	1.124***
21 – NAPM index	-0.037	0.047**	0.264*
22 – Housing starts	0.052	0.142	1.073***
23 – Index of leading indicators	-0.069	-0.017	-0.905***
24 – Initial unemployment claims	0.211*	-0.001	-0.664***

Table 15 – Parameter estimates for Dynamic Conditional Correlation model with exogenous variables for gold and U.S. Treasury Bond futures.

This table shows the results for Dynamic Conditional Correlation model for gold and U.S. Treasury Bond futures as given by

$$r^*_{12,t} = \omega_{12} + \gamma u_{1,t-1}u_{2,t-1} + \delta r_{12,t-1} + \sum_{k=1}^{K} \beta_k \mid S_{k,t} \mid$$

and

$$r_{12,t} = \frac{exp\left(2r^*_{12,t}\right) - 1}{exp\left(2r^*_{12,t}\right) + 1}$$

where $u_{i,t} = \frac{\varepsilon_{i,t}}{\sqrt{h_{ii,t}}}$, $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k, and the last equation is the Fisher transformation to ensure that $r_{12,t}$ lies on $[-1, 1]$. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

For the DCC model for gold and U.S. Treasury Bond futures, we see that five of the 24 types of macroeconomic announcements have a significant effect on the correlation when we consider 5-minute return intervals, all of which are positive. For the hourly returns, we see that seven announcements have significant effects, of which four are positive and three are negative. Finally, for the daily returns, we see that seventeen sources of macroeconomic news have a significant effect, of which ten are positive and 7 are negative.

In order to allow for a clearer distinction between the effects of positive and negative announcements, we continue by examining the asymmetric effects of the macroeconomic announcements. The conditional correlation is then given by

$$r^*_{12,t} = \omega_{12} + \gamma u_{1,t-1} u_{2,t-1} + \delta r_{12,t-1} + \sum_{k=1}^{K} \sum_{k=1}^{K} \beta_k S_{k,t} D\left(S_{k,t} < 0\right) + \sum_{k=1}^{K} \phi_k S_{k,t} D\left(S_{k,t} > 0\right) \tag{28}$$

where we still use the Fisher transformation as given by (15) in order to ensure that $r_{12,t}$ lies on $[-1, 1]$. The results for the asymmetric DCC model are shown in Table 16 on page 47 and Table 17 on page 49 for gold and S&P500 futures, and gold and U.S. Treasury Bond futures, respectively.

Dependent variable	5-minute β_k	5-minute ϕ_k	60-minute β_k	60-minute ϕ_k	Daily β_k	Daily ϕ_k
1 – GDP advance	-0.066	0.253	0.221	0.324	0.458	-0.306**
2 – GDP preliminary	0.046	-0.247	0.303	0.318	0.929	-1.080**
3 – GDP final	-0.389	-0.111	0.323	0.270	0.251	1.035**
Real activity						
4 – Nonfarm payroll employment	-0.060	-0.198	-0.116	0.109	0.832***	-0.494
5 – Retail sales	-0.029	-0.061	0.183	0.336	-1.675**	0.753***
6 – Industrial production	-0.060***	-0.102	-0.231	0.298	-0.643	-0.153
7 – Capacity utilization	-0.171	0.643	-0.170	0.300	0.862	1.130
8 – Personal income	-0.214	-0.167	0.303	0.036	0.133	0.079
9 – Consumer credit	0.393*	-0.840***	-0.667***	0.153	-0.452	0.362
Consumption						
10 – Personal consumption expenditures	0.108	-0.035	0.122	0.196	0.382	0.573
11 – New home sales investment	0.161	-0.055	0.305	0.095	-0.297	0.721**
Investment						
12 – Durable goods orders	-0.050	0.079	0.247	0.144	0.803***	0.139
13 – Construction spending	-0.197*	0.212	0.126	0.095	0.104	0.441
14 – Factory orders	0.016	-0.543*	-0.098	0.310	-0.820**	-1.636***
15 – Business inventories	-0.013*	-0.029	0.102	0.267	-0.508	-0.427
Government purchases						
16 - Government budget deficit	-0.027	0.059	0.051	0.329	0.930***	-1.224***
Net exports						
17 – Trade balance	0.008*	-0.019	0.277	0.169	0.115	0.008
Prices						
18 – Producer price index	-0.253	-0.014	0.170	0.319	1.330***	-0.401
19 – Consumer price index	-0.006	-0.026	0.102	0.114	0.576*	-0.317
Forward-looking						
20 – Consumer confidence index	-0.031	-0.095	-0.212	0.143	0.746**	0.494
21 – NAPM index	-0.151	-0.100	0.075	0.387	0.082	0.229
22 – Housing starts	0.083	-0.006	0.201	0.246	1.539***	-1.209
23 – Index of leading indicators	0.095	-0.064	0.199	0.104	-0.892	0.254
24 – Initial unemployment claims	-0.018	-0.057	-0.078	-0.226	-0.357	-0.581***

Table 16 – Parameter estimates for Dynamic Conditional Correlation model with asymmetric effects of exogenous variables for gold and S&P500 futures.

This table shows the results for Dynamic Conditional Correlation model for gold and S&P500 futures as given by

$$r^*_{12,t} = \omega_{12} + \gamma u_{1,t-1}u_{2,t-1} + \delta r_{12,t-1} + \sum_{k=1}^{K}\sum_{k=1}^{K}\beta_k S_{k,t} D\left(S_{k,t} < 0\right) + \sum_{k=1}^{K}\phi_k S_{k,t} D\left(S_{k,t} > 0\right)$$

and

$$r_{12,t} = \frac{exp\left(2r^*_{12,t}\right) - 1}{exp\left(2r^*_{12,t}\right) + 1}$$

where $u_{i,t} = \frac{\varepsilon_{i,t}}{\sqrt{h_{ii,t}}}$, $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k, the last equation is the Fisher transformation to ensure that $r_{12,t}$ lies on $[-1, 1]$, and $D\left(\cdot\right)$is a dummy variable which takes the value 1 if the condition $(\cdot)$ is met. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

Considering the asymmetric DCC model for gold and S&P500 futures, for 5-minute intervals we find that five variables have a significant effect in case of a negative surprise, and two have a significant effect in case of a positive surprise. For the hourly returns, only consumer credit has a significant and negative effect in case of a negative surprise, and no announcements have a in case of a positive surprise. When we examine the results for daily returns, we see that nine announcements are significant for negative surprises and eight are significant for positive surprises, although the announcements that are significant differ between positive and negative surprises.

For the daily returns, the majority of the significant coefficients for negative surprises are positive, indicating that a negative surprise decreases the correlation. Whilst it is hard to interpret whether this decrease only suggest that the comovement between gold and S&P500 futures becomes weaker, or actually stronger but negatively correlated, this could suggest that gold acts as a safe haven for S&P500 futures. For the positive surprises the majority of the significant effects is negative, suggesting that a positive surprises also decreases the correlation between both assets.

