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# The stance of U.S. monetary policy and the realized variance of gold-price returns

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## Abstract

We use a quantile-regression model to study the association between the stance of U.S. monetary policy and the realized variance of gold-price. We measure the stance of monetary policy using the spread between the real interest rate and the natural real interest rate. During a hawkish policy regime, tighter monetary policy is associated with a lower realized variance at the upper quantiles its conditional distribution. During the recent dovish policy regime, in contrast, the link between tighter monetary policy and the realized variance of gold price returns at the upper quantiles of its conditional distributionis positive.

Conflicts of interest: The authors declare no conflict of interest. The authors would like to thank two anonymous referees for many helpful comments. The usual disclaimer applies.

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# 1. Introduction

The Federal Reserve and other major central banks have responded to the recent upsurge of inflation rates by raising nominal short-term interest rates, ending the era of ultra-low interest rates. The sudden shift in the stance of monetary policy indicated by the steep increases in nominal short-term interest rates has been accompanied by elevated uncertainty due to geopolitical tensions and heightened financial market volatility. Periods of high financial market volatility, in turn, imply that investors start searching for opportunities to hedge their portfolios, and for "safe-haven" assets in particular. Because gold is a classic safe-haven asset, it is of paramount importance to inspect how the volatility of gold-price returns reacts to shifts in the stance of monetary policy. It is, therefore, not surprising that researchers have studied extensively the link between the stance of monetary policy and the volatility of gold-price returns in several earlier empirical studies. Hammoudeh and Yuan (2008), for example, measure the stance of monetary policy in terms of changes in the nominal three months T-bill rate and find that a tighter monetary policy exerts a dampening effect on the volatility of gold-price returns (on the link between monetary policy and monetary variables and gold-price volatility, see also Batten et al. 2010, and Hammoudeh et al. 2010).

Our empirical research contributes to this significant strand of literature in two ways. First, we use the novel metric of the stance of monetary policy that Bianchi et al. (2022) have proposed in recent research. They measure the stance of monetary policy in terms of the spread between the actual short-term real interest rate and the natural real interest rate, where the latter is estimated using the seminal model proposed by Laubach and Williams (2003).[1] A "hawkish" policy regime is associated with a persistent positive spread, while a persistently negative spread indicates a "dovish" policy regime. Second, we use a quantile-regression model to inspect the association between the stance of monetary policy and the entire conditional distribution of the variance of gold-price returns. Researchers have used several variants of quantile-regression models in recent research to shed light on various key facets of gold-price fluctuations (see, for example, Baur 2013, Zagaglia and Marzo, 2013, and Bonato et al. 2018). Studying the quantiles of the conditional distribution of realized volatility is important, for example, for option traders and risk managers who need to calculate the value-at-risk of a position.[2]

We find that during the sample period from 1968Q2 to 2020Q4 an increase in the U.S. monetary policy spread, that is, a tighter stance of U.S. monetary policy, is associated with a lower subsequent variance of gold-price returns when we study the upper quantiles of the conditional distribution of the variance. Like Gkillas et al. (2020), we measure the latter in terms of the realized variance of gold-price returns, which has the advantage that it is an observable and model-free metric of the intensity of gold-returns variability. Importantly, this inverse link between tighter monetary policy and mitigated peaks of

[1] The question whether fluctuations in commodity prices are linked to the the real interest rate has been extensively studied in earlier literature. Economic theory implies that a low real interest rate in an environment of expansionary monetary policy leads yield-searching investors to consider investments in commodities, driving up real commodity prices. Frankel (2014) finds support for the theoretically hypothesized negative link between the real interest rate and real commodity prices. The results that Frankel and Rose (2010) report are less supportive in this regard.

[2] A quantiles-based analysis also is warranted because (shifts between) "hawkish" and "dovish" monetary policy regimes may create uncertainty, which, in turn, may have quantile-specific effects on commodity markets (Apergis et al. 2020, Bahloul et al. 2018). Moreover, monetary policy may exert quantiles-specific effects on commodity markets via investor sentiment (Balcilar et al. 2017).

the realized variance can be observed mainly during a hawkish policy regime. According to the estimates reported by Bianchi et al. (2022), a hawkish policy regime prevailed from 1978Q4 to 2001Q3 (and during a short period of time from 2006Q2 to 2008Q2). In times of the more recent mainly dovish policy regime (from 2001Q4 until the end of the sample period), in contrast, the association between a tighter monetary policy and the subsequent realized variance of gold price returns at the upper quantiles of its conditional distribution tends to be positive.

We organize the remainder of this research note as follows. We briefly present the quantile-regression model in Section 2, we describe our data in Section 3, we summarize our results in Section 4, and we offer some concluding remarks in Section 5.

