Signaling Effects of Monetary Policy

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[1] The views in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Federal Reserve Bank of Chicago or any other person associated with the Federal Reserve System.

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- Consider a central bank expecting an inflationary shock

- Tightening money would contribute
  - to **curb the inflationary consequences of the shock**
  - to **raise inflation** if this action 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
- Estimation using the **SPF** as a measure of firms' expectations
- I use the model to study the dynamics of inflation and the effects of disinflation policies in the 1970s

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  2. Signaling effects can explain the sluggish adjustment of inflation to Volcker's disinflation policy

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 (2014)
- **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

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:

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

Model Details

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:

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

The Signaling Channel

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$\Longrightarrow$ Firms rely a lot on the policy signal to infer aggregate states

Examples

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

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

- The precision of private information:

$$\frac{\sigma_a}{\widetilde{\sigma}_a} = 0.47; \; \frac{\sigma_g}{\widetilde{\sigma}_g} = 0.08$$

$\Longrightarrow$ Firms rely on their private information to learn about technology

- The policy rate is
  1. mainly informative about aggregate technology $\Phi_a = 0.80$
  2. is roughly equally informative between dev.'s from the MP rule and demand conditions $\Phi_m \approx \Phi_g = 0.10$

$\Longrightarrow$ Hard for firms to tell whether changes in the policy rate are due to monetary or demand conditions

Posterior Table

Empirical Fit of the DIM

Log-Marginal Likelihood

Full Data Set		Excluding SPF	
DIM	PIM	DIM	PIM
-212.4445	-228.5888	-306.4532	-304.87466

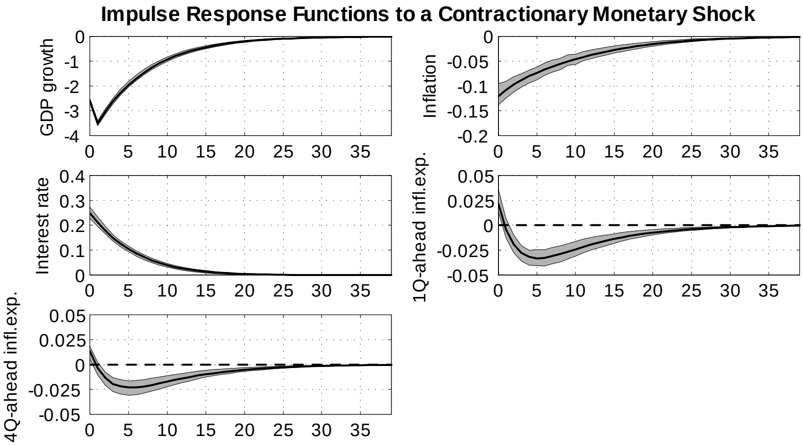
Propagation of Shocks in the IIM

Monetary Shocks

Preference Shocks

Technology Shocks

IRFs to a Monetary Shock



IRFs to a MP Shock: Decompositions

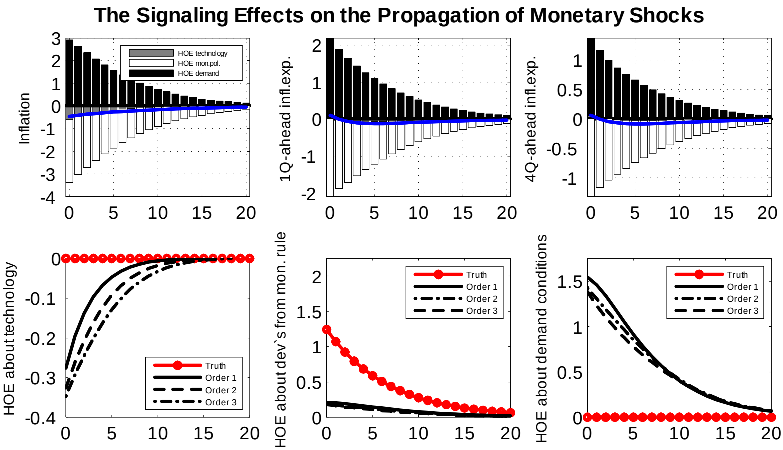


Figure:

