The Time Varying Effect of Monetary Policy Surprise on Stock Returns: Bursting Bubble Beating Forward Guidance

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Abstract

We study the time varying effects of monetary policy on the stock returns in order to capture changes in the effectiveness of monetary policy over time. We find that a one percentage point surprise federal funds rate increase decreases the one-day stock return by 1.33% during the period 1989 to 2000, and by 7.47% during the period 2001 to 2007, i.e., over five times more. Also, surprises of monetary policy announcements do not have significant effects on the stock returns for most of the 1990s, but have significant effects during the 2000s. The significant period coincides with higher transparency and greater efforts from the Federal Reserve to communicate with the public, especially in the grounds of future policy, i.e., forward guidance. Higher transparency could increase the effectiveness of monetary policy. At the same time, the insignificant period coincides with the period of stock prices' bubble. Recent work (Gali, 2014; Gali and Gambetti, 2015) has suggested that monetary policy might be ineffective during periods of bubbles. In order to distinguish between the two explanations, we explore the evolution effect of monetary policy surprise on bond returns. We find uniform response of bond returns before and after the 2000s. Thus, we conclude that our finding of low monetary policy effectiveness during the 1990s is specific to the stock market, making the theory of rational bubbles the prevailed explanation.

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Keywords: Monetary Policy's effectiveness; Stock prices; Forward Guidance; Time Varying Parameter Model.

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1 Introduction

Monetary policy's ability to influence the real economy is an issue of great importance for central bankers and policy makers. An avenue through which monetary policy affects the real economy is the stock market. Models of monetary policy suggest that an unexpected monetary policy tightening decreases stock market prices. We use an empirical model in order to test this idea. Given the many changes in recent decades in the conduct of monetary policy and the operation of financial markets, there is little reason to believe that this relationship has been a stable one. Here we allow for time variation in the effect of monetary policy surprises on stock price returns, in order to examine if and how this relationship has been changing over time.

Our findings suggest that the effect of monetary policy on stock returns exhibits substantial variations over time. A one percentage point surprise federal funds rate increase decreases the one-day stock price return by 1.33% during the period 1989 to 2000. The same change in monetary policy decreases the one-day stock price return by 7.47% during the period 2001 to 2007, i.e., over five times more. In addition, the effect is not significant during the first subsample but becomes significant during the second.

We suggest that the reason behind monetary policy's low impact on the stock market during the 1990s is the existence of a stock price bubble. According to previous work (Gali, 2014; Gali and Gambetti, 2015), tighter monetary policy reduces the fundamental component of the stock price but increases the bubble component, and hence might increase stock prices at periods when the rational bubble component is large relative to the fundamental component.[1] The contemporaneous effect of monetary policy on the stock prices becomes ambiguous, and thus it is possible that stock prices respond little or not at all to unexpected monetary policy. Given that from the mid-1990s to the beginning of the 2000s the stock market had been experiencing a bubble, the theory of rational bubble provides an explanation for our findings that monetary policy had been relatively less effective during that period.

A complicating issue is that another change occurred around the beginning of the 2000s, the introduction of forward guidance in the Federal Reserve's communication with the

[1] This is a bubble component under rational expectations.

public. The move to higher transparency had been a gradual one. Public announcements started after 1994, the federal funds rate target started being announced after 1995, and since then the Federal Reserve has been becoming more and more clear at revealing its thoughts. Especially after 1999, the Federal Reserve started announcing information about its future policy actions, providing forward guidance. We expect higher transparency in terms of forward guidance to make expectations about future policy actions less dispersed across individuals, and thus to make monetary policy more effective.

Our results are consistent with both explanations: Monetary policy might appear to be ineffective during the 1990s because of low transparency and high dispersion of expectations about its future path. It might also have been ineffective during the 1990s, because of a strong bubble component. In order to distinguish between these two explanations we estimate the time varying response of bond returns to a monetary policy surprise. There are no bubbles in bond prices. Therefore, a weaker response during the 1990s and stronger response during the 2000s would support the increased transparency and forward guidance explanation. A uniform response of bonds would support the bubble explanation because the bubble was in the stock market, not in the bond market. We find that the effects of a monetary policy surprise on bond returns is not stronger during the 2000s compared to the 1990s, leading us to conclude that the lower effectiveness of monetary policy in the 1990s is only in the stock market. Thus, Gali (2014)'s rational bubble effect is more consistent with our results than is the forward guidance effect.[2]

Earlier work has been conducted on the topic. Empirical studies that attempted to examine the effects of monetary policy on interest rates during the 1970s used the federal funds rate target as the monetary policy instrument, and found a strong and significant relationship between the federal funds rate target and the T-bill rate, yields on notes, and various maturities of bonds (Cook and Hahn, 1989). However, studies that used the same instrument but later data (Kuttner, 2001) found much weaker links.[3] A plausible explanation is that changes in the federal funds rates have become more anticipated in the recent past, as the Federal Reserve officials try to communicate in advance their intention

[2] Various explanations for the effect of macroeconomic announcements on asset prices have been suggested in the literature (e.g. see Goldberg and Grisse, 2013; Faust et al., 2007). We focus on explanations that also take into account the timing of our findings.

[3] Kuttner (2001) does such an exercise before using the futures market to construct a measure of surprise.

for policy changes. The market incorporates information at the time that it is given, which currently is much earlier than the time that the policy action is taken. It is expected that the markets are affected by unanticipated monetary policy actions, and the federal funds rate target changes are not as good a proxy for this surprise in more recent time. Various market-based measures of monetary policy surprise has been developed. Gürkaynak and Swanson (2007) singles out the measure developed by Kuttner (2001) as best, and this is the one we use.

We use Kuttner (2001)'s approach for identifying unexpected monetary policy and we ask the question of how the market responds to a monetary policy surprise. We specifically track the response of stock price returns to unanticipated changes of monetary policy. Previous research (Thorbecke, 1997; Bernanke and Kuttner, 2005; Basistha and Kurov, 2008; Jansen and Tsai, 2010; Neely and Fawley, 2014) found significant effects of monetary policy on stock returns, but there was no attempt to capture time variability in this relationship.[4,5,6] Another strand of the literature has been interested in the effectiveness of monetary policy depending on the degree of its communication with the public (see Blinder et al., 2008 for a review on the topic). Given that the communication attempts of the Federal Reserve have been changing over time, we expect that monetary policy effectiveness might also be changing over time. Our work adds to the conversation of how forward guidance and market conditions have been changing the effectiveness and impact of monetary policy on the stock market.

The rest of the paper is organized as follows. Section 2 explains in more detail the measure we use for monetary policy surprise and Section 3 describes the data. Section 4 presents results from the fixed coefficient approach. Section 5 introduces our econometric model of time varying parameter and Section 6 describes the estimation technique. Section 7 presents the results. Section 8 explores possible explanations. Section 9 concludes.

[4] A notable exception is Neely and Fawley (2014) who investigate different effects on the subsamples 1988-1993, 1994-2007 and 1988-2007. However, these subsamples do not reveal the significantly different effects of monetary policy on stock prices after the 2000s. Also, Kiley (2014) explores differences of monetary policy effects before and after the zero lower bound.

[5] Hausman and Wongswan (2011) attempts to track this relationship across countries.

[6] Goldberg and Grisse (2013) explored time variation on the effects of macroeconomic announcements on bond yields and exchange rates.

2 Measure of Unexpected Monetary Policy Changes

We define a monetary policy surprise at date t as the difference between the federal funds rate target announced at time t, $\tilde{r}_t$, from the public's previous period expectation about the federal funds rate target announcement at time t, i.e., a monetary policy surprise is $\tilde{r}_t - \mathrm{E}_{t-1}\tilde{r}_t$. As there are no available data about stock market participants' expectations for the federal funds rate, we follow Kuttner (2001) and measure monetary policy surprise using information from the federal funds rate futures market.

Kuttner (2001) uses market data on the spot-month federal funds futures contracts traded on the Chicago Board of Trade to extract a measure of the surprise change in the federal funds rates. The idea is that the federal funds rate futures contract price on the day prior to the FOMC announcement reflects the market's expectation of the FOMC announcement on the succeeding day. Also, the futures contract price at the end of the day of the FOMC announcement reflects information contained in the actual announcement. The difference in the futures contract prices at date $t-1$ and date t can be used to calculate the change in the federal funds rate that comes as a surprise to the futures market participants. The actual calculation must be scaled to take account of the fact that the futures contract settlement price is based on the monthly average federal funds rate. This measure of monetary policy surprise, $\Delta\tilde{r}_t^u$ is defined as:

$$\Delta\tilde{r}_t^u \equiv \frac{m}{m-t}(f_{s,t}^0 - f_{s,t-1}^0), \tag{1}$$

where $f_{s,t}^0$ is the spot-month futures rate for the (effective) federal funds rate, and m is the number of days in the specific month.[7] Under efficient markets and investors risk neutrality, the spot-month futures rate at any day t is defined as that days' expectation of the average of the months' S (effective) federal funds rates r_i.[8] Otherwise, the definition of $f_{s,t}^0$ includes an adjustment that has to do with the risk aversion of the buyer, or other compensations

[7] For announcements made on the first day of the month, the federal funds futures contract of the previous month is used in place of $f_{s,t-1}^0$.

[8] The futures contracts are based on monthly averages of the effective federal funds rate.

that are captured by the term $\mu^0_{s,t}$ below:

$$f^0_{s,t} = \mathrm{E}_t \frac{1}{m} \sum_{i \in S} r_i + \mu^0_{s,t}. \tag{2}$$

The term $\mu^0_{s,t}$ could be of important magnitude. However it is not expected to be changing from the one day to the next, and thus it is eliminated when the difference of the two subsequent days is considered in equation (1).[9]

One issue with this measure of policy is that it constrains our data set to begin in 1989, when the futures contracts started trading. A second issue is that it includes the specific announcement day targeting errors, scaled up by the term $\frac{m}{m-t}$. These errors are usually small when averaged across a month, but for a specific day they could be important. In order to avoid the large noise at the end of the month, if the target rate change falls within the last three days of the month we use the unscaled change in the 1-month ahead futures rate instead of the change in the spot-month rate.