Dependent variable	5-minute		60-minute		Daily	
	β_k	ϕ_k	β_k	ϕ_k	β_k	ϕ_k
1 – GDP advance	-0.091	-0.310	0.761	-0.263	-0.680	1.086***
2 – GDP preliminary	-0.081	0.193	1.155	-0.089	1.988***	1.437***
3 – GDP final	-0.024	0.000	-0.731*	0.202	-0.827***	1.147***
Real activity						
4 – Nonfarm payroll employment	-0.224***	-0.026	-0.443	0.210	-0.394	0.941
5 – Retail sales	0.182	0.709***	-0.703	-0.135	1.575	1.341***
6 – Industrial production	-0.017	0.093	-0.075	-0.286	-0.232	-0.191**
7 – Capacity utilization	-0.066	0.117	0.016	0.556	1.924	0.545
8 – Personal income	-0.023	0.046	-1.256	0.149	-0.382	-0.011
9 – Consumer credit	0.093	-0.023	-0.069	0.296	0.993**	-0.426
Consumption						
10 – Personal consumption expenditures	-0.403	0.048	0.041	0.206	-0.089	-0.103
11 – New home sales investment	-0.131	0.335	-0.296	0.105	0.476	0.619*
Investment						
12 – Durable goods orders	-0.210	0.083	0.031	-0.251	-1.126***	-0.144
13 – Construction spending	0.033	-0.204	0.098	-0.121	-0.480**	0.672*
14 – Factory orders	-0.068	-0.089	0.257	0.036	-0.350	0.602
15 – Business inventories	-0.063	0.456	0.073	-0.694	-0.678	0.144
Government purchases						
16 - Government budget deficit	0.086	0.106**	0.086	-0.526	-0.937***	0.650
Net exports						
17 – Trade balance	-0.002	0.156	0.121	0.243	-0.361	0.358
Prices						
18 – Producer price index	0.057	0.048	0.271	-0.145	-1.006	1.829***
19 – Consumer price index	-0.182	0.335	-0.262	0.541	0.425	0.603**
Forward-looking						
20 – Consumer confidence index	-0.048	0.014	-0.027	-0.021	-0.781*	1.702***
21 – NAPM index	0.217	0.005	-0.078	-0.382	0.636	-0.039
22 – Housing starts	-0.102	0.090	-0.172	-0.208	-1.580***	0.679
23 – Index of leading indicators	0.239	-0.143	0.078	-0.028	-0.359	-0.874***
24 – Initial unemployment claims	-0.134	0.052	-0.098	0.089	-0.220	0.606

Table 17 – Parameter estimates for Dynamic Conditional Correlation model with asymmetric effects of exogenous variables for gold and U.S. Treasury Bond futures.

This table shows the results for Dynamic Conditional Correlation model for gold and U.S. Treasury Bond futures as given by

$$r^*_{12,t} = \omega_{12} + \gamma u_{1,t-1}u_{2,t-1} + \delta r_{12,t-1} + \sum_{k=1}^{K}\sum_{k=1}^{K}\beta_k S_{k,t} D\left(S_{k,t} < 0\right) + \sum_{k=1}^{K}\phi_k S_{k,t} D\left(S_{k,t} > 0\right)$$

and

$$r_{12,t} = \frac{exp\left(2r^*_{12,t}\right) - 1}{exp\left(2r^*_{12,t}\right) + 1}$$

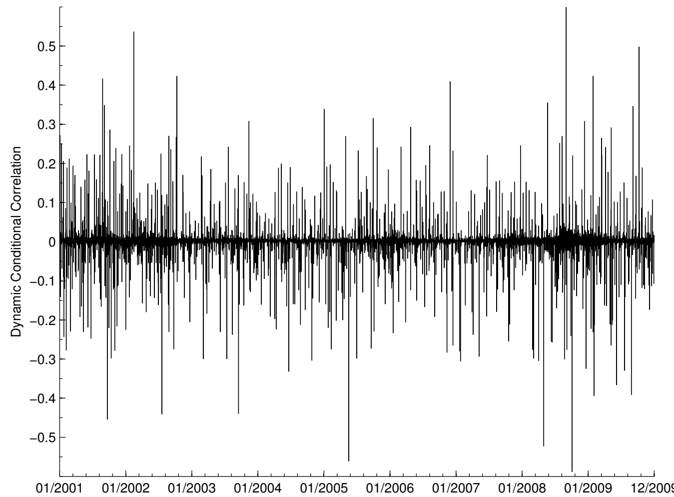
where $u_{i,t} = \frac{\varepsilon_{i,t}}{\sqrt{h_{ii,t}}}$, $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k, the last equation is the Fisher transformation to ensure that $r_{12,t}$ lies on $[-1, 1]$, and $D\left(\cdot\right)$is a dummy variable which takes the value 1 if the condition $(\cdot)$ is met. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

For the relationship between gold and U.S. Treasury Bond futures, we find that three of the announcements have significant, and negative, effects for the 5-minute returns. For the negative surprises, only nonfarm payroll employment has a significant effect, whilst for the positive surprises retail sales and government budget deficit have a positive and significant effect.

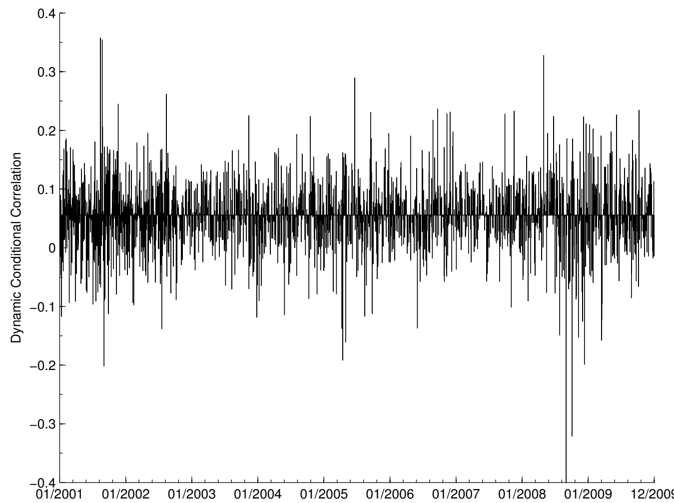
For the hourly returns, we find that only GDP final has a significant effect in the case of a negative surprise.

Considering daily returns, we find that eight of the 24 announcements have a significant effect in case of negative surprises, of which six have a negative coefficient. For the positive surprises, we see that eleven announcements have a significant effect, of which nine are positive, indicating that positive news increases the comovement between gold and U.S. Treasury Bond futures. Both these findings suggest that gold futures do not act as a safe haven for U.S. Treasury Bond futures.

Finally, we examine the fitted conditional correlation from the DCC model for 5-minute returns. The evolution of the conditional correlation is shown in Figure 7 on page 51



(a) Gold and S&P500 futures.



(b) Gold and U.S. Treasury Bond futures.

Figure 7 – Estimated Dynamic Conditional Correlation for asymmetric model for 5-minute returns.

From these figures we can see that the conditional correlation for gold and S&P500 futures centers around zero, and is relatively stable with most of the fitted correlations lying between 0.2 and -0.2. For gold and U.S. Treasury Bond futures, the correlation is centered a little higher, around 0.05, with the majority of the fitted correlations lying between 0.2 and -0.2 again. Some statistics for the conditional correlations are shown in Table 18 on page 52.

	Gold – S&P500	Gold – U.S. Treasury Bond
Mean	0.002	0.056
Standard deviation	0.009	0.005

Table 18 – Statistics for fitted Dynamic Conditional Correlations of asymmetric DCC model.

All things considered, our findings for the Dynamic Conditional Correlation models give us ambiguous results for the role of gold as a safe haven. The correlations between the assets are very low over the whole sample, suggesting that gold moves independently from S&P500 and U.S. Treasury Bond futures and thus offers some possibilities to reduce risk in times of financial distress, there is little proof for any hedging capacity however. For the S&P500 futures specifically, the proof of gold acting as a safe haven is ambiguous at best. Whilst for the U.S. Treasury Bond futures, the findings suggest that that they are actually more likely to move together with gold, which supports gold's role as a safe haven as U.S. Treasury Bonds are considered a generally considered as a safe asset.

