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Changes in the Federal Reserve Communication Strategy: A Structural Investigation

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Changes in the Federal Reserve Communication Strategy: A Structural Investigation*

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Abstract

This paper structurally investigates the changes in the Federal Reserve's communication strategy during the 1990s by analyzing anticipated and unanticipated disturbances to a Taylor rule. The anticipated monetary policy disturbances are identified by estimating a medium-scale dynamic stochastic general equilibrium model with the term structure of interest rates, using the U.S. data that includes bond yields. The estimation results show that the Fed made its future policy actions unanticipated for market participants until the mid-1990s, but thereafter, the Fed tended to coordinate market expectations about future policy actions. This finding suggests that the changes in the Fed's communication strategy are consistent with the rise of the academic views on central banking as management of expectations. The inclusion of bond yields in the data for estimation is indispensable to the finding because the yields contain crucial information on the expected future path of the federal funds rate. Moreover, it is demonstrated that the presence of bond yields data generates a substantial contribution of monetary policy disturbances to business cycles.

Keywords: Monetary policy disturbance, Central bank communication, Management of expectations, Term structure of interest rates, Federal Reserve

JEL Classification: E52, E58

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1 Introduction

Since the seminal work by Taylor (1993), the U.S. monetary policy has been studied with an estimated policy rule for the federal funds rate (e.g., Clarida, Galí, and Gertler, 1998, 2000; Judd and Rudebusch, 1998; Orphanides, 2001, 2002, 2003; Taylor, 1999).[1] This policy rule serves as a useful description of the Federal Reserve's adjustment of the federal funds rate, and decomposes this rate to a rule-based component and a disturbance. While the rule-based component represents the Fed's systematic adjustment of the rate for its target variables (e.g., inflation), the disturbance is regarded as the Fed's discretion constrained in the presence of the systematic adjustment (Bernanke, 2003).

In the existing literature, the disturbances to monetary policy rules have been called monetary policy shocks, since it is typically assumed that the disturbances are unanticipated for private agents. However, not all monetary policy disturbances are unanticipated. Some are anticipated through the Fed's communications. The statement of the Federal Open Market Committee (FOMC) in August 2003, for instance, announced "the Committee believes that policy accommodation can be maintained for a considerable period." Moreover, in June 2004, when the Fed started to raise the target rate for the federal funds at a measured pace, the FOMC statement included the sentence "the Committee believes that policy accommodation can be removed at a pace that is likely to be measured." These statements have a coordination effect on financial market expectations about the future path of the federal funds rate, and it can be considered that this effect arises from an anticipated future monetary policy disturbance that captures the Fed's management of expectations.

This paper structurally identifies the anticipated and unanticipated components of the monetary policy disturbances to investigate the changes in the Fed's communication strategy during the 1990s.[2] The Fed decided in 1994 to release a statement describing policy actions on the federal funds rate at the conclusion of any FOMC meeting at which a policy action was undertaken, and determined in 1999 to issue a statement reporting the settings of the target rate for the federal funds and the balance of risks to the Fed's objectives after every FOMC meeting. Our strategy for the identification of anticipated future monetary policy disturbances is based

[1]The role of the federal funds rate as the Fed's key policy instrument was established by Goodfriend (1991).

[2]Blinder et al. (2001) indicate that the Fed has changed its communication strategy dramatically since 1993 and that the Fed's attitudes toward communication changed between 1995 and 1999.

on the idea that the effects of these decisions regarding the Fed's communication strategy are contained in the financial market data. In this context, Blinder et al. (2001) indicate that, during the period from early 1996 to mid-1999, the U.S. bond market moved in response to the macroeconomic developments that helped to stabilize the U.S. economy, despite relatively little change in the current level of the federal funds rate. As Blinder et al. argue, this reflects an improvement in the financial market's ability to forecast the Fed's future policy actions. We thus include the U.S. Treasury bond yields, which contain information on the future path of the federal funds rate expected by the market participants, in the data for the estimation of a Taylor rule together with the term structure of interest rates, which relates the bond yields to the federal funds rate. More specifically, anticipated and unanticipated components of disturbances to the Taylor rule are identified by the Bayesian estimation of a version of Smets and Wouters' (2007) model incorporated with the term structure, using the bond yields data as well as other macroeconomic data.[3]

The estimation results show that a large fraction of the anticipated component of disturbances to the Taylor rule was not met until the mid-1990s, but thereafter, this component tended to materialize. Moreover, the variance decompositions of the monetary policy disturbances in two subsamples, before and after the mid-1990s, show that the contribution of the anticipated component to the whole policy disturbances became larger after the mid-1990s. These results imply that the Fed made its future policy actions unanticipated for market participants until the mid-1990s, but thereafter, the Fed tended to coordinate financial market expectations about future policy actions. Furthermore, it is demonstrated that the inclusion of bond yields in the data for estimation is indispensable to these results. Exclusion of the bond yields data results in no significant difference between the periods before and after the mid-1990s in the estimated series of the anticipated and unanticipated components of the policy disturbances.

The main finding of the Fed's coordinating future policy expectations after the mid-1990s suggests that the changes in the Fed's communication strategy are consistent with the rise of the academic views on central banking as management of expectations. As Goodfriend (2010) points out, the Fed in the mid-1990s was inclined to communicate to financial markets in terms

[3] De Graeve, Emiris, and Wouters (2009) empirically demonstrate that a variant of Smets and Wouters' (2007) model combined with the term structure of interest rates can well explain the movements in the U.S. yield curve.

of interest rate policy, since academic literature had developed indicating that communication could enhance the effectiveness of the policy. In this context, Woodford (2001, 2003, 2005) stresses that better information on the part of financial market participants about central banks' actions and intensions increases the degree to which the banks' policy decisions can actually influence market expectations about future policy actions, and thus improves the monetary policy effectiveness. Moreover, Blinder et al. (2008) emphasize the role of "news" or "signals" by central banks for the management of expectations. The anticipated future monetary policy disturbances examined in the present paper can be regarded as a form of such news or signals by the Fed.

This paper contributes to the business cycle literature as well. Since the seminal work by Beaudry and Portier (2004), there has been a surge of interest in the role of anticipated future technological changes for business cycles. Fujiwara, Hirose, and Shintani (2011), Khan and Tsoukalas (2009), and Schmitt-Grohe and Uribe (2008) investigate the empirical relevance of such technological changes using dynamic stochastic general equilibrium (DSGE) models.[4] With a methodology similar to the ones in these recent studies, the present paper empirically examines the importance of monetary policy disturbances for business cycles in the presence of the anticipated component. The variance decompositions of output growth, consumption growth, investment growth, and hours worked all demonstrate that the inclusion of bond yields in the data for estimation leads to a substantial contribution of the policy disturbances to the fluctuations in the four macroeconomic variables,[5] whereas the exclusion of the yields data makes the contribution negligible, regardless of whether or not the anticipated component is incorporated.

In the literature, Milani and Treadwell (2009) is the most closely related study. They estimate a simple DSGE model with anticipated and unanticipated components of monetary policy disturbances, but their model is neither incorporated with the term structure of interest rates nor fitted to bond yields data. They show that the anticipated component plays a larger role in the U.S. business cycles than the unanticipated one, by comparing the impulse responses

[4] For theoretical studies on the anticipated future technological changes using DSGE models, see, e.g., Christiano et al. (2010), Fujiwara (2010), Jaimovich and Rebelo (2009), and Lorenzoni (2009).

[5] Moreover, the subsample analysis shows that the contribution to business cycles by the anticipated (unanticipated) monetary policy disturbances relative to other disturbances became larger (much smaller) after the mid-1990s.

of output to these two components. The present paper obtains the same implication in the variance decompositions regarding macroeconomic fluctuations when the model is estimated with bond yields data. It is, however, demonstrated that the contributions of both anticipated and unanticipated monetary policy disturbances to business cycles are negligible in the absence of bond yields data in model estimation.

The remainder of the paper proceeds as follows. Section 2 describes anticipated and unanticipated components of monetary policy disturbances. Section 3 presents a version of Smets and Wouters' (2007) model incorporated with the anticipated monetary policy disturbances and the term structure of interest rates, and explains the data and econometric methods for estimating this model. Section 4 shows empirical results. Finally, Section 5 concludes.

2 Anticipated and Unanticipated Monetary Policy Disturbances

This section describes the anticipated and unanticipated components of monetary policy disturbances and explains how it is possible to identify these components using the term structure of interest rates. To this end, a simple Taylor rule is employed.

$$\hat{r}_t = r_\pi \hat{\pi}_t + r_y(\hat{y}_t - \hat{y}_t^*) + \varepsilon_t, \tag{1}$$

where $\hat{r}_t$ denotes the short-term nominal interest rate (i.e., the monetary policy rate), $\hat{\pi}_t$ is the inflation rate, $\hat{y}_t$ and $\hat{y}_t^*$ are the actual and potential output, and ε_t is a monetary policy disturbance. The hatted variables are expressed in terms of the log-deviations from steady-state values. The first and second terms in the right-hand side of the Taylor rule (1) represent a central bank's systematic adjustment of the policy rate, while the disturbance ε_t captures the bank's discretion constrained in the presence of the systematic adjustment. In the existing literature, this disturbance is called a monetary policy shock, since it is typically assumed that monetary policy disturbances consist only of an unanticipated component.

In addition to the unanticipated component, the present paper considers an anticipated component of the monetary policy disturbance. As in Beaudry and Portier (2004), who analyze the anticipated future technological changes, it is assumed that

$$\varepsilon_t = \nu_{0,t} + \nu_t^* = \nu_{0,t} + \sum_{n=1}^{N} \nu_{n,t-n}. \tag{2}$$

That is, the monetary policy disturbance ε_t is the sum of the unanticipated component $\nu_{0,t}$ and the (total) anticipated component $\nu_t^* = \sum_{n=1}^{N} \nu_{n,t-n}$, where $\nu_{n,t-n}$ is part of ν_t^* that was anticipated n periods before its realization in period t. This information structure implies that, in period t, a fraction of future monetary policy disturbances (i.e., $\nu_{n,t+j-n}$, $(j,n) \in \{1,2,\dots\} \times \{0,\dots,N\}$ such that $j \leq n$) is indeed anticipated. For the remaining fraction (i.e., $\nu_{n,t+j-n}$, $(j,n) \in \{1,2,\dots\} \times \{0,\dots,N\}$ such that $j > n$), the expected value of each component $\nu_{n,t+j-n}$ in period t is assumed to be zero.