3 Data Description

Our data set contains information on the monetary policy surprise calculated as described at Section 2, from 149 FOMC meetings over the period June 1989 through December 2007. We specify the meeting dates as in Barakchian and Crowe (2013). That is, we focus on regular policy announcements excluding intermeeting changes that are more likely to be associated with releases of other macroeconomic information and not with exogenous policy shocks. Indeed, by doing so, we only include three dates when FOMC meetings were followed by employment report releases.[10] As Gürkaynak et al. (2005) argues, although there are various releases that coincide with policy actions, especially before 1994, it is only the employment report releases that could create endogeneity issues. Thus, we partly-mitigate this problem by focusing on regular meeting dates. Finally, we exclude the September 17th, 2001 observation, the meeting following the September 11th, 2001 terrorist attack.

The futures contracts, officially referred to as '30 Day Federal Funds Futures', are traded

[9] Piazzesi and Swanson (2008) verifies the original assumption of Kuttner (2001).

[10] We repeat our analysis excluding those dates, with similar results.

Sample Period	June 89 - Dec 07
Number of events: FOMC meetings	149
Mean: Surprise federal funds rate change	-0.21
Standard Deviation: Surprise federal funds rate change	0.38
Mean: Surprise federal funds rate change, days of policy meeting	-0.28
Standard Deviation: Surprise federal funds rate change, days of policy meeting	0.3
Mean: S&P500 index daily returns	0.038
Standard Deviation: S&P500 index daily returns	0.98
Mean: S&P500 index daily returns, days of policy meeting	0.221
Standard Deviation: S&P500 index daily returns, days of policy meeting	0.944

Table 1: Descriptive Statistics. The Surprise federal funds rate change is measured in basis points. Note: All statistics exclude the September 17, 2001 observation.

on the Chicago Board of Trade. The implied futures rate is 100 minus the contract price. Table 1 provides descriptive statistics for our measure of monetary policy surprise and the stock price returns, for the whole sample and for the dates of policy meetings.

Our stock return measure is the daily return on the S&P500 index.

4 Fixed Coefficient Estimation

In this section we discuss the effects of monetary policy surprise on stock prices using a fixed coefficient model, similarly to what was done in the previous literature (e.g., Bernanke and Kuttner, 2005; Basistha and Kurov, 2008; Jansen and Tsai, 2010). We estimate the following equation:

$$R_t = \beta_0 + \beta_1 S_t + e_t, \tag{3}$$

where S_t is the monetary policy surprise based on the federal funds futures, and R_t is the stock price return. For the whole sample period, we find that the effect of monetary policy surprise on the stock prices is negative and significant. The results from the whole sample imply a decrease of 3.869% in the one-day stock price return in response to a one percentage point surprise federal funds rate increase. This is in line with the previous literature (e.g., Bernanke and Kuttner, 2005). However, as we see from Table 2 the results change depending on the sample period. A one percentage point surprise federal funds rate increase, decreases the one-day stock price return by 1.332% during the period 1989 to 2000 and by 7.473% during the period 2001 to 2007, i.e., five and a half times more. In addition, we find that the effect of monetary policy surprise on the stock price returns is not significant from the mid-1990s to the beginning of the 2000s, although it becomes very strong and significant in the later period.[11] Excluding the three dates of our dataset where announcements coincided with employment reports releases, does not change our conclusions.[12] As a second robustness test we employ Thornton (2014a)'s approach in our fixed coefficient estimation, using all the data instead of the event study method. Using this alternative methodology does not alter our findings about time variation and the magnitude of the change in the impact of monetary policy on stock returns.

	All	1989-1993	1989-2000	1994-2000	1994-2007	2001-2007
$\hat{\beta}_0$	0.211	0.209	0.259	0.289	0.211	0.156
$t_{\hat{\beta}_0}$	2.731	1.900	2.922	2.318	2.174	1.055
$\hat{\beta}_1$	-3.869	-4.450	-1.332	-0.343	-3.773	-7.473
$t_{\hat{\beta}_1}$	-2.485	-3.228	-0.736	-0.169	-2.125	-3.109
N	149	37	93	56	112	56

Table 2: The table shows how stock price returns are affected by monetary policy surprise for different sample periods, using the fixed coefficient approach and correcting for heteroskedasticity with Newy-West standard errors.

The fixed coefficient results are interesting; however, there are potential flaws associated with the approach of splitting the sample, including the assumption that parameters are stable within a sub-period and change drastically across sub-periods. We want to know when the coefficient changes during our sample, and thus we estimate a time varying coefficient model.

5 The Econometric Model

5.1 General Model Description

Our model is based on the time-varying parameters model of Kim and Nelson (1989) and Kim and Nelson (1999). We consider stock returns R_t affected by monetary policy surprise,

[11] Basistha and Kurov (2008) also points out increased significance on stock returns when a later sample is considered, but do not report estimates for the earlier sample.

[12] Those dates are July 5 1991, July 2 1992 and February 4 1994.

S_t, and an indicator variable taking into account economic conditions, i.e., recessions and expansions, C_t:

$$R_t = \beta_{0,t} + \beta_{1,t} S_t + \beta_{2,t} C_t + e_t, \tag{4}$$

where e_t is the random disturbance term.

We assume that the time varying coefficients follow random walk dynamics, so the effect of monetary policy surprise on asset prices is as in the previous period, yet allowing for a possible random shock:

$$\begin{aligned} &\beta_{k,t} = \beta_{k,t-1} + \epsilon_{k,t}, \\ &\epsilon_{k,t} \sim i.i.d.N(0, \sigma^2_{\epsilon,k}), \quad k = 0, 1, 2. \end{aligned} \tag{5}$$

5.2 Heteroscedastic Disturbances

Our model allows the variance of the disturbance term also to be changing over time, similarly to Kim and Nelson (2006). Otherwise, we could falsely detect instability in the coefficients that is actually due to the time varying variance of the disturbances. It is well known that financial variables exhibit changing variance.[13] To account for these effects we allow for a GARCH(1,1) process for the variance of the error term in the returns' equation. In our estimation we replace equation (4) with equation (6):

$$\begin{aligned} R_t =& \beta_{0,t} + \beta_{1,t} S_t + \beta_{2,t} C_t + e_t, \\ e_t \mid I_{t-1} \sim& \, i.i.d.N(0, \sigma^2_{e_t}), \end{aligned} \tag{6}$$

where

$$\sigma^2_{e_t} = a_0 + a_1 e^2_{t-1} + a_2 \sigma^2_{e_{t-1}}, \tag{7}$$

and I_{t-1} summarizes information up to time $t - 1$.

[13] GARCH models for modeling stock returns' variance have been commonly used since Bollerslev (1986).

6 Estimation

We now estimate the system of equations (5), (6) and (7), which allows for heteroskedastic disturbances and we present in the following state-space form:

$$R_t = \begin{bmatrix} \mathbf{X}'_{\mathbf{t|t-1}} & 1 \end{bmatrix} \begin{bmatrix} \boldsymbol{\beta_t} \\ e_t \end{bmatrix}, \tag{8}$$

$$(R_t = \tilde{\boldsymbol{X}}'_{\mathbf{t|t-1}} \tilde{\boldsymbol{\beta}}_{\boldsymbol{t}})$$

and

$$\begin{bmatrix} \boldsymbol{\beta_t} \\ e_t \end{bmatrix} = \begin{bmatrix} \mathbf{I_3} & \mathbf{0_3} \\ \mathbf{0_3}' & 0 \end{bmatrix} \begin{bmatrix} \boldsymbol{\beta_{t-1}} \\ e_{t-1} \end{bmatrix} + \begin{bmatrix} \epsilon_t \\ e_t \end{bmatrix},$$
$$\begin{bmatrix} \boldsymbol{\epsilon_t} \\ e_t \end{bmatrix} \sim i.i.d.N \left(\begin{bmatrix} \mathbf{0_3} \\ 0 \end{bmatrix}, \begin{bmatrix} \boldsymbol{\Sigma_\epsilon} & \mathbf{0_3} \\ \mathbf{0_3}' & \sigma^2_{e_t} \end{bmatrix} \right), \tag{9}$$

$$(\tilde{\boldsymbol{\beta}}_{\boldsymbol{t}} = \mathbf{B} \tilde{\boldsymbol{\beta}}_{\boldsymbol{t-1}} + \tilde{\boldsymbol{\epsilon}}_{\boldsymbol{t}}, \;\; \tilde{\boldsymbol{\epsilon}}_{\boldsymbol{t}} \sim i.i.d.N(\mathbf{0_4}, \boldsymbol{\Sigma_{\tilde{\epsilon}}}))$$

where $\boldsymbol{\beta_t} = [\beta_{0,t} \quad \beta_{1,t} \quad \beta_{2,t}]'$ and $\mathbf{X_t} = [1 \;\; S_t \;\; S_t C_t]'$. Also, $\boldsymbol{\Sigma_{\epsilon,i}}$ is a 3x3 diagonal matrix with $\sigma^2_{\epsilon,k}$ as diagonal elements, for $k = 0, 1, 2$, and $\sigma^2_{e_t}$ is given by equation (7).

The log-likelihood function that we maximize is:

$$\ln L_r = \sum_{t=1}^{T} \ln \left[\frac{1}{\sqrt{2\pi f_{t|t-1}}} \exp \left(- \frac{(R_t - R_{t|t-1})^2}{2 f_{t|t-1}} \right) \right],$$

where $R_{t|t-1} = \mathrm{E}(R_t \mid \bar{\boldsymbol{X}}_{\boldsymbol{T}}, \bar{R}_{T-1})$, for $\bar{g} = [g_1 \quad g_2 \quad \ldots \quad g_T]'$ and $f_{t|t-1} = \mathrm{E}(\eta^2_{t|t-1})$.

