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Measuring the time-varying impact of conventional monetary policy on stock markets via an identified multivariate GARCH model

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Abstract

This paper proposes a new approach to quantifying the impact of the short-term interest rate on the stock market, which is important to policy-makers. A multivariate GARCH model is considered, in which unexpected changes in Fed funds rates are used for identification. This approach combines the merits of events studies (information on exogenous shocks) with those of the time-series model. It permits the estimation of time-varying monetary policy effects on the stock market. Our results show that a cut of 25 basis points in the interest rate would induce a median increase of 1.78 percent in the equity index. In periods of high credit risks, the policy effect is stronger and the variation of the policy effect also increases. This pattern has become even more stronger since 2009.

Keywords: Time-varying parameters, monetary policy effect, stock market, multivariate GARCH, identification
JEL Classification: C32, E43, E52, G10

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1. Introduction

There is a consensus that the goal of monetary policy is to stabilise fluctuations in inflation and output. As the 2008-2009 financial crisis made clear, however, the unwinding of asset price and credit bubbles may have serious implications for both output and the inflation target. Thus, one might argue that mitigating excessive inflation or deflation in asset prices via policy rate adjustments should be part of forward-looking monetary policies. Conventional theories support the view that an increase in interest rates will reduce asset prices. A higher interest rate leads to a higher discount rate and lower future cash flows, and thus lowers stock prices. Empirical analysis of this relationship, however, is complicated by the issue of endogeneity. Stock-market movements may affect monetary policy, through their effects on real economic activity. Various methods have been used to identify the impact of conventional monetary policy on the stock market. Bernanke and Kuttner (2005) use an event-study approach with unexpected changes in the Fed-fund future rate as monetary-policy surprises. Rigobon and Sack (2004) use the heteroskedasticity in policy shocks measured by Eurodollar future rates. The recent literature has moved on from investigating the time-invariant impacts of monetary policy to detecting eventual time-varying effects. This line of enquiry has mainly focused on structural VAR models comprising monthly interest rate data, as well as other financial and economic variables. Galí and Gambetti (2015) employ timing restrictions (Cholesky factors), while Paul (2020) uses an external-variables approach for identification (proxy SVARs). Herwartz and Roestel (2022) adopted the MGARCH framework and identify time varying instantaneous effects by attributing specific sign and magnitude requirements to pre-selected periods of financial turmoil.

We propose a new structural identification approach for the MGARCH framework which uses surprises in Fed funds rates on event days (Kuttner, 2001) to identify the time-varying impacts of the three month T-Bill rate on S&P stock returns. The core idea is to identify the structural model such that its interest rate innovations are as close as possible to Fed-funds surprises (Kuttner, 2001) on event days.[1] In contrast to most VAR-based studies, we choose a daily and purely contemporaneous approach without macroeconomic control variables. This approach acknowledges that the impact of monetary policy news

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[1] The proposed identification technique differs from the one in Herwartz and Roestel (2022), where identification is guided by specific requirements on *parameters governing contemporaneous interactions* applying to pre-selected *periods* of financial turmoil. In this paper, we identify the model by requiring that specific model innovations are as close as possible to an observable benchmark.

on the US stock market is almost instantaneous, and allows a better isolation of respective surprises from other sources of variations.[2] The adopted model framework takes both endogeneity and time varying (co)variances of interest rates and stock market returns into account. By construction, therefore, it is well suited to describe changing market conditions that underlie the changes in policy effects we intend to measure.

The monetary policy indicator that we focus on is the unexpected change in the current-month Fed funds futures rate, not the forward guidance (Fed's communication). The former factor affects the current short-term interest rate, whereas the latter factor shapes the expectation of the future path of the short-term rates (and thus the long-term rate). Although the surprises in the current-month Fed funds futures can be related to Fed's private information on economic fundamentals (Romer and Romer, 2000), this association is weak. Gertler and Karadi (2015) have shown that only 10 percent of the variation in surprises from the current-month Fed funds future can be explained by private information from the Fed between 1991 and 2007.

We found the structural MGARCH model can mostly mimic the policy surprises, and the associated contemporaneous policy effects appear economically reasonable in terms of sign and magnitude. Our results show that the impact of the short-term rate is significant and time-varying. A cut in the interest rate of 25 basis points would induce a median increase in the equity index by 1.78 percent, 0.98 percent at the lower quartile and 3.30 percent at the upper quartile. This confirms the negative impact of conventional monetary policy on the stock market. Moreover, our result is consistent with that of Paul (2020), and contrasts with Galí and Gambetti (2015), who find that the short-term rate has a positive impact on the market during stock market booms. Our estimated negative policy impacts are more pronounced than those obtained by the constant policy impact frameworks, and are lower than those for time-varying policy impacts in Paul (2020). For the former, an unanticipated 25-basis-point cut in the Fed funds target rate produces an increase in stock returns of about 1 percent (Bernanke and Kuttner, 2005), while a 25-basis-point drop in Eurodollar future rates results in a 1.7 percent increase in stock returns on the same day (Rigobon and Sack, 2004). The impulse response analysis in Paul (2020) shows that a 20

