Signaling Effects of Monetary Policy

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24 May 2012

Motivation

- Disperse information about aggregate fundamentals
  Morris and Shin (2003), Sims (2003), and Woodford (2002)

- Publicly observable policy actions transfer information to market participants
  - Example: central bank setting the policy rate
  - The policy rate conveys information about the central bank's view on macroeconomic developments

  ⇒ **Signaling effects of monetary policy**

- Consider an interest cut in the face of a contractionary shock
  - Effect of **stimulating** the economy
  - But also **contractionary** effects if it convinces unaware market participants about the disturbance

What I do

- Develop a DSGE model in which
  1. price setters have dispersed information
  2. the interest rate set by the central bank is perfectly observable

- I use the model to answer the following questions:
  1. Do we find empirical support for signaling effects of policy?
  2. What are the implications for the transmission of shocks?

- Estimation using the **SPF** as a measure of public expectations

- **Main Findings:**
  1. Signaling effects of monetary policy supported by the data
  2. Signaling effects
     - **monetary shocks**: dampen the effect on inflation
     - **demand shocks**: enhance Fed's ability to stabilize inflation
     - **technology shocks**: are quite neutral

Related Literature

Signaling Effects of Monetary Policy

- **Optimal monetary policy:** Walsh (2010)
- **Empirical evidence:** Coibion and Gorodnichenko (2011)

Dispersed Information Models

- **Persistent effects of nominal shocks:** Woodford (2002), Angeletos and La'O (2009a), and Melosi (2010)
- **Provision of public information:** Amato, Morris, and Shin (2002), Morris and Shin (2002), Hellwig (2002), Angeletos and Pavan (2004 and 2007), Angeletos, Hellwig, and Pavan (2006 and 2007), and Lorenzoni (2009 and 2010)
- **Interactions with price rigidities:** Nimark (2008) and Angeletos and La'O (2009b)
- **Change in inflation persistence:** Melosi and Surico (2011)
- **Endogenous information structure:** Sims (2002 and 2006), Maćkowiak and Wiederholt (2009 and 2010)

The Model

The Model Environment

- Three types of agents: households, firms, and the fiscal and monetary authority

- Maintained assumptions:

  1. Firms produce differentiated goods and are monopolistically competitive
  2. Firms face a Calvo lottery (⇒**forward-looking behaviors**)
  3. **Firms have dispersed information**; they observe:
     - **Exogenous private signals**: their productivity and a signal on the demand conditions
     - **Endogenous public signal**: the interest rate set by the monetary authority

⇒ Higher-order uncertainty

The Time Protocol

- Every period t is divided into three stages:

STAGE 1: Shocks are realized, the central bank observes the aggregate shocks and sets the interest rate

STAGE 2: Firms observe their private signals, the outcome of the Calvo lottery, and the interest rate and set their prices

STAGE 3: Markets open. Households observe shocks and take their decisions. Firms hire labor to produce the demanded quantity at the price set at the STAGE 2. Government supplies bonds and levies taxes. Markets close.

▸ Non-Linear Model

Imperfect Information Model (IIM)

- The consumption Euler equation:

$$\widehat{g}_t - \widehat{y}_t = \mathbb{E}_t \widehat{g}_{t+1} - \mathbb{E}_t \widehat{y}_{t+1} - \mathbb{E}_t \hat{\pi}_{t+1} + \hat{R}_t$$

- The (Imperfect-Common-Knowledge) Phillips curve:

$$\hat{\pi}_t = (1-\theta)(1-\beta\theta) \sum_{k=0}^{\infty} (1-\theta)^k \, \widehat{mc}_{t|t}^{(k)} + \beta\theta \sum_{k=0}^{\infty} (1-\theta)^k \, \widehat{\pi}_{t+1|t}^{(k+1)}$$

where $\widehat{mc}_t^{(k)} = \widehat{y}_t^{(k)} - \widehat{a}_t^{(k-1)}$. HOEs

- The Taylor rule:

$$\hat{R}_t = \phi_\pi \hat{\pi}_t + \phi_y \left(\hat{y}_t - \widehat{y}_t^* \right) + \sigma_r \widehat{\eta}_{r,t}$$