The first round of Kalman filter iterations estimate the model's hyperparameters ($\boldsymbol{\Sigma_{\tilde{\epsilon}}}$) maximizing the likelihood function. The Kalman filter is as follows:

$$\tilde{\boldsymbol{\beta}}_{\boldsymbol{t|t-1}} = \mathbf{B} \tilde{\boldsymbol{\beta}}_{\boldsymbol{t-1|t-1}},$$

$$\boldsymbol{P_{t|t-1}} = \mathbf{B} \boldsymbol{P_{t-1|t-1}} \mathbf{B}' + \boldsymbol{\Sigma_{\tilde{\epsilon},i}},$$

$$\eta_{t|t-1} = R_t - \tilde{\boldsymbol{X}}'_{\mathbf{t|t-1}} \tilde{\boldsymbol{\beta}}_{\boldsymbol{t|t-1}},$$

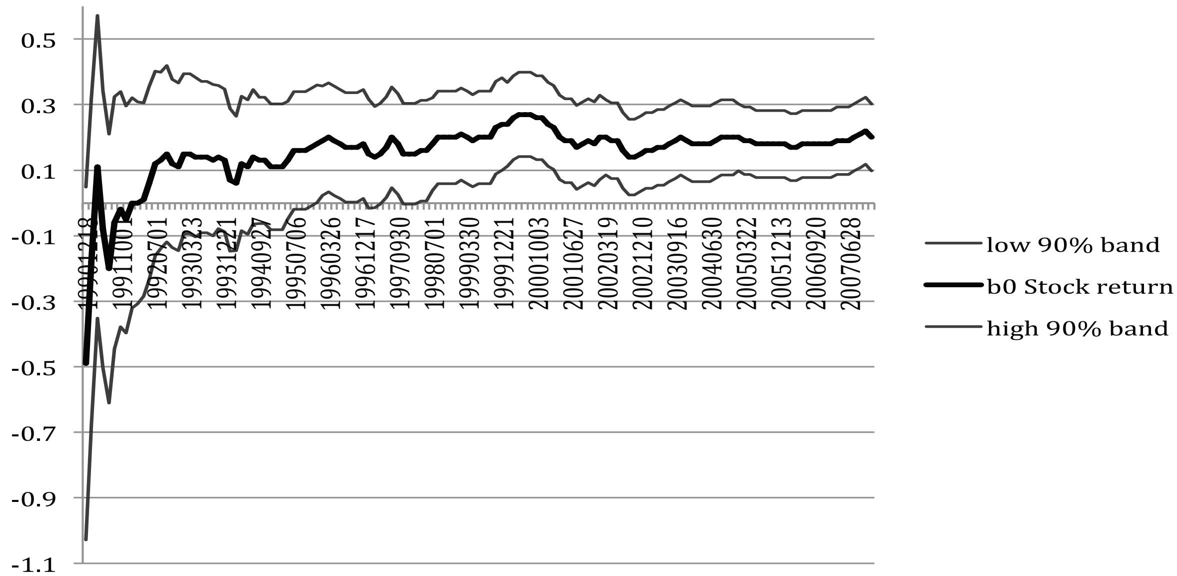


Figure 1: Time varying intercept and 90% significance bands in the model with homoskedastic disturbances.

$$f_{t|t-1} = \tilde{\boldsymbol{X}}'_{\mathbf{t|t-1}} \boldsymbol{P}_{\boldsymbol{t|t-1}} \tilde{\boldsymbol{X}}_{\boldsymbol{t|t-1}},$$

$$\tilde{\boldsymbol{\beta}}_{\boldsymbol{t|t}} = \tilde{\boldsymbol{\beta}}_{\boldsymbol{t|t-1}} + \boldsymbol{P}_{\boldsymbol{t|t-1}} \tilde{\boldsymbol{X}}_{\boldsymbol{t|t-1}} f^{-1}_{t|t-1} \eta_{t|t-1},$$

$$\boldsymbol{P}_{\boldsymbol{t|t}} = \boldsymbol{P}_{\boldsymbol{t|t-1}} - \boldsymbol{P}_{\boldsymbol{t|t-1}} \tilde{\boldsymbol{X}}_{\boldsymbol{t|t-1}} f^{-1}_{t|t-1} \tilde{\boldsymbol{X}}'_{\mathbf{t|t-1}} \boldsymbol{P}_{\boldsymbol{t|t-1}},$$

where $\tilde{\boldsymbol{\beta}}_{\boldsymbol{t|t-1}} = \mathrm{E}(\tilde{\boldsymbol{\beta}}_{\boldsymbol{t}} \mid I_{t-1})$, $\boldsymbol{P}_{\boldsymbol{t|t-1}} = \mathrm{E}(\tilde{\boldsymbol{\beta}}_{\boldsymbol{t}} - \tilde{\boldsymbol{\beta}}_{\boldsymbol{t|t}})^2$ and $\eta_{t|t-1} = R_t - R_{t|t-1}$, $f_{t|t-1} = \mathrm{E}(\eta^2_{t|t-1})$.

Note that for initial value for the last diagonal element of $\boldsymbol{P}_{\boldsymbol{t-1|t-1}}$, we use the unconditional mean of $\sigma^2_{e_t}$, which can be calculated from equation (7). Then, we use this information to construct an estimate of $\sigma^2_{e_t}$, which we have assumed that follows a GARCH(1,1) process as given by equation (7). This equation requires an estimate of e^2_{t-1}, which we approximate as follows: $\mathrm{E}(e^2_{t-1} \mid I_{t-1}) = \mathrm{E}(e_{t-1} \mid I_{t-1})^2 + \mathrm{Var}(e_{t-1} \mid I_{t-1})$. We get $E(e_{t-1} \mid I_{t-1})$ from the last component of $\tilde{\beta}_{t|t-1}$ and $\mathrm{Var}(e_{t-1} \mid I_{t-1})$ from the last diagonal element of $P_{t-1|t-1}$.

After estimating the hyperparameters, we run the Kalman filter second time, in order to get an estimate for $\boldsymbol{\beta_t}$ from the first three rows of $\tilde{\boldsymbol{\beta}}_{\boldsymbol{t}}$, and the standard errors of the coefficients from the first 3×3 block of $\boldsymbol{P}_{\boldsymbol{t|t-1}}$ and $\boldsymbol{P}_{\boldsymbol{t|t}}$.

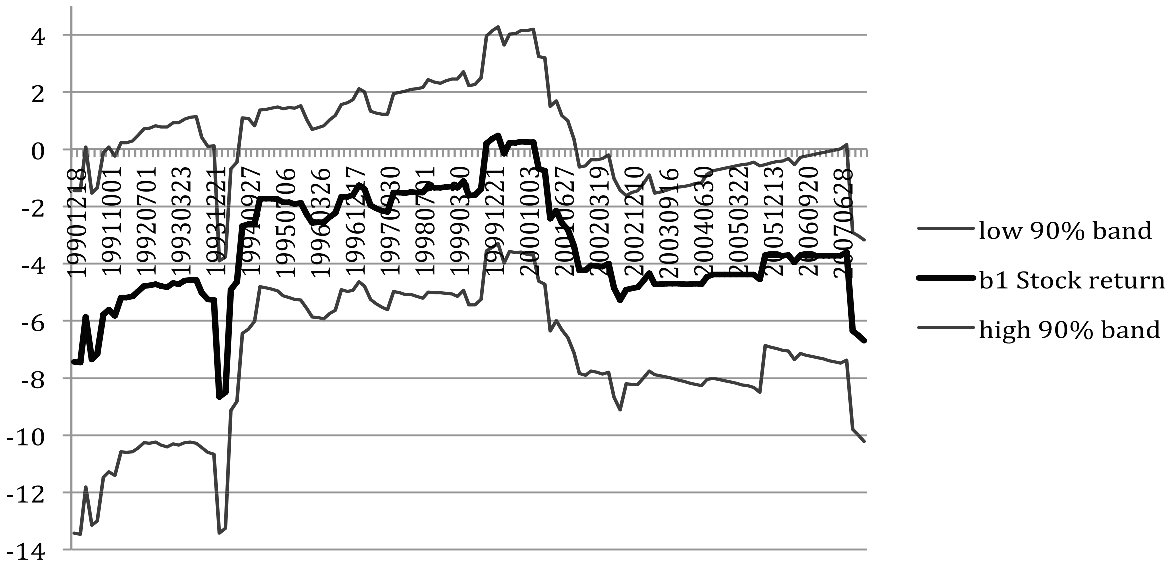


Figure 2: Time varying effects of monetary policy on stock price returns and 90% significance bands in the model with homoskedastic disturbances.

The smoothing algorithm is given as follows:

$$\tilde{\boldsymbol{\beta}}_{t|T} = \tilde{\boldsymbol{\beta}}_{t|t} + \boldsymbol{P}_{t|t}\boldsymbol{P}_{t+1|t}^{-1}(\tilde{\boldsymbol{\beta}}_{t+1|T} - \tilde{\boldsymbol{\beta}}_{t|t}),$$

$$\boldsymbol{P}_{t|T} = \boldsymbol{P}_{t|t} + \boldsymbol{P}_{t|t}\boldsymbol{P}_{t+1|t}^{-1}(\boldsymbol{P}_{t+1|T} - \boldsymbol{P}_{t+1|t})\mathbf{P}_{\mathbf{t+1|t}}^{-1\,\prime}\mathbf{P}_{\mathbf{t|t}}^{\prime},$$

where $\tilde{\boldsymbol{\beta}}_{t|T} = \mathrm{E}(\tilde{\boldsymbol{\beta}}_t \mid \bar{\boldsymbol{X}}_T)$ and $\boldsymbol{P}_{t|T} = \mathrm{Var}(\tilde{\boldsymbol{\beta}}_t \mid \bar{\boldsymbol{X}}_T)$, for $\bar{g} = [g_1 \quad g_2 \quad \dots \quad g_T]'$.