5.3 Copulas

Another method to model the dependence between assets is based on copulas, which were first introduced by Sklar (1959). The theory of copulas allows us to express the joint distribution of random variables as a function of the marginal distributions, and is a result of the following theorem.

Theorem (Sklar (1959)). *Given a joint cumulative distribution function $F(x_1, \ldots, x_n)$ for random variables $X_1, \ldots, X_n$ with marginal cumulative distribution function $F_1(x_1), \ldots, F_n(x_n)$. If $F_1(x_1), \ldots, F_n(x_n)$ are continuous, then there exists a unique function $C(\cdot)$ such that F can be written as a function of its marginals:*

$$F(x_1, \ldots, x_n) = C[F_1(x_1), \ldots, F_n(x_n)]$$

where $C(u_1, \ldots, u_n)$ is a joint distribution function with uniform marginals.

The aforementioned function C is the so called copula function. When we consider only continuous and differentiable F_i, we can write the joint density $f(x_1, \ldots, x_n)$ as

$$f(x_1, \ldots, x_n) = f_1(x_1) \cdot \ldots \cdot f_n(x_n) \cdot c[F_1(x_1), \ldots, F_n(x_n)] \tag{29}$$

where $f_i(x_i)$ is the density that corresponds to $F_i(x_i)$, and c is the copula density $c = \frac{\partial C^n}{(\partial F_1 \ldots \partial F_n)}$. This shows that the joint density of random variables can be written as the product of the marginal densities and the copula density.

The joint distribution $F(x_1, \ldots, x_n)$ holds all the univariate and multivariate information for the random variables $X_1, \ldots, X_n$, but since the marginal distributions $F_1(x_1), \ldots, F_n(x_n)$ contain only univariate information for the individual random variables X_i, it follows that the copula function $C(\cdot)$ holds all the information on the dependence between the random variables. We will therefore examine the effect of macroeconomic news announcements on the copula function.

A large variety of copulas are currently used in economic applications, which we will separate into two groups. The first group that we can discern consists of Gaussian and Student t copulas, which are derived from their multivariate counterparts. These copulas are of an elliptical form, and therefore do not allow for different dependencies for different tails.

The second family that we consider is that of the Archimedean copulas, which follow from generator functions. There are many different Archimedean copulas, all allowing for different forms and dependencies due to the flexibility of generator functions. Especially interesting are those that allow for asymmetrical tail dependencies, as it generally accepted that returns exhibit a difference in comovement between extreme negative and positive returns. Examples of Archimedean copulas that allow for asymmetric tail dependence are the Gumbel copula, which allows for upper-upper tail dependence, and the Clayton copula, which allows for lower-lower tail dependence.

As mentioned above, the tail dependence of a copula measures the comovement of assets in the tails of their joint distribution. For copulas, the lower-lower tail dependence is defined as

$$\lambda_{LL} = \lim_{v \downarrow 0} P\left(X_1 < F_1^{-1}(v) \mid X_2 < F_2^{-1}(v)\right) = \frac{C(v,v)}{v} \tag{30}$$

and, similarly, the upper-upper tail dependence is given by

$$\lambda_{UU} = \lim_{v \uparrow 1} P\left(X_1 > F_1^{-1}(v) \mid X_2 > F_2^{-1}(v)\right) = \frac{1-2v+C(v,v)}{1-v} \tag{31}$$

where $X_i = F_i(X_i)$, and F_i^{-1} is the generalized inverse distribution function of X_i.

We follow Patton (2006) and consider the symmetrized Joe-Clayton copula, as this is one of the few copulas that allows for different tail dependence in both the upper-upper and lower-lower quadrant. The Joe-Clayton copula has two parameters, τ^L and τ^U, which represent the lower-lower and upper-upper tail dependence respectively. The Joe-Clayton copula function is given by

$$\begin{aligned} C_{JC}\left(u,v \mid \tau^U,\tau^L\right) &= 1-\left(1-\left\{[1-(1-u)^{\kappa}]^{-\gamma}+[1-(1-v)^{\kappa}]^{-\gamma}-1\right\}^{-\gamma/1}\right)^{1/\kappa} \\ where \quad \kappa &= \frac{1}{\log_2\left(2-\tau^U\right)} \\ \gamma &= \frac{-1}{\log_2\left(2-\tau^L\right)} \\ and \quad \tau^U,\tau^L &\in (0,1) \end{aligned} \tag{32}$$

A problem with the Joe-Clayton copula is that for equal tail dependencies, $\tau^U = \tau^L$, there is asymmetry in the copula function. The symmetrized Joe-Clayton is a slightly modified version of the Joe-Clayton copula and is suggested to overcome this asymmetry by applying a Laplace transformation to the Clayton copula, which results in the symmetrized Joe-Clayton copula, as given by

$$C_{SJC}\left(u, v \mid \tau^U, \tau^L\right) = 0.5 \cdot \left(C_{JC}\left(u, v \mid \tau^U, \tau^L\right) + C_{JC}\left(1-u, 1-v \mid \tau^L, \tau^U\right) + u + v - 1\right) \tag{33}$$

While normally the lower-lower and upper-upper tail dependence are the measures of interest for assets, in our case of gold and the hypothesis that gold acts as a safe haven, we are interested in the upper-lower and lower-upper tail dependence. We define the lower-upper tail dependence as

$$\lambda_{LU} = \lim_{v \downarrow 0} P\left(X_1 < F_1^{-1}(v) \mid X_2 > F_2^{-1}(1-v)\right) = \frac{v - C(v, 1-v)}{v} \tag{34}$$

and, similarly, the upper-lower tail dependence as

$$\lambda_{UL} = \lim_{v \uparrow 1} P\left(X_1 > F_1^{-1}(1-v) \mid X_2 < F_2^{-1}(v)\right) = \frac{1 - v - C(1-v, v)}{1-v} \tag{35}$$

A problem is however that the symmetrized Joe-Clayton does not provide us with a direct way to estimate the upper-lower and lower-upper tail dependence. Therefore, we apply a transformation on the variables and derive the upper-lower and lower-upper tail dependence using the lower-lower and upper-upper tail dependence. We use the transformation $(X_1, X_2) = \left(X_1, 1 - X_2^{'}\right)$ to rotate X_2 $90°$, with the result that

$$\begin{aligned}
\lambda_{LL} &= \lim_{v \downarrow 0} P\left(X_1 < F_1^{-1}(v) \mid X_2 < F_2^{-1}(v)\right) \\
&= \lim_{v \downarrow 0} P\left(X_1 < F_1^{-1}(v) \mid 1 - X_2^{'} < F_2^{-1}(v)\right) \\
&= \lim_{v \downarrow 0} P\left(X_1 < F_1^{-1}(v) \mid X_2^{'} > F_2^{-1}(1-v)\right) \\
&= \lambda_{LU}
\end{aligned}$$

and

$$\begin{aligned}
\lambda_{UU} &= \lim_{v \uparrow 1} P\left(X_1 > F_1^{-1}(v) \mid X_2 > F_2^{-1}(v)\right) \\
&= \lim_{v \uparrow 1} P\left(X_1 > F_1^{-1}(v) \mid 1 - X_2^{'} > F_2^{-1}(v)\right) \\
&= \lim_{v \uparrow 1} P\left(X_1 > F_1^{-1}(v) \mid X_2^{'} < F_2^{-1}(1-v)\right) \\
&= \lambda_{UL}
\end{aligned}$$