Exogenous Processes and Signals

- The preference shifter evolves according to

$$\widehat{g}_t = \rho_g \widehat{g}_{t-1} + \sigma_g \varepsilon_{g,t}$$

- The process for technology becomes

$$\widehat{a}_t = \rho_a \widehat{a}_{t-1} + \sigma_a \varepsilon_{a,t}$$

- The process leading the state of monetary policy

$$\widehat{\eta}_{r,t} = \rho_r \widehat{\eta}_{r,t-1} + \sigma_r \varepsilon_{r,t}$$

- The equations for the private signals are:

$$\widehat{g}_{j,t} = \widehat{g}_t + \widetilde{\sigma}_g \varepsilon^g_{j,t}$$

$$\widehat{a}_{j,t} = \widehat{a}_t + \widetilde{\sigma}_a \varepsilon^a_{j,t}$$

- The public endogenous signal:

$$\hat{R}_t = \phi_\pi \hat{\pi}_t + \phi_y \left(\hat{y}_t - \widehat{y}^*_t\right) + \sigma_r \eta_{r,t}$$

Model Solution

- The model can be solved by characterizing the law of motion of the HOEs
- An analytical characterization is not available
- We guess the law of motion for the HOEs
- Conditional to this guess we solve the model
- Signal extraction delivers the implied law of motion for the HOEs

Perfect Information Model (PIM)

- The consumption Euler equation:

$$\widehat{g}_t - \widehat{y}_t = \mathbb{E}_t \widehat{g}_{t+1} - \mathbb{E}_t \widehat{y}_{t+1} - \mathbb{E}_t \hat{\pi}_{t+1} + \hat{R}_t$$

- The New-Keynesian Phillips curve:

$$\hat{\pi}_t = \frac{(1-\theta)(1-\theta\beta)}{\theta} \widehat{mc}_t + \beta \mathbb{E}_t \widehat{\pi}_{t+1}$$

where $\widehat{mc}_t = \widehat{y}_t - a_t$.

- The Taylor rule:

$$\hat{R}_t = \phi_\pi \hat{\pi}_t + \phi_y \left(\hat{y}_t - \widehat{y}_t^* \right) + \sigma_r \eta_{r,t}$$

The Signal Channel of Monetary Transmission

The Signaling Channel

- The policy rate signals information about non-policy shocks (*signaling effects*)

- Signaling effects are *strong* if two conditions *jointly* hold:

  1. Information about non-policy shocks is quite disperse
  2. The policy rate is very informative about non-policy shocks

  ⇒ Firms rely a lot on the policy signal to infer non-policy shocks

- Firms use the policy rate to jointly infer:

  - the history of non-policy shocks
  - potential exogenous deviations from the rule

⟹ The policy signal **confuses** firms about the exact nature of shocks

Signaling Effects

- Macroeconomic effects of the signal channel depend on:

1. **The quality of private information**
   - Better private information on non-policy shocks weakens the signaling effects

2. **The informative content of the public signal**
   - More information about monetary shocks weakens the signaling effects

3. **The expected inflationary consequences of shocks**
   - More accommodative monetary policy strengthens the signaling effects

Empirical Analysis

The Data and Bayesian Estimation

- The data set include five observables:
  1. GDP growth rate
  2. Inflation (GDP deflator)
  3. Federal funds interest rate
  4. One-quarter-ahead inflation expectations
  5. Four-quarter-ahead inflation expectations
- The last two observables are obtained from the *Survey of Professional Forecasters* (SPFs).
- The data set ranges from 1970:3 to 2007:4
- Combine the likelihood derived from the model and a prior
- Perform Bayesian inference

The Strength of the Signal Channel

- The strength of the signal channel depends on the extent to which the policy rate can influence firms' expectations about non-policy shocks

- Two important statistics:

  1. The precision of private information:

$$\frac{\sigma_a}{\widetilde{\sigma}_a} = 0.95; \ \frac{\sigma_g}{\widetilde{\sigma}_g} = 0.72$$

  2. Informative content of the policy rate:

	$\varepsilon_{a,t}$	$\varepsilon_{r,t}$	$\varepsilon_{g,t}$
Posterior medians	26.73%	35.13%	38.14%