7 Empirical results

Figures 1 and 2 show the time varying intercept and the time varying effect of monetary policy surprise on stock returns for the homoskedastic model. Figures 3 and 4 show the time varying intercept and the time varying effect of monetary policy surprise on stock returns for the same model but allowing GARCH errors.[14] Comparing the two sets of figures, we see that there is little difference in the results between the model with homoskedastic and heteroskedastic disturbances. However, as we see from Table 3, the first two GARCH

[14] We have extended the model in order to check for different effects during recessions and expansions. The effects of monetary policy surprise on stock returns were not significantly different across the two states.

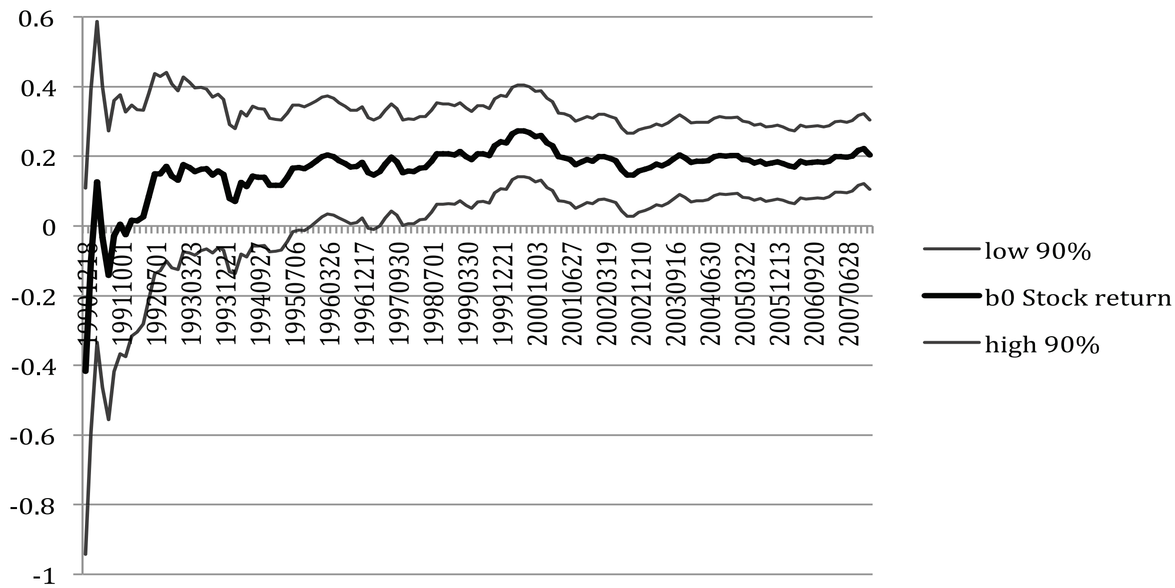


Figure 3: Time varying intercept and 90% significance bands in the model with heteroskedastic disturbances.

parameters are significantly different from zero, so the time variation in the shocks that hit stock prices is an important aspect of the model. Henceforth, we focus only on the model with heteroskedastic disturbances.

a_i	a_0	a_1	a_2
$\hat{a}_i$	0.4064	0.4630	0.0688
$t_{\hat{a}_i}$	5.485	6.377	0.681

Table 3: Estimation results for GARCH parameters, and t-statistic, based on equation (7), $\sigma^2_{e_t} = a_0 + a_1 e^2_{t-1} + a_2 \sigma^2_{e_{t-1}}$.

From Figure 4 we see that for almost all the sample our estimates indicate that a monetary policy surprise tightening will decrease stock price returns. This is in line with the conventional view that a surprise increase in federal funds rates decreases stock prices, and with prior literature. However, the effect varies in strength and significance over the sample. Figure 4 shows that monetary policy surprise has insignificant and weak effects on the stock price returns from the beginning of the 1990s to the beginning of the 2000s. However, after the 2000s the effect of monetary policy surprise on stock returns becomes strong, and significant. There is also a significant period for a few observations within 1994.

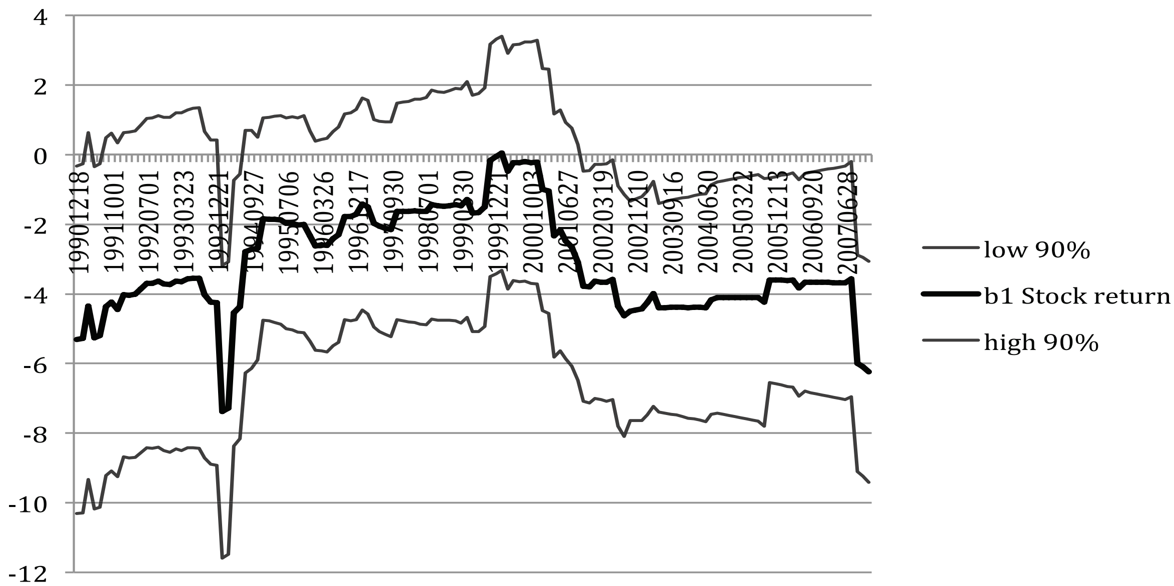


Figure 4: Time varying effects of monetary policy on stock price returns and 90% significance bands in the model with heteroskedastic disturbances.

From Figure 3 we see that the time varying intercept is positive, small, and more stable than the response of stock price returns to the monetary policy surprise. It is not significantly different from zero at the beginning of the sample, and becomes significant only after the mid-1990s.

8 Explanations

In this section, we explore explanations for the time varying response of stock price returns to monetary policy surprise. We focus on explanations that address the timing of our findings, i.e., we focus on events that occurred around the beginning of the 2000s.

8.1 Transparency and Forward Guidance

Recent research points out that the Federal Reserve's transparency has been much improved, following a gradual process starting from the early 1990's and peaking in the early 2000's (Swanson, 2006; Blinder et al., 2008). As Blinder et al. (2008) argues, it is indicative of the great changes in the Federal Reserve's communication policy with the public, that

Alan Greenspan transitioned from a period of low transparency where he was 'mumbling with great incoherence' to a period of great transparency, announcing that the Federal Reserve would keep the federal funds rate low 'for a considerable period'.

Table 4 shows dates when important changes in the Federal Reserve's transparency were implemented. The first very important year is 1994, when the Federal Reserve started making regularly announcements after the FOMC meetings, including descriptions of the rationale for the policy change. In addition, explicit announcements of changes in the federal funds rate target started in July 1995. Another important year is 1999, when the Federal Reserve started announcing the direction, or "tilt", of its near future policy. This is a step towards forward guidance, which has taken various forms since then. In the beginning of the 2000s the Federal Reserve gives to its publication releases the final form to follow, so far, and started releasing statements about its projections of future economic risks.[15] We believe that the central bank's transparency, and especially transparency that refers to its future plans, might affect the estimates of our model.

Monetary policy surprises can be large or small, and are measured through changes in the federal funds futures rate, as we described in Section 2. This is a measure of the public's surprise; yet, it is not true that the surprise is the same for everybody. An event might result in a large surprise for one and in a smaller surprise for another agent, relative to the measure we are using. This is because there is dispersion in people's expectations about future monetary policy actions. This dispersion, or disagreement, about future monetary policy actions can be especially large when the Federal Reserve is not transparent. Given the significant change in the Federal Reserve's transparency and the initiation of forward guidance, there should also be changes in the dispersion of expectations across individuals. Specifically, we should observe lower dispersion in beliefs about future monetary policy actions, and thus lower dispersion in monetary policy surprise across individuals, when transparency increases, especially transparency about future monetary policy actions.

The Survey of Professional Forecasters provides a measure of dispersion across forecasts of the 3-months T-bills.[16] We observe that the dispersion among forecasts decreased from

[15] For a detailed history of the timing of the Federal Reserve's transparency see Rudebusch and Williams (2008).

[16] The 3-month T-bill is the shortest term interest rate for which the the Survey of Professional Forecasters provides dispersion measure.

Table 4: Highlighted Changes in FOMC transparency

1992-2000	Gradually shifts policy actions to regularly scheduled meeting dates.
March 1993	Begins releasing minutes of FOMC meetings (with 6-8 week lag).
November 1993	Begins releasing transcripts of FOMC meetings (with 5 year lag).
February 4, 1994	Begins making announcements after FOMC meetings about rationale for policy action.
August 1994	Begins describing state of economy and more detailed rationale for policy action after FOMC decisions.
1994-2003	Gradually shifts to longer, more descriptive press releases after FOMC decisions.
July 1995	Begins making explicit announcements of changes in the federal funds rate target.
May 1999	Begins announcing policy tilt indicating most likely future interest rate action.
January 2000	Replaces tilt with statement describing balance of risks to economic outlook.
October 2001	Chairman Greenspan delivers a speech highlighting FOMCs moves toward greater transparency.
March 2002	Begins releasing votes of individual Committee members and preferred policy choices of any dissenters.
August 2003	Begins releasing more explicit signals of future policy.
February 2005	Begins releasing expedited minutes, so they are available before the subsequent FOMC meeting.
November 2007	Begins releasing more frequent, more detailed and longer horizon forecasts.