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[2] In contrast to lower frequency (monthly/quarterly) VAR models, the omission of standard macroeconomic control variables is unlikely to severely bias estimated contemporaneous variation of financial data at the daily frequency. Periodic macroeconomic news releases on inflation and output occur on a monthly or quarterly basis and rarely overlap with policy announcements at the daily level. At the daily frequency, common financial factors might play a more prominent role in this respect. We address this issue in the robustness section.

basis-point cut in the Fed funds rate is associated with a 4 to 5 percent increase in stock prices in the same month. The wide range of these results might reflect either distinct methodological approaches or the analysis of empirical data drawn at different frequencies.

Variation in monetary-policy effects can inform policy planning. To proceed further, we investigate time-varying responses of stock markets in environments with different degrees of financial market stress. In a high stress market environment, financial constraints are more binding, which therefore might channel a stronger effect of the short-term rate on stock market returns. We consider a measure for credit risk to gauge states of market stress. In periods of relatively high credit risk, investors demand higher returns to compensate for higher default risks, which could limit each firm's access to credit. When the net worth of firms and borrowing conditions are affected, an interest-rate change can be expected to have stronger implications, particularly for firms (close to) facing binding financial constraints. Thus, the market's response to monetary policy will be stronger during periods of relatively high credit risk. Our results confirm that the average effects of policy on the stock market are stronger in periods of relatively high credit risk. In periods of low credit risk, stock returns increases by 1.63 percentage points to a 25-basis-point cut in the interest rate. This response increases by another 1.61 percentage points in periods of relatively high credit risk. In addition, we find that variability of the policy effect increases in periods of relatively high credit risk. We use the squared policy effect to gauge the degree of variation the policy effects. This measure increases by 15.03 in periods of high credit risk, from 4.08 in periods of low credit risk. Therefore, during high financial market stress periods, impacts of monetary policy on stock markets can be stronger on average, and the variation (i.e. uncertainty) associated with such effects increases at the same time. This pattern becomes even more stronger since 2009.

The remainder of the paper is organised as follows: the next section briefly sketches the MGARCH framework and discusses the suggested approach to identification in detail. The results are presented in Section 3. Section 4 investigates the time-varying effects of monetary policy on the stock market. Section 5 examines the robustness of the results and Section 6 contains the conclusions.

2. An identified multivariate GARCH model

Our baseline model is a bivariate GARCH model with the S&P500 value-weighted returns (from CRSP) and changes in the three-month Treasury Bill rate (from FRED) (see Figure 1). Kuttner (2001) shows that the response of this T-bill rate to unexpected changes in the monetary-policy target rate is strong and highly significant. This rate is closely related to changes in the Fed funds target rate, and this is aligned with our aim of identifying the impact of monetary policy on stock returns through unexpected changes in Fed funds rates. [3] For monetary policy surprises, we use unexpected changes in the Fed funds target rate based on current-month fed funds futures contracts (from Kenneth Kuttner's website). The sample period is from 3 January 1989 to 30 December 2019.

In this section, we introduce the identified MGARCH model which specifies the link between the underlying model innovations and the heteroskedastic financial market data. Firstly, we sketch a stylised bivariate GARCH model and highlight the identification problem. Secondly, we suggest an identification approach that matches the stochastic components of the MGARCH model with market-based assessments of monetary-policy surprises.

2.1. A reduced-form MGARCH representation

Let $y_t = (r_t, \Delta i_t)'$ denote a bivariate vector comprising stock returns and interest-rate changes. Multivariate GARCH processes provide a conditioning of second order moments of y_t on a filtration $\mathcal{F}_{t-1}$ that summarises system information up to time $t-1$. Formally,

$$y_t = \mu_t + e_t, \qquad (1)$$

where $\mu_t = E[y_t|\mathcal{F}_{t-1}]$ and, hence, $E[e_t] = 0$.[4] Time-varying symmetric and positive definite return covariances are denoted as

$$\mathrm{Cov}[e_t|\mathcal{F}_{t-1}] = H_t. \qquad (2)$$

Alternative MGARCH specifications differ in the parametric form that relates the covariance matrices H_t to historic information (see Bauwens et al., 2006, for a review of the class of MGARCH models). In this work we pursue the empirical analysis by means of a restricted model variant, namely the so-called BEKK(1,1,1) model (Engle and Kroner, 1995), i.e.,