Prior Posterior

Model Evaluation

- To evaluate the empirical relevance of the signal channel, we address two questions:

1. How does the IIM fare at fitting the data?
2. Does the IIM fit the observed inflation expectations?

Question 1: MDD Comparison

- Bayesian tests rely on computing the marginal data density (MDD):

$$P(Y|\mathcal{M}) = \int \mathcal{L}(Y|\Theta, \mathcal{M}) \cdot p(\Theta)\, d\Theta$$

- The MDD is the density to update prior probabilities over competing models
- Log-MDD:

	IIM	PIM
$\ln P(Y|\mathcal{M}_P)$	-252.3	-266.3

- Prior probability in favor of IIM has to be **smaller than 8.50E-7** to select the PIM

▸ Appendix

Question 2: Predictive Paths

- Two competing models:
    1. Imperfect information model (IIM)
    2. Perfect information model (PIM)

- Compute *predictive paths* implied by the two competing models

$$\mathbb{E}\left(\pi^{(1)}_{t+1|t}|\widetilde{Y},\mathcal{M}\right) \text{ and } \mathbb{E}\left(\pi^{(1)}_{t+4|t}|\widetilde{Y},\mathcal{M}\right)$$

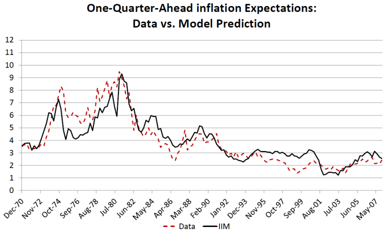
where $\widetilde{Y}$ is the data set **NOT including the Surveys**

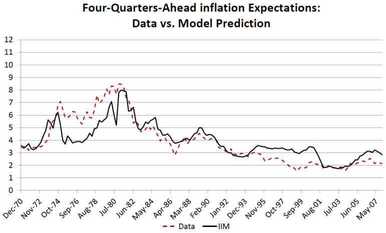
- Compare the *predictive paths* with the data on the observed inflation expectations

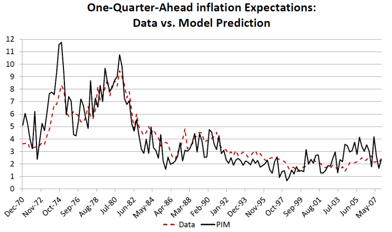
Model Predictions and the SPFs

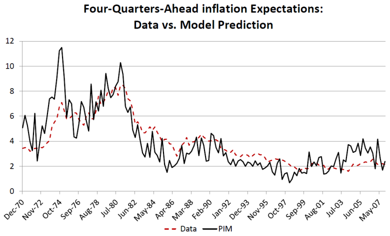
Inflation Expectations

RMSE Posterior









Propagation of Shocks in the IIM

Monetary Shocks

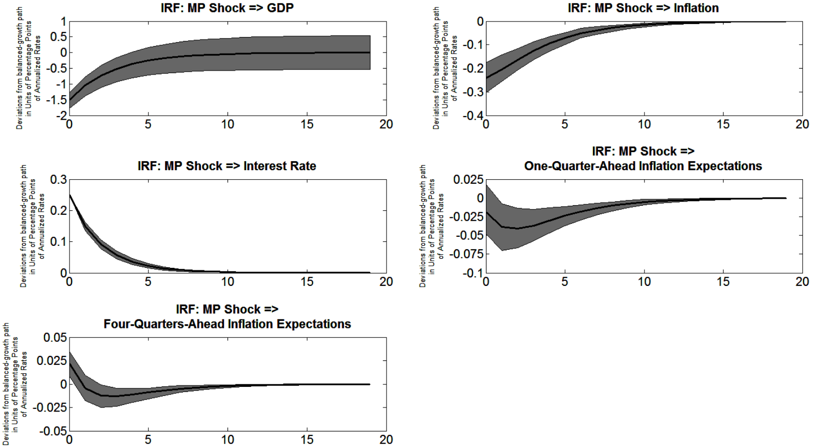
Preference Shocks

Technology Shocks

Overview of the Findings

- **Contractionary monetary shocks**:
  - monetary tightening signals a positive demand shock
  - **signaling effects dampen the response of inflation**
- **Positive preference shocks**:
  - monetary tightening signals a contractionary monetary shock
  - **signaling effects help the Fed to stabilize inflation**
- **Negative technology shocks**:
  - monetary tightening signals both a positive preference shocks and a contractionary monetary shock
  - conflicting effects on inflation expectations and inflation
  - **signaling effects are quite neutral**
- **Reason:** Policy rate mainly informative about monetary and preference shocks