How can we identify the anticipated and unanticipated components of the monetary policy disturbance ε_t? For simplicity, consider the case of $N = 1$ in (2). Then, the disturbance becomes

$$\varepsilon_t = \nu_{0,t} + \nu_t^* = \nu_{0,t} + \nu_{1,t-1}. \tag{3}$$

Note that the anticipated component $\nu_{1,t}$ influences the expectations about the future policy rate, since (1) and (3) imply that

$$E_t \hat{r}_{t+1} = r_\pi E_t \hat{\pi}_{t+1} + r_y E_t[\hat{y}_{t+1} - \hat{y}_{t+1}^*] + \nu_{1,t}. \tag{4}$$

Therefore, the anticipated component $\nu_{1,t}$ captures an announcement about future monetary policy actions that will raise or lower the expected policy rate in the next period beyond the level warranted by the systematic adjustment in the Taylor rule (1).

According to the expectation hypothesis of the term structure of interest rates, the two-period bond yield equation in terms of the log-deviations from steady-state values is given by

$$\hat{r}_t^{2P} = \frac{1}{2}\left(\hat{r}_t + E_t \hat{r}_{t+1}\right) = \frac{1}{2}(\hat{r}_t + r_\pi E_t \hat{\pi}_{t+1} + r_y E_t[\hat{y}_{t+1} - \hat{y}_{t+1}^*] + \nu_{1,t}), \tag{5}$$

where the second equality follows from (4).

In this example, the estimation of the Taylor rule (1) with (3) and the two-period bond yield equation (5) generates a series of the pair of the anticipated component $\nu_{1,t}$ and the unanticipated component $\nu_{0,t}$. Similarly, the estimation of a longer-term bond yield equation can lead to a series of anticipated components with a longer forecast horizon. Because the regressors in these equations are endogenous and contain the expected values of inflation and the output gap, the present paper estimates a monetary policy rule and bond yield equations jointly with a DSGE model, using a full-information likelihood-based approach, which gives rise to, in principle, an optimal set of instruments to adjust the endogeneity of model variables. Moreover, this joint estimation enables us to investigate how and to what extent the anticipated and unanticipated monetary policy disturbances influence business cycles. Although this approach is potentially sensitive to model misspecification, such an issue can be mitigated by employing a version of Smets and Wouters' (2007) model, which fits well with the U.S. data and exhibits an out-of-sample forecasting performance comparable to that of a reduced-form VAR model. Moreover, as demonstrated by De Graeve, Emiris, and Wouters (2009), a variant of Smets and Wouters' model combined with the expectation hypothesis of the term structure of interest rates can well explain the movements in the U.S. yield curve.

3 The Model and Econometric Methodology

This section first describes a version of Smets and Wouters' (2007) model incorporated with the anticipated future monetary policy disturbances and the term structure of interest rates. Then, the data and econometric methods for estimating this model are presented.

3.1 The Estimated Model

This paper uses a version of the quarterly model used in Smets and Wouters (2007). This version differs from their original model in the following five respects.

First, the monetary policy rule is modified in line with Taylor (1993) so that the policy rate is adjusted in response to the annual inflation rate and a practical output gap instead of the quarterly inflation rate and the theoretical output gap (i.e., the gap between real output and output that would be obtained in the absence of nominal rigidities),[6] but not to the change in the theoretical output gap[7]

$$\hat{r}_t = \rho_R \hat{r}_{t-1} + (1-\rho_R)\left[r_\pi \left(\frac{1}{4} \sum_{n=0}^{3} \hat{\pi}_{t-n} \right) + r_y (\hat{y}_t - \hat{y}_t^*) \right] + \varepsilon_t^r.$$

Here, ρ_R is the degree of policy rate smoothing and r_π, r_y are the degrees of policy responses to inflation and the output gap. This gap is given by

$$\hat{y}_t - \hat{y}_t^* = \Phi\Big(\alpha \, \hat{k}_t^s + (1-\alpha) \, \hat{l}_t \Big) \, ,$$

where the parameter Φ is one plus the share of fixed costs in output, α is the capital-service elasticity of output, and $\hat{l}_t$ and $\hat{k}_t^s$ denote the log-deviations of the labor input and detrended

[6] Our specification of the output gap is consistent with the output-gap measure estimated by, e.g., the U.S. Congressional Budget Office.

[7] An alternative specification of the monetary policy rule, which responds additionally to output growth, is examined as a robustness exercise later.

capital services from their steady-state values. The capital services are given by

$$\hat{k}_t^s = \hat{z}_t + \hat{k}_{t-1},$$

where $\hat{z}_t$ and $\hat{k}_{t-1}$ denote the log-deviations of the capital utilization rate and detrended capital installed in the previous period.

Second, the monetary policy disturbance consists not only of an unanticipated component but also of anticipated components up to two-year ahead

$$\varepsilon_t^r = \nu_{0,t}^r + \nu_t^{r*} = \nu_{0,t}^r + \sum_{n=1}^{7} \nu_{n,t-n}^r,$$

where each component $\nu_{n,t-n}^r$, $n = 0, 1, \ldots, 7$ is a normally distributed innovation with mean zero and standard deviation $\sigma_{\nu n}$. The length of the anticipation horizon is determined on the basis of the forecast horizon for the FOMC members' projections for several macroeconomic variables, in which the maximum horizon was two years until the release of the projection in October 2007.[8] As Woodford (2008) argues, the regular publication of the Fed's projections plays a central role in its communication policies, and the public should be able to form expectations about the Fed's future policy actions from these projections. Therefore, it is plausible to assume that the Fed's communication strategy can influence the anticipated future policy disturbances up to the same horizon as the one for the FOMC projections.

Third, the expectation hypothesis of the term structure of interest rates is assumed for one- and two-year bond yields[9]

$$\hat{r}_t^{1Y} = \frac{1}{4} \sum_{n=0}^{3} E_t \hat{r}_{t+n}, \qquad \hat{r}_t^{2Y} = \frac{1}{8} \sum_{n=0}^{8} E_t \hat{r}_{t+n}.$$

Fourth, the deterministic trend in neutral technology is replaced by the stochastic one. As a consequence, a disturbance to the rate of neutral technological change (i.e., a neutral technology disturbance) is introduced instead of the disturbance to the level of total factor productivity.[10]

[8] The forecast horizon for the projections has been extended to three years since the first "Summary of Economic Projections" was published along with the minutes of the October 2007 FOMC meeting.

[9] Constant term premia are assumed in the bond yields. The robustness exercise presented later allows for a time-varying component of the term premia.

[10] Smets and Wouters (2007) assume that the disturbance to the level of total factor productivity follows a stationary autoregressive process in the presence of the deterministic trend in the neutral technology. Their estimate of the autoregressive coefficient, however, is very close to unity. Therefore, we choose the stochastic trend to ensure the stationarity of the system of detrended equilibrium conditions.

That is, in the model the neutral technology level A_t follows the stochastic process

$$\log A_t = \log \gamma + \log A_{t-1} + \varepsilon_t^a,$$

where γ is the steady-state gross rate of neutral technological change and ε_t^a is a disturbance to the rate of the change. Then, for estimation, the equilibrium conditions are expressed in terms of the variables detrended by A_t, e.g., output $y_t = Y_t/A_t$, consumption $c_t = C_t/A_t$, investment $i_t = I_t/A_t$, and the real wage $w_t = W_t/A_t$. The following log-linearized equilibrium conditions represented in terms of the detrended variables are different from those of Smets and Wouters (2007):

$$\begin{aligned}\hat{c}_t = &\frac{\lambda/\gamma}{1+\lambda/\gamma}\left(\hat{c}_{t-1} - \varepsilon_t^a\right) + \frac{1}{1+\lambda/\gamma}\left(E_t\hat{c}_{t+1} + E_t\varepsilon_{t+1}^a\right) + \frac{(\sigma_c - 1)w^h l/c}{\sigma_c(1+\lambda/\gamma)}\left(\hat{l}_t - E_t\hat{l}_{t+1}\right) \\ &- \frac{1-\lambda/\gamma}{\sigma_c(1+\lambda/\gamma)}\left(\hat{r}_t - E_t\hat{\pi}_{t+1} + \varepsilon_t^b\right), \end{aligned} \tag{6}$$

$$\hat{\imath}_t = \frac{1}{1+\beta\gamma^{1-\sigma_c}}\left(\hat{\imath}_{t-1} - \varepsilon_t^a\right) + \frac{\beta\gamma^{1-\sigma_c}}{1+\beta\gamma^{1-\sigma_c}}\left(E_t\hat{\imath}_{t+1} + E_t\varepsilon_{t+1}^a\right) + \frac{1}{\gamma^2\varphi(1+\beta\gamma^{1-\sigma_c})}\hat{q}_t + \varepsilon_t^i, \tag{7}$$

$$\hat{y}_t = \Phi\Big[\alpha\left(\hat{k}_t^s - \varepsilon_t^a\right) + (1-\alpha)\,\hat{l}_t\Big], \tag{8}$$

$$\hat{k}_t = \frac{1-\delta}{\gamma}\left(\hat{k}_{t-1} - \varepsilon_t^a\right) + \left(1 - \frac{1-\delta}{\gamma}\right)\left(\hat{\imath}_t + \gamma^2\varphi(1+\beta\gamma^{1-\sigma_c})\varepsilon_t^i\right), \tag{9}$$

$$\hat{\mu}_t^p = \alpha\left(\hat{k}_t^s - \hat{l}_t - \varepsilon_t^a\right) - \hat{w}_t, \tag{10}$$

$$\hat{r}_t^k = -\left(\hat{k}_t^s - \hat{l}_t - \varepsilon_t^a\right) + \hat{w}_t, \tag{11}$$

$$\hat{\mu}_t^w = \hat{w}_t - \left\{\sigma_l\hat{l}_t + \frac{1}{1-\lambda/\gamma}\left[\hat{c}_t - \frac{\lambda}{\gamma}\left(\hat{c}_{t-1} - \varepsilon_t^a\right)\right]\right\}, \tag{12}$$

$$\begin{aligned}\hat{w}_t = &\frac{1}{1+\beta\gamma^{1-\sigma_c}}\left(\hat{w}_{t-1} - \varepsilon_t^a\right) + \frac{\beta\gamma^{1-\sigma_c}}{1+\beta\gamma^{1-\sigma_c}}\left(E_t\hat{w}_{t+1} + E_t\varepsilon_{t+1}^a + E_t\hat{\pi}_{t+1}\right) \\ &- \frac{1+\beta\gamma^{1-\sigma_c}\iota_w}{1+\beta\gamma^{1-\sigma_c}}\hat{\pi}_t + \frac{\iota_w}{1+\beta\gamma^{1-\sigma_c}}\hat{\pi}_{t-1} - \frac{(1-\xi_w)(1-\beta\gamma^{1-\sigma_c}\xi_w)}{\xi_w(1+\beta\gamma^{1-\sigma_c})[(\phi_w - 1)\varepsilon_w + 1]}\hat{\mu}_t^w + \varepsilon_t^w. \end{aligned} \tag{13}$$