# 2. The quantile-regression model

For our empirical analysis, we use a standard long-horizon regression model, framed in terms of a quantile-regression model, as developed by Koenker and Bassett (1978). We let $\tau \in (0, 1)$ denote the quantile being studied. The vector of quantile-specific coefficients, $\mathbf{b}_\tau = (\beta_0(\tau), \beta_1(\tau), \beta_2(\tau))$, of our quantile-regression model solves the following minimization problem:

$$\mathbf{b}^*_\tau = \underset{\mathbf{b}_\tau}{\arg\min} \sum_t \rho_\tau(RV_{t+h} - \mathbf{X}_t\mathbf{b}_\tau) \tag{1}$$

where $\mathbf{X}_t\mathbf{b}_\tau = \beta_0(\tau) + \beta_1(\tau)RV_t + \beta_2(\tau)MPS_t$, and $RV_t$ denotes the realized variance of gold-price returns (and is included in the model to control for any potential clustering of $RV$), $MPS_t$ denotes the stance of monetary policy (that is, the monetary policy spread), $t$ denotes a time index, and $h$ denotes the horizon under consideration. We set $h = 1, 2, 4, 8, 12$, so that the horizon ranges from one quarter to three years. We construct our data matrix such that its dimension is identical for all horizons. $RV_{t+h}$ denotes the average realized variance of gold-price returns over the horizon, $h$, being studied. Finally, we define $\rho_\tau(u) = u(\tau - \mathbf{1}_{u<0})$ as the check function, where $\mathbf{1}_{(.)}$ denotes the indicator function.[3]

# 3. Data

The internet page of the London Bullion Market Association (LBMA) is the source we use to compile daily (AM) data on the U.S. dollar price of gold.[4] We compute daily gold-price returns by taking the first-difference of the log price data. We then sum up the squared daily returns for every quarter to obtain the quarterly realized variance of gold-price returns. Figure 1 plots the resulting quarterly realized variance of the gold-price. The sample period ranges from 1968Q2 to 2020Q2, where the start (end) of the sample period reflects the availability of gold-price data (data on the natural interest rate).

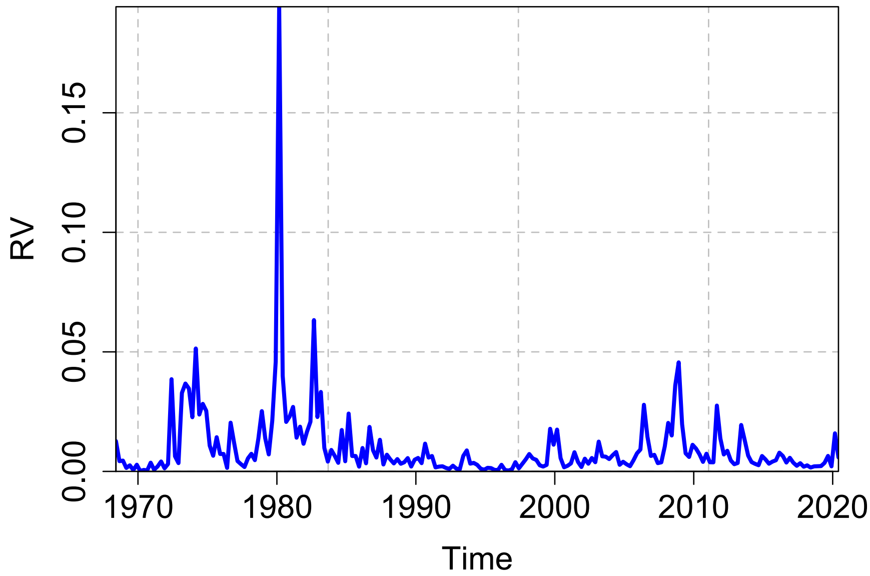
The data on the natural interest rate are downloaded from the internet page of the Federal Reserve Bank of New York.[5] We use the data on the natural interest rate to

[3]We use the R language and environment for statistical computing (R Core Team 2022) to conduct our empirical analysis, and the R add-on package "quantreg" (Koenker 2022) to estimate the quantile-regression model.

[4]Link: https://www.lbma.org.uk/prices-and-data/precious-metal-prices#/.

[5]Link: https://www.newyorkfed.org/research/policy/rstar. We use the "current estimates". As stated on that internet page, updates of the estimates were suspended on November 30, 2020, due

Figure 1: Realized Variance of Gold-Price Returns




Note: The quarterly realized variance of gold-price returns is computed by summing up for every quarter the continuously compounded returns of daily gold-price changes.

compute the monetary policy spread, $MPS$, as described by Bianchi et al. (2022). First, we compute the inflation rate (percentage change from year ago) using quarterly data on the seasonally adjusted personal consumption expenditures excluding food and energy (chain-type price index).[6] Second, we compute expected inflation as the four-quarter backward-looking moving average of the inflation rate. Third, we compute the monetary policy spread by subtracting the expected inflation rate and the natural interest rate from the Federal funds effective rate (quarterly average).[7]

Figure 2 depicts the monetary policy spread. As described by Bianchi et al. (2022), the mainly positive monetary policy spread indicates a hawkish stance of monetary policy from 1978Q4 to 2001Q3 and during a short period of time from 2006Q2 to 2008Q2, while a mainly negative monetary policy spread indicates that a dovish monetary policy regime prevailed from 2001Q4 to 2006Q1 and then again starting in 2008Q3 until the end of the sample period.[8]