NOTE: Part of the table is taken from Swanson (2006).

the 1980s to the end of the 1990s; it increased in the beginning of the 2000s, decreased again in the mid 2000s, and then increased just before the Great Recession. After that it stayed very low, as expected, given the promise of the Federal Reserve to keep the interest rate low. This timing of lower dispersion does not appear to coincide with the timing of increased transparency. Swanson (2006) also documents that there is generally declining level of cross-sectional dispersion during the 1990s, but it increases from the early 2001 and until 2003, when his data set ends. Investigating the link between transparency and available measures of dispersion, Swanson (2006) suggests that the decrease in dispersion in the beginning of the 1990s is due to increased transparency. However, the increase of dispersion in the beginning of 2000s is due to the recession and increased volatility of the federal funds rate target, not to decreased transparency. Thus, using the observed measures of dispersion is not a good proxy of transparency for our purposes.

A better measure is provided by the Blue Chip Financial Forecast (BCFF) survey. This survey includes forecasts for the US federal funds rate from 1986 to 2013. The data are

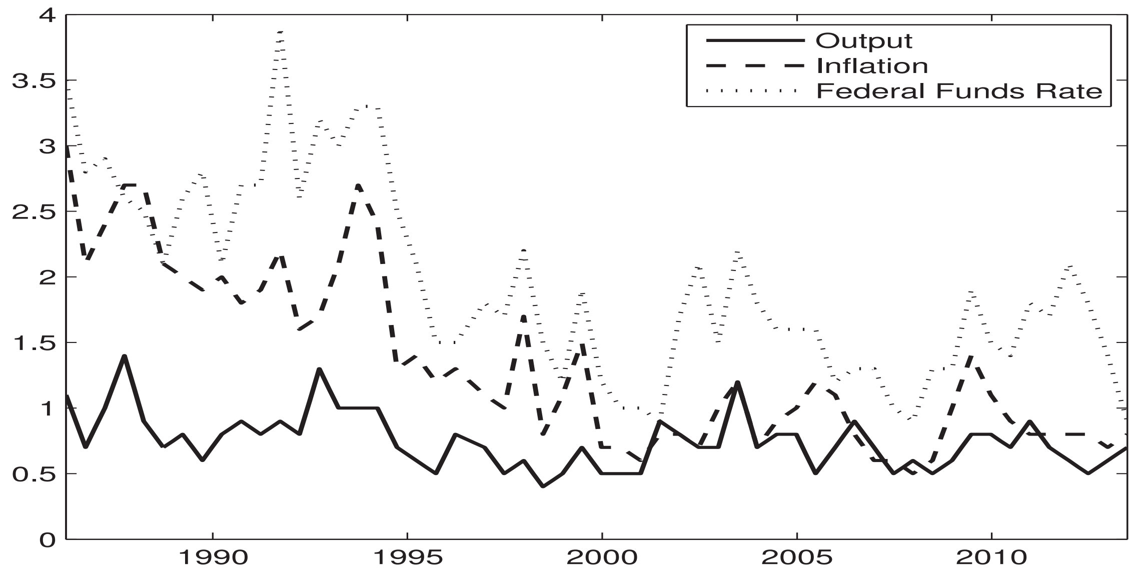


Figure 5: Disagreement about the 6 to 11 years ahead forecast of the federal funds rate (and other variables), from 1986-2013. Graph taken from Andrade et al. (2014).

analyzed by Andrade et al. (2014), and include measured disagreement about the federal funds rates expected in the future.[17] Figure 5 shows the time series of the 6 to 11 years ahead forecast disagreement for the federal funds rate (and other variables). From this we see that disagreement about future federal funds rates has been reduced after the mid-1990s.

Changes in transparency, forward guidance and thus changes in the degree of disagreement about future monetary policy, might impact our estimation. We analyze this argument below. Let each of the N households involved in the pricing in the S&P market observe the current federal funds rate target $\tilde{r}_t$ and realize a surprise, $S_t^i = \tilde{r}_t - \mathrm{E}_{t-1}^i \tilde{r}_t$. Then, the individual pricing equation might be written as:

$$R_t^i = \beta_0^i + \beta_1^i S_t^i + e_t^i.$$

Assuming that the observed pricing of the S&P portfolio is the average one, R_t, then,

[17] Disagreement is defined as the average forecast of the highest ten responses minus that of the lowest ten responses. The survey interviews participants ranging from broker-dealers to economic consulting firms.

ignoring for a while the time-varying technique, we have that:

$$R_t = \beta_0 + \frac{1}{N}\sum_{i=1}^{N}\beta_1^i S_t^i + e_t,$$

for $R_t = \frac{1}{N}\sum_{i=1}^{N} R_t^i$, $\beta_0 = \frac{1}{N}\sum_{i=1}^{N}\beta_0^i$, $e_t = \frac{1}{N}\sum_{i=1}^{N} e_t^i$. If there is no dispersion of expectations then $\mathrm{E}_{t-1}\tilde{r}_t = \mathrm{E}_{t-1}^i\tilde{r}_t$ for every i, the surprise is the same across households, $S_t^i = S_t^j$, and thus the above equation becomes:

$$R_t = \beta_0 + \beta_1 S_t + e_t,$$

for $\beta_1 = \frac{1}{N}\sum_{i=1}^{N}\beta_1^i$ and $S_t = \frac{1}{N}\sum_{i=1}^{N} S_t^i$.[18] If this is the case, using an average measure of market expectation, $\bar{\mathrm{E}}_{t-1}\tilde{r}_t = \frac{1}{N}\sum_{i=1}^{N}\mathrm{E}_{t-1}^i\tilde{r}_t$, and thus the average surprise, seems like a good idea.[19]

However, as explained earlier, dispersion of expectations across individuals was high in the earlier part of our sample, and we cannot assume $\mathrm{E}_{t-1}\tilde{r}_t = \mathrm{E}_{t-1}^i\tilde{r}_t$ for every i. Then, using an average measure of market expectation, and thus an average measure of surprise, involves error. The regression that we run is:

$$R_t = \beta_0 + \frac{1}{N}\sum_{i=1}^{N}\beta_1^i S_t^i + e_t = \beta_0 + \beta_1 S_t + \sum_{i=1}^{N}(\beta_1^i - \beta_1)(S_t^i - S_t) + e_t,$$

and thus,

$$R_t = \beta_0 + \beta_1 S_t + \omega_t, \tag{10}$$

where $\omega_t = e_t + \sum_{i=1}^{N}(\beta_1^i - \beta_1)(S_t^i - S_t)$. Note that the mispecification error disappears when expectations are homogenous, i.e., when $S_t^i = S_t$ for each i.

Earlier work that has attempted to estimate the effect of dispersion of expectations about future consumption growth on excess returns (Anderson et al., 2005) find that dispersion increases excess returns. In addition, Bernanke and Kuttner (2005) finds that the monetary policy surprise affects stock prices through its effect on excess returns. Thus, the

[18] Which is the same as equation (3).

[19] Note that the same is true, if we assume that all individual responses are the same, i.e., $\beta_1^i = \beta_1^j$, for every i, j. We do not make this assumption here.

dispersion of expectations about monetary policy surprise, should be important for asset pricing. In our model, the extra component in the error term increases the variance of the residual, and thus we tend to reject less frequently the null hypothesis for the β_1 coefficient being equal to zero. This could explain our findings for the earlier part of the sample, when dispersion of expectations was high, increasing the variance of the error term, and making the stock returns response to monetary policy surprise insignificant.

8.2 Theory of Rational Bubbles

According to the theory of rational bubbles, tight monetary policy might act to increase the expected bubble component of asset prices (Gali, 2014). This is contrary to the conventional view which demands monetary authorities' reaction of implementing tight policy with the intention to shrink or eliminate bubbles. To see that, consider a simple partial equilibrium asset pricing model, as analyzed by Gali (2014) and Gali and Gambetti (2015). As usual, the fundamental part of stock price, Q_t^F, is given by the present value of all future dividends, discounted by the interest rate:

$$Q_t^F = \mathrm{E}_t \sum_{k=1}^{\infty} \left(\prod_{j=0}^{k-1} \frac{1}{R_{t+j}^r} \right) D_{t+k},$$

where R_t^r is the riskless gross real interest rate, and D_{t+k} is the dividend distributed at period $t+k$. Given that after a tight monetary policy shock dividends decrease and the real interest rate declines, we get into the conventional wisdom argument that tight monetary policy decreases (the fundamental part of) stock prices. However, there could be also a bubble component, Q_t^B, i.e., the stock price is $Q_t = Q_t^F + Q_t^B$.

We will focus on the "rational bubble", i.e., the bubble component under rational expectations. Then it is true that the stock price satisfies that:

$$Q_t R_t^r = \mathrm{E}_t (D_{t+1} + Q_{t+1}),$$

and

$$Q_t^F R_t^r = \mathrm{E}_t (D_{t+1} + Q_{t+1}^F).$$

Thus, the bubble component has the property that $Q_t^B R_t^r = \mathrm{E}_t Q_{t+1}^B$, or in terms of logs, denoted by small letters of the original variables:

$$\mathrm{E}_t \Delta q_{t+1}^B = r_t^r. \tag{11}$$

The above equation shows that the expected growth of the bubble component of the stock price would increase with tight monetary policy. In order to study the contemporaneus effects of monetary policy surprise on stock prices Gali and Gambetti (2015) suggests the following formulation of equation (11):

$$\Delta q_t^B = r_{t-1}^r + \chi_t,$$

where $\chi_t = q_t^B - \mathrm{E}_{t-1} q_t^B$, with zero mean. Without loss of generality, we can express the innovation of the size of the bubble as follows:

$$\chi_t = \psi_t (r_t^r - \mathrm{E}_{t-1} r_t^r) + \chi_t^*, \tag{12}$$

where χ_t^* has zero mean. Gali and Gambetti (2015) emphasizes that the sign and size of ψ_t is not pinned down by theory, and thus the contemporaneous effect of monetary policy surprise on the bubble component is indeterminate. That leaves the possibility for monetary policy surprise tightening to increase the stock price. Note that the size of the bubble plays a role in determining that effect.