Eq. (6) is the consumption Euler equation, where ε_t^b represents a disturbance to the risk premium in the return on assets held by households relative to the policy rate, λ is the degree of external habit persistence in consumption preferences, σ_c is the degree of relative risk aversion, and $w^h l/c$ is the steady-state value of labor relative to consumption. Eq. (7) is the investment adjustment equation, where $\hat{q}_t$ denotes the log-deviation of the real value of the existing capital stock from its steady-state value, ε_t^i represents a disturbance to investment efficiency, β is the subjective discount factor, and φ is the steady-state elasticity of investment adjustment costs. Eq. (8) is the Cobb-Douglas production function with fixed costs. Eq. (9) is the capital accumulation equation, where δ is the depreciation rate of capital. Eq. (10) is the equation for the price markup $\hat{\mu}_t^p$, where $\hat{w}_t$ is the real wage. Eq. (11) is the condition for capital and labor inputs in production, where $\hat{r}_t^k$ is the real rental rate of capital. Eq. (12) is the equation for the wage markup $\hat{\mu}_t^w$, where σ_l is the inverse elasticity of labor supply. Eq. (13) is the wage equation, where ε_t^w represents a wage markup disturbance, ξ_w and ι_w are the degrees of wage stickiness and wage indexation to past inflation, $(\phi_w - 1)$ is the steady-state labor market markup, and ε_w is the curvature of the Kimball labor market aggregator. The other log-linearized equilibrium conditions are the same as those in Smets and Wouters (2007):

$$\hat{y}_t = c_y \hat{c}_t + i_y \hat{\imath}_t + r^k k_y \hat{z}_t + \varepsilon_t^g, \tag{14}$$

$$\hat{q}_t = \frac{1-\delta}{r^k + 1 - \delta} E_t \hat{q}_{t+1} + \frac{r^k}{r^k + 1 - \delta} E_t \hat{r}_{t+1}^k - \left(\hat{r}_t - E_t \hat{\pi}_{t+1} + \varepsilon_t^b \right), \tag{15}$$

$$\hat{z}_t = \frac{1-\psi}{\psi} \hat{r}_t^k, \tag{16}$$

$$\begin{aligned} \hat{\pi}_t = & \frac{\iota_p}{1 + \beta\gamma^{1-\sigma_c}\iota_p} \hat{\pi}_{t-1} + \frac{\beta\gamma^{1-\sigma_c}}{1 + \beta\gamma^{1-\sigma_c}\iota_p} E_t \hat{\pi}_{t+1} \\ & - \frac{(1-\xi_p)(1-\beta\gamma^{1-\sigma_c}\xi_p)}{\xi_p(1+\beta\gamma^{1-\sigma_c}\iota_p)[(\phi_p - 1)\varepsilon_p + 1]} \hat{\mu}_t^p + \varepsilon_t^p. \end{aligned} \tag{17}$$

Eq. (14) is the aggregate resource constraint, where ε_t^g represents an exogenous spending disturbance, c_y, i_y, k_y are the steady-state output ratios of consumption, investment, and capital, and r^k is the steady-state real rental rate of capital. Eq. (15) is the no arbitrage condition for the value of capital. Eq. (16) is the condition for the capital utilization rate, where ψ is determined by a function of the steady-state elasticity of the rate adjustment costs. Eq. (17) is the New Keynesian Phillips curve, where ε_t^p represents a price markup disturbance, ξ_p and ι_p are the degrees of price stickiness and price indexation to past inflation, $(\phi_p - 1)$ is the steady-state goods market markup, and ε_p is the curvature of the Kimball goods market aggregator.

Last, the exogenous spending disturbance ε_t^g, the wage markup disturbance ε_t^w, and the price markup disturbance ε_t^p are all governed by stationary first-order autoregressive processes.[11] Each of the six exogenous disturbances ε_t^x, $x \in \{a, b, i, w, p, g\}$ thus follows

$$\varepsilon_t^x = \rho_x \varepsilon_{t-1}^x + \nu_t^x,$$

where ρ_x is an autoregressive coefficient and ν_t^x is a normally distributed innovation with mean zero and standard deviation σ_x.

[11] In Smets and Wouters (2007), the exogenous spending disturbance is affected by a contemporaneous innovation to the total factor productivity, and the price and wage markup disturbances follow ARMA(1,1) processes.

3.2 Econometric Methodology

The model is estimated with Bayesian methods using nine quarterly U.S. time series as observable variables: output Y_t, consumption C_t, investment I_t, the real wage W_t, hours worked l_t, the output price deflator P_t, the short-term nominal interest rate r_t, and one- and two-year bond yields r_t^{1Y}, r_t^{2Y}. The first seven series are the same as those in Smets and Wouters (2007).[12] The remaining two series are one- and two-year U.S. Treasury yields estimated by the Federal Reserve Board based on the methodology of Gürkaynak, Sack, and Wright (2007).

The sample period is from 1987:3Q to 2008:4Q. The beginning of the sample period is set at the time when Alan Greenspan became the Chairman of the Federal Reserve, because thereafter, the style of the Fed's policy conduct seems consistent and stable. The end of the sample period follows from the fact that our estimation strategy is not able to take into account the non-linearity in monetary policy rules due to the zero lower bound on the federal funds rate, which has been binding since 2009:1Q.

The corresponding observation equations are

$$\begin{bmatrix} 100\Delta\log Y_t \\ 100\Delta\log C_t \\ 100\Delta\log I_t \\ 100\Delta\log W_t \\ 100\log l_t \\ 100\Delta\log P_t \\ 100\log r_t \\ 100\log r_t^{1Y} \\ 100\log r_t^{2Y} \end{bmatrix} = \begin{bmatrix} \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{l} \\ \bar{\pi} \\ \bar{r} \\ \bar{r}+c^{1Y} \\ \bar{r}+c^{2Y} \end{bmatrix} + \begin{bmatrix} \hat{y}_t - \hat{y}_{t-1} + \varepsilon_t^a \\ \hat{c}_t - \hat{c}_{t-1} + \varepsilon_t^a \\ \hat{\imath}_t - \hat{\imath}_{t-1} + \varepsilon_t^a \\ \hat{w}_t - \hat{w}_{t-1} + \varepsilon_t^a \\ \hat{l}_t \\ \hat{\pi}_t \\ \hat{r}_t \\ \hat{r}_t^{1Y} \\ \hat{r}_t^{2Y} \end{bmatrix},$$

where $\bar{\gamma} = 100(\gamma - 1)$, $\bar{l}$ is the steady-state hours worked, $\bar{\pi} = 100(\pi - 1)$, $\bar{r} = 100(\beta^{-1}\gamma^{\sigma_c}\pi - 1)$, and c^{1Y}, c^{2Y} denote the constant term premia in one- and two-year bond yields.

As in Smets and Wouters (2007), five parameters are fixed in our model estimation. The capital depreciation rate δ is set at 0.025 (on the quarterly basis), the exogenous spending-output ratio g_y is set at 0.18, the steady-state wage markup λ_w is set at 1.5, and the curvature parameters of the Kimball aggregators in the goods and labor markets $\varepsilon_p, \varepsilon_w$ are both set at

[12] See Smets and Wouters (2007) for a detailed description of the seven time series data.

10. For identification, all innovations to the disturbances are, *a priori*, mutually and serially uncorrelated.

The prior distributions of the parameters to be estimated are shown in the second to fourth columns of Table 1. The same prior distributions as those in Smets and Wouters (2007) are used. In addition, equal weights on the unanticipated component and on the total anticipated component of monetary policy disturbances are used in the prior of these components' standard deviations; that is, $\sigma_{\nu n}$, $n = 1, 2, \ldots, 7$ are distributed around $7^{-1/2} \times 0.1$ so that $\sum_{n=1}^{7} \sigma_{\nu n}^2 = \sigma_{\nu 0}^2$. The prior distributions of the constant term premia c^{1Y}, c^{2Y} are set to be the normal distributions with standard deviation 0.05 and mean given by the sample mean of the spreads between the one- and two-year Treasury yields and the federal funds rate.

In the Bayesian estimation, the Kalman filter is used to evaluate the likelihood function for the system of log-linearized equilibrium conditions of the model, and the Metropolis-Hastings algorithm is applied to generate draws from the posterior distribution of model parameters.[13] Based on these draws, we make inference on the parameters and obtain the Kalman smoothed estimates and the historical and variance decompositions of the model variables.

4 Empirical Results

This section presents the empirical results. First, the estimates of the model parameters are shown. Then, the estimated series of monetary policy disturbances and their implications are examined. Finally, several robustness exercises are conducted.

4.1 Parameter Estimates

Each parameter's posterior mean and 90% posterior interval are reported in the last two columns of Table 1. Basically, most of the estimates are similar to those in Table 5 of Smets and Wouters (2007) for the sample period from 1984:1Q to 2004:4Q, since the model of the present paper is a simple variant of their model. The estimated degrees of price stickiness and policy rate smoothing ($\xi_p = 0.87$, $\rho_R = 0.94$) are higher than Smets and Wouters' estimates ($\xi_p = 0.73$, $\rho_R = 0.84$). Moreover, the estimates of the autoregressive coefficients of distur-

[13] In each estimation, 500,000 draws are generated and the first half of these draws is discarded. The scale factor for the jumping distribution in the Metropolis-Hastings algorithm is adjusted so that the acceptance rate of 24% is obtained. The Brooks and Gelman measure is used to check the convergence of parameters.

bances to the neutral technology, the risk premium, and the wage markup ($\rho_a = 0.08$, $\rho_b = 0.97$, $\rho_w = 0.25$) differ from Smets and Wouters' estimates ($\rho_a = 0.94$, $\rho_b = 0.14$, $\rho_w = 0.74$). These differences are attributed to the introduction of the stochastic trend in neutral technology as well as the difference in the sample period. For the same reason, the estimate of the standard deviation of the innovation to neutral technological change ($\sigma_a = 0.75$) differs from Smets and Wouters' estimate ($\sigma_a = 0.35$).

The parameters specific to the present model are the constant term premia, c^{1Y}, c^{2Y}, and the standard deviations of the anticipated components of monetary policy disturbances, $\sigma_{\nu 1}, \sigma_{\nu 2}, \ldots, \sigma_{\nu 7}$. The estimates of $c^{1Y} = 0.04$ and $c^{2Y} = 0.11$ are almost the same as their prior mean, each of which is set at the sample mean of the spread between the corresponding bond yields and the federal funds rate. Although each of the estimates of $\sigma_{\nu 1}, \sigma_{\nu 2}, \ldots, \sigma_{\nu 7}$ is smaller than the estimate of $\sigma_{\nu 0}$, the total variance of the anticipated components is larger than the variance of the unanticipated component. This suggests the importance of the anticipated components of monetary policy disturbances in the estimated model.

4.2 Historical Decomposition of Monetary Policy Disturbances

This subsection examines the changes in the Fed's communication strategy during the 1990s through a lens of the estimated series of the anticipated and unanticipated components of monetary policy disturbances. The Fed decided in 1994 to release a statement describing policy actions on the federal funds rate at the conclusion of any FOMC meeting at which a policy action was undertaken,[14] and determined in 1999 to issue a statement reporting the settings of the target rate for the federal funds and the balance of risks to the Fed's objectives after every FOMC meeting. If these decisions on the Fed's communication strategy are reflected in the U.S. bond yields, the effects of the decisions should appear in the estimated series of the anticipated and unanticipated components of the policy disturbances.