As we are interested in the evolution of the joint density of assets, and the effect of the macroeconomic announcements thereon, we need to allow for time variation in our copula model. There are several ways to accomplish this. In our case, we assume that the form of the copula function remains the same over the entire sample, instead of a copula form that is regime switching. To account for the time variation we allow the parameters of the copula function to change over time following an ARMA-like process, where this process is given by

$$\tau_t^i = \Lambda\left(\omega_i + \alpha_i \tau_{t-1}^i + \beta_i \cdot \frac{1}{10}\sum_{j=1}^{10} \mid x_{1,t-j} - x_{2,t-j} \mid + \sum_{k=1}^{K} \beta_{i,k} \mid S_k \mid\right) \tag{36}$$

where $i = L, U$ and $\Lambda(x)$ is the logistical transformation given by $\Lambda(x) = (1 + e^{-x})^{-1}$ to ensure that τ_t^i lies on $(0, 1)$. The model for the time-varying tail dependencies is resemblant of an ARMAX(1,10) process, where $\alpha_i \tau_{t-1}^i$ is an autoregressive term, $\beta_i \cdot \frac{1}{10}\sum_{j=1}^{10} \mid x_{1,t-j} - x_{2,t-j} \mid$ is a forcing variable which resembles the mean absolute difference between $x_{1,t}$ and $x_{2,t}$ of the last ten observations, and $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k as given by (1). As the interpretation of the forcing variable is not very straightforward it requires some further explanation. The mean absolute difference between the last ten observations is inversely related to the concordance ordering of the copula. If two series have perfect positive dependence the forcing variable would equal zero, under perfect negative dependence it would equal $\frac{1}{2}$, and in case there is no dependence between the series it would equal $\frac{1}{3}$.

We estimate the copula parameters using a two-step maximum likelihood procedure known as the inference functions for margins (IFM) method as proposed by Joe (1997). This method allows us to separate the maximum likelihood estimation into two parts. First, we estimate the parameters of the marginal distributions $F_1(x_1), \ldots, F_n(x_n)$ with maximum likelihood using the specification as given by (6). Based on these estimated marginal models we then compute the standardized residuals and compute their cumulative distribution function using the empirical cumulative distribution method. Next, we estimate the copula parameters individually using maximum likelihood.

The estimation of the copula parameters proves to be very intensive computationally, especially for the time-varying model for 5-minute return intervals. Unfortunately, we are therefore unable to estimate the time-varying copulas for 5-minute return intervals.

First, we consider the unconditional tail dependence measures τ^{LU} and τ^{UL} for different interval lengths, for which the estimation are shown in Table 19 on page 56.

	5-minute	60-minute	Daily
τ^{UL}	0.000	0.000	0.000
τ^{LU}	0.000	0.000	0.008

(a) Gold and S&P500 futures.

	5-minute	60-minute	Daily
τ^{UL}	0.000	0.000	0.000
τ^{LU}	0.000	0.000	0.000

(b) Gold and U.S. Treasury Bond futures.

Table 19 – Unconditional parameter estimates for symmetrized Joe-Clayton copula.

We find that the tail dependence measures are incredibly close to zero for almost all return intervals and both asset combinations, except for the lower-upper tail dependence of gold and S&P500 futures for daily returns. This suggest that there is almost no upper-lower and lower-upper tail dependence between our futures series.

Next, we continue with the estimation of the time varying tail dependence measures as given by (36). The effects of the macroeconomic news announcements on these tail dependence measures are shown in Table 20 on page 57 and Table 21 on page 59.

Dependent variable	60-minute $\beta_k - \tau^{UL}$	60-minute $\beta_k - \tau^{LU}$	Daily $\beta_k - \tau^{UL}$	Daily $\beta_k - \tau^{LU}$
1 – GDP advance	-2.199	-0.799	0.447	-0.263
2 – GDP preliminary	-0.509	-0.662	-0.110	-0.666
3 – GDP final	0.330	1.730***	0.554	0.344
Real activity				
4 – Nonfarm payroll employment	-2.479***	-3.319***	-0.033	0.932***
5 – Retail sales	-4.281***	2.869***	0.203	-1.920***
6 – Industrial production	-4.113***	-4.134*	-0.617	-0.443
7 – Capacity utilization	-6.244***	-5.067**	0.340	1.853***
8 – Personal income	2.597***	1.174	-0.220	0.780***
9 – Consumer credit	-1.346	-3.850***	-0.864	-0.208***
Consumption				
10 – Personal consumption expenditures	0.214	0.934	-0.026	1.096***
11 – New home sales investment	0.687	-1.821*	0.841	0.084
Investment				
12 – Durable goods orders	-1.446	0.787	-1.182	-1.649***
13 – Construction spending	-4.152***	-1.718**	-1.502	-1.791***
14 – Factory orders	3.044***	4.171***	3.577***	2.098***
15 – Business inventories	2.824***	1.678*	-1.066	-0.479***
Government purchases				
16 - Government budget deficit	-0.847**	0.943***	-1.556	-1.462
Net exports				
17 – Trade balance	1.849*	-0.061	0.034	0.010
Prices				
18 – Producer price index	1.370***	4.134***	-1.553	-2.242***
19 – Consumer price index	4.741***	3.437***	1.443	-0.630***
Forward-looking				
20 – Consumer confidence index	-1.302	-0.663	0.853	-0.420
21 – NAPM index	0.644	1.265	0.556	-0.441
22 – Housing starts	-1.287	3.936***	-0.083	-1.102
23 – Index of leading indicators	-2.302	1.744***	-0.105	0.019
24 – Initial unemployment claims	2.892***	0.987	-1.909	-3.132***
Copula parameters				
α	0.132	0.141***	0.098	0.112

Table 20 – Parameter estimates for exogenous variables in time-varying tail dependence of symmetrized Joe-Clayton copula for gold and S&P500 futures.

This table shows the estimation results for the time-varying parameters of the copula function for gold and S&P500 futures as given by

$$\tau_t^i = \Lambda\left(\omega_i + \alpha_i \tau_{t-1}^i + \beta_i \cdot \frac{1}{10}\sum_{j=1}^{10} \mid x_{1,t-j} - x_{2,t-j} \mid + \sum_{k=1}^{K} \beta_k \mid S_k \mid\right)$$

where $i = L, U$ and $\Lambda(x)$ is the logistical transformation given by $\Lambda(x) = \left(1 + e^{-x}\right)^{-1}$ to ensure that τ_t^i lies on $(0, 1)$. The model for the time-varying tail dependencies is resemblant of an ARMAX(1,10) process, where $\alpha_i \tau_{t-1}^i$ is an autoregressive term, $\beta_i \cdot \frac{1}{10} \sum_{j=1}^{10} \mid x_{1,t-j} - x_{2,t-j} \mid$ is a forcing variable which resembles the mean absolute difference between $x_{1,t}$ and $x_{2,t}$ of the last ten observations, and $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k as given by (1). The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

For the relationship between gold and S&P500 futures, we find that for hourly returns, thirteen of the 24 macroeconomic variables have a significant effect on the upper-lower tail dependence measure and fifteen of the 24 have a significant effect on the lower-upper tail dependence. The sign of the coefficient is split evenly between positive and negative for the upper-lower tail dependence, whilst for the lower-upper tail dependence the majority of the coefficients have a positive sign, indicating that the chance that a high gold futures return occurs with a low stock futures return increases with the surprise in the announcements.

When we consider the daily returns, we find that only factory orders has a significant and positive effect on the upper-lower tail dependence. For the lower-upper tail dependence, we find that thirteen announcements have a significant effect. Eight of these have a negative coefficient, indicating that negative news increases the lower-upper tail dependence.