$$H_t \;=\; CC' + A'e_{t-1}e_{t-1}'A + B'H_{t-1}B, \qquad (3)$$

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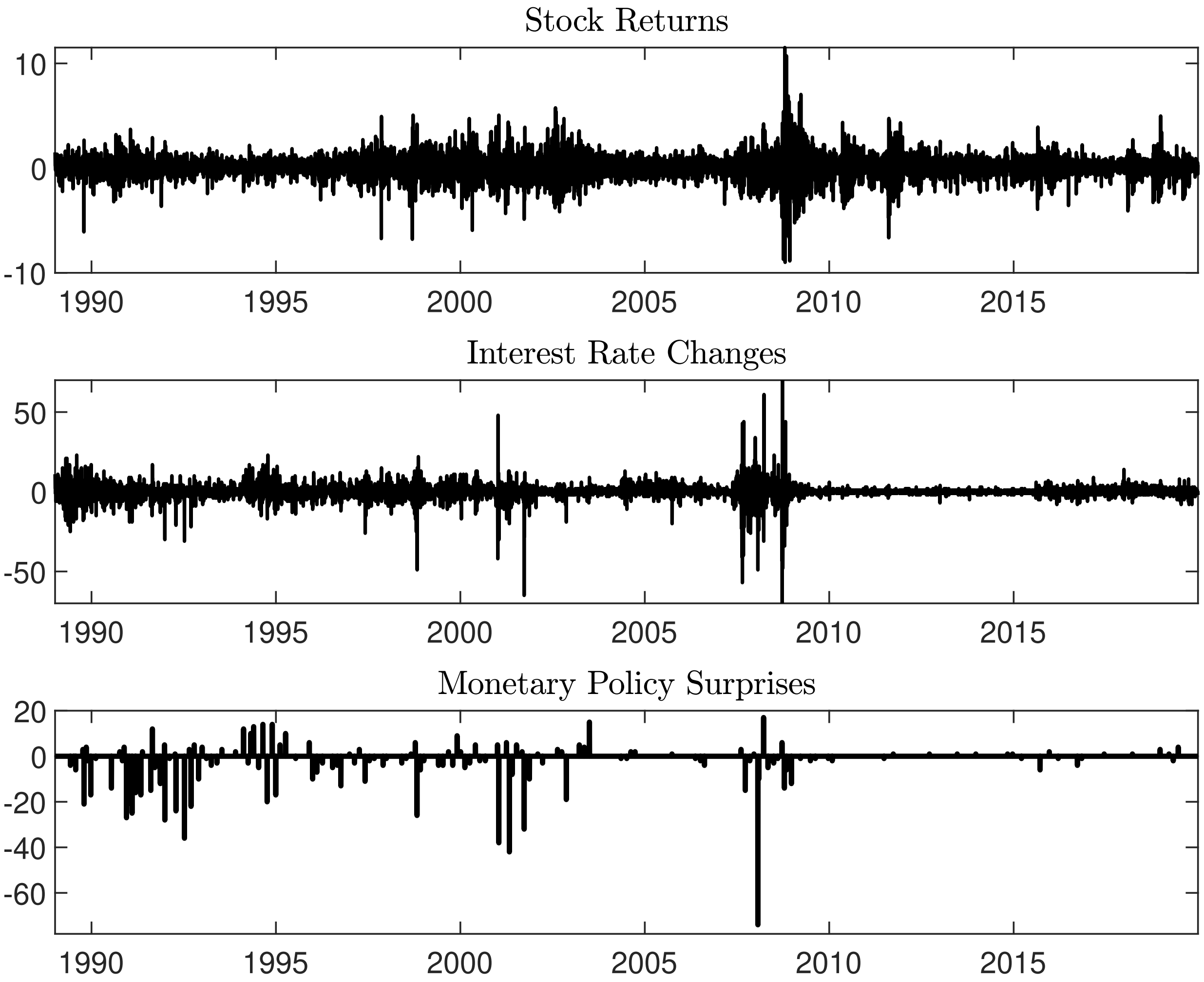
[3] At daily frequency, the effective Fed funds rate deviates from the target rate. This series contains many large outliers. So we refrain from using the Fed funds rate to avoid distortion of the dynamics.

[4] For daily data, one may assume $\mu_t = 0$ (or $\mu_t = \mu$) and subject raw or centred data (or VAR residuals) to MGARCH analysis. The empirical analysis in this paper is based on centred observations.

Figure 1: Data



This figure depicts stock returns based on the S&P500 index (in percentage points), changes in the three-month T-Bill rate (in basis points), and unexpected changes in the Fed funds target rate (in basis points).

where A, B and C are $N \times N$ parameter matrices with C being lower triangular. For a discussion of the consistency and asymptotic normality of the quasi-maximum likelihood (QML) estimator of the BEKK model parameters, we refer the reader to Comte and Lieberman (2003) and Hafner and Preminger (2009). Owing to the model specification in quadratic terms, BEKK-implied covariance paths are positive definite under mildly restricted initial conditions. Let θ be a column vector that collects the parameters of the model in (3), i.e. $\theta = (\text{vech}(C)', \text{vec}(A)', \text{vec}(B)')'$. We refer to the parameters in θ as reduced-form model parameters, since they can be uniquely estimated, conditional on the sample information.