Figure 1 illustrates the historical decomposition of monetary policy disturbances into the unanticipated and the total anticipated components, evaluated at the posterior mean estimates of parameters. The estimated series of the policy disturbances consist mainly of the anticipated component during the sample period, i.e., the Greenspan-Bernanke era. From a historical

[14] Goodfriend (2010) mentions that this decision "was a dramatic moment for those in the room like the author who were aware of the longstanding reluctance of the Fed to be fully clear about its interest rate policy, and for those who thought more openness was necessary and beneficial" (p. 3).

perspective, the relationship between the unanticipated and the total anticipated components changed after the mid-1990s. The total anticipated component was offset by the unanticipated one until the mid-1990s, but thereafter, both the components contributed to the whole policy disturbances in almost the same direction.[15] That is, a large fraction of the total anticipated component was not met before the mid-1990s, but thereafter, the total anticipated component tended to materialize.

4.3 Subsample Analysis

The historical decomposition of monetary policy disturbances has shown that the relationship between the unanticipated and the anticipated components changed after the mid-1990s. To investigate this change in more detail, the model is estimated for two subsamples: 1987:3Q–1996:4Q and 1997:1Q–2008:4Q. Each parameter's posterior mean and 90% posterior interval in the two subsamples are reported in Table 2. Most of the parameter estimates are similar between these two subsamples, but there is a remarkable difference in the estimate of the standard deviation of the unanticipated component of monetary policy disturbances. The variance of the unanticipated component became smaller in the latter subsample ($\sigma_{\nu 0} = 0.12$ for 1987:3Q–1996:4Q, $\sigma_{\nu 0} = 0.07$ for 1997:1Q–2008:4Q).[16] This result implies that after the mid-1990s, the relative importance of the unanticipated component was diminished and the Fed focused more on the role of the anticipated component in its policy conduct. This finding is also confirmed by the variance decomposition of monetary policy disturbances presented in Table 3. This table indicates the relative importance of the unanticipated and the total anticipated components in the whole policy disturbances, and shows that the contribution of the total anticipated component relative to the unanticipated one became much larger in the latter subsample (59.0% for 1987:3Q–1996:4Q, 80.5% for 1997:1Q–2008:4Q).

The above historical decomposition and subsample analysis of monetary policy disturbances demonstrate that until the mid-1990s, the Fed made its future policy actions unanticipated for

[15] In the econometric approach, all components of monetary policy disturbances are, *a priori*, mutually uncorrelated. However, they can be, *ex post*, correlated with each other as shown in this result.

[16] There are also differences in the standard deviation of the innovation to neutral technological changes, the autoregressive coefficient of the wage markup disturbance, and the standard deviation of the innovation to the markup disturbance ($\sigma_a = 0.55, \rho_w = 0.82, \sigma_w = 0.10$ for 1987:3Q–1996:4Q; $\sigma_a = 0.87, \rho_w = 0.21, \sigma_w = 0.37$ for 1997:1Q–2008:4Q).

participants in financial markets. Indeed, Greenspan (1989) stated in the Congress that "a public announcement requirement also could impede timely and appropriate adjustments to policy."[17] After the mid-1990s, the Fed tended to coordinate financial market expectations about future policy actions, i.e., the future path of the federal funds rate. According to Goodfriend (2010), the Fed, in the mid-1990s, was inclined to talk openly in terms of interest rate policy, since academics had begun to do so a few years earlier and an academic literature had developed indicating that communication could enhance the effectiveness of the policy.[18] In this context, Woodford (2001, 2003, 2005) insists that central banks' ability to affect the economy depends crucially on their ability to manage financial market expectations about the future path of the policy rate. Particularly, Woodford stresses that better information on the part of market participants about the central banks' actions and intensions increases the degree to which the banks' policy decisions can actually influence the market expectations on future policy actions, and thereby improves the effectiveness of monetary policy. These arguments suggest that the changes in the Fed's communication strategy are consistent with the rise in the academic views on central banking as management of expectations. For this management, Blinder et al. (2008) emphasize the role of "news" or "signals" by central banks. The anticipated monetary policy disturbances examined in the present paper can be regarded as a form of such news or signals by the Fed. Therefore, the finding about the importance of the anticipated policy disturbances after the mid-1990s would reflect the Fed's understanding of the importance of managing expectations about its future policy actions (i.e., forward guidance on the policy rate).

The finding regarding the composition of the anticipated and unanticipated components of monetary policy disturbances poses the questions of whether and how the business cycle implications of the policy disturbances changed after the mid-1990s. Table 4 reports the variance

[17] Goodfriend (1986) documented the Fed's defense of secrecy and argued against central bank secrecy.

[18] Goodfriend (2010) also raises three practical reasons for the change in the Fed's communication strategy in 1994. First, more timely announcements of policy actions would not impair the FOMC's deliberative process, which it was most anxious to protect. Second, to do otherwise would be to invite leaks of its intended policy stance. Third, continued delayed announcement of its interest rate policy stance would feed into an increasingly unfavorable opinion about the Fed's secrecy building in Congress and the media. Indeed, in the FOMC meeting held in November 1993, Greenspan's concern was to avoid "premature, detailed disclosure of our deliberations" that would compromise the "openness and free exchange of views so essential to monetary policy"(FOMC Transcripts, November 16, 1993, p. 6).

decompositions of output growth, consumption growth, investment growth, and hours worked in each subsample.[19] The relative contribution of the total anticipated component of the policy disturbances to the variances of the four macroeconomic variables increased in the latter subsample, whereas the contribution of the unanticipated component declined. This suggests that after the mid-1990s, the expectation channel by the anticipated components of monetary policy disturbances played a larger role in the transmission mechanism of the Fed's monetary policy to the U.S. economy.

4.4 Importance of Bond Yields Data in Estimation

Thus far, the paper has identified the anticipated and unanticipated components of monetary policy disturbances by including bond yields in the data for model estimation. However, as in Milani and Treadwell (2009), it may be possible to identify these components without using the bond yields data because the anticipated component has a different effect on output than the unanticipated one.[20] Thus, in order to examine the importance of bond yields data in our estimation, this subsection estimates the model without using the bond yields data and compares the result with that of the baseline estimation.

The second and third columns of Table 5 report the posterior mean and the 90% posterior interval of each parameter in the model estimated with no bond yields data.[21] Although most of these estimates are similar to the baseline estimates presented in the last two columns of Table 1, there are crucial differences in the estimates of the standard deviations of the unanticipated component and the two-period-ahead anticipated component of monetary policy disturbances.[22] In the absence of bond yields data, the estimated variances of the anticipated and unanticipated components are smaller ($\sigma_{\nu 0} = 0.10, \sigma_{\nu 2} = 0.08$ in the baseline estimation, $\sigma_{\nu 0} = 0.05, \sigma_{\nu 2} =$

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[19] Table 4 presents the decompositions of the asymptotic forecast error variances at an infinite horizon. Almost the same result is obtained even when the variance decompositions are computed at the business cycle frequency, e.g., 8 and 32 quarters. These variance decompositions are available upon request. The same argument applies to Tables 6 and 8.

[20] Milani and Treadwell (2009) indicate that the anticipated component of monetary policy disturbances has a larger, more delayed, and more persistent effect on output than the unanticipated one.

[21] The prior distributions are the same as those in the baseline estimation shown in the second to fourth columns of Table 1.

[22] There is also a difference in the degree of policy rate smoothing ($\rho_R = 0.94$ in the baseline estimation, $\rho_R =$ 0.67 in the estimation with no bond yields data).

0.03 in the estimation with no bond yields data).

To see how these differences affect the estimated series of the unanticipated and the total anticipated components of monetary policy disturbances, Figure 2 illustrates the historical decomposition of the disturbances, evaluated at the posterior mean estimates without using the bond yields data. The decomposition in this figure is radically different from the one based on the baseline estimates in Figure 1. The former shows that throughout the sample period, both the unanticipated and the total anticipated components contributed in the same direction to the whole monetary policy disturbances, suggesting no qualitative change in the policy disturbances. Therefore, in the absence of the bond yields data in model estimation, the estimated series of monetary policy disturbances is not able to capture the actual changes in the Fed's communication strategy during the 1990s.

These changes in the estimates can also alter the effect of monetary policy disturbances on macroeconomic volatilities. Table 6 compares the variance decompositions of output growth, consumption growth, investment growth, and hours worked between the baseline estimates shown in the first four rows and the estimates with no bond yields data in the fifth to eighth rows. This comparison shows that the magnitude of the contribution of monetary policy disturbances relative to the other disturbances is dramatically different. While the contribution of the whole monetary policy disturbances is around 15%–30% in the baseline estimation, it is around 0.5%–1% in the estimation with no bond yields data. Therefore, the use of the bond yields data in model estimation leads to a substantial relative contribution of the monetary policy disturbances to business cycles.

For comparison, the model with no anticipated component of monetary policy disturbances is estimated.[23] The fourth and fifth columns of Table 5 report the posterior mean and the 90% posterior interval of each parameter. All of the estimates, except the standard deviation of the unanticipated component, are almost the same as those with no bond yields data presented in the second and third columns of the same table. The estimated variance of the unanticipated monetary policy disturbances is larger in the absence of the anticipated components ($\sigma_{\nu 0} = 0.1$ in the model with no anticipated components, $\sigma_{\nu 0} = 0.05$ in the baseline model estimated with no bond yields data). The last four rows of Table 6 show the variance decompositions of output

[23] Note that no bond yields data is used for this estimation. The estimation of the model with no anticipated component of monetary policy disturbances using bond yields data leads to the singularity of the likelihood function, since the number of data series exceeds the number of disturbances in the model.

growth, consumption growth, investment growth, and hours worked in the estimated model with no anticipated component of monetary policy disturbances. This decomposition indicates that the relative contribution of monetary policy disturbances is quite marginal, as is the case with the baseline model estimated with no bond yields data. Therefore, the exclusion of the bond yields data in model estimation makes the contribution of monetary policy disturbances to business cycles negligible, regardless of whether or not the anticipated components of the policy disturbances are incorporated.

4.5 Robustness Analysis

This subsection assesses the robustness of the baseline results in the following three respects. First, an alternative specification of the monetary policy rule is examined. Second, time-varying components of term premia are allowed in one- and two-year bond yields. Third, the data on bond yields excluding term premia are used in model estimation. These three robustness exercises are conducted in turn.