IRFs to a Monetary Shock



Measuring Signaling Effects on Inflation

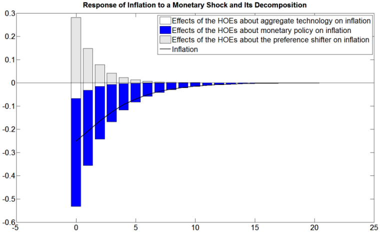
- The law of motion of inflation reads:

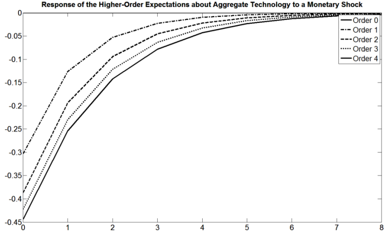
$$\widehat{\pi}_t = \left[\mathbf{v}_a', \mathbf{v}_m', \mathbf{v}_g'\right] \cdot \begin{bmatrix} X_t^a \\ X_t^m \\ X_t^g \end{bmatrix}$$

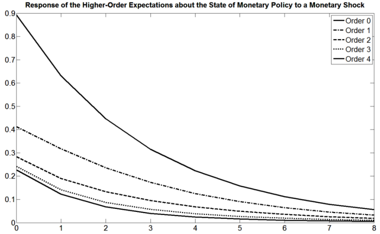
- Decompose the effects of a monetary shock:

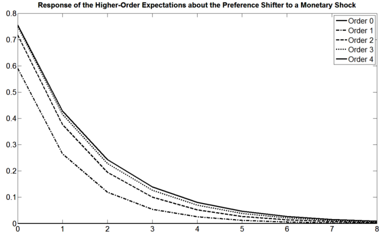
$$\frac{\partial \widehat{\pi}_{t+h}}{\partial \varepsilon_{r,t}} = \mathbf{v}_a' \cdot \frac{\partial X_{t+h}^a}{\partial \varepsilon_{r,t}} + \mathbf{v}_m' \cdot \frac{\partial X_{t+h}^m}{\partial \varepsilon_{r,t}} + \mathbf{v}_g' \cdot \frac{\partial X_{t+h}^g}{\partial \varepsilon_{r,t}}$$

IRFs to a MP Shock: Decompositions









Propagation of Monetary Shocks

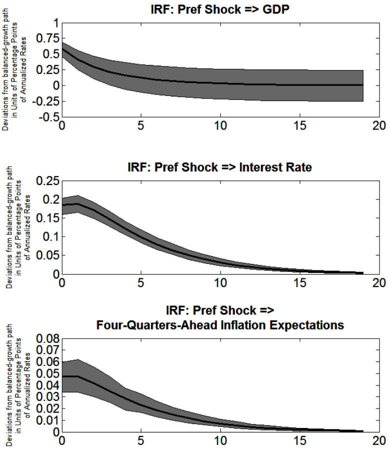
Main Findings

- Firms interpret a rise in the policy rate as the central bank's response to a positive demand shock

$\Rightarrow$ Medium-term inflation expectations respond positively

$\Rightarrow$ The signal channel raises the real effects of monetary shocks

IRFs to a Preference Shock



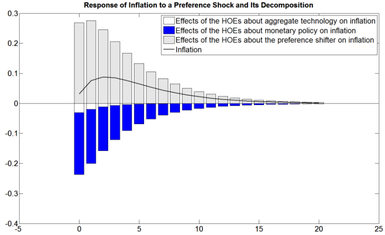
Propagation of Preference Shocks

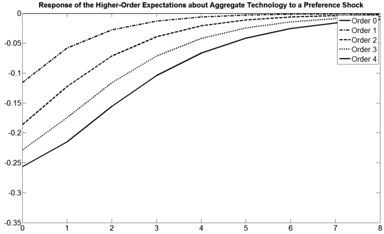
- The signal channel has two effects:

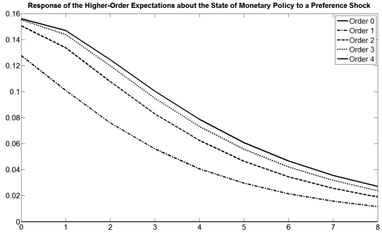
    1. it may confuse firms leading them to believe that a contractionary monetary shock has occurred

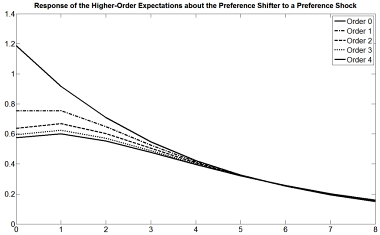
    2. it may confuse firms leading them to believe that a negative technology shock has hit the economy

IRFs to a Preference shock: Decompositions





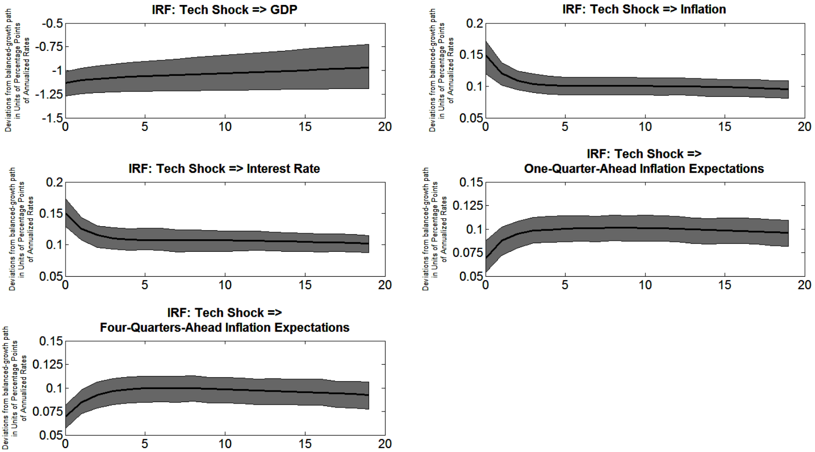




Propagation of Preference Shocks

- Response of inflation to a preference shock is damped by the signal channel
- **WHY?**
- A monetary tightening persuades firms that
  - a **contractionary monetary shock** is likely to have occurred
  - a **technology shock** must play a **little** role because:
    1. Precise private information about tech shocks
    2. Little information about tech shocks from the policy signal

IRFs to a Technology Shock



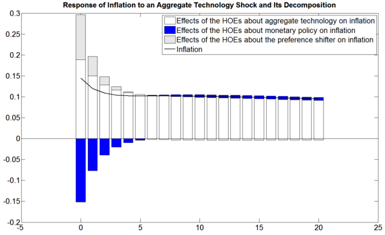
Propagation of Technology Shocks

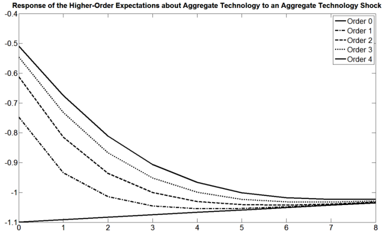
- The signal channel has two effects:

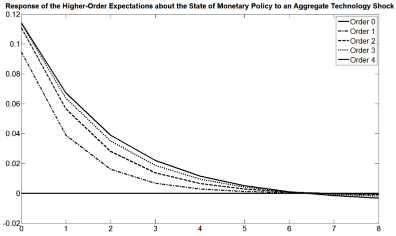
  1. it may confuse firms leading them to believe that a contractionary monetary shock has occurred

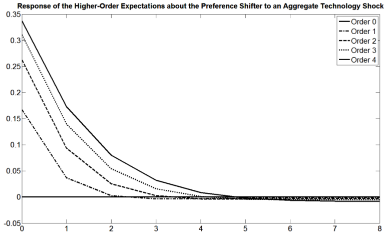
  2. it may confuse firms leading them to believe that a positive preference shock has hit the economy

