Changes in the Federal Reserve Communication Strategy: A Structural Investigation

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March 13, 2012

The views expressed herein are those of the authors and should not be interpreted as those of the Bank of Japan.

Outline

Motivation

- Since Taylor (1993), US monetary policy has been studied with estimated policy rules for FF rate.
  - Clarida, Gali & Gertler (1998, 2000), Judd & Rudebusch (1998), Orphanides (2001, 2002, 2003), Taylor (1999)

- The policy rule is a useful description of Fed's adjustment of FF rate.

$$\hat{r}_t = \underbrace{r_\pi \hat{\pi}_t + r_y(\hat{y}_t - \hat{y}_t^*)}_{\text{Rule-based component}} + \underbrace{\varepsilon_t}_{\text{Disturbance}}$$

  - Rule-based component: Fed's systematic adjustment of FF rate for its target variables (e.g., inflation, output gap)
  - Disturbance: Fed's discretion constrained by the systematic adjustment

Motivation (cont.)

- Disturbances to MP rules are called "*MP shocks*," since they are assumed to be unanticipated for private agents.
- However, not all disturbances are unanticipated.
- Some are anticipated through Fed's communications.
  - FOMC statement in August 2003: "the Committee believes that policy accommodation can be maintained for a considerable period."
  - FOMC statement in June 2004: "the Committee believes that policy accommodation can be removed at a pace that is likely to be measured."

Motivation (cont.)

- FOMC statements of this sort have a coordination effect on financial market expectations about the future path of FF rate.
- Such an effect can be characterized by an anticipated future MP disturbance that captures Fed's management of expectations.

Purpose & Strategy

- We structurally identify anticipated and unanticipated disturbances to a Taylor rule to examine the changes in Fed's communication strategy during 1990s.
    - In 1994, Fed decided to issue a statement describing FF rate policy actions after FOMC meeting where an action was undertaken.
    - In 1999, Fed decided to issue a statement reporting the settings of target FF rate and the balance of risks to Fed's objectives after every FOMC meeting.
- Our strategy for identifying anticipated future disturbances is based on the idea that the effects of these decisions are contained in financial market data.

Purpose & Strategy (cont.)

- Blinder et al. (2001): From early 1996 to mid-1999, the US bond market moved in response to macroeconomic developments, despite relatively little change in FF rate.
- This observation reflects an improvement in the financial market's ability to forecast Fed's future policy actions.
- We thus use US Treasury bond yields data, which contain information on the future path of the FF rate, to identify the anticipated component of MP disturbances.

Outline

Contribution to Monetary Policy Literature

- Show that a large fraction of the anticipated component of MP disturbances was not met until mid-1990s, but thereafter, this component tended to materialize.
- The contribution of the anticipated component to the total MP disturbances became larger after mid-1990s.
- Imply that Fed made future policy actions unanticipated for market participants until mid-1990s, but thereafter, tended to coordinate financial market expectations about future policy actions
- Inclusion of bond yields data for estimation is indispensable to these results.

Contribution to Monetary Policy Literature (cont.)

- Suggest that the changes in Fed's communication strategy are consistent with the rise of academic views on central banking as management of expectations.
  - Goodfriend (2010): Fed in mid-1990s was inclined to communicate to financial markets, since academics indicated that communication could enhance the policy effectiveness.
  - Woodford (2001, 2003, 2005): Market participants' better information about central banks' actions and intensions improves the MP effectiveness.
  - Blinder et al. (2008) stress the role of "news" or "signals" by central banks for management of expectations.
    - Anticipated MP disturbances can be regarded as a form of such news or signals.

Contribution to Business Cycle Literature

- Study the importance of MP disturbances for business cycles in the presence of the anticipated component.
    - Since Beaudry & Portier (2004), there has been a surge of interest in the role of anticipated future technological changes for business cycles: Fujiwara, Hirose & Shintani (2011), Khan & Tsoukalas (2009), Schmitt-Grohe & Uribe (2008)
- Find that the inclusion of bond yields data for estimation leads to a substantial contribution of MP disturbances to business cycles.
    - Exclusion of the yields data makes the contribution negligible.
    - Milani & Treadwell (2009) do not use bond yields data in estimating a simple DSGE model with anticipated and unanticipated components of MP disturbances.