Dependent variable	60-minute $\beta_k - \tau^{UL}$	60-minute $\beta_k - \tau^{LU}$	Daily $\beta_k - \tau^{UL}$	Daily $\beta_k - \tau^{LU}$
1 – GDP advance	-3.430***	-4.624***	-11.387***	-7.082**
2 – GDP preliminary	1.037	1.191	-8.951**	-10.221***
3 – GDP final	-0.450	-5.049**	-1.560	-2.091
Real activity				
4 – Nonfarm payroll employment	-50.752***	-34.055***	-58.150***	-54.850***
5 – Retail sales	-12.971***	-11.849***	-23.664***	-15.022**
6 – Industrial production	-6.850	-13.734*	-23.157**	-13.412*
7 – Capacity utilization	-9.001	-14.652*	-29.365***	-21.114**
8 – Personal income	-5.692	-3.370	-5.380	-13.674*
9 – Consumer credit	-1.238	0.641	-15.112**	-23.593***
Consumption				
10 – Personal consumption expenditures	-2.106	-2.788	-12.407	-9.441
11 – New home sales investment	-8.155	-11.130	-15.699	-6.405
Investment				
12 – Durable goods orders	-11.279***	-12.393***	-3.538	-5.018
13 – Construction spending	-12.878***	-12.448***	-1.785	-9.683***
14 – Factory orders	-1.059	0.343	-38.293***	-33.873***
15 – Business inventories	-9.813	-3.059	-22.549***	-17.579**
Government purchases				
16 - Government budget deficit	22.381***	7.751	-3.322	1.619
Net exports				
17 – Trade balance	-2.004	-3.276	-4.304	-5.657
Prices				
18 – Producer price index	-4.687**	-8.431***	-10.374***	-10.814***
19 – Consumer price index	-4.073**	-7.287***	-37.951***	-32.411***
Forward-looking				
20 – Consumer confidence index	-10.888***	-2.666	-12.064	-10.694
21 – NAPM index	-3.886	1.642	-30.538***	-26.684***
22 – Housing starts	-9.221	-10.802	-25.423***	-33.843***
23 – Index of leading indicators	-6.853	-1.108	3.915	4.702
24 – Initial unemployment claims	-22.801***	-18.788***	-42.269***	-8.011*
Copula parameters				
α	0.099	0.098	0.100	0.104

Table 21 – Parameter estimates for exogenous variables in time-varying tail dependence of symmetrized Joe-Clayton copula for gold and U.S. Treasury Bond futures.

This table shows the estimation results for the time-varying parameters of the copula function for gold and S&P500 futures as given by

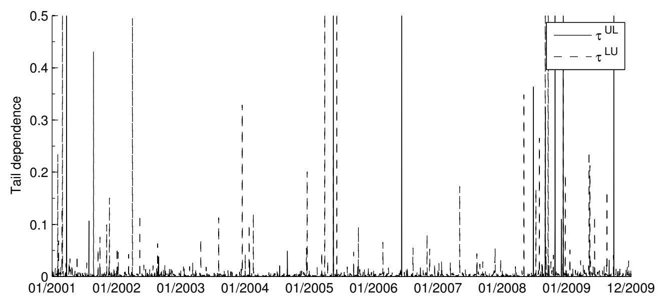
$$\tau_t^i = \Lambda\left(\omega_i + \alpha_i \tau_{t-1}^i + \beta_i \cdot \frac{1}{10}\sum_{j=1}^{10} \mid x_{1,t-j} - x_{2,t-j} \mid + \sum_{k=1}^{K} \beta_k \mid S_k \mid\right)$$

where $i = L, U$ and $\Lambda(x)$ is the logistical transformation given by $\Lambda(x) = \left(1 + e^{-x}\right)^{-1}$ to ensure that τ_t^i lies on $[0, 1]$. The model for the time-varying tail dependencies is resemblant of an ARMAX(1,10) process, where $\alpha_i \tau_{t-1}^i$ is an autoregressive term, $\beta_i \cdot \frac{1}{10}\sum_{j=1}^{10} \mid x_{1,t-j} - x_{2,t-j} \mid$ is a forcing variable which resembles the mean absolute difference between $x_{1,t}$ and $x_{2,t}$ of the last ten observations, and $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k as given by (1). The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

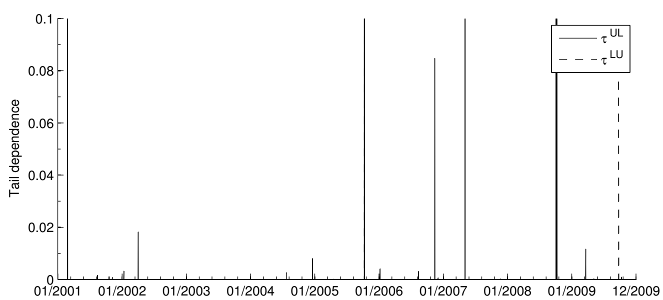
Looking at the results for the gold and U.S. Treasury Bond futures, for the hourly return interval, we find that ten variables are significant for the upper-lower tail dependence, and that eleven are significant for the lower-upper tail dependence. All but one of the significant coefficients have a negative sign.

For the daily returns, we see that fourteen announcements are significant for the upper-lower tail dependence. The lower-upper tail dependence is significantly influenced by nine macroeconomic announcements. For both the lower-upper and upper-lower tail dependence, the sign of the significant variables is negative in all cases, indicating that the absolute surprise in an announcement lowers the tail dependence. It should be noted, however, that the model is trying to fit tail dependencies which are so little for the U.S. Treasury Bond futures, that whilst the results might be statistically significant they should not be considered to be significant from an economical point of view.

Next, we plot the estimated time-varying tail dependence measures for the daily returns, which are shown in Figure 8 on page 60.



(a) Gold and S&P500 futures.



(b) Gold and U.S. Treasury Bond futures.

Figure 8 – Time-varying tail depence measures for symmetrized Joe-Clayton copula for daily returns.

As we can see from these figures, the tail dependence for both tails is close to zero for the gold and S&P500 futures. At some points during our sample they show some jumps to a higher level of tail dependence, but these shocks disappear almost immediately. For the gold and U.S. Treasury Bond futures, the tail dependences are even closer to zero, and they show less jumps to higher tail dependences. This shows, again, that there is almost no upper-lower and lower-upper tail dependence and that gold can not be considered to be a safe haven for U.S. Treasury Bond futures. When we consider our earlier findings concerning the conditional correlation, where we saw that gold and U.S. Treasury Bond futures are positively correlated, these low tail dependences might be due to the fact that the relationship between these two assets is actually characterized by upper-upper and lower-lower tail dependence.

The mean tail dependencies for the daily returns are shown in Table 22 on page 61.

	Gold – S&P500		Gold – U.S. Treasury Bond	
	τ^{UL}	τ^{LU}	τ^{UL}	τ^{LU}
Mean	0.002	0.006	0.001	0.000
Standard deviation	0.033	0.038	0.030	0.004

Table 22 – Statistics for estimated time-varying tail dependence measures for daily returns.

In order to formally test whether there is tail dependence in our data, we test the null hypothesis that the tail dependences are equal to zero. For gold and S&P500 futures, we can reject this for both the upper-lower and lower-upper tail dependences, indicating that tail dependence is present. For the gold and U.S. Treasury Bond futures we can only reject the null hypothesis for the lower-upper tail dependence.

6 Discussion

In this thesis, we have extensively studied gold futures in order to examine their role as a safe haven for investors. No one thesis can cover such an extensive topic of research by itself however. Therefore, we would like to offer some suggestions for further research on this topic.