Vertical Bars
Back to 3rd Attempt

Propagation of Monetary Shocks

Main Findings

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

Expect's about TFP

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- **WHY?**

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- **WHY?**

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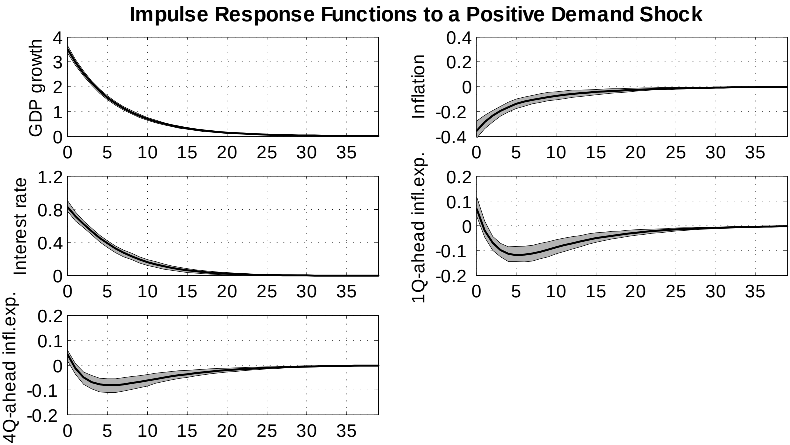


Figure:

Back to Gradualism

IRFs to a Preference shock: Decompositions

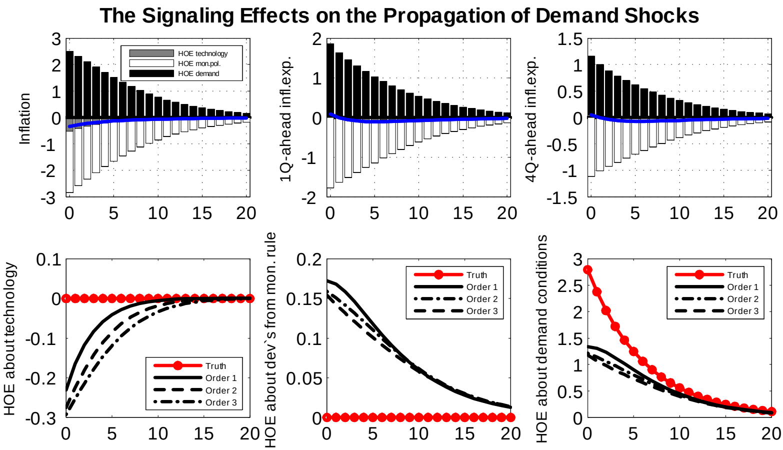


Figure:

Vertical Bars
Back to Gradualism
Back to the Disinflation of the 80s

Propagation of Preference Shocks

Main Findings

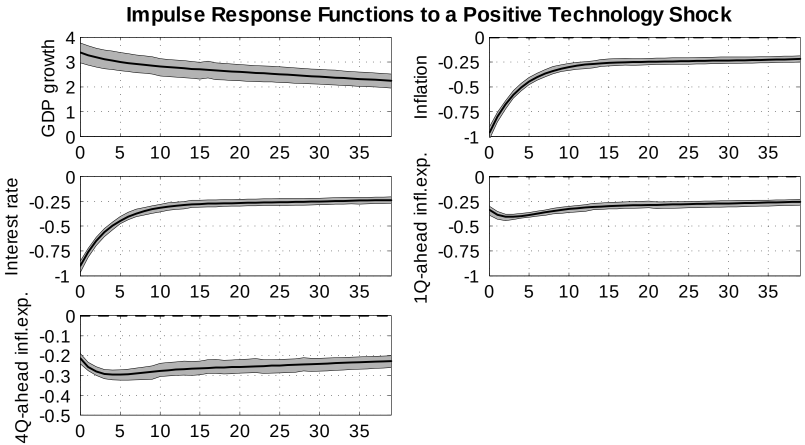
- The signaling effects associated with a *positive* preference shock lead firms to believe that a *contractionary* MP shock has occurred
    - i.e., firms partially interpret the rise of the policy rate as the result of a contractionary MP shock