IRFs to a Tech shock: Decompositions









The Signal Channel and Technology Shocks

- The signal channel seems to have a neutral impact on the response of inflation to a technology shock

- **WHY?**

- The monetary tightening signals firms that

a **positive preference shock**

or

a **contractionary monetary shock**

may have hit the economy

- The effects of such a confusion on inflation expectations turn out to **cancel each other out**

Concluding Remarks

- I develop a model in which
  - Information is dispersed across price setters
  - Since the policy rate is perfectly observed, monetary policy has signaling effects
- Estimation using SPF as a measure of public expectations
- The signal channel is found
  - to be empirically relevant
  - to raise the real effects of monetary disturbances
  - to curb the inflationary effects of demand shocks
  - to have little impact on the propagation of technology shocks

Appendix

Stage 3: Households' Problem

- Households choose consumption $C_{j,t}$, labor N_t, and bond holdings B_t under perfect information
- The representative household maximizes:

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^{t+s} g_{t+s} \left[\ln C_{t+s} - \chi_n N_{t+s} \right]$$

- The demand shock is a preference shifter that follows:

$$\ln g_t = \rho_g \ln g_{t-1} + \sigma_g \varepsilon_{g,t}, \quad \varepsilon_{g,t} \backsim \mathcal{N}(0,1)$$

- Composite consumption

$$C_t = \left(\int_0^1 C_{j,t}^{\frac{\nu-1}{\nu}} di \right)^{\frac{\nu}{\nu-1}}$$

Stage 3: Households' Problem (cont'd)

- The flow budget constraint:

$$P_t C_t + B_t = W_t N_t + R_{t-1} B_{t-1} + \Pi_t + T_t$$

- The price level

$$P_t = \left(\int (P_{j,t})^{1-\nu} \, di \right)^{\frac{1}{1-\nu}}$$

- The representative household
  - chooses $C_{j,t}$, labor N_t, and bond holdings B_t
  - subject to the sequence of the flow budget constraints
  - R_t, W_t, Π_t, T_t, and $P_{j,t}$ are taken as given

Back

Stage 3: The Fiscal Authority

- The fiscal authority has to finance maturing government bonds
- The flow budget constraint of the fiscal authority reads

$$R_{t-1}B_{t-1} - B_t = T_t$$

- Fiscal policy is Ricardian

Back

Stage 2: Firms' Technology

- Firms are endowed with a linear technology:

$$Y_{j,t} = A_{j,t} N_{j,t}$$

where

$$A_{j,t} = A_t e^{\widetilde{\sigma}_a \varepsilon^a_{j,t}}$$

with $\varepsilon^a_{j,t} \overset{iid}{\backsim} \mathcal{N}(0,1)$, and

$$A_t = \gamma^t a_t$$

where $\gamma > 1$ is the linear trend of the aggregate technology

- a_t is the de-trended level of aggregate technology

$$\ln a_t = \rho_a \ln a_{t-1} + \sigma_a \varepsilon_{a,t} \quad \text{with } \varepsilon_{a,t} \overset{iid}{\backsim} \mathcal{N}(0,1)$$

Stage 2: Firms' Information Set

- Firm's information set at stage 2 of time t is

$$\mathcal{I}_{j,t} \equiv \{A_{j,\tau}, g_{j,\tau}, R_{\tau}, P_{j,\tau} : \tau \leq t\}$$

where $g_{j,t}$ denotes the private signal concerning the preference shifter g_t:

$$g_{j,t} = g_t e^{\widetilde{\sigma}_g \varepsilon^g_{j,t}}, \quad \text{with } \varepsilon^g_{j,t} \overset{iid}{\backsim} \mathcal{N}(0,1)$$