Considering our thesis in general, first, we suggest that further research could include a wider body of macroeconomic announcements. With the globalization of the economy, and the fact that gold futures are traded almost 24 hours per day, it could be useful to examine the effects of macroeconomic announcements from countries other than the United States. Also, the consideration of irregular macroeconomic announcements could add additional explanatory power. Furthermore, it is also interesting to include private sources of news, such as order flow, or other liquidity measures, and the bid-ask spread, as these have been shown to have a significant effect on other asset classes.

Second, whilst we have only studied the asymmetric effects of the macroeconomic announcements, conditioning our models on different variables could provide additional insight. It could for instance be interesting to test whether the macroeconomic announcements have different effects when we condition our models on the state of the economy. Especially since the last decade has been such a tumultuous one, and previous research has found different effects for different states, this might be a valuable addition.

With respect to the specific models used in this thesis, we provide some points of discussion and suggestions for further research. First, for our research on the effect of macroeconomic announcements on gold futures returns and return volatility, we have used a Component-GARCH model in order to account for the short-run and long-run volatility that is clearly present in high-frequency data. Whilst our model was able to model the intra-day volatility adequately, there might be other models that do so more appropriately. Specifically, a Spline-GARCH model as suggested by Engle and Rangel (2008) could be used.

Secondly, considering the copula approach of our multivariate analysis, we would have preferred to be able to also estimate these on the 5-minute return intervals, but where unfortunately unable to do so due to computational restrictions. This could therefore be an interesting extension of our research. Furthermore, other copula functions, or mixtures of copulas functions, could prove interesting to examine.

7 Conclusion

In this thesis we have used high-frequency intra-day data on gold, S&P500 and U.S. Treasury Bond futures, together with precisely timed macroeconomic announcements, to examine the effects of macroeconomic news on the returns and return volatility of gold futures, and the comovement of gold futures with S&P500 and U.S. Treasury Bond futures.

We start with univariate analysis of the effects of the macroeconomic announcements on the gold futures returns with ordinary least squares analysis. We find that a large number of the macroeconomic announcements have a significant effect on the gold futures returns. Of these significant announcements, we find that all but one has the sign that supports the fact that gold prices rise when the announcement contains a negative surprise. This is in line with our hypothesis that gold acts as a safe haven in times of economic distress.

Then, we continue by including the return volatility of the gold futures in our analysis. We do this by estimating a Component-GARCH model, which allows us to separate the long-run and short-run volatility. This enables us to model the intra-day pattern of volatility and the effects of macroeconomic announcements in the short-run volatility component. Our results show that fourteen of the announcements significantly influence the volatility of the gold futures returns. Twelve of these fourteen announcements increase volatility when there is a surprise in the announcement. We also consider the contemporaneous effect of individual announcement on the return and return volatility of the gold futures. The estimation results of these regressions support the findings of our more elaborate models.

After the univariate analysis, we continue with multivariate analysis on the comovement between gold, S&P500 and U.S. Treasury Bond futures. We start with a simple examination of the correlation in our sample. Then we estimate contemporaneous regressions to examine the direct effect of the announcements on realized and bipower correlation. We find that only few of the announcements have a significant effect.

In order to model the comovement for our whole sample, subsequently, we consider the multivariate GARCH class of models. Specifically, we use a Dynamic Conditional Correlation model with exogenous variables, and find mixed results. A majority of the announcements have a significant effect on the conditional correlation and the results suggest that gold moves independently from S&P500 and U.S. Treasury Bond futures and thus offers some possibilities to reduce risk in times of financial distress, there is little proof for any hedging capacity however.

Subsequently, we continue our multivariate analysis with copulas. We use the symmetrized Joe-Clayton copula, as this allows for asymmetric tail dependencies, and modify our data so that we can analyse the upper-lower and lower-upper time-varying tail dependence and the effect of macroeconomic variables. We find that the tail dependences in our data are very low, although we can reject the null hypothesis that it is equal to zero for all but the upper-lower tail dependence for gold and U.S. Treasury Bond futures. With respect to the effect of macroeconomic announcements, we find that a large number of announcements significantly influence the tail dependences. For the upper-lower tail dependence, almost all the coefficients support our hypothesis that gold acts as a safe haven.

To summarize, we find, in general, that macroeconomic announcements influence the returns and return volatility of gold futures, and that their influence is in line with the hypothesis that gold acts as a safe haven. The results of our multivariate analysis are less clear unfortunately, mostly indicating that there is very little comovement between gold and S&P500 and U.S. Treasury Bond futures. The effects of the macroeconomic announcements in our copula analysis do however support the fact that gold acts as a safe haven for S&P500 futures.

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Appendix

Dependent variable	Cond. Mean β_k	Cond. Volatility $\gamma_{k,0}$
1 – GDP advance	-12.206**	6.257***
2 – GDP preliminary	-7.982**	1.560
3 – GDP final	-0.264	1.203
Real activity		
4 – Nonfarm payroll employment	-16.827***	16.639***
5 – Retail sales	-11.127***	4.313***
6 – Industrial production	-0.902	-0.575
7 – Capacity utilization	-0.815	1.066
8 – Personal income	-0.267***	-0.081
9 – Consumer credit	0.052	-2.305***
Consumption		
10 – Personal consumption expenditures	0.500***	-1.638*
11 – New home sales investment	-3.433**	0.602
Investment		
12 – Durable goods orders	-4.715**	2.716***
13 – Construction spending	0.477	0.879
14 – Factory orders	-2.521*	0.310
15 – Business inventories	-0.908	1.864**
Government purchases		
16 - Government budget deficit	0.026	-0.264
Net exports		
17 – Trade balance	-8.540***	4.673***
Prices		
18 – Producer price index	3.500**	-0.038
19 – Consumer price index	0.640	1.067
Forward-looking		
20 – Consumer confidence index	-4.154**	2.153***
21 – NAPM index	-5.357***	1.635**
22 – Housing starts	-1.658	-0.417
23 – Index of leading indicators	0.351	2.915***
24 – Initial unemployment claims	3.508***	1.576***
Dummy		0.609***

Table A.1 – Effect of macroeconomic news on gold futures returns and volatility.
This table shows the results for two-step feasible weighted least squares regression, given by

$$r_t = \beta_o + \sum_{i=1}^{I} \beta_i r_{t-i} + \sum_{k=1}^{K}\sum_{j=0}^{J} \beta_{k,j} S_{k,t-j} + \varepsilon_t$$

and

$$\mid \hat{\varepsilon}_t \mid = \gamma_o + \gamma_1 D\left(ann\right) + \sum_{i=1}^{I} \gamma_i \mid \hat{\varepsilon}_{t-i} \mid + \sum_{k=1}^{K}\sum_{j=0}^{J} \gamma_{k,j} \mid S_{k,t-j} \mid + \sum_{q=1}^{Q} \left(\delta_q \cos\left(\frac{q2\pi t}{288}\right) + \phi_q \sin\left(\frac{q2\pi t}{288}\right)\right) + \nu_t$$

for $t = 1, \ldots, T$, where r_t is the 5-minute log-return for the gold futures at time t, $\mid \hat{\varepsilon}_t \mid$ is the absolute value of the residual of (2) at time t, $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k, and $D\left(\cdot\right)$is a dummy variable which takes the value 1 if an announcement is released on that day. It also includes a flexible Fourier form for the intra-day volatility patterns, as given by the part with cosine and sine. The model is estimated using $I = 2$ lagged returns and $J = 0$ lagged surprises in the return equation and with $I = 2$ lagged residual, 0 lagged surprises and $Q = 3$ flexible Fourier form terms. The estimates for all the parameters are shown in the table above. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