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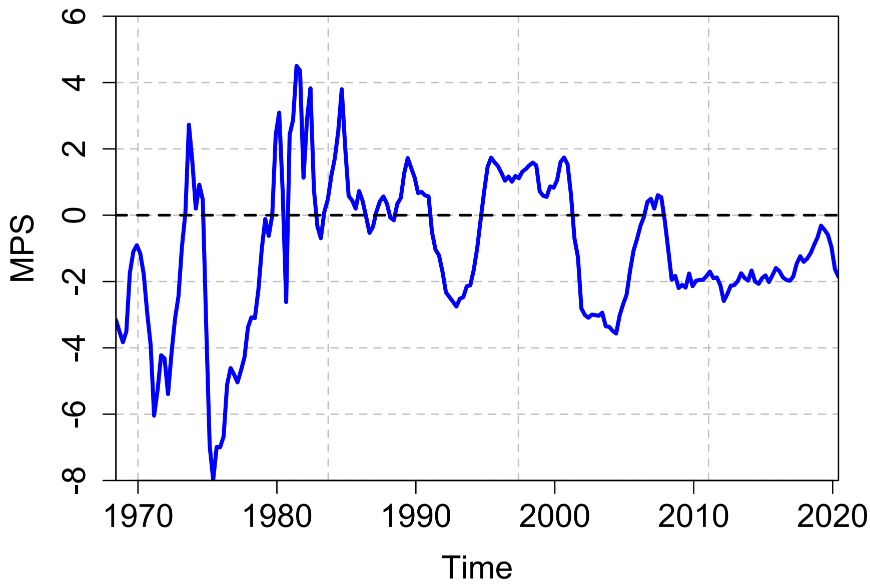
to the extraordinary volatility in GDP following the COVID-19 pandemic.

[6]Link: https://fred.stlouisfed.org/series/PCEPILFE.

[7]Link: https://fred.stlouisfed.org/series/FEDFUNDS. We use the filtered (one-sided) estimates of the natural interest rate, but we obtain qualitatively similar results (not reported but available from the authors upon request) when we use the smoothed (two-sided) estimates. We use the filtered estimates because they are more likely to reflect the period-$t$ information of market participants. Another possibility is to use real-time estimates. We leave a closer study of real-time estimates to future research.

[8]As suggested by an anonymous reviewer, we tested for a unit-root in the realized variance and the monetary policy spread. Results (not reported for reasons of space, but available from the authors upon request) provided no signs of a unit root.

Figure 2: Monetary Policy Spread




Note: The monetary policy spread, $MPS$, is computed by subtracting from the Federal funds effective rate (quarterly average) the expected inflation rate and the natural interest rate.

# 4. Empirical results

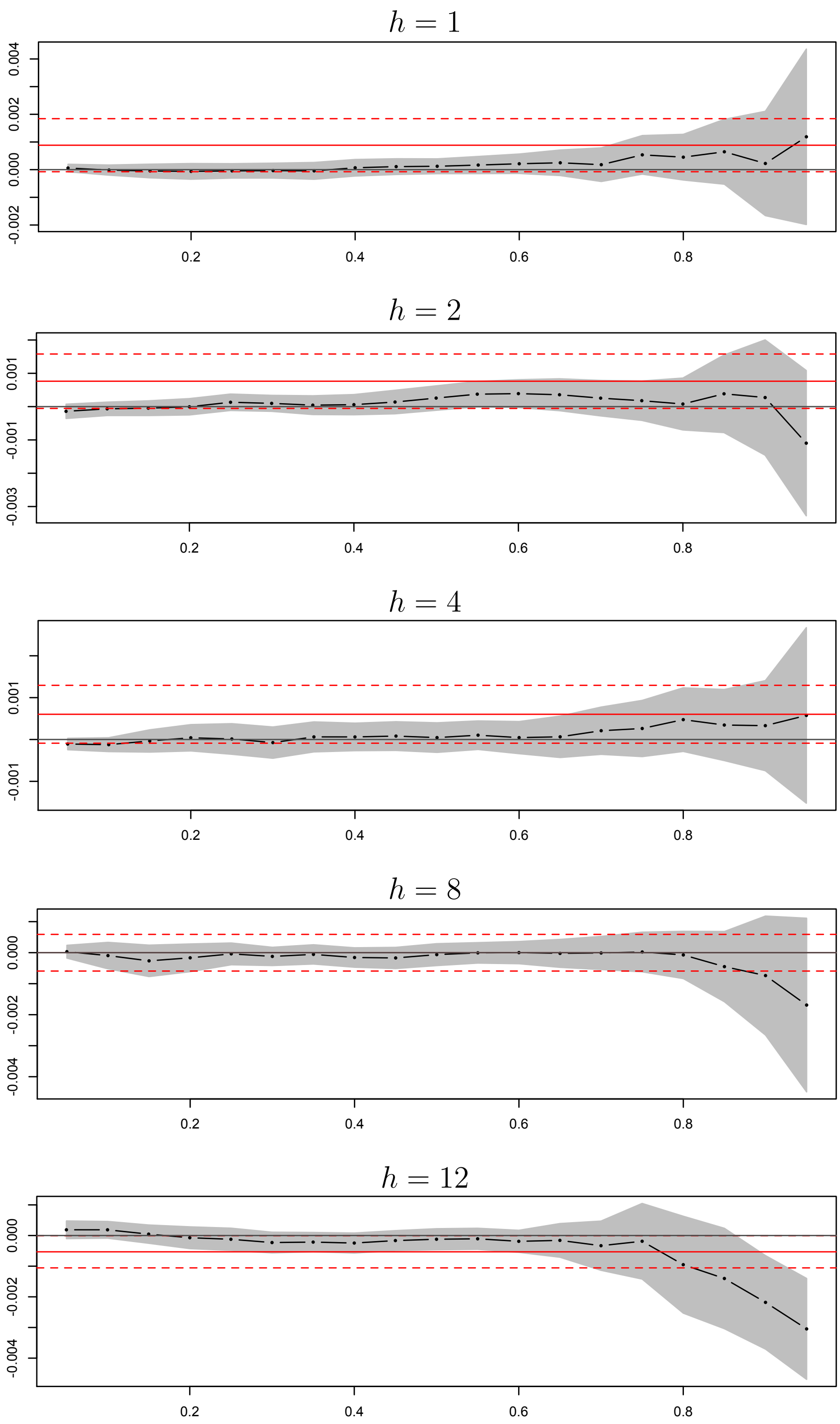
Figure 3 depicts our baseline results. The figure shows the estimated coefficients, $\beta_2(\tau)$, of the monetary policy spread as a function of the quantiles, where the shaded areas are bootstrapped 95% confidence intervals. The main result is that the subsequent realized variance of gold-price returns is not associated with the stance of monetary policy, as measured in terms of the monetary policy spread, when we study the short horizons. In sharp contrast, the estimated coefficient of the monetary policy spread becomes negative for the upper quantiles for $h = 8$, and it becomes significantly negative for the long horizon. Hence, a restrictive monetary policy, as indicated by a positive monetary policy spread, tends to be associated with a subsequent decrease in the realized variance of gold-price returns at the two long horizons when we study the upper quantiles of the conditional distribution of the latter. An accomodative monetary policy in times of a negative monetary policy spread, in turn, inflates at the two longer horizons the realized variance of gold-price returns at the upper quantiles.[9]