$\Longrightarrow$ **Inflation falls after a positive preference shock**

- **WHY?**

1. Firms' private information about $\hat{g}_t$ is imprecise $\left(\frac{\sigma_g}{\tilde{\sigma}_g} = 0.08\right)$
2. $\hat{R}_t$ is equally informative about $\eta_{r,t}$ and $\hat{g}_t$ $(\Phi_m \approx \Phi_g = 0.10)$

IRFs to a Technology Shock



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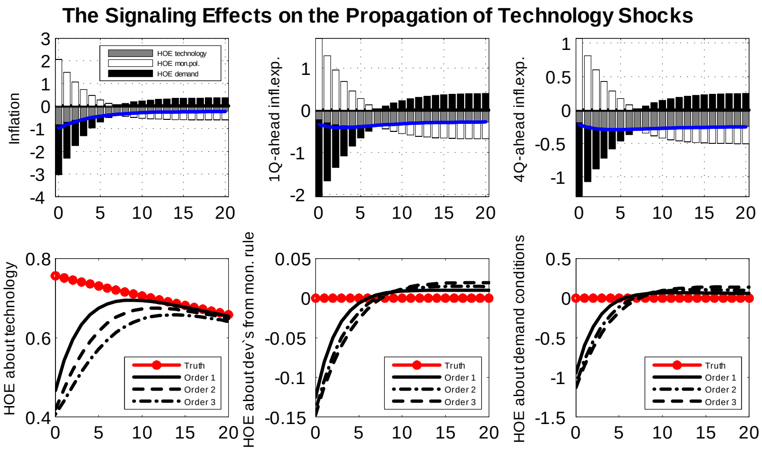

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The Signal Channel and Technology Shocks

- 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**

Bayesian Evaluation of the Signaling Channel

Bayesian Counterfactual Experiment

1. For every posterior draw obtain the model's predicted series for the three shocks
2. Simulate real output, inflation, and inflation expectations from the following two models using the filtered shocks (step 1):
   2.1 the Dispersed Information Model (DIM)
   2.2 The DIM in which MP has **no signaling effects** (i.e., $R^t \notin I_{j,t}$ all j and t)
3. Compute the mean of the simulated series across posterior draws for the two models

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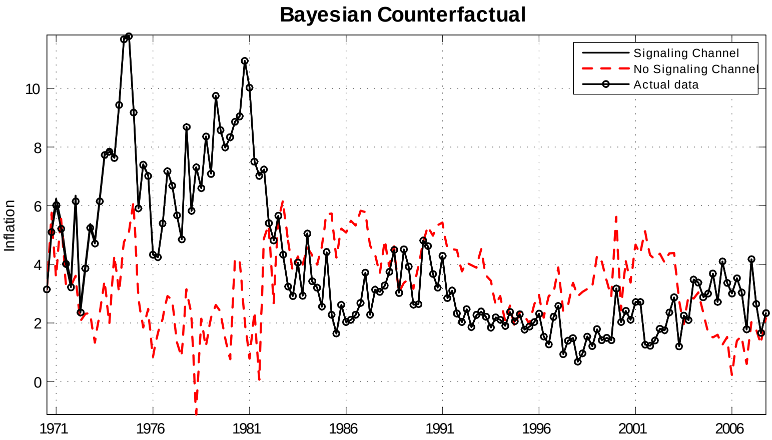
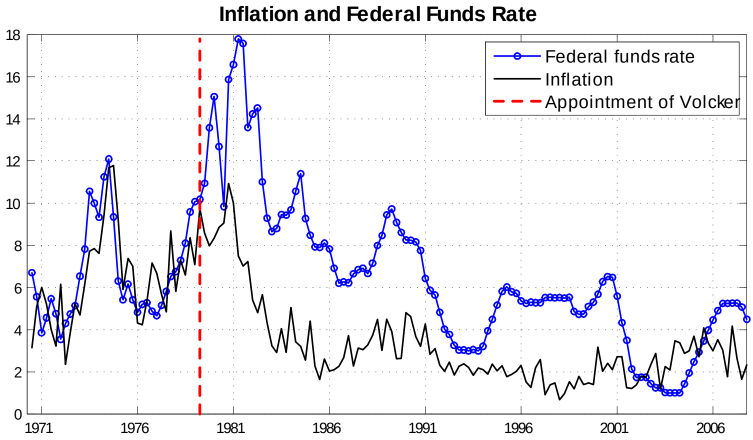