Dependent variable	α_k	β_k	R^2
1 – GDP advance	-3.845	11.419	0.057
2 – GDP preliminary	22.458***	-13.620**	0.152
3 – GDP final	13.798*	1.074	0.001
Real activity			
4 – Nonfarm payroll employment	18.139***	9.980*	0.033
5 – Retail sales	9.115*	5.449	0.013
6 – Industrial production	-13.927***	18.088***	0.169
7 – Capacity utilization	-14.429***	18.507***	0.179
8 – Personal income	16.448***	-5.954*	0.028
9 – Consumer credit	-3.688	2.252	0.002
Consumption			
10 – Personal consumption expenditures	9.517**	4.871	0.014
11 – New home sales investment	1.379	2.508	0.003
Investment			
12 – Durable goods orders	0.428	5.503	0.008
13 – Construction spending	5.357	7.310*	0.029
14 – Factory orders	8.199*	-4.428	0.009
15 – Business inventories	0.865	5.533	0.023
Government purchases			
16 - Government budget deficit	0.845	9.162***	0.072
Net exports			
17 – Trade balance	12.449***	-6.063	0.017
Prices			
18 – Producer price index	-0.431	2.187	0.004
19 – Consumer price index	10.660***	-4.351	0.014
Forward-looking			
20 – Consumer confidence index	7.306**	-2.030	0.003
21 – NAPM index	0.438	3.666	0.010
22 – Housing starts	5.012	-1.669	0.002
23 – Index of leading indicators	2.825	-8.251*	0.051
24 – Initial unemployment claims	10.015***	0.216	0.000

Table A.2 – Contemporaneous effect of macroeconomic news on realized volatility.

This table shows the results for the contemporaneous regressions as given by

$$\Delta RV_t = \alpha_k + \beta_{k,j} \mid S_{k,t} \mid + \varepsilon_t$$

where ΔRV_t is the difference between the realized volatility around a macroeconomic announcement minus the realized volatility of the same window one day earlier, and $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

Dependent variable	Negative		Positive		R^2	Wald test H_0 :	
	α_1	β_1	α_2	β_2		$\alpha_1 = \alpha_2$	$\beta_1 = \beta_2$
1 – GDP advance	15.922*	7.024	-24.093***	29.226**	0.233	6.230**	1.975
2 – GDP preliminary	21.118	5.718	21.899*	-16.607	0.197	0.003	2.868*
3 – GDP final	3.533***	-10.545	16.416	-4.556**	0.026	0.426	0.125
Real activity							
4 – Nonfarm payroll employment	22.349	-4.165	6.855	25.311	0.063	1.576	6.125**
5 – Retail sales	5.006	-14.528	8.853	3.144	0.025	0.134	2.347
6 – Industrial production	-18.100***	-23.385***	-4.066	-0.548	0.219	2.729*	5.775**
7 – Capacity utilization	-32.946***	-32.598***	2.344	-5.286	0.346	20.571***	11.799***
8 – Personal income	23.904**	13.284	14.738***	-5.380	0.035	0.782	2.075
9 – Consumer credit	-9.341	-4.855	3.616	-1.373	0.021	1.483	0.105
Consumption							
10 – Personal consumption expenditures	14.508**	-1.869	6.914	7.299	0.021	0.771	1.084
11 – New home sales investment	-2.603	-6.924	3.824	0.008	0.010	0.517	0.612
Investment							
12 – Durable goods orders	2.770	-7.290	-2.635	4.049	0.016	0.178	0.828
13 – Construction spending	13.222**	-4.879	0.846	7.494	0.067	2.283	2.190
14 – Factory orders	8.113	1.521	10.752*	-12.326	0.026	0.072	1.952
15 – Business inventories	6.149	-5.647	-0.525	1.941	0.068	0.802	1.113
Government purchases							
16 - Government budget deficit	-0.125	-11.886***	4.741	-0.336	0.094	0.479	2.078
Net exports							
17 – Trade balance	24.157***	15.453**	5.791	-1.609	0.052	3.922**	3.235*
Prices							
18 – Producer price index	2.714	0.026	-3.128	3.761	0.010	0.620	0.265
19 – Consumer price index	25.900***	13.316*	8.057**	-4.354	0.048	3.153*	4.371**
Forward-looking							
20 – Consumer confidence index	8.027*	-0.032	6.578	-4.464	0.020	0.045	0.416
21 – NAPM index	0.004	-6.936	0.734	1.532	0.021	0.009	1.340
22 – Housing starts	5.593	2.704	4.494	-0.883	0.003	0.024	0.281
23 – Index of leading indicators	6.156	13.742	2.811	-6.516	0.059	0.128	4.758**
24 – Initial unemployment claims	8.760**	-3.129	11.457***	-3.403	0.004	0.271	0.003

Table A.3 – Contemporaneous asymmetric effect of macroeconomic news on realized volatility. This table shows the results for the contemporaneous regressions taking into account possible asymmetric effects as given by

$$\Delta RV_t = (\alpha_{1,k} + \beta_{1,k} S_{k,t})\, D\,(S < 0) + (\alpha_{2,k} + \beta_{2,k} S_{k,t})\, D\,(S > 0) + \varepsilon_t$$

where ΔRV_t is the difference between the realized volatility around a macroeconomic announcement minus the realized volatility of the same window one day earlier, $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k, and $D\,(\cdot)$is a dummy variable which takes the value 1 if the condition $(\cdot)$ is met. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

Dependent variable	Gold – S&P500 α_k	β_k	R^2	Gold – U.S. Treasury α_k	β_k	R^2
1 – GDP advance	-0.077	0.066	0.011	-0.041	0.009	0.000
2 – GDP preliminary	-0.039	-0.019	0.001	0.020	-0.193	0.042
3 – GDP final	0.005	-0.073	0.014	-0.119	0.155	0.035
Real activity						
4 – Nonfarm payroll employment	-0.021	0.040	0.003	-0.035	0.088	0.010
5 – Retail sales	0.091	-0.084	0.022	0.045	-0.046	0.004
6 – Industrial production	0.097	-0.182*	0.040	-0.029	-0.028	0.000
7 – Capacity utilization	0.059	-0.116	0.020	-0.038	-0.011	0.000
8 – Personal income	0.019	-0.032	0.005	-0.017	-0.071	0.014
9 – Consumer credit	0.117	-0.111	0.022	0.048	0.029	0.001
Consumption						
10 – Personal consumption expenditures	-0.013	0.017	0.001	-0.143*	0.119	0.027
11 – New home sales investment	-0.031	0.039	0.004	0.076	-0.099	0.016
Investment						
12 – Durable goods orders	0.007	-0.038	0.005	-0.116	0.168*	0.040
13 – Construction spending	-0.010	-0.003	0.000	0.164*	-0.191*	0.045
14 – Factory orders	-0.051	0.091	0.016	-0.102	0.051	0.005
15 – Business inventories	0.022	-0.006	0.000	-0.048	0.001	0.000
Government purchases						
16 - Government budget deficit	-0.004	0.011	0.000	0.053	-0.137	0.013
Net exports						
17 – Trade balance	0.003	-0.008	0.000	0.014	-0.001	0.000
Prices						
18 – Producer price index	-0.054	0.077	0.015	-0.132	0.121	0.019
19 – Consumer price index	0.045	0.008	0.000	0.076	-0.065	0.005
Forward-looking						
20 – Consumer confidence index	-0.025	0.017	0.001	-0.079	0.097	0.009
21 – NAPM index	0.059	-0.092	0.018	0.044	-0.079	0.007
22 – Housing starts	0.044	-0.009	0.000	-0.019	0.076	0.007
23 – Index of leading indicators	-0.014	0.052	0.006	-0.129	0.275**	0.075
24 – Initial unemployment claims	-0.041	0.028	0.002	0.045	-0.093**	0.012

Table A.4 – Contemporaneous effect of macroeconomic news on realized correlations for gold and S&P500 futures, and gold and U.S. Treasury Bond futures.