We obtain qualitatively similar results to those we document in Figure 3 when we study the realized volatility (that is, the square root of the realized variance) of gold-price returns, when we drop $RV$ as a predictor from the quantile-regression model, when we study PM data, and when we study the $h-$period ahead realized variance (rather than its average), showing that our results are quite robust to the details of the specification of the quantile-regression model (results are not reported, but are available from the authors upon request).[10]

[9] It should also been noted that the estimated ordinary-least-squares coefficient (horizontal red solid line in Figure 3) is positive for the short horizons and negative for the long horizon.

[10] As suggested by an anonymous reviewer, the results for realized volatility may be particularly interesting because, for example, it plays a key role in the pricing of derivative securities. We, therefore, report the results for realized volatility at the end of the paper (Appendix).

Figure 3: Baseline Estimation Results




Note: This figure plots on the vertical axis the estimated coefficients, $\beta_2(\tau)$, of the monetary policy spread. The quantiles, $\tau$, are depicted on the horizontal axis. $h$ denotes the horizon. The shaded areas are bootstrapped 95% confidence intervals (1,000 boostrap simulation runs). The horizontal red solid line is the ordinary-least-squares estimate, while the horizontal red dashed lines are the boundaries of the corresponding 95% confidence interval.

Next, we estimate the quantile-regression model for two subsample periods. To this end, and based on the estimation results that Bianchi et al. (2022) report, we study a hawkish and a mainly dovish policy regime. The first subsample period covers a hawkish policy regime, and is based on data for the monetary policy stance for the period from 1978Q4 to 2001Q3. The second subsample period covers a mainly dovish regime, and is based on data for the monetary policy stance for the period from 2001Q4 until the end of the sample period.[11] As for the hawkish policy regime (Figure 4), we find that, for the intermediate quantiles (above and below the median), the estimated coefficient of the monetary policy spread is significantly positive for the two long horizons. Importantly, the estimated coefficient for the upper quantiles of the realized variance of gold-price returns turns negative in the hawkish policy regime when we increase the horizon. In contrast, in the dovish policy regime (Figure 5), the estimated coefficient of the monetary policy spread turns out to be significantly positive for a broad range of quantiles, and the quantiles above the median in particular, for the intermediate and long horizons. Hence, an increase in the monetary policy spread dampens the subsequent realized variance of gold-price returns at the upper quantiles of the conditional distribution of the latter in the hawkish policy regime, but it increases the realized variance of gold-price returns in the more recent mainly dovish policy regime.

It is interesting to note that Figures 4 and 5 illustrate a key advantage of the quantile-regression model over the ordinary-least-squares technique. The estimated ordinary-least-squares coefficient (red solid horizontal line in the figures, with the dashed red horizontal line denoting the boundaries of the 95% confidence interval) of the monetary policy spread is positive (albeit statistically significant only for $h \geq 4$ in the mainly dovish policy regime) for all horizons. Hence, the ordinary-least-squares estimates cloud the negative effect that we estimate at the long horizons for the upper quantiles of the conditional distribution of the realized variance in the hawkish monetary policy regime, and the insignificant effect that we estimate for the lower quantiles in the mainly dovish monetary policy regime.[12]