2.2. *The identification problem*

The covariance in (2) describes the second-order characteristics of e_t in a time-varying and conditional manner. However, it is not explicit about the origins of the stochastic behaviour of e_t. In the MGARCH literature, it has become conventional to describe the link between latent innovations and observable returns (or their residuals) by means of the symmetric matrix square root of H_t, i.e.,[5]

$$e_t = H_t(\theta)^{1/2}\tilde{\xi}_t, \ \tilde{\xi}_t \overset{iid}{\sim} (0, I_N). \tag{4}$$

While $H_t(\theta)^{1/2}$ respects the (covariance) restriction, it is only one of an infinite number of alternative covariance decompositions that align with the reduced-form covariance model. In a strictly structural sense, the transmission from latent stochastic innovations in ξ_t to observables in e_t constitutes an identification problem. To provide an explicit structural representation of the MGARCH model, consider the following parameterised space of covariance decompositions

$$H_t(\theta) = H_t(\theta)^{1/2}H_t(\theta)^{1/2'} = H_t(\theta)^{1/2}R_\delta R_\delta' H_t(\theta)^{1/2'} = W_t(\theta, \delta)W_t(\theta, \delta)', \tag{5}$$

where R_δ is a rotation matrix (satisfying $R_\delta \neq I_N$ and $R_\delta R_\delta' = I_N$), formulated as

$$R(\delta) = \begin{pmatrix} \cos(\delta) & -\sin(\delta) \\ \sin(\delta) & \cos(\delta) \end{pmatrix} \text{ with rotation angle } \delta \in [0, \pi).$$

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[5] The symmetric square-root matrix is $H_t^{1/2} = \Gamma_t \Lambda_t^{1/2} \Gamma_t'$, where the eigenvectors of H_t are the columns of Γ_t, and the diagonal matrix Λ_t has the eigenvalues of H_t along its diagonal. As an alternative a-priori choice, an analyst might also consider Cholesky factors of H_t.

In this specification, the identification problem is equivalent to choosing a specific rotation angle δ, which, in turn, implies a particular covariance decomposition matrix to obtain $W_t(\theta, \delta) = H_t^{1/2}(\theta)R_\delta$. The corresponding identified counterpart of the ad-hoc specification in (4) then reads as

$$e_t \; = \; W_t\xi_t, \; \xi_t \overset{iid}{\sim} (0, I_N). \tag{6}$$

2.3. Identification of time varying marginal effects

Taking advantage of the informational content of policy surprises s_t, we suggest an economic approach to identifying shocks that are processed within the dynamic MGARCH model. More specifically, we aim to identify a stochastic model component which represents the market-perceived monetary-policy surprises, denoted s_t, most accurately. For this purpose, let Ω_s denote the set of all days with nonzero policy surprises. The number of these events equals the magnitude of Ω_s, denoted $|\Omega_s|$.

First reconsider the model (6), where the stochastic model components on the right-hand side are homoskedastic and have unity covariance matrix. Apparently, this structural model aligns with a contemporaneous SVAR model in its so-called B-form. In model (6), however, 'B' is time varying. To approach the model identification intuitively, one might first think about matching the surprise information s_t to respective model innovations on the right-hand side of (6). However, the latter are conditionally normalized such that their magnitude is not measured in terms of units of the left hand side variable. For instance, this implies that an interest rate shock of size '1' in scenarios of low market volatility might be associated with a 5-basis-point change in interest rates, whereas a same sized shock could be associated with a 10-basis-point interest rate change in scenarios of market turmoil. The monetary policy indicator, in contrast, is throughout measured in basis points. Thus, matching such conditionally standardized 'scale free' shocks to the observable policy indicators given in basis points is not coherent. Hence, it is natural to solve the identification problem with a focus on those stochastic model components (i.e. shocks) that are measured in the same units as their left hand side variable counterpart. For this purpose, we have to consider heteroscedastic shocks. As in Herwartz and Roestel (2022), the corresponding A-model variant of the identified MGARCH model is

$$\begin{aligned} A_t e_t \; &= \; \Sigma_t \xi_t \qquad (7) \\ &\overset{!}{=} \; \xi_t^*, \end{aligned}$$

where Σ_t is a diagonal matrix of time-varying standard deviations. With '$\odot$' denoting element-by-element multiplication, it is the case that $\Sigma_t = (W_t^{-1} \odot I_N)^{-1}$ and $A_t = \Sigma_t W_t^{-1}$. By construction, the elements of ξ_t^* are uncorrelated but heteroskedastic, and the diagonal elements of A_t are normalised to unity. Apparently, ξ_t^* are measured in the same units of the corresponding left hand side variables, i.e. percentage points. Accordingly, the off-diagonal elements in A_t describe the way in which the observables in e_t impact on each other contemporaneously within a feedback system. More specifically, estimates of the typical elements $-a_{t,12}$ ($-a_{t,21}$) quantify the time-varying marginal effects of a unit change in the second (first) element of e_t on the first (second) element, conditional on the history of the process.