Outline

Monetary Policy Disturbances

- Consider a Taylor rule:

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

- MP disturbance ε_t $(= \nu_{0,t} + \nu_t^*)$ is decomposed into
  1. Unanticipated component: $\nu_{0,t}$
  2. Anticipated component: $\nu_t^* = \sum_{n=1}^{N} \nu_{n,t-n}$
     - $\nu_{n,t-n}$ is part of ν_t^* that was anticipated n periods before its realization in period t.
     - Each $\nu_{n,t-n}$ is assumed to be of mean zero.

- E.g., in the case of $N = 1$,

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

- Anticipated component $\nu_{1,t}$ influences the expectations about the future policy rate, since

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

- The two-period bond yield equation is

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

- Estimating the Taylor rule and the two-period bond yield equation generates $\{\nu_{0,t}, \nu_{1,t}\}$.

Identifying Anticipated and Unanticipated Components (cont.)

- The regressors in the Taylor rule and the two-period bond yield equation are endogenous and contain expected values of inflation and the output gap.
- Thus we estimate a MP rule and bond yield equations together with a DSGE model, using a full-information likelihood-based approach.
- This joint estimation enables us to investigate how and to what extent the anticipated and unanticipated MP disturbances influence business cycles.

Identifying Anticipated and Unanticipated Components (cont.)

- The full-information likelihood-based approach is potentially sensitive to model misspecification.
- This issue can be mitigated by employing a version of Smets & Wouters' (2007) model, which fits well with US data and exhibits an out-of-sample forecasting performance comparable to those of VAR models.
- De Graeve, Emiris & Wouters (2009): A variant of SW model combined with the expectations hypothesis of interest-rate term structure can well explain the movements in US yield curve.

Outline

Overview of Smets & Wouters' Model

- Households
  - Consumption habit
  - Sticky wage: set wage monopolistically but cannot change with prob ξ_w (with inflation indexation ι_w).
- Firms
  - Final good producers use intermediate goods.
  - Producers of intermediate good use capital and labor.
  - Adjustment cost of investment: $\left[1 - S\left(I_t/I_{t-1}\right)\right] I_t$
  - Choose utilization rate of capital.
  - Sticky price: set prices monopolistically but cannot change with prob ξ_p (with inflation indexation ι_p).
- Central Bank
  - Adjusts interest rate following a Taylor-type MP rule.

Our model differs Smets & Wouters' (2007) in five respects.

1. In line with Taylor (1993), the MP rule responds to the annual inflation rate and a practical output gap

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

The output gap is

$$\hat{y}_t - \hat{y}_t^* = \Phi\left(\alpha \hat{k}_t^s + (1-\alpha)\,\hat{l}_t \right), \quad \hat{k}_t^s = \hat{k}_{t-1} + \hat{z}_t.$$

- This specification is consistent with the output-gap measure estimated by, e.g., the CBO.

2. The MP disturbance consists of an unanticipated component and anticipated components up to seven-period ahead.

$$\varepsilon_t^r = \nu_{0,t}^r + \nu_t^{r*} = \nu_{0,t}^r + \sum_{n=1}^{7} \nu_{n,t-n}^r, \qquad \nu_{n,t}^r \sim N(0, \sigma_{\nu n}^2)$$

- The length of the anticipation horizon is based on the forecast horizon for FOMC projections, where the maximum horizon was two years until October 2007.
- Woodford (2008): The regular publication of Fed's projections plays a central role in its communication policies. The public should be able to form expectations about Fed's future policy actions from these projections.
- Hence, plausible to assume that Fed's communication strategy can influence anticipated MP disturbances up to the same horizon as the one for FOMC projections.