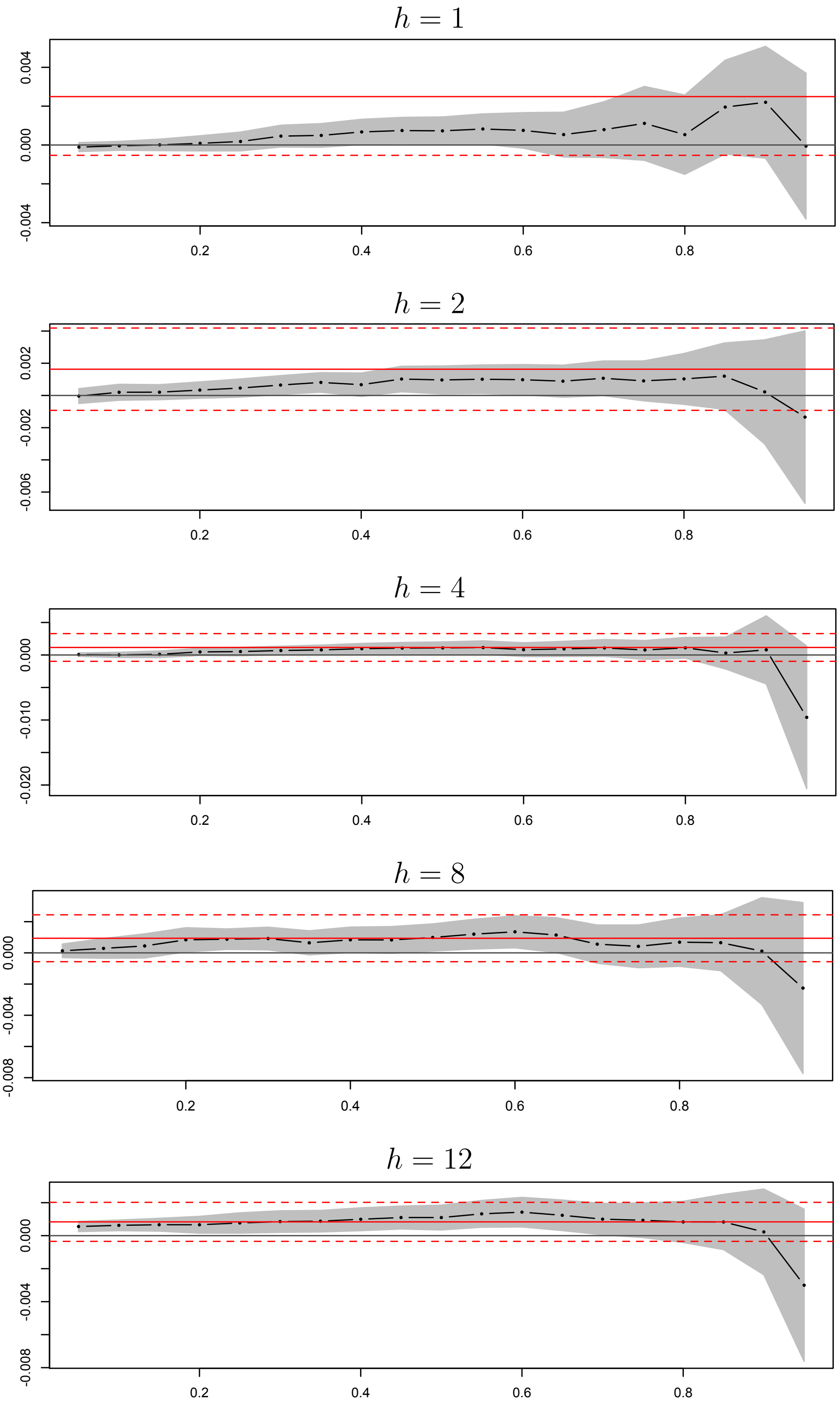
As another robustness check, we present in Figure A2 results for an alternative monetary policy spread that we calculate based on a traditional Taylor (1993) rule. To this end, we subtract the interest rate as implied by a Taylor rule of the format $i = \pi^e + 0.5 \times y_{gap} + 0.5 \times \pi_{gap} + 2$ from the Federal funds rate.[13] The results based on the Taylor rule are in line with the results we report in Figure 3.

[11] As mentioned before, Bianchi et al. (2022) find that the dovish policy regime was interrupted by a short hawkish period from 2006Q2 to 2008Q2, which is why we call the second subsample period a "mainly" dovish policy regime.

[12] The sign of the estimated ordinary-least-squares coefficient turns from positive to negative in Figure 3 when we increase the horizon, but it clearly understates the significantly negative effect that we estimate at the long horizon for the upper quantiles of the conditional distribution of the realized variance of gold-price returns.