The theory of rational bubbles is in line with some of Gali and Gambetti (2015)'s empirical findings, i.e., that tightening of monetary policy contributed to inflating asset prices after the 1990s. Their explanation is based on the strong bubble component in stock prices that they find from the 1990s. Note that Gali and Gambetti (2015) uses a time varying VAR model where monetary policy shocks are identified through VAR methods.

Our results differ in some ways and agree in some others with those of Gali and Gambetti (2015). First, given that the bubble burst after the beginning of 2000s, the theory of rational bubbles implies that the effect of monetary policy should get stronger in the later part of the sample when the bubble component was smaller or possibly even nonexistent.[20] This

[20] Gali (2014) argues that the effect on the bubble can be permanent. However, after the bubble bursts

is what we find in our estimation, but Gali and Gambetti (2015) finds that the peculiar effects of monetary policy on stock returns remain also for the 2000s. The discrepancy between Gali and Gambetti (2015)'s results and our results is possibly due to the different identification measures used for the monetary policy surprise, their VAR identification versus our market-based measure of the monetary policy surprise.

Second, Gali and Gambetti (2015) does not discuss significance bands. We believe this is an important issue, as we are interested in both the direction and the significance of monetary policy's effects on asset prices. Our estimation reveals that monetary policy had been less effective during the 1990s, and especially towards the end of the 1990s and beginning of 2000s, when the bubble component had been stronger. After that period, monetary policy becomes very effective, having strong and significant effects on stock returns.

Our results are in line with the rational bubble theory: Monetary policy has insignificant effects on stock returns at the beginning of the 1990s, when the bubble component starts developing. Monetary policy has essentially no effect on stock returns at the end of the 1990s, when the bubble component was strong. Monetary policy becomes effective and significant after the 2000s, when the bubble bursts and the bubble component becomes small.

8.3 Comparing to Bond Returns

Our finding that monetary policy surprise is more significant after the 2000s compared to the 1990s, is in line with both explanations discussed above, i.e., the possibility that increased transparency through forward guidance made monetary policy more effective after the 2000s, and that an enhanced bubble component made monetary policy ineffective during the 1990s. We explore the validity of these two explanations by examining the effects of a monetary policy surprise on bond returns. We expect forward guidance to have enhanced the effects of monetary policy surprise on bond returns. Thus, finding stronger bond returns' response after the 2000s would indicate that improved transparency is a plausible explanation for the response of the stock returns as well. However, bond returns have no bubble component. Therefore, finding that the response of bond returns to a

we expect that the fundamental component gains strength. The final result is theoretically ambiguous.

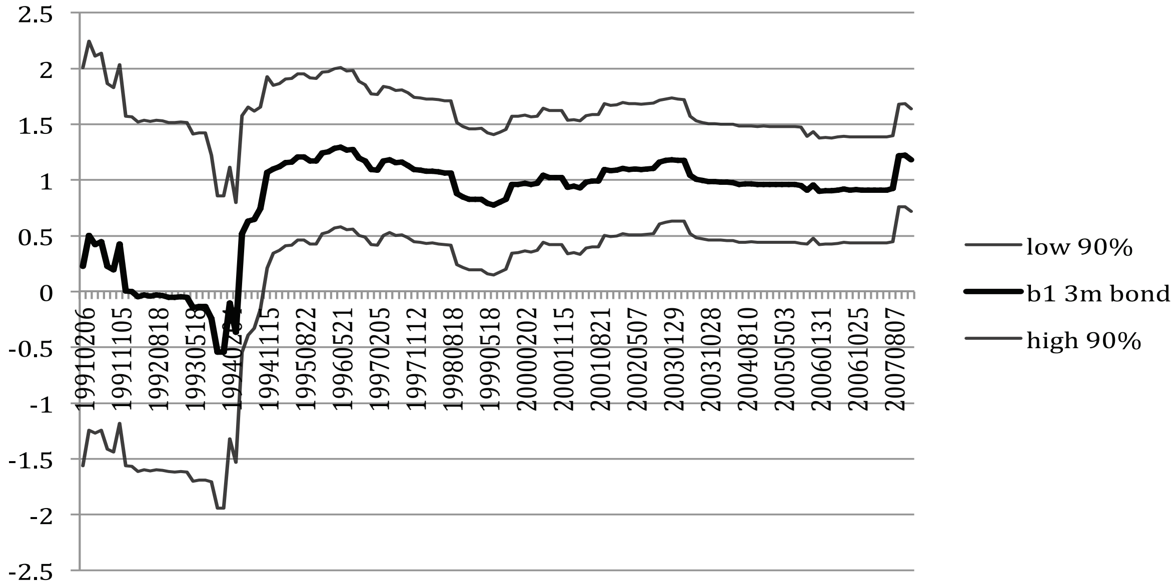


Figure 6: Time varying effects of monetary policy on the 3-month bond returns and 90% significance bands in the model with heteroskedastic disturbances.

monetary policy surprise does not change after the 2000s, would indicate that the theory of rational bubble is a plausible explanation for the behavior of stock returns.

The time varying effects of monetary policy surprise on the returns of 3-month constant maturity government bonds and on the returns of 5-year constant maturity government bonds, can be seen in Figures 6 and 7 respectively.[21] Our results indicate that for all maturity bonds, the effect of monetary policy surprise on bond returns spikes in 1994, when the Federal Reserve started announcing its policy. Apart from that, the effect of monetary policy surprise on bonds differs with maturity. The effect on the 3-month bonds is always significant. However, the effect on the 5-year bonds and in general in the longer maturity bonds, seems to decrease over time, and it is almost always insignificant. These results are in line with previous research (Thornton, 2014a; Thornton, 2014b) that also reports that the effect of monetary policy surprises on bonds with a maturity longer than one year is low and insignificant.[22] Our analysis of the bond market suggests that forward guidance has not made the effect of the monetary policy surprise on the bond returns more apparent after the 2000s.

[21] Additional results for different maturity bonds can be found in the appendix A.

[22] For an intuitive discussion on reasons behind this result see Thornton (2014b).

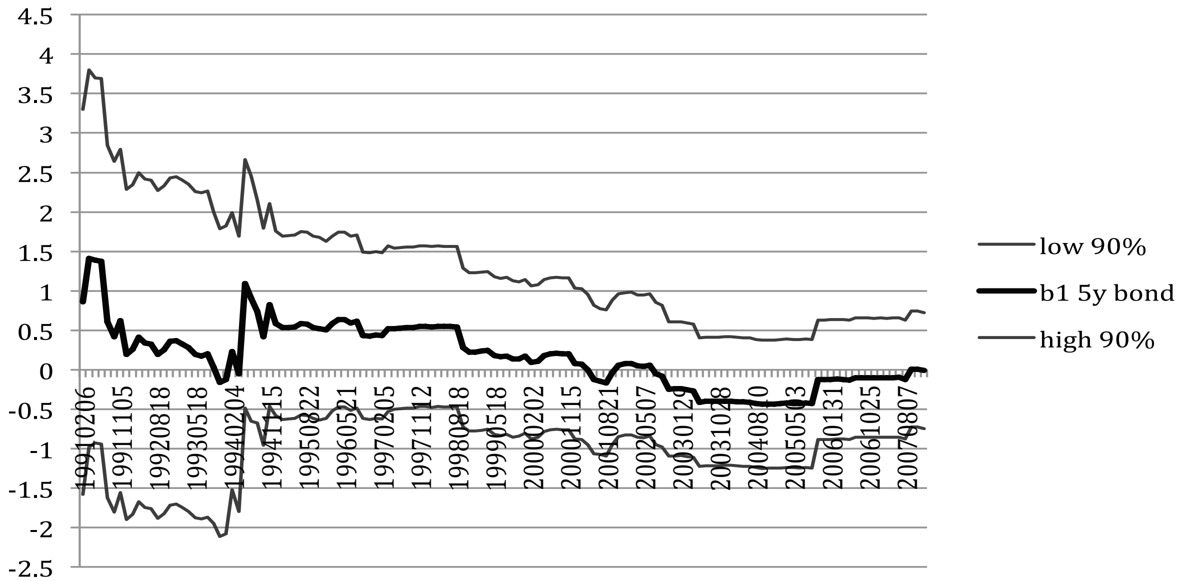


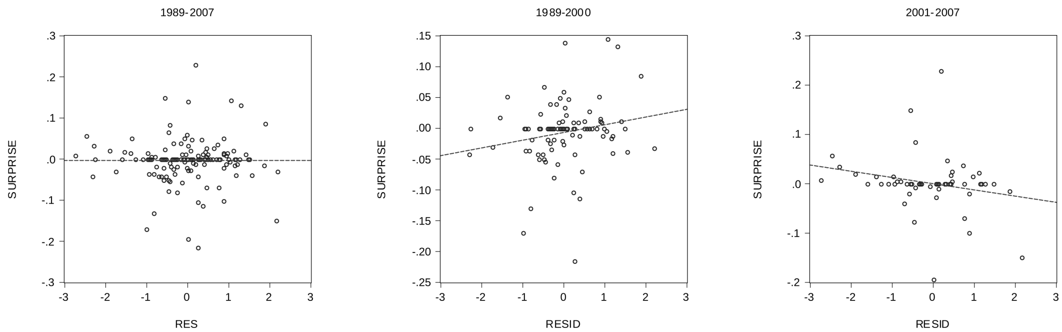
Figure 7: Time varying effects of monetary policy on the 5-year bond returns and 90% significance bands in the model with heteroskedastic disturbances.

Given the mispecification we argued about in Section 8.1, we examine the relationship between the monetary policy surprise S_t and the fitted values of the residuals ω_t from running equation (10) with fixed coefficients. We do that for various subsamples, in order to observe if there is any pattern in the relationship between the error and our measure of surprise. We compare our findings for stocks and bonds.