3. The expectation hypothesis of interest-rate term structure is assumed for one- and two-year bond yields.

$$\hat{r}_t^{1Y} = \frac{1}{4}\sum_{n=0}^{3} E_t \hat{r}_{t+n}, \qquad \hat{r}_t^{2Y} = \frac{1}{8}\sum_{n=0}^{7} E_t \hat{r}_{t+n}.$$

- De Graeve, Emiris & Wouters (2009) show that a variant of SW model with the expectations hypothesis of interest-rate term structure can well explain the movements in US yield curve.
- The robustness analysis studies the case of time-varying term premia, and confirms that the qualitative results obtained with constant term premia survive.

4. The deterministic trend in neutral technology is replaced by the stochastic one; i.e., the level of neutral technology, A_t, follows

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

- Smets & Wouters' estimate of the autoregressive coefficient for the TFP shock is very close to unity. Hence, we choose the stochastic trend to ensure the stationarity of the detrended model.
- For estimation, equilibrium conditions are expressed in terms of the variables detrended by A_t, e.g., output $y_t = Y_t / A_t$.

The stochastic trend leads to eight log-linearized equilibrium conditions different from those of Smets & Wouters:

$$\hat{c}_t = \frac{\lambda/\gamma}{1+\lambda/\gamma}\left(\hat{c}_{t-1} - \varepsilon_t^a\right) + \frac{1}{1+\lambda/\gamma}\left(E_t\hat{c}_{t+1} + E_t\varepsilon_{t+1}^a\right)$$

$$+ \frac{(\sigma_c - 1)w^h l/c}{\sigma_c(1+\lambda/\gamma)}\left(\hat{l}_t - E_t\hat{l}_{t+1}\right) - \frac{1-\lambda/\gamma}{\sigma_c(1+\lambda/\gamma)}\left(\hat{r} - E_t\hat{\pi}_{t+1} + \varepsilon_t^b\right)$$

$$\hat{\imath}_t = \frac{1}{1+\beta\gamma^{1-\sigma_c}}\left(\hat{\imath}_{t-1} - \varepsilon_t^a\right) + \frac{\beta\gamma^{1-\sigma_c}}{1+\beta\gamma^{1-\sigma_c}}\left(E_t\hat{\imath}_{t+1} + E_t\varepsilon_{t+1}^a\right)$$

$$+ \frac{1}{\gamma^2\varphi(1+\beta\gamma^{1-\sigma_c})}\hat{q}_t + \varepsilon_t^i$$

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

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

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

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

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

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

Four log-linearized equilibrium conditions are the same as those of Smets & Wouters:

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

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

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

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

5. Exogenous spending disturbance ε_t^g, wage markup disturbance ε_t^w, and price markup disturbance ε_t^p follow univariate stationary AR(1) processes.

   Each of the six exogenous disturbances ε_t^x, $x \in \{a, b, i, w, p, g\}$ follows the univariate stationary AR(1) process

$$\varepsilon_t^x = \rho_x \varepsilon_{t-1}^x + \nu_t^x, \qquad \nu_t^x \sim N(0, \sigma_x^2)$$

- Bayesian estimation
- Data: One- and two-year US Treasury yields estimated by FRB (Gurkaynak, Sack & Wright, 2007) and seven macro time series used in Smets & Wouters (2007).
- Sample period: 1987:3Q-2008:4Q
- Observation equations:

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

Prior Distributions

- As in SW (2007), five parameters are fixed in the estimation: $\delta = 0.025$, $g_y = 0.18$, $\lambda_w = 1.5$, $\varepsilon_p = 10$, $\varepsilon_w = 10$.
- Priors are basically the same as in Smets and Wouters (2007).
- All innovations to the disturbances are, *a priori*, mutually and serially uncorrelated.
- Equal weights on the unanticipated component and on the total anticipated component of MP disturbances are used for these standard deviations; i.e., $\sum_{n=1}^{7} \sigma_{\nu n}^2 = \sigma_{\nu 0}^2$.
- Prior means for c^{1Y}, c^{2Y} are set based on the sample mean of the spreads between the one- and two-year Treasury yields and the federal funds rate.