- Firms are assumed to know the model equations and the parameters

Stage 2: Firms' Price-Setting

- The optimizing firm j sets its price $P^*_{j,t}$ so as to maximize

$$\mathbb{E}_{j,t}\left[\sum_{s=0}^{\infty}(\beta\theta)^s\,\Xi_{t|t+s}\left(\pi_*^s P^*_{j,t} - MC_{j,t+s}\right)Y_{j,t+s}\right]$$

subject to

$$Y_{j,t} = \left(\frac{P_{j,t}}{P_t}\right)^{-\nu} Y_t$$

with $MC_{j,t} = W_t / A_{j,t}$ and taking W_t and P_t as given

- Firms will satisfy any demanded quantity that will arise at stage 3 at the price they have set at stage 2
- Non-optimizing firms index prices to the steady-state inflation

Back

Stage 1: Monetary Policy

- The central bank sets the nominal interest rate according to the reaction function

$$R_t = (r_* \pi_*) \left(\frac{\pi_t}{\pi_*} \right)^{\phi_\pi} \left(\frac{Y_t}{Y_t^*} \right)^{\phi_y} \eta_{r,t}$$

- This process is assumed to follow an AR process:

$$\ln \eta_{r,t} = \rho_r \ln \eta_{r,t-1} + \sigma_r \varepsilon_{r,t}, \quad \text{with } \varepsilon_{r,t} \overset{iid}{\sim} \mathcal{N}(0,1).$$

- We refer to the innovation $\varepsilon_{r,t}$ as a monetary policy shock

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Higher-Order Expectations

Definitions

$$\widehat{mc}_{t|t}^{(k)} \equiv \underbrace{\int \mathbb{E}_{j,t} \dots \int \mathbb{E}_{j,t}}_{k} \widehat{mc}_{j,t}$$

$$\widehat{\pi}_{t+1|t}^{(k)} \equiv \underbrace{\int \mathbb{E}_{j,t} \dots \int \mathbb{E}_{j,t}}_{k} \widehat{\pi}_{t+1}$$

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Priors

Name	Support	Density	Median	95% Interval
θ	$[0, 1]$	Beta	0.65	$(0.28, 0.99)$
ϕ_π	$\mathbb{R}+$	Gamma	2.0	$(1.61, 2.40)$
ϕ_y	$\mathbb{R}+$	Gamma	0.25	$(0.00, 0.65)$
ρ_r	$[0, 1]$	Beta	0.50	$(0.15, 0.90)$
ρ_a	$[0, 1]$	Beta	0.85	$(0.30, 0.99)$
ρ_g	$[0, 1]$	Beta	0.50	$(0.15, 0.90)$

Priors (cont'd)

Name	Support	Density	Median	95% Interval
σ_a	$\mathbb{R}+$	InvGamma	0.70	$(0.35, 1.70)$
$\widetilde{\sigma}_a$	$\mathbb{R}+$	InvGamma	1.40	$(0.95, 2.20)$
σ_g	$\mathbb{R}+$	InvGamma	1.00	$(0.50, 2.40)$
$\widetilde{\sigma}_g$	$\mathbb{R}+$	InvGamma	1.00	$(0.67, 1.55)$
σ_r	$\mathbb{R}+$	InvGamma	0.10	$(0.05, 0.85)$
σ_{m_1}	$\mathbb{R}+$	InvGamma	0.45	$(0.22, 1.10)$
σ_{m_2}	$\mathbb{R}+$	InvGamma	0.45	$(0.22, 1.10)$
$\ln \gamma$	$\mathbb{R}$	Normal	0.00	$(-0.20, 0.20)$
$\ln \pi_*$	$\mathbb{R}$	Normal	0.00	$(-0.20, 0.20)$

▸ Variance Decomposition ▸ Back

Posteriors

Name	IIM			PIM		
		95% Interval			95% Interval	
	Median	Lower	Upper	Median	Lower	Upper
θ	0.46	0.39	0.53	0.61	0.57	0.65
ϕ_π	1.07	1.03	1.12	1.33	1.22	1.45
ϕ_y	0.25	0.17	0.33	0.24	0.16	0.35
ρ_r	0.71	0.66	0.75	0.49	0.42	0.55
ρ_a	0.99	0.98	0.99	0.98	0.97	0.99
ρ_g	0.77	0.74	0.80	0.84	0.81	0.87

Posteriors (cont'd)