The results for the stocks are given in Figure 8. The first panel depicts the relationship between the residuals of equation (10) with the surprise for the whole sample, the second for the period 1989 to 2000, and the third for the period 2001 to 2007. From there we see that there is no pattern when the whole sample is considered. However, there is a positive relationship for the first part of the sample, which drastically changes to negative for the second part of the sample.[23]

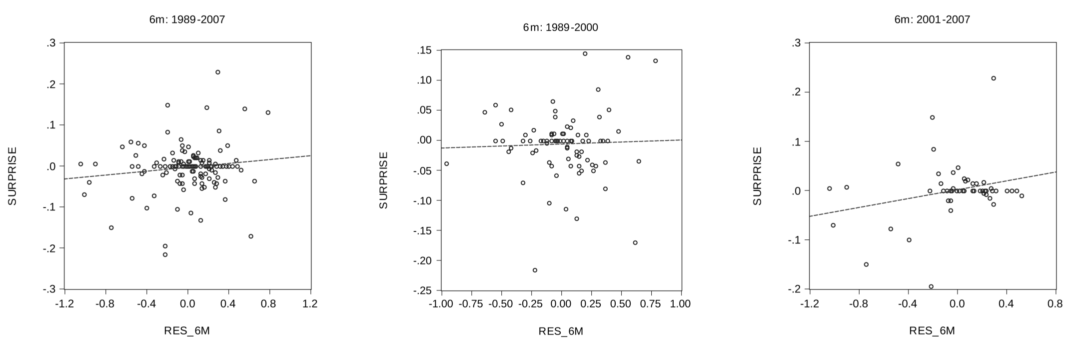
If the difference in pattern across subsamples is due to changes in the specification error, then we should observe it when we consider the same exercise using bond returns. Figures 9 and 10 have the respective three panels for 6-month and 5-year bonds. From there we see that although there are differences across subsamples, nothing resembles the

[23]The slope from large positive and significant at the 1% level that it is for the early subsample, becomes large negative and significant at the 10% level for the later subsample.



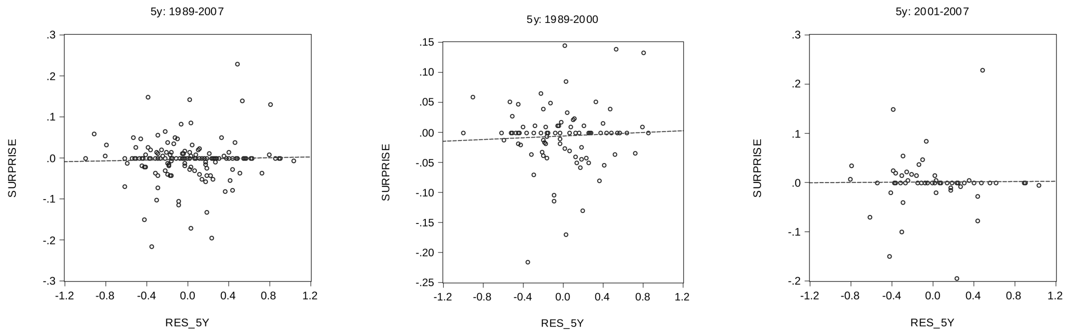
(a) Whole sample **(b)** Early subsample **(c)** Later subsample

Figure 8: Relationship between monetary policy surprise S_t and the fitted values of residuals ω_t for the stocks. The sample does not include the dates of employment report releases.



(a) Whole sample **(b)** Early subsample **(c)** Later subsample

Figure 9: Relationship between monetary policy surprise S_t and the fitted values of residuals for the 6-month bonds. The sample does not include the dates of employment report releases.



(a) Whole sample **(b)** Early subsample **(c)** Later subsample

Figure 10: Relationship between monetary policy surprise S_t and the fitted values of residuals for the 5-year bonds. The sample does not include the dates of employment report releases.

drastic difference observed for the stocks.[24] The relationship is always positive and weak. Thus, we conclude that there is something specific to the stock market that changes the relationship between the monetary policy surprise and the stock returns. Thus, the stock market bubble effect becomes our dominant explanation.

9 Conclusions

We use a time varying parameter model in order to study the changing effects of monetary policy surprise on the stock returns. We are using a measure of monetary policy surprise based on the futures federal funds rates market. Our novel results indicate that the effect of monetary policy surprise on stock returns is changing over time. Specifically, monetary policy surprises have weak and statistically insignificant effects during most of the 1990s; the effects become strong and statistically significant during the 2000s.

Our results are in line with previous literature (Gali, 2014; Gali and Gambetti, 2015) that supports weak and insignificant contemporaneous effect of monetary policy surprise on stock prices during periods with large bubbles. However, our findings differ from previous empirical literature (Gali and Gambetti, 2015) in that they suggest that the effect of monetary policy shocks is restored after the bubble bursts.

Further research is motivated in order to improve our understanding on the effects of

[24]For the 6-month bonds, the slope changes from small positive and insignificant in the first part of the sample, to small positive and significant at the 10% level in the second part of the sample. For the 5-year bonds the slope is always small, positive and insignificant.

monetary policy decisions and on how and why these effects might change over time. Our findings have shed light on the issue, by first, revealing the changing effectiveness pattern of monetary policy on the stock market, second, by exploring various justification and third, by pointing to a specific explanation consistent with our findings.

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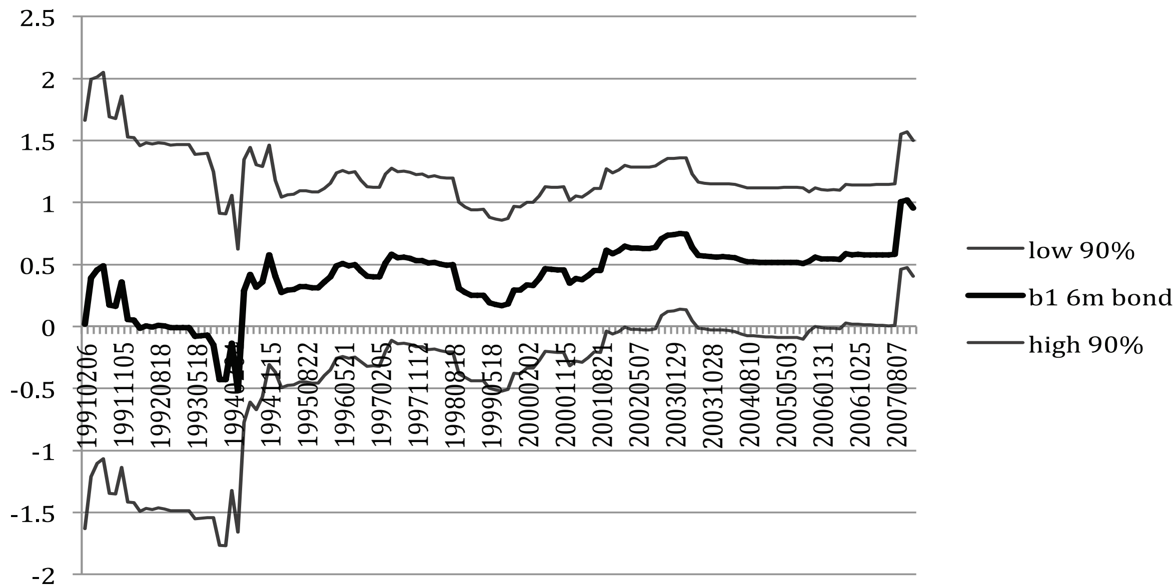

Figure 11: Time varying effects of monetary policy on the 6-month bond returns and 90% significance bands in the model with heteroskedastic disturbances.

A Appendix

In this appendix we present results for the effect of monetary policy surprise on the 6 months bonds, and on the 1, 2, 3, 7 and 10 year bonds. The results are shown in Figures 11 to 16. From there we see that the effect for the 6 months bonds becomes significant after the beginning of the 2000s. However, the effect on all the other bonds decreases over time, and it is almost always insignificant. An exception in our results is the 10 years bond, which has a significant period towards the end of the sample.

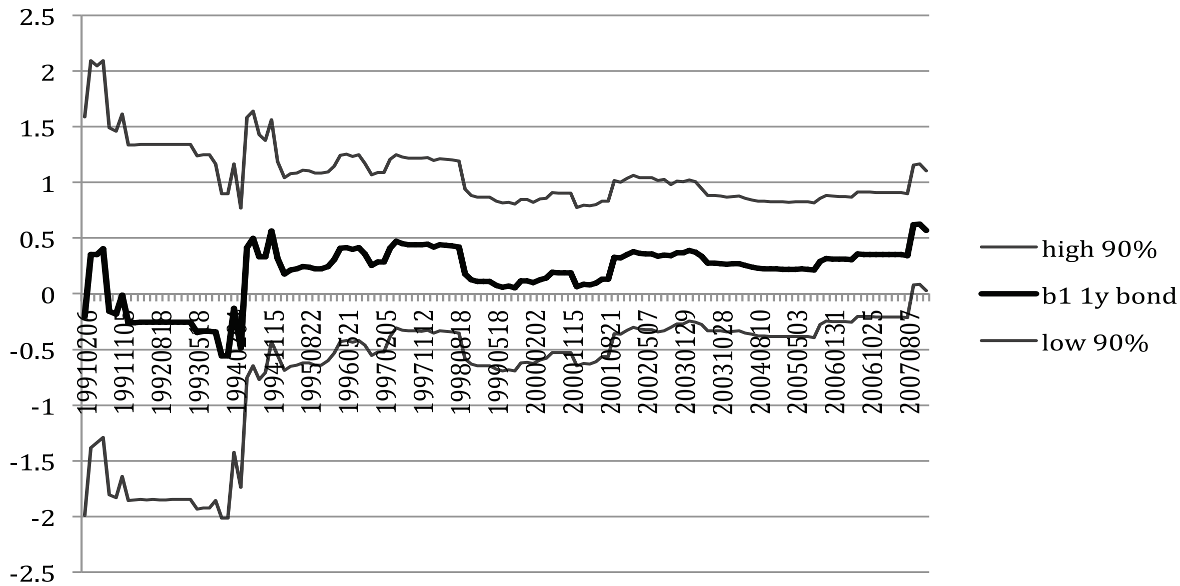

Figure 12: Time varying effects of monetary policy on the 1-year bond returns and 90% significance bands in the model with heteroskedastic disturbances.