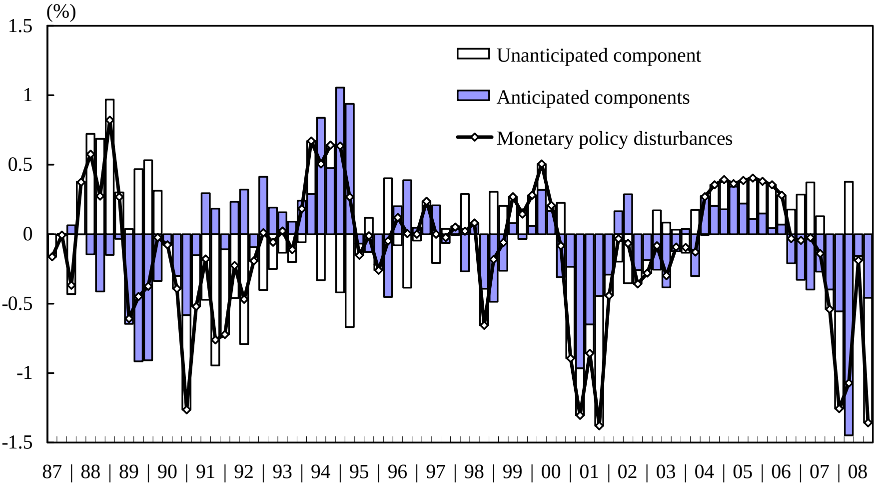
Outline

Parameter Estimates

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]

Parameter Estimates (cont.)

Parameter	Prior distribution			Posterior distribution	
	Distribution	Mean	S.D.	Mean	90% interval
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]


(%)
1.5
1
0.5
0
-0.5
-1
-1.5
Unanticipated component
Anticipated components
Monetary policy disturbances
87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08

Parameter	87:3Q–96:4Q		97:1Q–08:4Q	
	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]

Subsample Estimates (cont.)

Parameter	87:3Q–96:4Q		97:1Q–08:4Q	
	Mean	90% interval	Mean	90% interval
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]

Variance Decompositions of Monetary Policy Disturbances

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

Variance Decompositions of Output, Consumption, Investment & Hours

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

Main Findings

- Baseline estimation: A large fraction of the anticipated components of MP disturbances was not met until mid-1990s, but thereafter, the anticipated components tended to materialize.
- Subsample analysis: After the mid-1990s, anticipated MP disturbances played more important role in the conduct of monetary policy and in explaining business cycles.
- Suggest 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.
  - Goodfriend (2010), Woodford (2001, 2003, 2005), Blinder et al. (2008)

Bond Yields Matter?

- A novel feature in our analysis is the use of bond yields data for identifying anticipated MP disturbances.
- Milani and Treadwell (2009): Identify anticipated MP disturbances without using bond yields data.
  - Possibly identified because the anticipated MP component has a different effect on output than the unanticipated one.
- To examine the importance of bond yields data in our estimation, we estimate the model without bond yields data.

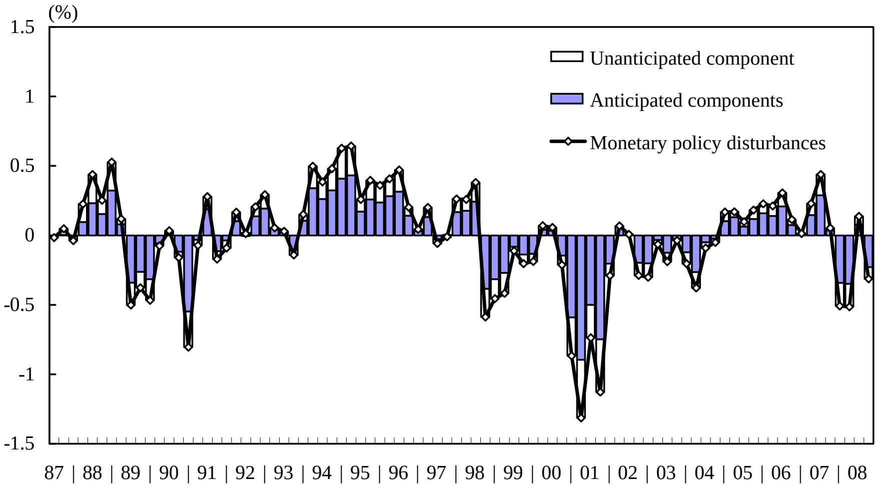
Estimates without Bond Yields Data

Parameter	No bond yields data		No anticipated component	
	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]

Estimates without Bond Yields Data (cont.)