Four Observables Back to Gradualism Back to the Disinflation of the 80s

Three Attempts at Disinflating



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  2. The rise of FFR was *too gradual* ($\hat{\eta}_{r,t} < 0$) to offset the signaling effects on inflation due to adverse demand conditions

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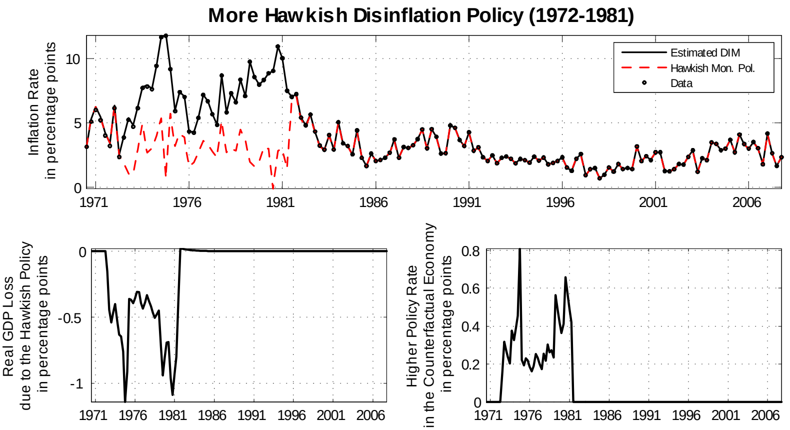
- Signaling effects account for the high inflation of the 70s
- Not the only mechanism to explain high inflation

Gradualism Failed to Neutralize Signaling Effects on Inflation



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- Also positive technology shocks ($\hat{a}_t > 0$) and even more aggressive disinflation policy ($\hat{\eta}_{r,t} >> 0$)

Concluding Remarks

- I develop a model in which monetary policy has signaling effects
- Estimation using SPF as a measure of public expectations
- Main findings
  1. The signaling channel magnifies the real effects of money
  2. Demand shocks lead to large inflationary signaling effects
  3. Signaling effects associated with Burn's gradualism account for the heightened inflation of the 1970s
  4. Signaling effects explain the sluggish adjustment of inflation to Volcker's disinflation policy

Appendix

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 STAGE 2. Government supplies bonds and levies taxes. Markets close.

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

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

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

$$Y_{j,t+s}=\left(\frac{\pi_{*}^{s}P_{j,t}}{P_{t+s}}\right)^{-\nu}Y_{t+s}$$

with $MC_{j,t}=W_{t}/A_{j,t}$

- 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

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:

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

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

Back

Higher-Order Expectations

Definitions

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

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

Back

Posteriors Statistics

	DIM - Posterior			PIM - Posterior		
Name	Mean	5%	95%	Mean	5%	95%
θ	0.2613	0.2450	0.2801	0.5796	0.5468	0.6114
ϕ_π	1.0629	1.0451	1.0820	1.3234	1.2324	1.4200
ϕ_y	0.3416	0.3212	0.3607	0.4356	0.1918	0.6560
ρ_r	0.8613	0.8520	0.8713	0.4690	0.4163	0.5224
ρ_a	0.9932	0.9911	0.9963	0.9751	0.9667	0.9832
ρ_g	0.8505	0.8408	0.8597	0.8192	0.7949	0.8435