To formalise the novel identification scheme in the context of our empirical analysis of $y_t = (r_t, \Delta i_t)'$, let ξ_{2t}^* denote a shock to which we wish to assign a structural interpretation (i.e. the monetary-policy shock). Evidently, the elements of ξ_t^* depend on the transmission matrix $W_t(\theta, \delta)$ that allows the extraction of iid innovation vectors ξ_t from the data ($\xi_t = W_t^{-1} e_t$). To identify the stochastic model components in (7), we select the rotation angle δ, according to the following criterion:

$$\delta^* = \min_{\delta} \sum_{t \in \Omega_s} (\xi_{2t}^* - s_t)^2 , \quad \text{with } \xi_t^* = (W_t^{-1} \odot I_N)^{-1} W_t^{-1} e_t, \; W_t = W_t(\theta, \delta). \tag{8}$$

We chose the rotation angle(s) which minimise the sum of the squared deviations between the observed policy surprises s_t and our model-implied shocks, conditional on the sample Ω_s. As a result of the matching with s_t, the implied shocks ξ_{2t}^* can be considered as structural. We focus on the identification of one shock, while we leave the remaining shock ξ_{1t}^* unidentified.

3. Empirical results

This section presents the results of the baseline bivariate GARCH model. We find substantial variations in the stock-market response to monetary policy. Also, both the average market response and the variability of the market response are stronger in periods of relatively high credit risk.[6]

By solving the optimisation problem in (8), we obtain the rotation angle of $\delta^* = 6.0322$

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[6] Detailed results for estimated MGARCH models are available from the authors upon request. The conditional (co)variances of e_t show responses to lagged observations e_{t-1} and lagged covariances H_{t-1} that are highly significant.

radiant and the following estimated rotation matrix[7]

$$R_{\delta^*} = \begin{pmatrix} 0.9695 & 0.2453 \\ -0.2453 & 0.9695 \end{pmatrix}.$$

The corresponding estimated innovations (ξ^*_{2t}) in the interest-rate equation mimic the variation of the monetary-policy surprises fairly well, see Figure 2. Regressing the estimated model innovations onto the policy surprises, s_t, yields

$$\xi^*_{2t} = \underset{(0.4420)}{-0.9886} + \underset{(0.0695)}{0.6989}\ s_t + u^*_t \quad \forall t \in \Omega_s, \text{ where } |\Omega_s| = 151, \quad R^2 = 0.63,$$

with HAC robust standard errors in the parenthesis below. Thus, while the fit is good, evidence is at odds with a perfect one-to-one relation between model innovations and surprises.

The time path of the estimated policy impacts on stock markets and their corresponding bootstrap confidence intervals are sketched in the upper panel of Figure 3. It shows that the policy impacts are both negative and time-varying, with high significance. On average, estimated policy effects seem to be moderate, with the full sample median of -0.0715 percentage points. This result suggests that an unexpected 25-basis-point cut in interest rates would induce a 1.78 (-25×-0.0715) percentage-point increase in the equity index. This estimate is in the range documented by the literature on time-invariant policy impacts (1.7 percentage points in Rigobon and Sack (2004) and 1 percentage point in Bernanke and Kuttner (2005) from a 25-basis-point cut) and the time-varying approach of Paul (2020) (around 4 to 5 percentage points associated with a 20-basis-point cut). Our estimates suggest mostly moderate policy effects until the end of 2008, with a median of 1.41 percentage points. During the zero lower bound period, however, point estimates strengthen markedly. Policy effects become more erratic and confidence bands widen. The associated point estimates with a median of 4.93 percentage points seem rather large and might overstate the true effect. While such magnitudes are also found in the related literature (Paul, 2020), confidence bands are wide and include those values that appear more