This table shows the results for the contemporaneous regressions as given by

$$\Delta RC_{ij,t} = \alpha_k + \beta_{k,j} \mid S_{k,t} \mid + \varepsilon_t$$

and where $\Delta RC_{ij,t}$ is the difference between the realized correlation around a macroeconomic announcement minus the realized correlation of the same window one day earlier between futures i and j, and $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

Dependent variable	Negative α_1	Negative β_1	Positive α_2	Positive β_2	R^2	Wald test H_0 : $\alpha_1 = \alpha_2$	Wald test H_0 : $\beta_1 = \beta_2$
1 – GDP advance	-0.204	-0.167	0.071	-0.037	0.051	0.859	0.216
2 – GDP preliminary	0.055	0.028	-0.097	-0.021	0.029	0.269	0.030
3 – GDP final	0.024	0.050	0.011	-0.143	0.026	0.001	0.466
Real activity							
4 – Nonfarm payroll employment	0.002	-0.002	-0.066	0.129	0.010	0.191	0.556
5 – Retail sales	-0.074	-0.097	0.166**	-0.119*	0.055	2.744*	0.015
6 – Industrial production	0.041	0.179	0.104	-0.095	0.060	0.156	1.577
7 – Capacity utilization	-0.046	0.057	0.086	-0.094	0.036	0.612	0.572
8 – Personal income	0.290*	0.489**	0.009	0.003	0.079	3.074*	6.088**
9 – Consumer credit	0.112	0.098	0.124	-0.125	0.023	0.006	1.742
Consumption							
10 – Personal consumption expenditures	-0.011	0.003	-0.022	0.061	0.005	0.006	0.185
11 – New home sales investment	0.024	-0.112	-0.106	0.012	0.068	0.747	0.757
Investment							
12 – Durable goods orders	-0.039	-0.049	0.031	-0.101	0.025	0.283	0.167
13 – Construction spending	-0.028	-0.031	0.005	-0.043	0.003	0.042	0.005
14 – Factory orders	-0.100	-0.148	-0.005	0.001	0.025	0.364	0.753
15 – Business inventories	-0.101	-0.116	0.091	-0.105	0.025	1.241	0.005
Government purchases							
16 - Government budget deficit	-0.018	0.081	0.032	0.037	0.013	0.182	0.043
Net exports							
17 – Trade balance	-0.122	0.007	0.060	0.042	0.053	1.084	0.029
Prices							
18 – Producer price index	0.086	0.105	-0.123	0.166**	0.058	1.960	0.173
19 – Consumer price index	0.057	-0.026	0.049	-0.047	0.008	0.001	0.015
Forward-looking							
20 – Consumer confidence index	0.004	0.046	-0.053	0.087	0.013	0.175	0.076
21 – NAPM index	0.009	0.050	0.087	-0.114	0.021	0.219	0.987
22 – Housing starts	0.036	-0.072	0.045	-0.059	0.024	0.003	0.008
23 – Index of leading indicators	0.137	0.041	-0.054	0.037	0.030	1.262	0.000
24 – Initial unemployment claims	0.008	0.018	-0.089*	0.074	0.008	2.009	0.662

Table A.5 – Contemporaneous asymmetric effect of macroeconomic news on realized volatility.

This table shows the results for the contemporaneous regressions taking into account possible asymmetric effects as given by

$$\Delta RC_{ij,t} = \left(\alpha_{1,k} + \beta_{1,k} S_{k,t}\right) D\left(S_{k,t} < 0\right) + \left(\alpha_{2,k} + \beta_{2,k} S_{k,t}\right) D\left(S_{k,t} > 0\right) + \varepsilon_t$$

where $\Delta RC_{ij,t}$ is the difference between the realized correlation around a macroeconomic announcement minus the realized correlation of the same window one day earlier between futures i and j, $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k, and $D(\cdot)$is a dummy variable which takes the value 1 if the condition $(\cdot)$ is met. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

Dependent variable	Negative α_1	Negative β_1	Positive α_2	Positive β_2	R^2	Wald test H_0 : $\alpha_1 = \alpha_2$	Wald test H_0 : $\beta_1 = \beta_2$
1 – GDP advance	0.193	0.239	-0.295	0.256	0.120	2.258	0.003
2 – GDP preliminary	0.131	0.371	-0.026	-0.100	0.063	0.139	1.370
3 – GDP final	-0.171	-0.298	-0.082	-0.078	0.099	0.040	0.355
Real activity							
4 – Nonfarm payroll employment	-0.002	-0.058	-0.089	0.146	0.012	0.201	0.894
5 – Retail sales	0.087	0.228	0.085	-0.020	0.024	0.000	1.102
6 – Industrial production	-0.108	-0.067	0.039	-0.150	0.007	0.383	0.064
7 – Capacity utilization	-0.081	0.011	-0.036	0.042	0.005	0.033	0.011
8 – Personal income	0.153	0.171	-0.071	-0.065	0.033	1.114	0.817
9 – Consumer credit	0.122	0.153	-0.038	0.237	0.057	0.604	0.157
Consumption							
10 – Personal consumption expenditures	0.045	0.045	-0.256***	0.319**	0.085	3.077*	2.718*
11 – New home sales investment	0.168	0.298*	0.054	-0.007	0.059	0.348	2.762*
Investment							
12 – Durable goods orders	-0.203	-0.226	-0.040	0.129	0.049	0.681	3.600*
13 – Construction spending	0.018	0.084	0.251**	-0.262*	0.063	1.502	2.968*
14 – Factory orders	-0.183	-0.078	-0.072	0.066	0.015	0.435	0.640
15 – Business inventories	0.214	0.104	-0.136	0.014	0.041	2.215	0.167
Government purchases							
16 - Government budget deficit	-0.112	-0.313	0.197*	-0.341**	0.084	3.596*	0.009
Net exports							
17 – Trade balance	0.003	-0.014	0.021	-0.013	0.000	0.006	0.000
Prices							
18 – Producer price index	-0.261	-0.192	-0.041	0.083	0.035	1.075	1.751
19 – Consumer price index	0.048	0.040	0.084	-0.081	0.006	0.017	0.251
Forward-looking							
20 – Consumer confidence index	-0.131	-0.146	-0.032	0.051	0.012	0.212	0.710
21 – NAPM index	-0.148	-0.091	0.152	-0.165	0.030	1.803	0.113
22 – Housing starts	0.065	-0.091	-0.111	0.090	0.027	0.593	0.745
23 – Index of leading indicators	0.030	-0.096	-0.163	0.354**	0.087	0.624	3.063*
24 – Initial unemployment claims	0.052	0.083	0.039	-0.107	0.013	0.020	4.363**

Table A.6 – Contemporaneous asymmetric effect of macroeconomic news on realized volatility.
This table shows the results for the contemporaneous regressions taking into account possible asymmetric effects as given by

$$\Delta RC_{ij,t} = (\alpha_{1,k} + \beta_{1,k} S_{k,t})\, D\,(S_{k,t} < 0) + (\alpha_{2,k} + \beta_{2,k} S_{k,t})\, D\,(S_{k,t} > 0) + \varepsilon_t$$

where $\Delta RC_{ij,t}$ is the difference between the realized correlation around a macroeconomic announcement minus the realized correlation of the same window one day earlier between futures i and j, $S_{k,t}$ is the standardized surprise at time t for macroeconomic variable k, and $D\,(\cdot)$is a dummy variable which takes the value 1 if the condition $(\cdot)$ is met. The superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.