Parameter	No bond yields data		No anticipated component	
	Mean	90% interval	Mean	90% interval
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]	–	–

No Bond Yields Data: Historical Decomposition of MP Disturbances



Main Findings

- Without bond yields data, the estimated series of MP disturbances does not capture the actual changes in the Fed's communication strategy during the 1990s.
- Suggests that bond yields contain crucial information on the expected future path of the federal funds rate.

Variance Decompositions of Output, Consumption, Investment & Hours 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

- The exclusion of the bond yields data in model estimation makes the contribution of MP disturbances to business cycles negligible.

Outline

- The misspecification of the MP rule directly affects the estimates of its disturbances.
- Examine the MP rule that additionally responds to the output growth rate.

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

  - This specification is close to the one used by SW (2007), in which the MP responds to the change in the (theoretical) output gap.

Robustness Analysis: Time-Varying Term Premia

- The baseline model has assumed constant term premia in one- and two-year bond yields.
  - The estimates of anticipated MP disturbances may contain the possible time-varying components of term premia.
- Following De Graeve, Emiris & Wouters (2009), the observation equations for one- and two-year bond yields are replaced by

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

  - ξ_t^{1Y}, ξ_t^{2Y}: Measurement errors interpreted as the time-varying components of term premia, which follow the AR(1) processes.

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

Robustness Analysis: Alternative Yields Data

- Use of the data on bond yields excluding term premia in model estimation.
  - Another way to resolve the issue regarding the inclusion of possible time-varying term premia in anticipated MP disturbances.
- Observation equations for one- and two-year bond yields are replaced by

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

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

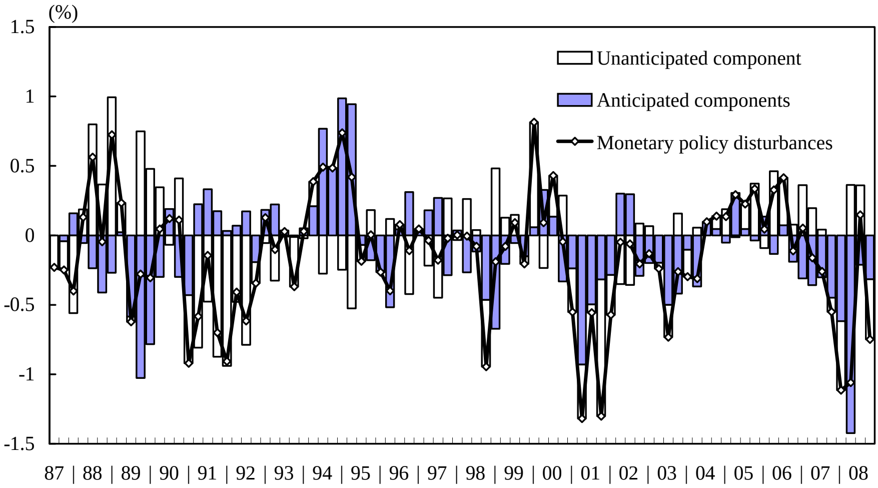
Parameter Estimates in Robustness Exercises

Parameter	Alternative policy rule		Time-varying premia		Alternative yields data	
	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]	–	–