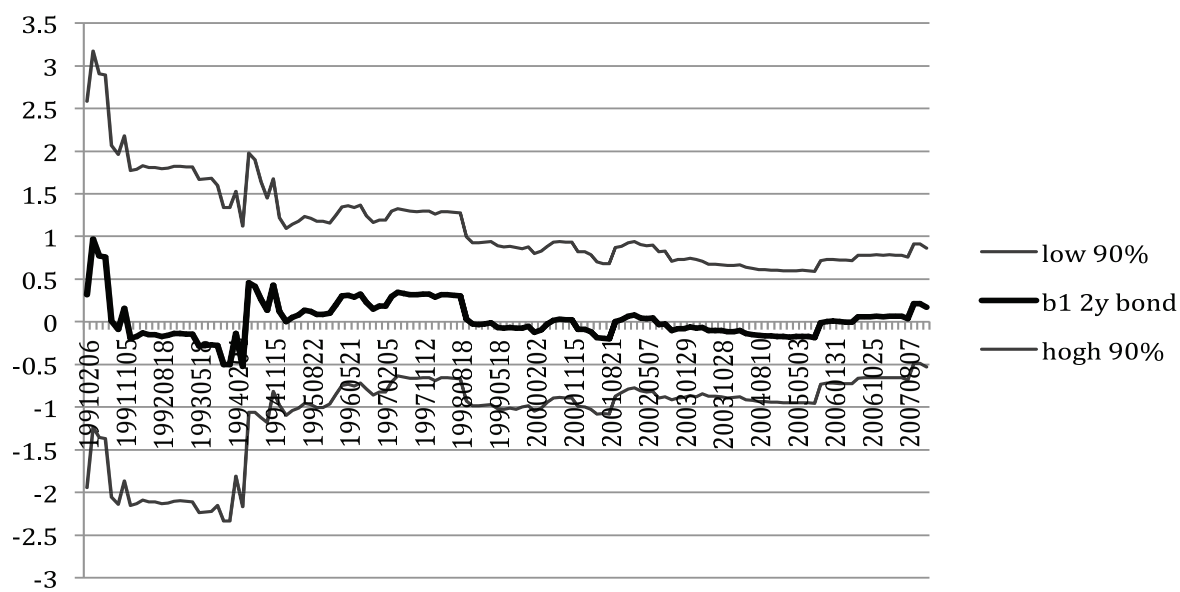

Figure 13: Time varying effects of monetary policy on the 2-year bond returns and 90% significance bands in the model with heteroskedastic disturbances.

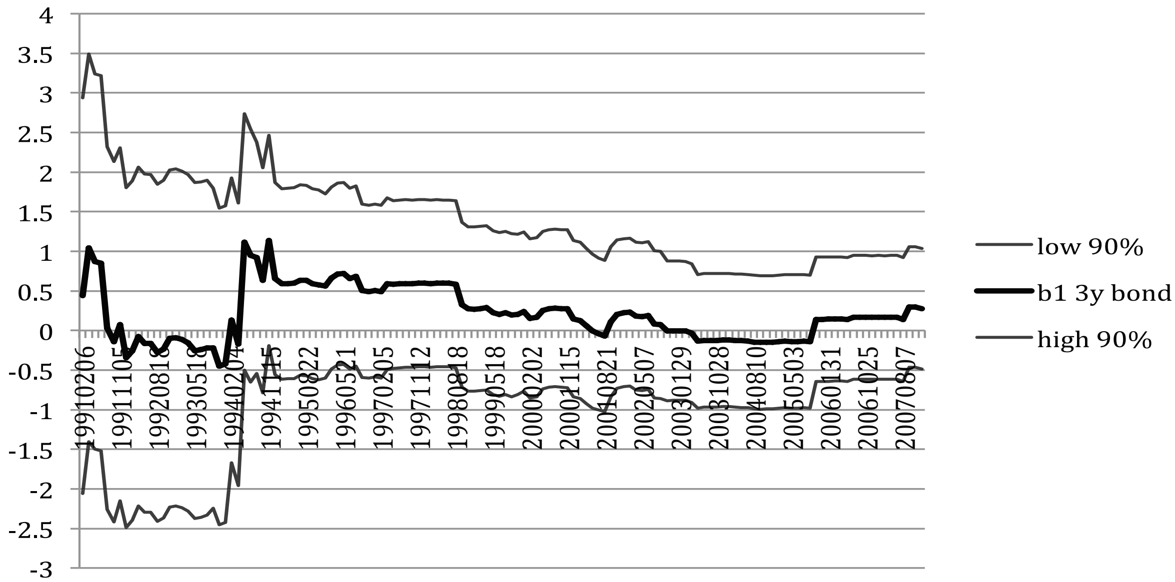

Figure 14: Time varying effects of monetary policy on the 3-year bond returns and 90% significance bands in the model with heteroskedastic disturbances.

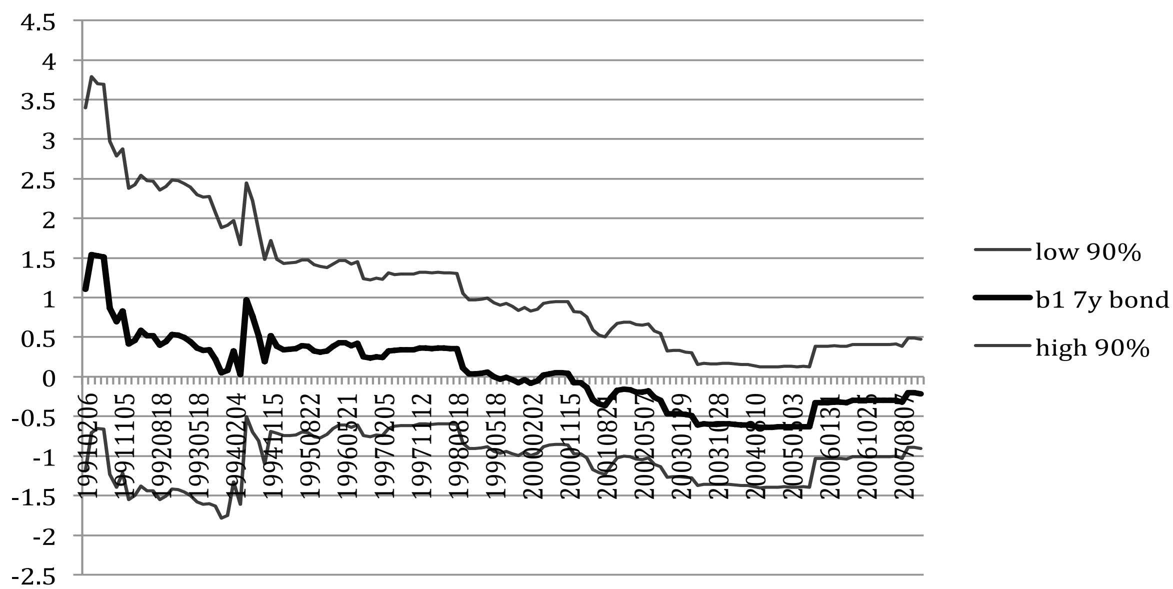

Figure 15: Time varying effects of monetary policy on the 7-year bond returns and 90% significance bands in the model with heteroskedastic disturbances.

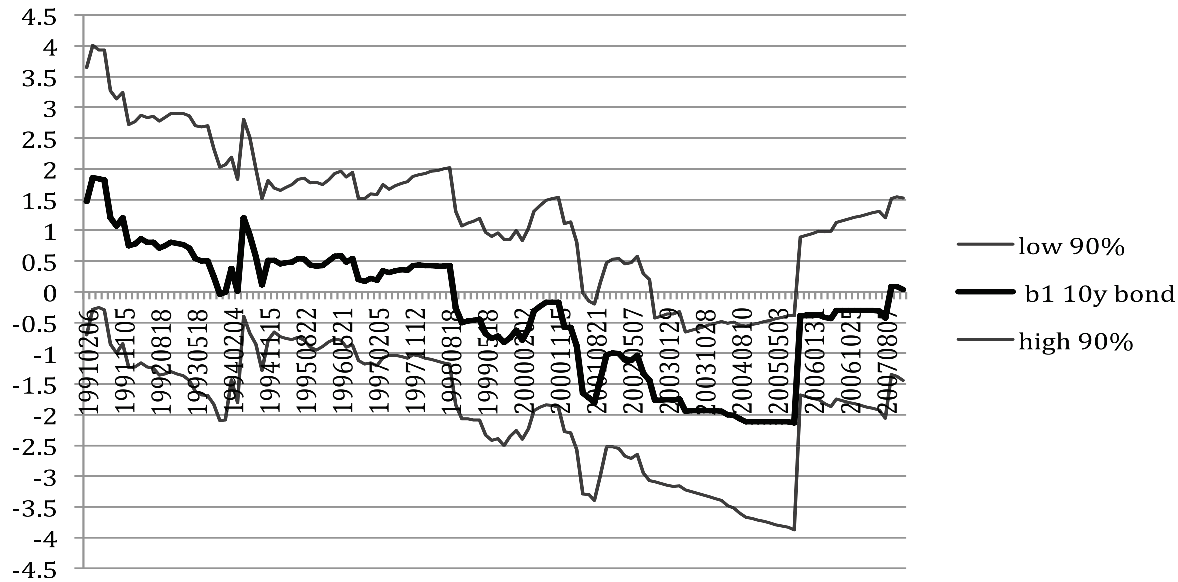

Figure 16: Time varying effects of monetary policy on the 10-year bond returns and 90% significance bands in the model with heteroskedastic disturbances.