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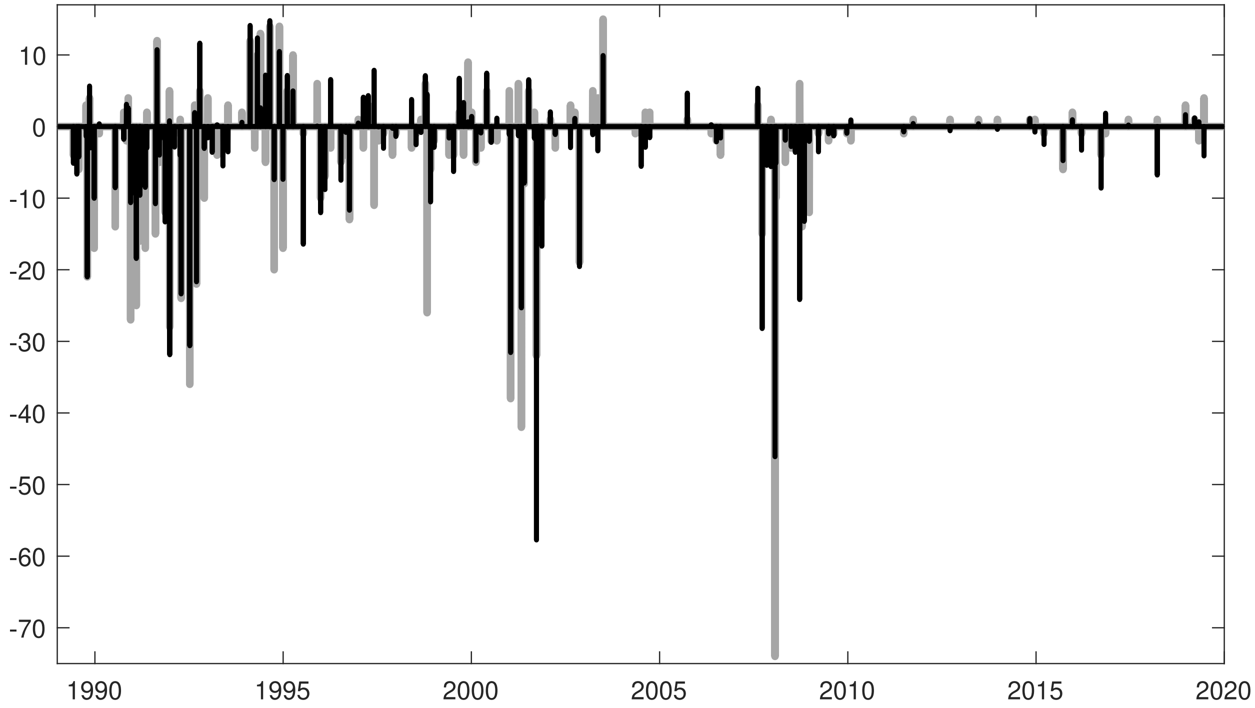
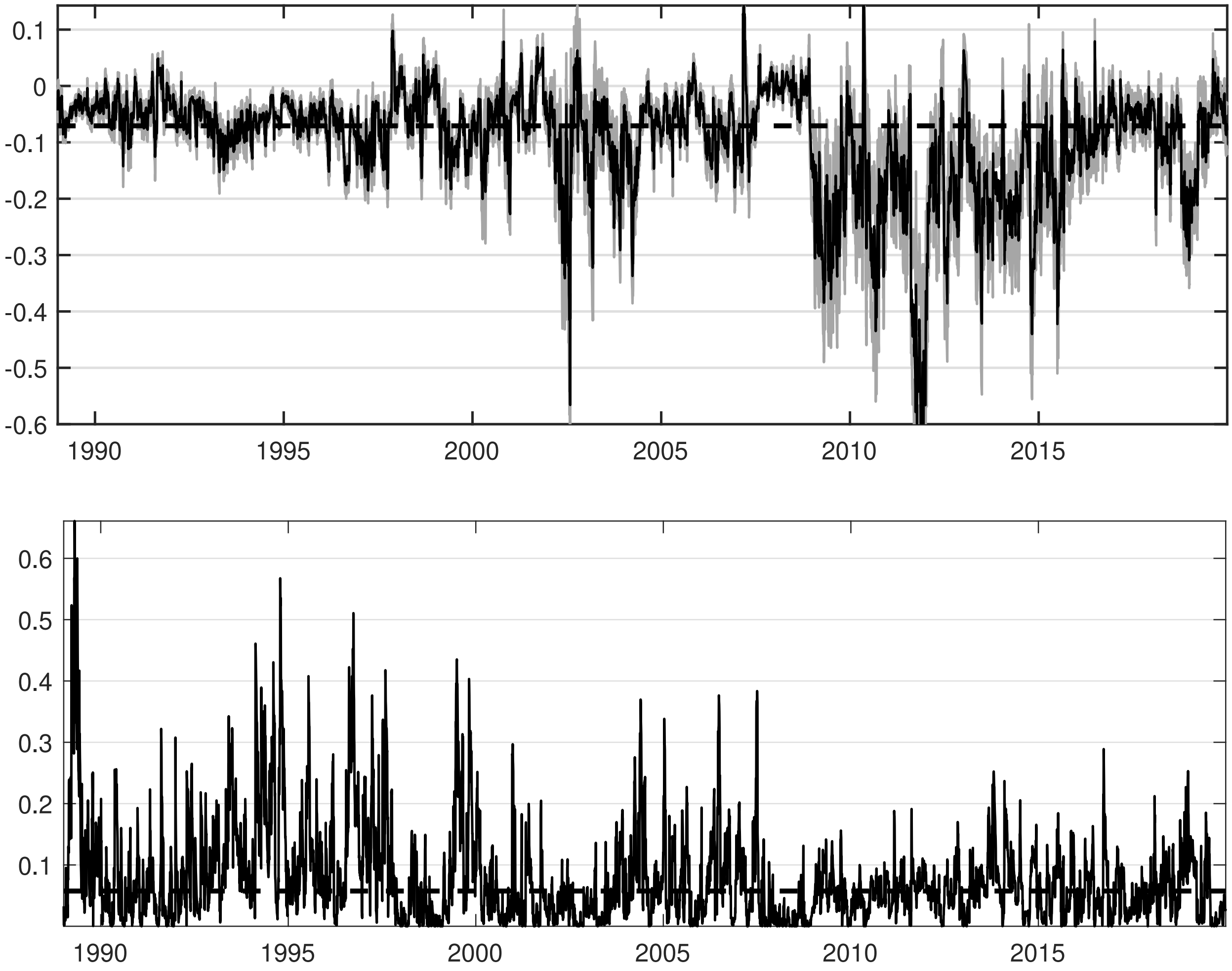
[7] Regarding policy surprises, we removed an influential outlier in the matching process. On March 18, 2008, there was an expected policy rate change of -92 basis points (the largest one in the sample), whereas the actual change was -75 basis points. Due to scale effects and uncertainty, therefore, we get a relatively strong positive surprise of 17 basis points when an outstanding cut took place. Since this 'odd' matching requirement reduces the R2 around 13%, we decided to skip this outlying observation.