4.5.1 Alternative Specification of Monetary Policy Rule

The misspecification of the monetary policy rule directly affects the estimates of its disturbances, and hence may change the qualitative properties of the baseline results. Thus, an alternative specification of the policy rule is estimated together with the rest of the baseline model. The specification examined here adds the policy response to the deviation of the output growth rate from its steady-state value (i.e., $100\Delta \log Y_t - \bar{\gamma} = \hat{y}_t - \hat{y}_{t-1} + \varepsilon_t^a$) to the baseline specification.

$$\hat{r}_t = \rho_R \hat{r}_{t-1} + (1-\rho_R)\left[r_\pi \left(\frac{1}{4} \sum_{n=0}^{3} \hat{\pi}_{t-n} \right) + r_y (\hat{y}_t - \hat{y}_t^*) \right] + r_{\Delta y} (\hat{y}_t - \hat{y}_{t-1} + \varepsilon_t^a) + \varepsilon_t^r,$$

where $r_{\Delta y}$ is the degree of the policy response to output growth. This specification expresses the Fed's concern about stable growth of the U.S. economy in its policy conduct. The specification is very close to the one used by Smets and Wouters (2007), in which the policy rate is adjusted in response to the change in the (theoretical) output gap.[24] The prior of $r_{\Delta y}$ is thus set to be the normal distribution with mean 0.125 and standard deviation 0.05, following Smets and Wouters (2007).

[24] Adding the policy response to the change in our practical output gap has been also investigated. We have confirmed that the results are almost the same.

In Table 7, the second and third columns report the posterior mean and the 90% posterior interval of each parameter in the estimated model with the alternative specification of the monetary policy rule. The estimated degree of the policy response to output growth ($r_{\Delta y} = 0.09$) is smaller than its prior mean, and the estimates of the other parameters are not remarkably different from those in the case of the baseline specification shown in Table 1. Figure 3 illustrates the historical decomposition of monetary policy disturbances. This decomposition is very similar to that in the baseline shown in Figure 1. The fifth to eighth rows of Table 8 show the variance decompositions of output growth, consumption growth, investment growth, and hours worked under the alternative policy rule. The monetary policy disturbances, their total anticipated component in particular, have a substantial contribution to the fluctuations in the four macroeconomic variables, as is the case with the baseline policy rule presented in the first four rows of the same table. Therefore, the baseline results are robust with respect to the alternative specification of the monetary policy rule.

4.5.2 Time-Varying Term Premia

The second robustness exercise allows for time-varying components of term premia in one- and two-year bond yields. In these relatively short-term bond yields, the baseline model has assumed the constant term premia, and as a consequence, the estimates of the anticipated monetary policy disturbances may contain the possible time-varying components of term premia. To investigate this issue, the present exercise follows De Graeve, Emiris, and Wouters (2009) to replace the observation equations for one- and two-year bond yields by

$$\begin{bmatrix} 100 \log r_t^{1Y} \\ 100 \log r_t^{2Y} \end{bmatrix} = \begin{bmatrix} \bar{r} + c^{1Y} \\ \bar{r} + c^{2Y} \end{bmatrix} + \begin{bmatrix} \hat{r}_t^{1Y} + \xi_t^{1Y} \\ \hat{r}_t^{2Y} + \xi_t^{2Y} \end{bmatrix},$$

where ξ_t^{1Y}, ξ_t^{2Y} represent the measurement errors interpreted as the time-varying components of term premia in one- and two-year bond yields and evolve according to the stochastic processes

$$\xi_t^{1Y} = \rho_{1Y} \xi_{t-1}^{1Y} + \eta_t^{1Y},$$
$$\xi_t^{2Y} = \rho_{2Y} \xi_{t-1}^{2Y} + \eta_t^{2Y},$$

where ρ_{1Y}, ρ_{2Y} are autoregressive coefficients and η_t^{1Y}, η_t^{2Y} are normally distributed innovations with mean zero and standard deviation σ_{1Y}, σ_{2Y}, respectively. The prior distributions of the autoregressive coefficients ρ_{1Y}, ρ_{2Y} and the standard deviations σ_{1Y}, σ_{2Y} are the same as those for the other disturbances, i.e., the beta distributions with mean 0.5 and standard deviation 0.2 for ρ_{1Y}, ρ_{2Y} and the inverse gamma distributions with mean 0.1 and standard deviation 2 for σ_{1Y}, σ_{2Y}.

The fourth and fifth columns of Table 7 report each parameter's posterior mean and 90% posterior interval in the presence of the time-varying components of term premia. The estimated standard deviations of the innovations to term premia ($\sigma_{1Y} = 0.02, \sigma_{2Y} = 0.03$) are comparable to that of each anticipated monetary policy disturbance, and the estimated degrees of the persistence of term premia ($\rho_{1Y} = 0.78, \rho_{2Y} = 0.84$) are larger than their prior mean. The other estimates are almost the same as the baseline estimates presented in Table 1. Even when the time-varying components of term premia are introduced in the bond yields, the historical decomposition of monetary policy disturbances illustrated in Figure 4 is very similar to that for the baseline model in Figure 1. Table 8 compares the variance decompositions of output growth, consumption growth, investment growth, and hours worked between the baseline estimates shown in the first four rows and the estimates with the time-varying term premia in the ninth to twelfth rows. Although the contribution of anticipated monetary policy disturbances is smaller in the estimates with the time-varying term premia, it remains sufficiently large. Therefore, the baseline results still hold even when the model allows for the time-varying components of term premia in the bond yields.

4.5.3 Alternative Data on Bond Yields

The last robustness exercise concerns another way to resolve the issue regarding the inclusion of possible time-varying components of the bond yields' term premia in anticipated monetary policy disturbances. The exercise conducted here is the use of the data on bond yields excluding term premia in model estimation. Specifically, the observation equations for one- and two-year bond yields are replaced by

$$\begin{bmatrix} 100 \log \tilde{r}_t^{1Y} \\ 100 \log \tilde{r}_t^{2Y} \end{bmatrix} = \begin{bmatrix} \bar{r} \\ \bar{r} \end{bmatrix} + \begin{bmatrix} \hat{r}_t^{1Y} \\ \hat{r}_t^{2Y} \end{bmatrix},$$

where $\tilde{r}_t^{1Y}, \tilde{r}_t^{2Y}$ represent the gross rates of one- and two-year bond yields excluding term premia, estimated by the Federal Reserve Board based on the methodology of Kim and Wright (2005).

The posterior mean and the 90% posterior interval of each parameter in the baseline model estimated with the data on bond yields excluding term premia are reported in the last two columns of Table 7. The estimates are very similar to those in the baseline. According to the historical decomposition of monetary policy disturbances illustrated in Figure 5, the alternative bond yields data leads to the somewhat obvious compositional change in monetary policy disturbances. The total anticipated component of the policy disturbances was offset by the unanticipated one in the 1990s, and thereafter, both the components tended to contribute in almost the same direction. Regarding the importance of monetary policy disturbances in business cycles, the last four rows of Table 8 show that the relative contribution of each policy disturbance is slightly smaller than that in the baseline estimation but larger than that in the model with time-varying term premia in the bond yields. These demonstrate that the qualitative properties of the baseline results still hold even with the use of the alternative bond yields data in the estimation.

5 Concluding Remarks

This paper has structurally investigated the changes in the Fed's communication strategy during the 1990s through a lens of the anticipated and unanticipated components of monetary policy disturbances. These components have been identified in a version of Smets and Wouters' (2007) model with the term structure of interest rates, using the U.S. data that includes bond yields. According to the estimation results, the Fed made its future policy actions unanticipated for financial market participants until the mid-1990s, but thereafter, the Fed placed more emphasis on the coordination of the market expectations about the future policy actions, reflecting the rise of the academic views on central banking as management of expectations. It is important to stress that the inclusion of bond yields in the data for estimation is indispensable to the meaningful change in the composition of the anticipated and unanticipated components of monetary policy disturbances in the mid-1990s. This is because the bond yields contain crucial information on the expected future path of the federal funds rate. Moreover, it has been demonstrated that the model estimated with the bond yields data suggests substantial influence of monetary policy disturbances on business cycles whereas the model without them does not.

A more detailed investigation of the estimated series of the anticipated component of monetary policy disturbances would help to understand the Fed's forward guidance on the federal funds rate. For instance, the estimation results suggest that in 2003 and 2008, the Fed successfully coordinated financial market expectations so that the market participants could anticipate that the federal funds rate would be lower than that suggested by the estimated Taylor rule for some time in the future. Then, the questions arise as to how and to what extent this management of expectations by the Fed influenced the U.S. macroeconomic performance in those periods. Addressing these issues is left for future research.

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Table 1: Prior and posterior distributions of parameters

Parameter	Prior distribution			Posterior distribution	
	Distribution	Mean	S.D.	Mean	90% interval
φ	Normal	4.000	1.500	7.451	[5.654, 9.168]
σ_c	Normal	1.500	0.375	1.340	[0.906, 1.762]
λ	Beta	0.700	0.100	0.637	[0.530, 0.746]
ξ_w	Beta	0.500	0.100	0.886	[0.840, 0.931]
σ_l	Normal	2.000	0.750	1.481	[0.317, 2.592]
ξ_p	Beta	0.500	0.100	0.867	[0.823, 0.913]
ι_w	Beta	0.500	0.150	0.396	[0.175, 0.618]
ι_p	Beta	0.500	0.150	0.290	[0.095, 0.487]
ψ	Beta	0.500	0.150	0.726	[0.570, 0.889]
Φ	Normal	1.250	0.125	1.415	[1.292, 1.539]
r_π	Normal	1.500	0.250	1.635	[1.263, 2.008]
ρ_R	Beta	0.750	0.100	0.944	[0.926, 0.962]
r_y	Normal	0.125	0.050	0.148	[0.094, 0.200]
$\bar{\pi}$	Gamma	0.625	0.100	0.645	[0.523, 0.768]
$100(\beta^{-1}-1)$	Gamma	0.250	0.100	0.219	[0.088, 0.349]
$\bar{l}$	Normal	0.000	2.000	0.332	[-1.473, 2.109]
$\bar{\gamma}$	Normal	0.400	0.100	0.411	[0.311, 0.512]
α	Normal	0.300	0.050	0.175	[0.135, 0.215]
c^{1Y}	Normal	0.030	0.050	0.040	[0.020, 0.059]
c^{2Y}	Normal	0.100	0.050	0.105	[0.065, 0.144]
ρ_a	Beta	0.500	0.200	0.078	[0.014, 0.139]
ρ_b	Beta	0.500	0.200	0.968	[0.951, 0.986]
ρ_g	Beta	0.500	0.200	0.977	[0.964, 0.992]
ρ_I	Beta	0.500	0.200	0.667	[0.507, 0.832]
ρ_p	Beta	0.500	0.200	0.344	[0.099, 0.574]
ρ_w	Beta	0.500	0.200	0.246	[0.092, 0.389]
σ_a	Inv. Gamma	0.100	2.000	0.748	[0.626, 0.869]
σ_b	Inv. Gamma	0.100	2.000	0.173	[0.113, 0.229]
σ_g	Inv. Gamma	0.100	2.000	0.388	[0.339, 0.436]
σ_I	Inv. Gamma	0.100	2.000	0.374	[0.269, 0.479]
σ_p	Inv. Gamma	0.100	2.000	0.113	[0.082, 0.142]
σ_w	Inv. Gamma	0.100	2.000	0.272	[0.215, 0.327]
$\sigma_{\nu 0}$	Inv. Gamma	0.100	2.000	0.099	[0.084, 0.113]
$\sigma_{\nu 1}$	Inv. Gamma	0.038	2.000	0.044	[0.013, 0.073]
$\sigma_{\nu 2}$	Inv. Gamma	0.038	2.000	0.080	[0.056, 0.107]
$\sigma_{\nu 3}$	Inv. Gamma	0.038	2.000	0.066	[0.044, 0.087]
$\sigma_{\nu 4}$	Inv. Gamma	0.038	2.000	0.021	[0.010, 0.032]
$\sigma_{\nu 5}$	Inv. Gamma	0.038	2.000	0.023	[0.010, 0.037]
$\sigma_{\nu 6}$	Inv. Gamma	0.038	2.000	0.029	[0.010, 0.052]
$\sigma_{\nu 7}$	Inv. Gamma	0.038	2.000	0.048	[0.022, 0.070]

Note: For the posterior distribution, 500,000 draws were generated using the Metropolis-Hastings algorithm, and the first half of these draws was discarded.