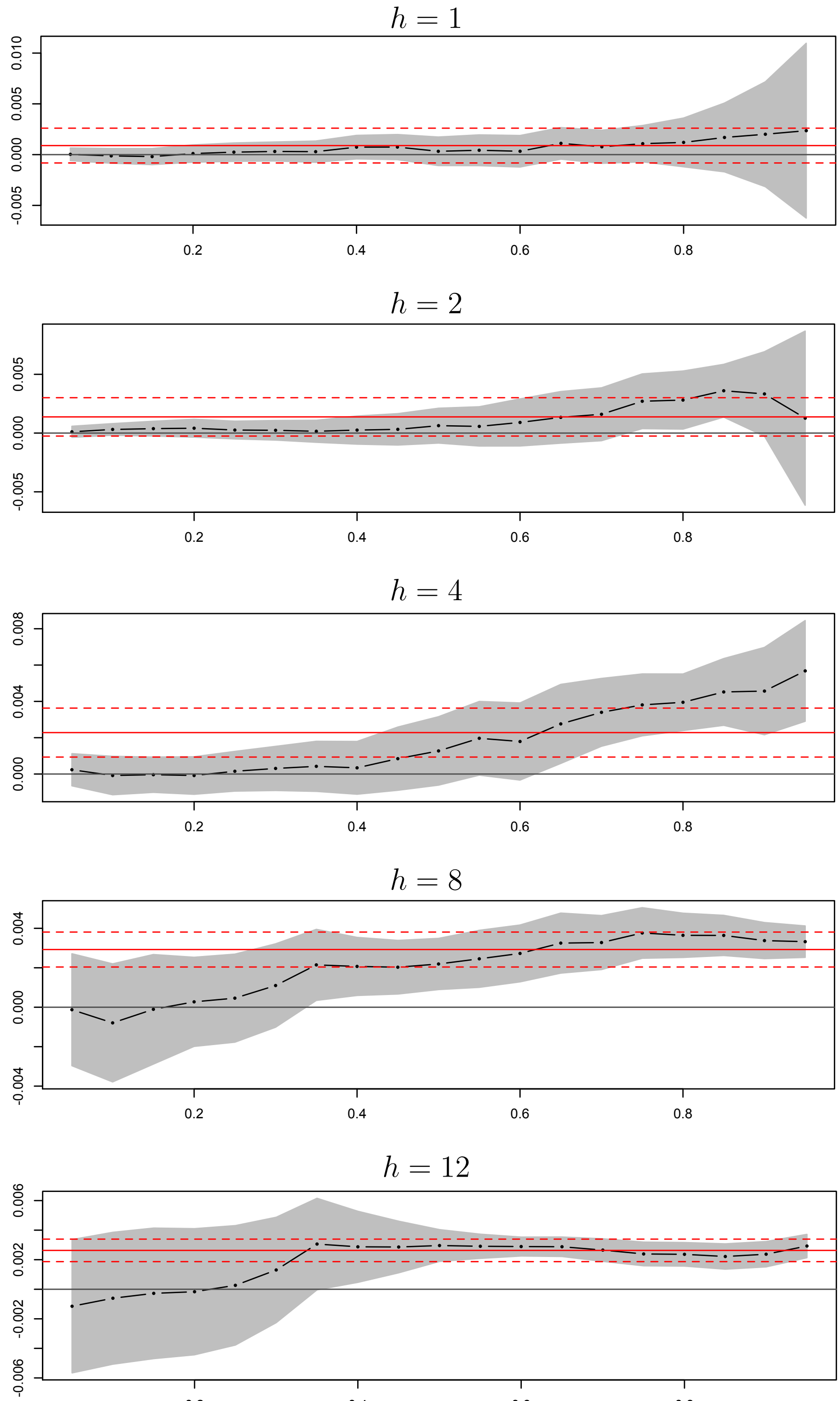
[13] In the Taylor rule, $i$ denotes the Federal funds rate, $\pi^e$ denotes the expected personal-consumption-expenditures inflation rate as proxied by the four-quarter backward-looking average of inflation, $y_{gap}$ denotes the output gap, and $\pi_{gap}$ denotes the inflation gap calculated as the expected inflation rate minus 2. Data on the output gap were taken from Laubach and Williams (2003). Link: https://www.newyorkfed.org/research/policy/rstar. Results for an estimated Taylor rule (that is, a rule with estimated rather than calibrated parameters) are similar (not reported for reasons of space, but available from the authors upon request).

Figure 4: Estimation Results for the Hawkish Policy Regime (1978Q4−2001Q3)




Note: This figure plots on the vertical axis the estimated coefficients, $\beta_2(\tau)$, of the monetary policy spread. The quantiles, $\tau$, are depicted on the horizontal axis. $h$ denotes the horizon. The shaded areas are bootstrapped 95% confidence intervals (1,000 boostrap simulation runs). The horizontal red solid line is the ordinary-least-squares estimate, while the horizontal red dashed lines are the boundaries of the corresponding 95% confidence interval.

Figure 5: Estimation Results for the Dovish Policy Regime (2001Q4−2020Q4)




Note: This figure plots on the vertical axis the estimated coefficients, $\beta_2(\tau)$, of the monetary policy spread. The quantiles, $\tau$, are depicted on the horizontal axis. $h$ denotes the horizon. The shaded areas are bootstrapped 95% confidence intervals (1,000 boostrap simulation runs). The horizontal red solid line is the ordinary-least-squares estimate, while the horizontal red dashed lines are the boundaries of the corresponding 95% confidence interval.