Figure 2: Monetary-policy surprises and rotated interest-rate shocks



The figure shows the model-implied structural policy shocks ξ^{*}_{2t} (in black) jointly with the monetary-policy surprises (in grey) on the dates of policy action (excluding the outlier on march 18, 2008, see footnote 7).

Figure 3: Conditional policy effects and respective variance shares



The figure shows the time paths of conditional policy effects a_{21t} (along with bootstrap-based 99% confidence bands) and the respective share of conditionally explained stock-market variance, obtained from the identified model in (6). Noting that the squared elements w_{ijt}^2 of W_t measure the conditional contribution of shock ξ_{jt} to $E(e_{it}^2)$, the conditional share of explained stock-market variance attributed to the policy-shock variance is $w_{12t}^2/(w_{11t}^2 + w_{12t}^2)$. The respective medians are indicated by dashed lines.

intuitive from the economic point of view. The estimates during the zero lower bound period need to be taken with a grain of salt. On the one hand, the lack of economically meaningful variations in the Fed funds rate in this period erodes the basis of policy effect assessment. On the other hand, arguably, stock markets might react very sensitively to any surprises in the policy rate when it is already very close to zero. After the zero lower bound period, estimates return to mostly moderate pre-crisis levels with a median of 1.78 percentage points. The lower panel of Figure 3 shows the conditional share of the stock-market variance which is explained by structural policy shocks. As one might expect, explained variations in stock prices due to interest-rate movements seem to decrease after 2008. This might reflect that, with the advent of unconventional monetary polices, the perceived importance of conventional monetary policy decreased.

Overall, we observe considerable variation in the responsiveness of asset prices to monetary policy. The 25% and 75% quantile of the policy effects are -0.1318 and -0.0392 percentage points, respectively. This implies an increase of between 0.98 and 3.295 percentage points in stock prices in response to an unexpected 25-basis-point cut. The next section explores this variation in the context of the general market environment.

4. Time-varying policy effects

This section focuses on the time variation of policy effects in environments of relatively low or high financial market stress. It also addresses the variability of policy effects, which might also increase when firms begin to face binding financial constraints. Such enhanced variation of policy effects is important for monetary authorities, as it is likely to be more difficult to anticipate policy effects when planning policy in such environments.

To gauge states of market stress, we use a measure of the credit risk. We consider a high credit-risk period to be a period when the credit spread (Moody's BAA corporate-bond yield minus yield on ten-year treasury with constant maturity) was above its sample median. When the financial conditions of firms deteriorate, the default risk increases, as does the credit spread. The credit spread is a direct market-based measure of credit risk, and reflects daily real-time market conditions.

The policy effects on the stock market tend to be significantly stronger in environments of enhanced market stress. The stock return's response to a 25-basis-point cut in the interest rate increases by 1.61 percentage points in high credit-risk periods, compared to 1.63 percentage points in periods of relatively low credit risk (see Panel A of Table 1). We further divide the whole sample into pre- and post-2009 samples. For both sub-samples, interest rate changes have a significantly more pronounced impact on stock markets during periods with enhanced market stress (with an increase of 2.17 percentage points in the policy effects in the post-2009 sample). The US fed funds rates converged to the zero lower bound from 2009 since the 2007-2008 financial crisis. This further strengthens the view that the market stress plays an important role in the impact of interest rates on stock markets. In addition, the degree of variation in policy effects also increases in stressful market periods. We measure this variation in terms of squared policy effects (i.e., $a_{t,21}^2$). This variation increases, on average, by 15.03 in periods of relatively high credit risk, see Panel B of Table 1. Considering two sub-samples, the increase in the variation is also stronger in the post-2009 periods. Compared with average levels of 7.39 in periods of relatively low credit risk, the degree of variation in policy effects increases by 20.79 in high credit risk period.