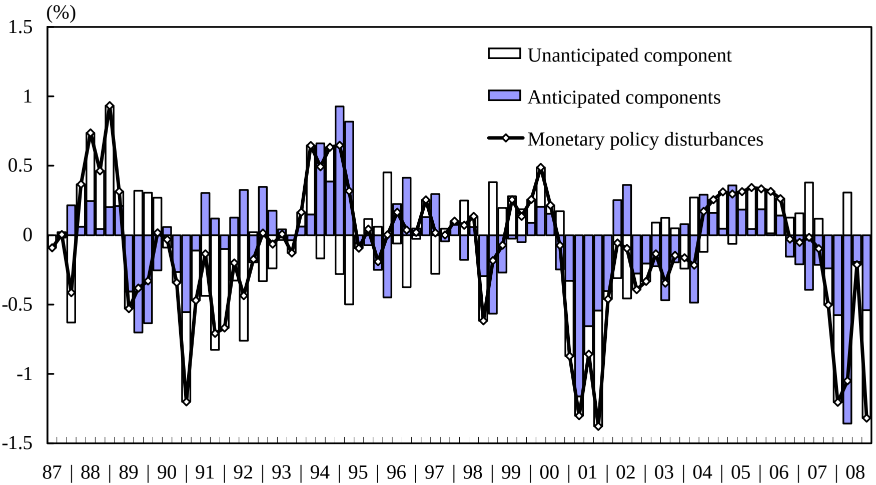
Parameter Estimates in Robustness Exercises (cont.)

Parameter	Alternative policy rule		Time-varying premia		Alternative yields data	
	Mean	90% interval	Mean	90% interval	Mean	90% interval
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]	–	–

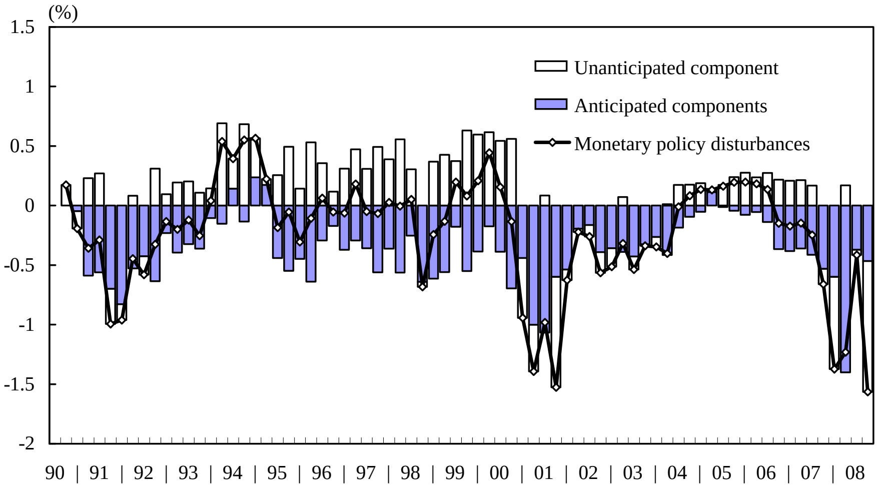
Alternative Policy Rule: Historical Decomposition of MP Disturbances



Time-Varying Term Premia: Historical Decomposition of MP Disturbances



Alternative Yields Data: Historical Decomposition of MP Disturbances



Variance Decompositions of Output, Consumption, Investment & Hours 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

Outline

- Examine the changes in Fed's communication strategy during the 1990s by structurally identifying anticipated and unanticipated components of MP disturbances.
- Estimate a version of SW (2007) model incorporated with the anticipated MP disturbances and the interest-rate term structure, using US data that includes bond yields.
- Show that Fed made future policy actions unanticipated for market participants until mid-1990s, but thereafter, tended to coordinate market expectations about future policy actions.
- Suggest that the changes in Fed's communication strategy are consistent with the rise of academic views on central banking as management of expectations.

Concluding Remarks (cont.)

- Inclusion of bond yields in the estimation data is indispensable to these results.
- Inclusion of bond yields in the estimation data leads to a substantial contribution of MP disturbances to business cycles.
- Estimated series of anticipated MP disturbances would help to understand the Fed's forward guidance.
  - Future research: How and to what extent the Fed's management of expectations influenced the U.S. macroeconomic performance?

Thank you very much for your attention.