Table 2: Posterior distributions of parameters in subsamples

	87:3Q–96:4Q		97:1Q–08:4Q	
Parameter	Mean	90% interval	Mean	90% interval
φ	6.387	[4.439, 8.287]	6.448	[4.637, 8.292]
σ_c	0.817	[0.550, 1.085]	1.242	[0.880, 1.600]
λ	0.723	[0.601, 0.850]	0.635	[0.534, 0.742]
ξ_w	0.601	[0.452, 0.751]	0.675	[0.548, 0.802]
σ_l	0.625	[-0.723, 1.990]	0.565	[-0.421, 1.537]
ξ_p	0.845	[0.796, 0.894]	0.841	[0.778, 0.904]
ι_w	0.507	[0.273, 0.747]	0.431	[0.189, 0.663]
ι_p	0.345	[0.150, 0.532]	0.272	[0.097, 0.435]
ψ	0.571	[0.350, 0.797]	0.727	[0.562, 0.898]
Φ	1.370	[1.221, 1.514]	1.411	[1.270, 1.558]
r_π	1.711	[1.334, 2.094]	1.545	[1.160, 1.915]
ρ_R	0.908	[0.874, 0.943]	0.927	[0.901, 0.953]
r_y	0.122	[0.047, 0.196]	0.128	[0.074, 0.184]
$\bar{\pi}$	0.642	[0.502, 0.781]	0.569	[0.447, 0.690]
$100(\beta^{-1}-1)$	0.320	[0.135, 0.494]	0.179	[0.067, 0.285]
$\bar{l}$	-0.160	[-1.677, 1.369]	0.237	[-1.583, 2.015]
$\bar{\gamma}$	0.439	[0.321, 0.556]	0.390	[0.269, 0.510]
α	0.178	[0.128, 0.228]	0.178	[0.131, 0.228]
c^{1Y}	0.051	[0.023, 0.079]	0.025	[0.005, 0.044]
c^{2Y}	0.146	[0.095, 0.197]	0.061	[0.019, 0.101]
ρ_a	0.248	[0.087, 0.398]	0.082	[0.013, 0.149]
ρ_b	0.928	[0.873, 0.982]	0.922	[0.884, 0.960]
ρ_g	0.877	[0.796, 0.963]	0.958	[0.925, 0.991]
ρ_I	0.517	[0.228, 0.803]	0.670	[0.501, 0.846]
ρ_p	0.250	[0.045, 0.445]	0.373	[0.127, 0.619]
ρ_w	0.821	[0.682, 0.951]	0.209	[0.045, 0.362]
σ_a	0.553	[0.425, 0.675]	0.866	[0.688, 1.041]
σ_b	0.260	[0.099, 0.433]	0.267	[0.145, 0.382]
σ_g	0.375	[0.302, 0.446]	0.398	[0.330, 0.465]
σ_I	0.447	[0.253, 0.636]	0.352	[0.234, 0.471]
σ_p	0.095	[0.069, 0.121]	0.123	[0.084, 0.160]
σ_w	0.101	[0.067, 0.135]	0.374	[0.285, 0.457]
$\sigma_{\nu 0}$	0.117	[0.093, 0.141]	0.068	[0.049, 0.087]
$\sigma_{\nu 1}$	0.034	[0.010, 0.062]	0.082	[0.039, 0.123]
$\sigma_{\nu 2}$	0.090	[0.050, 0.132]	0.056	[0.013, 0.093]
$\sigma_{\nu 3}$	0.086	[0.051, 0.123]	0.076	[0.046, 0.110]
$\sigma_{\nu 4}$	0.024	[0.010, 0.038]	0.029	[0.010, 0.048]
$\sigma_{\nu 5}$	0.025	[0.010, 0.041]	0.032	[0.011, 0.054]
$\sigma_{\nu 6}$	0.031	[0.010, 0.052]	0.026	[0.010, 0.043]
$\sigma_{\nu 7}$	0.031	[0.011, 0.052]	0.031	[0.011, 0.051]

Note: For the posterior distribution, 500,000 draws were generated using the Metropolis-Hastings algorithm, and the first half of these draws was discarded.

Table 3: Variance decompositions of monetary policy disturbances in subsamples

	87:3Q–96:4Q	97:1Q–08:4Q
Unanticipated	41.0	19.5
Total anticipated	59.0	80.5

Note: The table shows the forecast error variance decomposition of monetary policy disturbances at an infinite horizon evaluated at the posterior mean estimates of parameters. "Unanticipated" denotes the contribution of the unanticipated component $\nu_{0,t}^r$ to the variance of the whole monetary policy disturbances. "Total anticipated" denotes the sum of the contribution of each anticipated component $\nu_{n,t-n}^r$, $n = 1, 2, \ldots, 7$.

Table 4: Variance decompositions of output growth, consumption growth, investment growth, and hours worked in subsamples

87:3Q–96:4Q	Output	Consumption	Investment	Hours worked
Unanticipated	7.4	9.5	4.8	7.9
Total anticipated	11.2	11.7	10.1	16.0
Others	81.4	78.8	85.2	76.1
97:1Q–08:4Q	Output	Consumption	Investment	Hours worked
Unanticipated	3.3	4.3	2.2	4.0
Total anticipated	14.2	16.7	11.7	21.4
Others	82.6	79.1	86.1	74.5

Notes: The table shows the forecast error variance decompositions of output growth, consumption growth, investment growth, and hours worked at an infinite horizon evaluated at the posterior mean estimates of parameters. "Unanticipated" denotes the contribution of the unanticipated monetary policy disturbance $\nu^r_{0,t}$ to the variance of each of these four variables. "Total anticipated" denotes the sum of the contribution of each anticipated monetary policy disturbance $\nu^r_{n,t-n}$, $n = 1, 2, \ldots, 7$.

Table 5: Posterior distributions of parameters in analysis without bond yields data

	No bond yields data		No anticipated component	
Parameter	Mean	90% interval	Mean	90% interval
φ	5.370	[3.592, 7.069]	5.484	[3.719, 7.234]
σ_c	1.001	[0.710, 1.283]	0.986	[0.704, 1.269]
λ	0.650	[0.543, 0.762]	0.665	[0.556, 0.773]
ξ_w	0.801	[0.729, 0.875]	0.800	[0.726, 0.877]
σ_l	1.536	[0.514, 2.574]	1.549	[0.500, 2.571]
ξ_p	0.838	[0.793, 0.885]	0.837	[0.790, 0.886]
ι_w	0.448	[0.211, 0.678]	0.448	[0.214, 0.680]
ι_p	0.343	[0.133, 0.539]	0.343	[0.138, 0.541]
ψ	0.715	[0.549, 0.893]	0.713	[0.539, 0.884]
Φ	1.311	[1.193, 1.428]	1.313	[1.189, 1.428]
r_π	1.756	[1.486, 2.020]	1.745	[1.485, 2.008]
ρ_R	0.673	[0.604, 0.741]	0.665	[0.599, 0.734]
r_y	0.204	[0.173, 0.235]	0.201	[0.171, 0.231]
$\bar{\pi}$	0.632	[0.509, 0.753]	0.631	[0.509, 0.755]
$100(\beta^{-1} - 1)$	0.212	[0.086, 0.333]	0.213	[0.086, 0.335]
$\bar{l}$	0.257	[-0.609, 1.099]	0.255	[-0.573, 1.076]
$\bar{\gamma}$	0.399	[0.302, 0.496]	0.399	[0.302, 0.495]
α	0.138	[0.106, 0.171]	0.137	[0.104, 0.170]
ρ_a	0.093	[0.017, 0.162]	0.094	[0.019, 0.165]
ρ_b	0.904	[0.862, 0.949]	0.899	[0.854, 0.946]
ρ_g	0.974	[0.958, 0.991]	0.973	[0.957, 0.990]
ρ_I	0.622	[0.470, 0.782]	0.617	[0.457, 0.781]
ρ_p	0.313	[0.077, 0.526]	0.312	[0.080, 0.531]
ρ_w	0.327	[0.147, 0.502]	0.325	[0.143, 0.503]
σ_a	0.676	[0.570, 0.776]	0.675	[0.574, 0.774]
σ_b	0.350	[0.232, 0.469]	0.376	[0.244, 0.505]
σ_g	0.388	[0.339, 0.435]	0.388	[0.339, 0.436]
σ_I	0.379	[0.280, 0.478]	0.381	[0.279, 0.482]
σ_p	0.115	[0.086, 0.144]	0.115	[0.086, 0.143]
σ_w	0.267	[0.207, 0.327]	0.268	[0.207, 0.327]
$\sigma_{\nu 0}$	0.052	[0.028, 0.075]	0.096	[0.083, 0.109]
$\sigma_{\nu 1}$	0.026	[0.010, 0.043]	–	–
$\sigma_{\nu 2}$	0.027	[0.010, 0.047]	–	–
$\sigma_{\nu 3}$	0.028	[0.010, 0.049]	–	–
$\sigma_{\nu 4}$	0.028	[0.010, 0.048]	–	–
$\sigma_{\nu 5}$	0.029	[0.010, 0.050]	–	–
$\sigma_{\nu 6}$	0.029	[0.009, 0.050]	–	–
$\sigma_{\nu 7}$	0.030	[0.009, 0.054]	–	–

Note: For the posterior distribution, 500,000 draws were generated using the Metropolis-Hastings algorithm, and the first half of these draws was discarded.