# 5. Concluding Remarks

Based on a quantile-regression model and using quarterly data for the sample period from 1968 to 2022, we have re-examined the association between the stance of U.S. monetary policy and the realized variance of gold-price returns. Our main finding is that tighter monetary policy is associated with a lower subsequent realized variance at the upper quantiles of the conditional distribution of the latter. We observe this inverse link mainly during an extended period of a hawkish policy regime (1978Q4−2001Q3), while the association between the stance of monetary policy and the realized variance of gold-price returns turns positive in a more recent mainly dovish policy regime (2001Q4−2020Q2). Hence, tighter monetary policy mitigates peaks in the realized variance in the hawkish policy regime, while it tends to inflate outbursts of the realized variance in the dovish policy regime. One reason for why an increase in the monetary policy spread tends to go in line with a subsequent increase in realized volatility at some upper quantiles may be that tighter monetary policy in a dovish policy regime contains − to a stronger extent than in a hawkish policy regime − a substantial surprise component. Such a surprise component could, given that market participants have to adjust their perception of the stance of monetary policy, lead to larger volatility peaks through an ensuing gradual adjustment of expectations regarding the stance of monetary policy.

In terms of future research, it is interesting to study the link between the stance of monetary policy and the realized variances of other major commodity-price returns (like those of the returns of other precious metal and agricultural commodity prices). In this regard, it is particularly interesting to inspect the implications of our results for the link between the stance of monetary policy and the gold-to-platinum price ratio. Huang and Kilic (2019) use the gold-to-platinum price ratio as a measure of risk, and show that this measure predicts stock returns and is correlated with option-implied tail-risk measures. Given the prominence of the gold-to-platinum price ratio in recent research, it is interesting to explore whether our main result that the stance of monetary policy has differential effects on the realized variance of gold-price returns across the conditional distribution of the latter and across hawkish and dovish policy regimes has implications for the properties and dynamics of the gold-to-platinum price ratio, and the predictive value of this ratio for (the realized variance of) other asset and commodity price movements.

Finally, it is also interesting to extend our quantile-regression model to include other control variables that have been studied in earlier literature. In addition, it is interesting to compile international data on the monetary policy spread and to examine in detail the effects of the stance of monetary policy in other countries than the U.S. on the realized variance of major commodity-price returns. Such analyses should help to deepen further our understanding of the link between the stance of monetary policy, the prevailing policy regime, and fluctuations of commodity prices.