Table 1: Time-varying policy effects (from identified bivariate MGARCH)

	Panel A: policy effect			Panel B: (policy effect)^2		
	Full	Pre-2009	Post-2009	Full	Pre-2009	Post-2009
constant	−1.63	−1.54	−2.22	4.08	3.57	7.39
	(0.04)	(0.02)	(0.12)	(0.38)	(0.15)	(1.55)
Credit Risk	−1.61	−0.10	−2.17	15.03	2.97	20.79
	(0.05)	(0.04)	(0.13)	(0.53)	(0.27)	(1.73)
R^2	0.12	0.00	0.09	0.09	0.02	0.05

Panel A of this table shows estimation results for the regression of policy effects (measured as percentage changes in stock returns to a 25-basis-point increase in the interest rate) on a constant and the index of periods of relatively high credit risk (equal to 1 for periods when the credit spread is above its sample median, and 0 otherwise). Panel B of this table shows estimation results for the regression of squared policy effects on a constant and the index for high credit-risk periods. Estimated coefficients are shown with the corresponding standard errors in parentheses. The parameter estimate for the index of credit risk in the pre-2009 sample in Panel A is significant at 5% level. All other parameter estimates are significant at 1% level.

5. Robustness of the results

The two main issues when estimating the relationship between monetary policy and stock prices are the endogeneity of the variables and the potential of omitted variable biases. The adopted GARCH framework explicitly models the endogenous relationship, but may suffer from omitted variables in its stylised bivariate form. Shocks to the macroeconomy and the financial markets can simultaneously affect monetary policy and the stock market. In this section, we extract a common shock from suitable financial-market variables and integrate it into our model as a third variable. For this purpose, we consider the first differences of i) log exchange rates (the weighted average of the U.S. dollar value against a basket of currencies), ii) log gold prices, and iii) log crude oil prices.[8] From these log differences we obtain the first principal component (denoted as c_t) to approximate a common exogenous factor that might induce joint movements in asset prices including stock-market and interest-rate variation. It is integrated into a corresponding trivariate GARCH model with $y_t = (r_t, \Delta i_t, c_t)'$. We then identify the policy effects as before, while treating the remaining two shocks in an agnostic manner.

Our results show that the estimated policy effects from the trivariate model are similar to those from the bivariate model. The correlation between the two is 0.99. A 25-basis-point cut in the interest rate would induce a median increase in the stock index of 1.78 percentage points in the bivariate model and 1.62 percentage points in the trivariate model. The results of the time-varying policy effects are also similar, and are documented in Table 2. In periods of relatively large credit risk, the policy effect on the market is stronger and the variation of the policy effect also increases. From 2009 onward, this pattern becomes stronger.

Table 2: Time-varying policy effects (from identified trivariate MGARCH)

	Panel A: policy effect			Panel B: (policy effect)^2		
	Full	Pre-2009	Post-2009	Full	Pre-2009	Post-2009
constant	−1.49	−1.40	−2.04	3.58	3.14	6.45
	(0.03)	(0.02)	(0.11)	(0.29)	(0.12)	(1.17)
Credit Risk	−1.35	0.08	−1.89	11.56	1.89	15.98
	(0.05)	(0.04)	(0.12)	(0.41)	(0.22)	(1.30)
R^2	0.09	0.00	0.08	0.09	0.01	0.05

For further notes, see Table 1. Parameter for the index of credit risk in the pre-2009 sample in Panel A is significant at 10% level. All other parameters are significant at 1% level.

6. Conclusions

This paper proposes a new approach to estimating the impact of monetary policy on the stock market. We investigate the endogenous relationship between the two variables

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[8] These are downloaded from FRED with the respective codes DTWEXM, GOLDPMGBD228NLBM, DCOILWTICO.

using an identified multivariate GARCH model, in which the heteroskedasticity of shocks in both interest rates and stock markets are taken into account. We use the informational content embedded in the monetary-policy surprises on event days to identify the market's response to monetary policy, and enable the estimation of time-varying policy effects on the market.

Our results show that a cut of 25 basis points in the interest rate would induce a median 1.78 percent increase in the equity index. Furthermore, during periods of relatively large credit risk, the monetary-policy effects on the stock market are stronger and the variation of the policy effect is larger.

A potential direction for future research, based on the approach of this paper, would be out-of-sample forecasting. Our methodology enables predictions of asset-market reactions to an unexpected policy interest-rate change to be made, based on the most recent market conditions. Because covariance modelling/prediction works well for financial market data, one might expect good out-of-sample forecasting of policy effects.

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