Table 6: Variance decompositions of output growth, consumption growth, investment growth, and hours worked in analysis without bond yields data

Baseline	Output	Consumption	Investment	Hours worked
Unanticipated	8.6	11.1	5.2	9.1
Total anticipated	15.4	18.0	11.3	20.1
Others	76.0	70.9	83.5	70.7
No bond yields data	Output	Consumption	Investment	Hours worked
Unanticipated	0.2	0.4	0.0	0.1
Total anticipated	0.5	0.6	0.3	0.7
Others	99.3	99.0	99.6	99.1
No anticipated component	Output	Consumption	Investment	Hours worked
Unanticipated	0.7	1.1	0.1	0.4
Total anticipated	–	–	–	–
Others	99.3	98.9	99.9	99.6

Notes: The table shows the forecast error variance decompositions of output growth, consumption growth, investment growth, and hours worked at an infinite horizon evaluated at the posterior mean estimates of parameters. "Unanticipated" denotes the contribution of the unanticipated monetary policy disturbance $\nu^r_{0,t}$ to the variance of each of these four variables. "Total anticipated" denotes the sum of the contribution of each anticipated monetary policy disturbance $\nu^r_{n,t-n}$, $n = 1, 2, \ldots, 7$.

Table 7: Posterior distributions of parameters in robustness exercises

	Alternative policy rule		Time-varying premia		Alternative yields data	
Parameter	Mean	90% interval	Mean	90% interval	Mean	90% interval
φ	6.495	[4.589, 8.259]	6.591	[4.779, 8.405]	6.661	[4.865, 8.427]
σ_c	1.493	[1.105, 1.883]	1.230	[0.876, 1.582]	1.489	[1.141, 1.831]
λ	0.471	[0.375, 0.565]	0.615	[0.508, 0.728]	0.583	[0.480, 0.683]
ξ_w	0.880	[0.830, 0.932]	0.838	[0.779, 0.898]	0.795	[0.729, 0.862]
σ_l	1.348	[0.283, 2.394]	1.697	[0.610, 2.763]	1.509	[0.540, 2.485]
ξ_p	0.850	[0.789, 0.910]	0.862	[0.815, 0.910]	0.872	[0.826, 0.917]
ι_w	0.394	[0.178, 0.613]	0.424	[0.197, 0.654]	0.422	[0.187, 0.651]
ι_p	0.283	[0.080, 0.483]	0.274	[0.089, 0.458]	0.251	[0.090, 0.413]
ψ	0.787	[0.659, 0.915]	0.699	[0.532, 0.870]	0.711	[0.548, 0.878]
Φ	1.412	[1.284, 1.538]	1.373	[1.244, 1.494]	1.414	[1.281, 1.551]
r_π	1.890	[1.545, 2.235]	1.616	[1.254, 1.970]	1.434	[1.064, 1.788]
ρ_R	0.921	[0.896, 0.946]	0.909	[0.881, 0.938]	0.907	[0.883, 0.931]
r_y	0.107	[0.052, 0.162]	0.139	[0.090, 0.187]	0.089	[0.043, 0.134]
$r_{\Delta y}$	0.086	[0.057, 0.116]	–	–	–	–
$\bar{\pi}$	0.675	[0.535, 0.814]	0.636	[0.528, 0.742]	0.594	[0.496, 0.689]
$100(\beta^{-1}-1)$	0.217	[0.085, 0.345]	0.187	[0.074, 0.295]	0.210	[0.089, 0.327]
$\bar{l}$	0.120	[-1.750, 2.002]	0.201	[-1.143, 1.569]	-0.594	[-2.186, 0.976]
$\bar{\gamma}$	0.426	[0.326, 0.522]	0.399	[0.299, 0.496]	0.386	[0.294, 0.482]
α	0.185	[0.148, 0.221]	0.163	[0.126, 0.200]	0.167	[0.131, 0.204]
c^{1Y}	0.034	[0.015, 0.052]	0.037	[0.009, 0.065]	–	–
c^{2Y}	0.095	[0.060, 0.131]	0.102	[0.054, 0.150]	–	–
ρ_a	0.070	[0.012, 0.126]	0.076	[0.014, 0.136]	0.074	[0.012, 0.131]
ρ_b	0.980	[0.968, 0.991]	0.930	[0.895, 0.968]	0.858	[0.806, 0.913]
ρ_g	0.984	[0.974, 0.995]	0.971	[0.955, 0.987]	0.964	[0.948, 0.981]
ρ_I	0.754	[0.665, 0.841]	0.668	[0.513, 0.822]	0.637	[0.471, 0.796]
ρ_p	0.408	[0.132, 0.656]	0.345	[0.116, 0.570]	0.297	[0.086, 0.493]
ρ_w	0.252	[0.096, 0.398]	0.290	[0.123, 0.453]	0.240	[0.080, 0.392]
ρ_{1Y}	–	–	0.779	[0.599, 0.958]	–	–
ρ_{2Y}	–	–	0.840	[0.715, 0.966]	–	–
σ_a	0.752	[0.626, 0.871]	0.720	[0.602, 0.832]	0.776	[0.640, 0.908]
σ_b	0.106	[0.078, 0.134]	0.232	[0.141, 0.321]	0.362	[0.203, 0.513]
σ_g	0.385	[0.336, 0.431]	0.389	[0.339, 0.439]	0.365	[0.315, 0.416]
σ_I	0.324	[0.258, 0.388]	0.361	[0.262, 0.457]	0.388	[0.276, 0.501]
σ_p	0.107	[0.076, 0.138]	0.114	[0.085, 0.142]	0.123	[0.095, 0.153]
σ_w	0.273	[0.216, 0.326]	0.272	[0.213, 0.331]	0.303	[0.240, 0.365]
$\sigma_{\nu 0}$	0.103	[0.086, 0.119]	0.092	[0.074, 0.110]	0.094	[0.081, 0.108]
$\sigma_{\nu 1}$	0.052	[0.016, 0.082]	0.060	[0.028, 0.089]	0.027	[0.010, 0.045]
$\sigma_{\nu 2}$	0.094	[0.071, 0.119]	0.046	[0.013, 0.077]	0.107	[0.084, 0.132]
$\sigma_{\nu 3}$	0.068	[0.045, 0.092]	0.054	[0.016, 0.083]	0.043	[0.016, 0.064]
$\sigma_{\nu 4}$	0.023	[0.010, 0.037]	0.023	[0.009, 0.036]	0.018	[0.009, 0.026]
$\sigma_{\nu 5}$	0.025	[0.010, 0.040]	0.025	[0.010, 0.040]	0.019	[0.010, 0.029]
$\sigma_{\nu 6}$	0.035	[0.011, 0.060]	0.025	[0.009, 0.042]	0.022	[0.010, 0.034]
$\sigma_{\nu 7}$	0.040	[0.013, 0.062]	0.027	[0.010, 0.045]	0.025	[0.011, 0.037]
σ_{1Y}	–	–	0.020	[0.016, 0.024]	–	–
σ_{2Y}	–	–	0.032	[0.024, 0.040]	–	–

Note: For the posterior distribution, 500,000 draws were generated using the Metropolis-Hastings algorithm, and the first half of these draws was discarded.

Table 8: Variance decompositions of output growth, consumption growth, investment growth, and hours worked in robustness exercises

Baseline	Output	Consumption	Investment	Hours worked
Unanticipated	8.6	11.1	5.2	9.1
Total anticipated	15.4	18.0	11.3	20.1
Others	76.0	70.9	83.5	70.7
Alternative policy rule	Output	Consumption	Investment	Hours worked
Unanticipated	10.6	14.6	4.2	9.4
Total anticipated	19.4	23.2	10.2	23.8
Others	69.9	62.3	85.6	66.8
Time-varying premia	Output	Consumption	Investment	Hours worked
Unanticipated	5.5	7.5	2.8	6.3
Total anticipated	7.5	9.1	5.2	11.2
Others	86.9	83.4	92.0	82.5
Alternative yields data	Output	Consumption	Investment	Hours worked
Unanticipated	6.0	7.7	3.9	8.4
Total anticipated	12.5	14.5	9.9	21.4
Others	81.5	77.8	86.2	70.2

Notes: The table shows the forecast error variance decompositions of output growth, consumption growth, investment growth, and hours worked at an infinite horizon evaluated at the posterior mean estimates of parameters. "Unanticipated" denotes the contribution of the unanticipated monetary policy disturbance $\nu^r_{0,t}$ to the variance of each of these four variables. "Total anticipated" denotes the sum of the contribution of each anticipated monetary policy disturbance $\nu^r_{n,t-n}$, $n = 1, 2, \ldots, 7$.

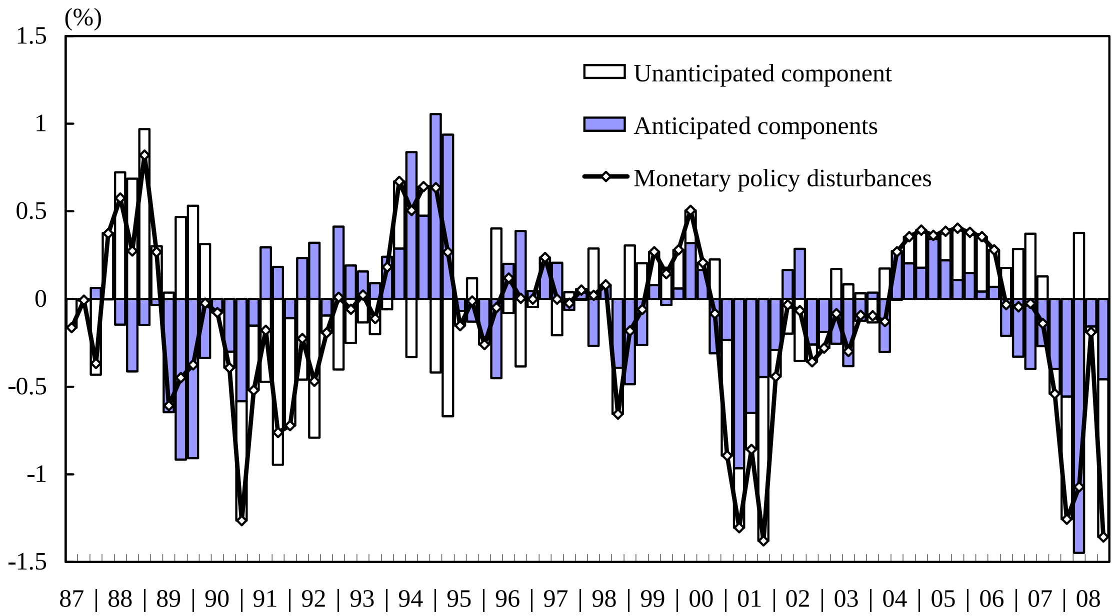

Figure 1: Historical decomposition of monetary policy disturbances

Notes: The figure shows the historical decomposition of monetary policy disturbances evaluated at the posterior mean estimates of parameters. "Unanticipated component" denotes the contribution of the unanticipated component $\nu^r_{0,t}$ to the whole monetary policy disturbances. "Anticipated components" denotes the sum of the contribution of each anticipated component $\nu^r_{n,t-n}$, $n = 1, 2, \ldots, 7$.