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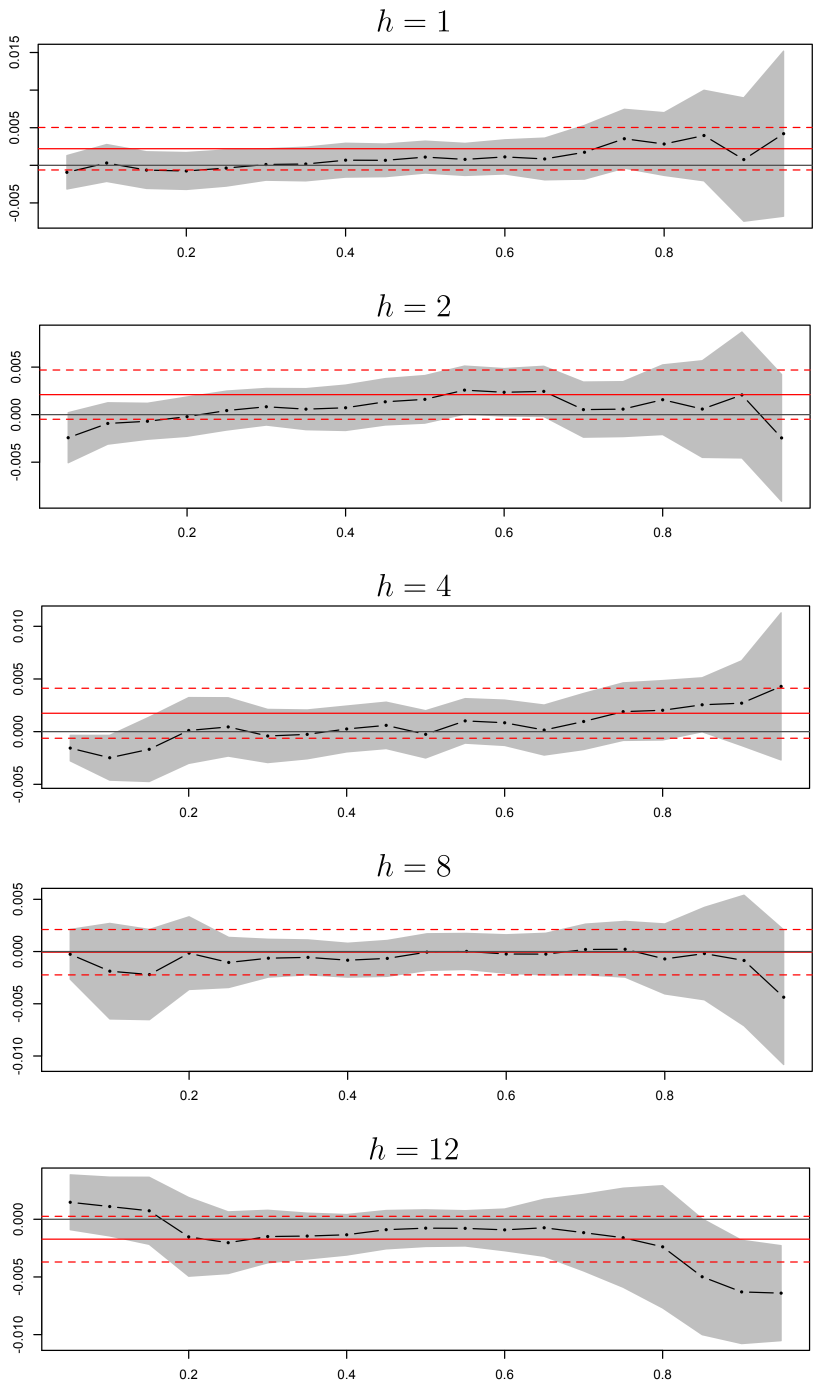
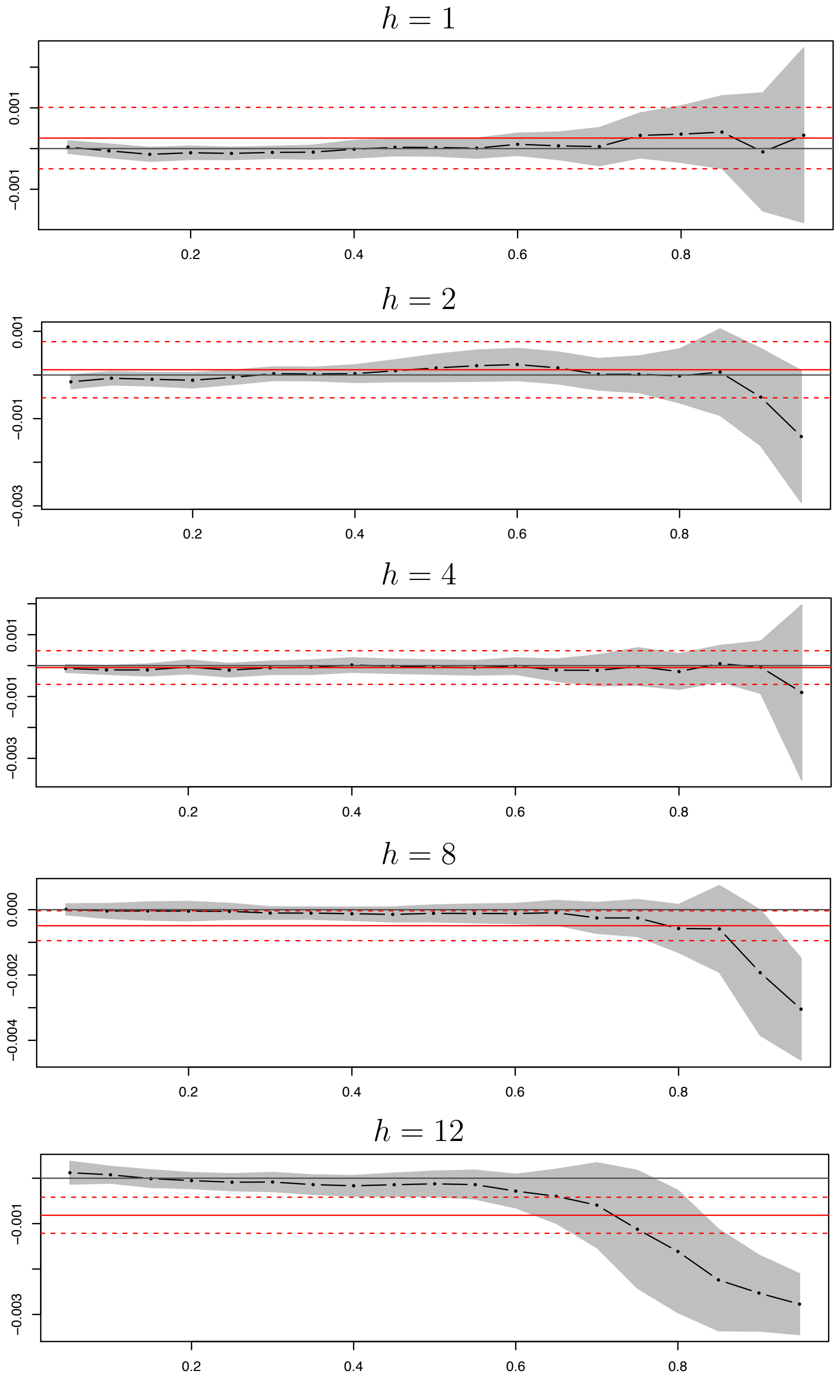
# Appendix

Figure A1: Estimation Results for Realized Volatility




Note: This figure plots on the vertical axis the estimated coefficients, $\beta_2(\tau)$, of the monetary policy spread and the quantiles, $\tau$,the horizontal axis. $h$ denotes the horizon. The shaded areas are bootstrapped 95% confidence intervals (1,000 boostrap simulation runs). The horizontal red solid line is the ordinary-least-squares estimate, while the horizontal red dashed lines are the boundaries of the 95% corresponding confidence interval.

Figure A2: Estimation Results Based on a Taylor Rule




Note: This figure plots on the vertical axis the estimated coefficients, $\beta_2(\tau)$, of the monetary policy spread and the quantiles, $\tau$,the horizontal axis. $h$ denotes the horizon. The shaded areas are bootstrapped 95% confidence intervals (1,000 boostrap simulation runs). The horizontal red solid line is the ordinary-least-squares estimate, while the horizontal red dashed lines are the boundaries of the 95% corresponding confidence interval. The monetary policy spread is calculated based on a standard Taylor rule.