Name	IIM			PIM		
		95% Interval			95% Interval	
	Median	Lower	Upper	Median	Lower	Upper
σ_a	1.10	0.94	1.26	1.03	0.92	1.16
$\widetilde{\sigma}_a$	1.14	0.90	1.40	NA	NA	NA
σ_g	1.21	1.05	1.31	0.81	0.67	0.95
$\widetilde{\sigma}_g$	1.57	0.94	2.52	NA	NA	NA
σ_r	0.61	0.50	0.70	0.57	0.50	0.65
σ_{m_1}	0.16	0.15	0.19	0.19	0.17	0.22
σ_{m_2}	0.16	0.14	0.18	0.18	0.16	0.21
$100\ln\gamma$	0.32	0.28	0.35	0.31	0.26	0.34
$100\ln\pi_*$	0.80	0.62	0.99	0.81	0.59	1.01

Variance Decomposition Posterior (NoSPFs) Back

Variance Decomposition

Table: Prior Variance Decomposition

Observable Variables	Shocks		
	ε_a	ε_r	ε_g
GDP Growth	0.56	0.05	0.39
Inflation	0.61	0.01	0.39
FedFunds	0.46	0.04	0.50
1Q-ahead Inflation Expectations	0.65	0.01	0.07
4Q-ahead Inflation Expectations	0.70	0.00	0.00

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Variance Decomposition

Table: Posterior Variance Decomposition

Observable Variables	Shocks		
	ε_a	ε_r	ε_g
GDP Growth	0.44	0.42	0.14
Inflation	0.73	0.18	0.09
FedFunds	0.63	0.09	0.28
1Q-ahead Inflation Expectations	0.93	0.01	0.06
4Q-ahead Inflation Expectations	0.96	0.00	0.03

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One-step-ahead forecasts

Table: RMSE for Models' One-Step-Ahead Predictions

Observable Variables	RMSE	
	IIM	PIM
GDP Growth	11.05	11.40
Inflation	3.58	3.91
FedFunds	3.21	3.30
1Q-ahead Inflation Expectations	2.06	2.29
4Q-ahead Inflation Expectations	1.85	2.45

Note: The table provides the root mean squared errors (RMSEs) for the model's one-step ahead prediction about observables

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RMSE

Table: Forecasting Performance of the Smoothed Estimates

	RMSEs			
	1Q-ahead SPF		4Q-ahead SPF	
	IIM	PIM	IIM	PIM
1970:3-1986:4	1.18	1.49	1.25	1.75
Full Sample	0.90	1.18	0.97	1.34

Note: The table provides the root mean squared errors (RMSEs) for the smoothed estimates of the inflation expectations

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Posteriors

NO SPFs

Name	IIM			PIM		
		95% Interval			95% Interval	
	Median	Lower	Upper	Median	Lower	Upper
θ	0.43	0.35	0.51	0.60	0.56	0.64
ϕ_π	1.76	1.54	1.97	1.27	1.14	1.42
ϕ_y	0.30	0.22	0.40	0.75	0.21	1.42
ρ_r	0.52	0.45	0.58	0.48	0.42	0.55
ρ_a	0.99	0.98	1.00	0.98	0.97	0.99
ρ_g	0.90	0.85	0.93	0.85	0.82	0.88

Posteriors (cont'd)

NO SPFs

Name	IIM			PIM		
		95% Interval			95% Interval	
	Median	Lower	Upper	Median	Lower	Upper
σ_a	0.91	0.76	1.03	1.02	0.90	1.13
$\widetilde{\sigma}_a$	1.78	1.01	2.67	NA	NA	NA
σ_g	0.72	0.58	0.93	1.03	−6.93	9.66
$\widetilde{\sigma}_g$	0.71	0.61	0.82	NA	NA	NA
σ_r	1.80	1.16	2.24	0.94	0.74	1.17
σ_{m_1}	0.55	0.24	1.03	0.19	0.17	0.22
σ_{m_2}	0.56	0.22	1.10	0.19	0.16	0.21
$100\ln\gamma$	0.35	0.26	0.43	0.31	0.28	0.33
$100\ln\pi_*$	0.98	0.98	0.98	0.82	0.55	1.06

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