Prior

Posteriors (cont'd)

	DIM - Posterior			PIM - Posterior		
Name	Mean	5%	95%	Mean	5%	95%
$100\sigma_a$	0.7569	0.6440	0.8516	0.9961	0.8973	1.0957
$100\widetilde{\sigma}_a$	1.6048	1.3517	1.8332	—	—	—
$100\sigma_g$	2.7843	2.6976	2.8610	0.8169	0.6908	0.9421
$100\widetilde{\sigma}_g$	34.277	30.789	38.068	—	—	—
$100\sigma_r$	0.6372	0.6267	0.6429	0.6832	0.5717	0.7947
$100\sigma_{m_1}$	0.1291	0.1145	0.1452	0.1753	0.1585	0.1923
$100\sigma_{m_2}$	0.1222	0.1087	0.1381	0.1727	0.1565	0.1892
$100\ln\gamma$	0.4889	0.3786	0.5927	0.3302	0.3030	0.3556
$100\ln\pi_*$	0.8327	0.7181	0.9514	0.7374	0.6124	0.8655

Prior Variance Decomposition Appendix Back

Priors

Back

Name	Type	Mean	Std.
θ	$\mathcal{B}$	0.50	0.30
ϕ_π	$\mathcal{G}$	1.50	0.10
ϕ_y	$\mathcal{G}$	0.25	0.10
ρ_r	$\mathcal{B}$	0.50	0.20
ρ_a	$\mathcal{B}$	0.50	0.20
ρ_g	$\mathcal{B}$	0.50	0.20
$100\sigma_a$	$\mathcal{IG}$	0.80	1.50
$100\widetilde{\sigma}_a$	$\mathcal{U}$	50.00	28.87
$100\sigma_g$	$\mathcal{IG}$	0.80	1.50
$100\widetilde{\sigma}_g$	$\mathcal{U}$	50.00	28.87
$100\sigma_r$	$\mathcal{IG}$	0.80	1.50
$100\sigma_{m_1}$	$\mathcal{IG}$	0.10	0.08
$100\sigma_{m_2}$	$\mathcal{IG}$	0.10	0.08
$100\ln\gamma$	$\mathcal{N}$	0.62	0.10
$100\ln\pi_*$	$\mathcal{N}$	0.65	0.10

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

Back

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

Back

Posteriors

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)

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

Back Posterior Table

Measuring the Effects of the Signal Channel 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:

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

Back to IRF to MP shock Back to IRF to Pref Shock

Back to Numerical Cases

Simple Calibration

- For simplicity assume that $\sigma_g = 0$ (i.e., no demand shock)
- Baseline calibration

Name	Value	Name	Value
θ	0.65	ρ_a	0.85
ϕ_π	1.50	$100\sigma_a$	0.70
ϕ_y	0.00	$100\widetilde{\sigma}_a$	0.70
ρ_r	0.65	$100\sigma_r$	0.5

- We study how the effects of the signal channel on inflation depends on:
  1. More precise information about aggregate technology
  2. Changing the informative content of the policy signal
  3. Changing the expected inflationary consequences of shocks

Baseline Calibration: Effects of the Signal Channel

Back Vertical Bars

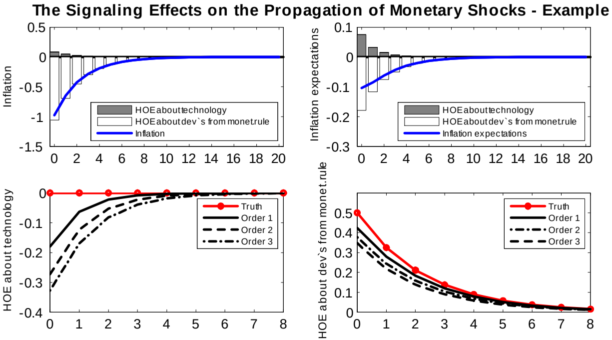


Figure: Impulse response functions to a one-standard deviation contractionary monetary shock: the case of $\sigma_a/\widetilde{\sigma}_a = 1$ and $\sigma_r = 0.5$. HOE means higher-order expectations.