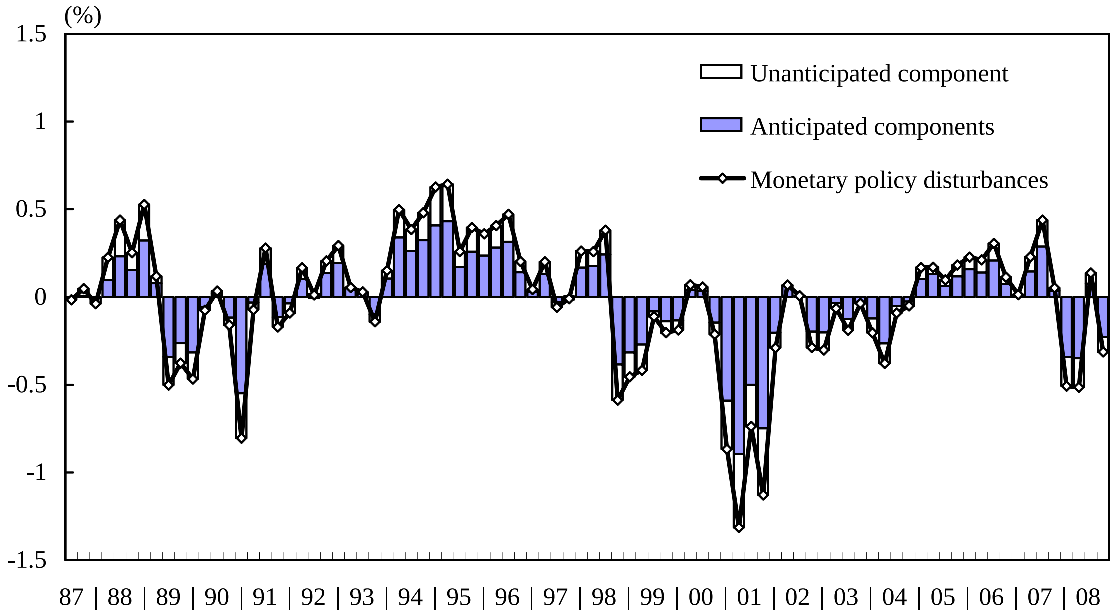

Figure 2: Historical decomposition of monetary policy disturbances estimated without bond yields data

Notes: The figure shows the historical decomposition of monetary policy disturbances evaluated at the posterior mean estimates of parameters. “Unanticipated component” denotes the contribution of the unanticipated component $\nu^r_{0,t}$ to the whole monetary policy disturbances. “Anticipated components” denotes the sum of the contribution of each anticipated component $\nu^r_{n,t-n}$, $n = 1, 2, \ldots, 7$.

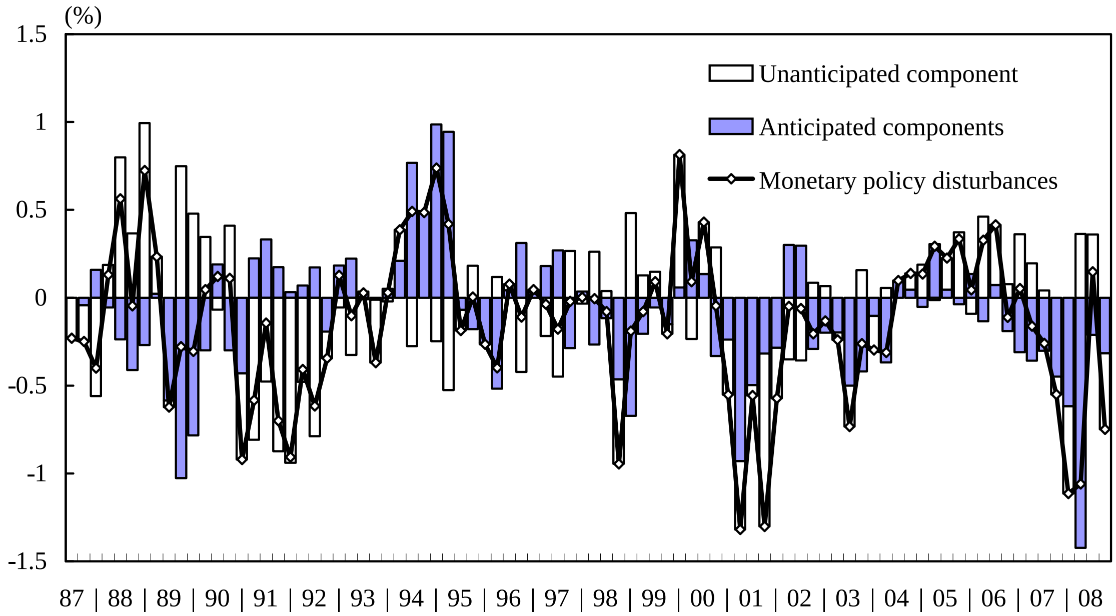

Figure 3: Historical decomposition of monetary policy disturbances estimated with alternative specification of monetary policy rule

Notes: The figure shows the historical decomposition of monetary policy disturbances evaluated at the posterior mean estimates of parameters. "Unanticipated component" denotes the contribution of the unanticipated component $\nu^r_{0,t}$ to the whole monetary policy disturbances. "Anticipated components" denotes the sum of the contribution of each anticipated component $\nu^r_{n,t-n}$, $n = 1, 2, \ldots, 7$.

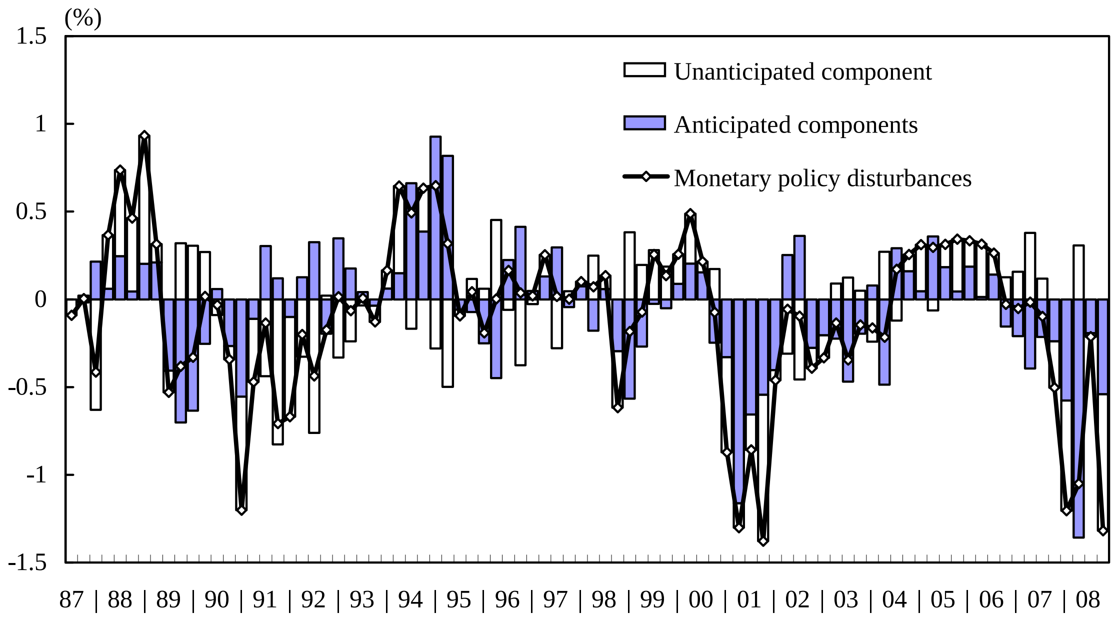

Figure 4: Historical decomposition of monetary policy disturbances estimated with time-varying term premia in bond yields

Notes: The figure shows the historical decomposition of monetary policy disturbances evaluated at the posterior mean estimates of parameters. "Unanticipated component" denotes the contribution of the unanticipated component $\nu^r_{0,t}$ to the whole monetary policy disturbances. "Anticipated components" denotes the sum of the contribution of each anticipated component $\nu^r_{n,t-n}$, $n = 1, 2, \ldots, 7$.

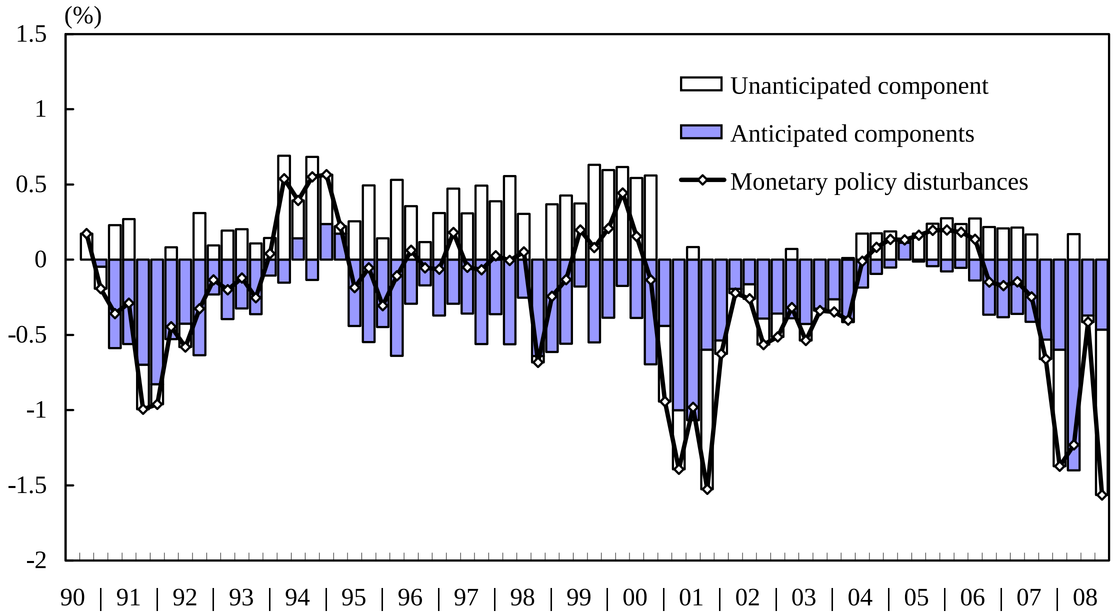

Figure 5: Historical decomposition of monetary policy disturbances estimated with data on bond yields excluding term premia

Notes: The figure shows the historical decomposition of monetary policy disturbances evaluated at the posterior mean estimates of parameters. "Unanticipated component" denotes the contribution of the unanticipated component $\nu_{0,t}^r$ to the whole monetary policy disturbances. "Anticipated components" denotes the sum of the contribution of each anticipated component $\nu_{n,t-n}^r$, $n = 1, 2, \ldots, 7$.