Less Precise Private Information

Back Vertical Bars

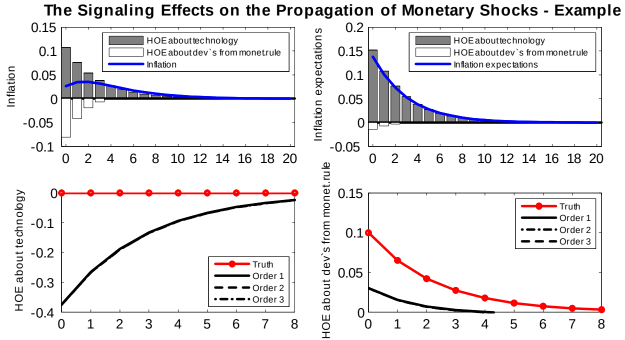


Figure: Impulse response functions to a one-standard deviation contractionary monetary shock: the case of $\sigma_a/\widetilde{\sigma}_a = 0.05$ and $\sigma_r = 0.1$. HOE means higher-order expectations.

Other Examples

Back Vertical Bars

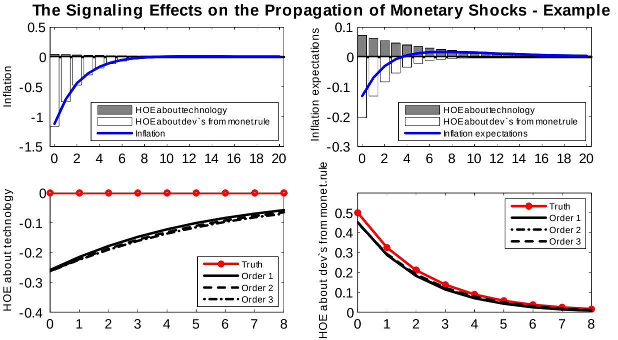


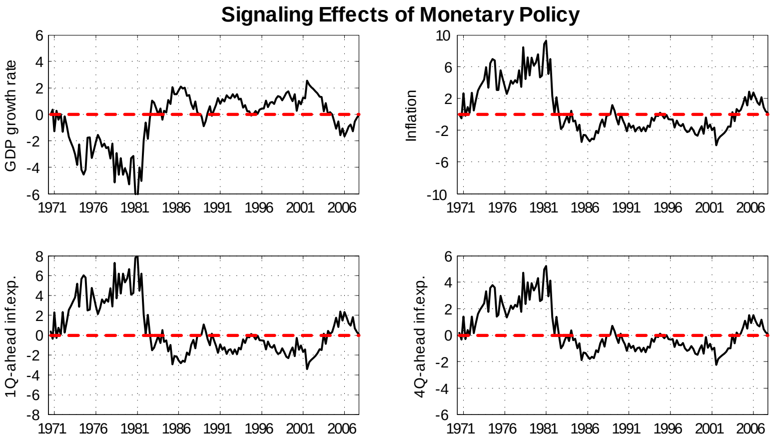
Figure: Impulse response functions to a one-standard deviation contractionary monetary shock: the case of $\sigma_a/\widetilde{\sigma}_a = 0.05$ and $\sigma_r = 0.5$. HOE means higher-order expectations.

Beliefs about TFP after a MP shock

- Expecting a negative technology shock has:
  - **small effects** as private information about aggregate technology is quite precise
  - **deflationary effects** as firms anticipate a sharp fall in demand due to highly persistent tech shocks and flexible price contracts

Back

Signaling Effects of Monetary Policy



Back