Evolving Reputation for Commitment: The Rise, Fall and Stabilization of US Inflation

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Overview

Consensus:

- Inflation expectations are important for inflation dynamics
- Inflation expectations respond to CB policy communication
- Managing expectations is central to inflation policy

This paper:

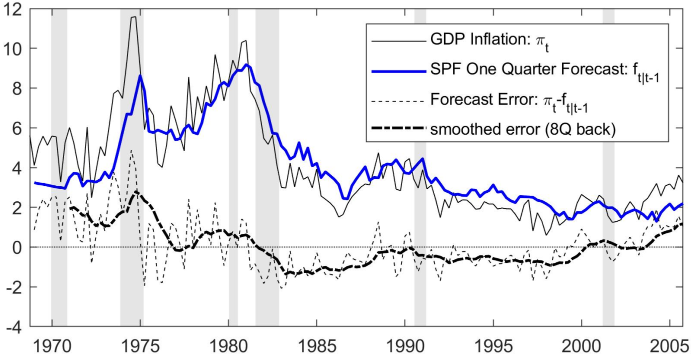
- A theory for interaction b/w inflation expectation and policy
- Quantitative theory validated by U.S. inflation history
- Testable implications supported by SPF forecast revision regressions

Context and Questions

- Managing Expectations needs (perceived) commitment
  - Central Bank communicates *intentions* about inflation, output, etc
  - Macrotheory portrays CB as dominant player with *strategic power*
  - Strategic power derives from *commitment capability*
- What if private sector is *skeptical* about commitment capability?
  - What is private sector's belief that policymaker can commit?
    – can that belief (reputation) be affected?
  - What alternative policies expected by private sector?
    – can such perceived alternatives be affected?
- How important is evolving reputation for commitment?
  - conceptually, optimal policy path to promise or to implement
  - empirically, joint behavior of US expected and actual inflation.

Features of US inflation: private sector learning

Quarterly PGDP inflation and prior quarter SPF forecast



- Lengthy runs of positive and negative forecast errors
- Croushore (2010), Coiboin et al (2018), Farmer et al (2023), Carvalho et al (2023).

What we do

- Augment a plain-vanilla NK model with:
  - Private agents learning which policy regime they are in
  - Committed regime policies: managing expectations
  - Opportunistic regime policies: responding to expectations
  - Interplay between agents learning and optimal policies
- New theoretical and numerical approaches:
  - Dynamic game with expectations linkages across periods
  - Mechanism design approach to solve equilibrium
  - Recursive formulation
  - Model-consistent nonlinear Kalman filter with Markov-switching

Our results

- Extract latent states (reputation etc.) only from SPF1Q, SPF3Q
- Model-implied inflation tracks observed inflation
- Model-implied long-term expectation track surveyed forecast
- Nonlinear responses of forecast revision to forecast error in SPF consistent with theory

Contribution to the literature

- Learning-based reputation approach: Milgrom and Roberts(1982), Kreps and Wilson(1982), Backus and Driffill(1983), Barro(1986), Phelan(2006), King et al.(2008), Lu(2013), Lu et al.(2016), Dovis and Kirpalani(2021), Morelli an Moretti (2023) etc.

  new approach to solve equilibrium with expectation forward-looking and both types optimizing

- Reputation force as substitute for commitment capability: Barro and Gordon(1983), Chari and Kehoe(1990), Ireland(1997), Kurozumi(2008), Loisel(2008), Sunakawa(2015) etc.

  richer reputation dynamics, punishment varies with deviation from plan

- Literature on US inflation dynamics: Sargent(1999), Primiceri(2006), Bianchi(2013), Matthes(2015), Carvalho et al.(2023), Hazell et al.(2022) etc.

  private sector beliefs and purposeful policymaking jointly determine expected and actual inflation

Policymaker: type and objective

- Committed type (τ_a) chooses and commits to contingent plan $\{a_t\}_{t=0}^{\infty}$
- Opportunistic type (τ_α) chooses intended policy α_t
- Inflation deviates from policy intentions by i.i.d. error $v_\pi \sim N(0, \sigma_{v,\pi})$

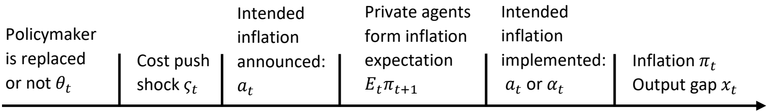
$$\pi_t = \begin{cases} a_t + v_{\pi,t} & \text{with committed type } \tau_a \\ \alpha_t + v_{\pi,t} & \text{with opportunistic type } \tau_\alpha \end{cases} \quad (1)$$

- Quadratic objective in inflation π and output gap x

$$u(\pi, x) = -\frac{1}{2}\{(\pi - \pi^*)^2 + \vartheta_x (x - x^*)^2\} \quad (2)$$

- Committed type (τ_a) patient with β_a
- Opportunistic type (τ_α) patient with β_α

Private sector: information and NK inflation dynamics



- Information structure
  - Policymaker is replaced ($\theta = 1$) w/ prob q each period.
  - Replacement event is observed by private agents.
  - Policymaker type and policy intention not observed.
  - Private agents must learn policymaker type from π_t.
- NK standard Phillips curve

$$\pi_t = \underbrace{\beta E_t^p \pi_{t+1}}_{e_t} + \kappa x_t + \varsigma_t \tag{3}$$

ς Markov-chain cost-push shock

Reputation and Inflation Expectations

- History within a regime $h_t = \{h_{t-1}, \pi_{t-1}, \varsigma_t\}$
- **Reputation** within a regime $\rho(h_t) = \Pr(\tau_a | h_t)$

$$\rho(h_{t+1}) = \rho(h_t, \pi_t) \equiv \frac{\rho(h_t)\, g(\pi_t | a(h_t))}{\rho(h_t)\, g(\pi_t | a(h_t)) + (1 - \rho(h_t)) g(\pi_t | \alpha(h_t))} \quad (4)$$

- Private sector inflation expectations: Detail

$$\begin{aligned} e(h_t) &= \beta E^p(\pi_{t+1} | h_t) \\ &= \beta\rho(h_t) \underbrace{E\pi_{t+1} | (h_t, \tau_a)}_{\text{committed policy}} + \beta(1 - \rho(h_t)) \underbrace{E\pi_{t+1} | (h_t, \tau_\alpha)}_{\text{opportunistic policy}} \end{aligned} \quad (5)$$

- Reputation passes on to a new regime with prob δ_ρ
  - New policymaker's reputation $\rho_0 = \phi_t \rho(h_t) + (1 - \phi_t) v_{\rho,t}$
  - $\phi_t \sim \text{Bernoulli}(\delta_\rho)$ and $v_{\rho,t} \sim \text{Beta}(\overline{\rho}, \sigma_\rho)$.

Optimal opportunistic policy: myopic

- Opportunistic type chooses α_t that generates $\pi_t = \alpha_t + v_{\pi,t}$

$$\alpha_t = \underset{\alpha_t}{\text{argmax}} \int u(\pi_t, \frac{\pi_t - e_t - \varsigma_t}{\kappa}) g\left(\pi_t | \alpha_t\right) d\pi_t \tag{6}$$

  taking $e_t = e(h_t)$ as given

- Linear best response

$$\alpha(h_t) = Ae(h_t) + B(\varsigma_t) \tag{7}$$

- Lower optimal $\alpha(h_t)$ if lower $e(h_t)$.

Inflation bias without commitment

contrasting two concepts

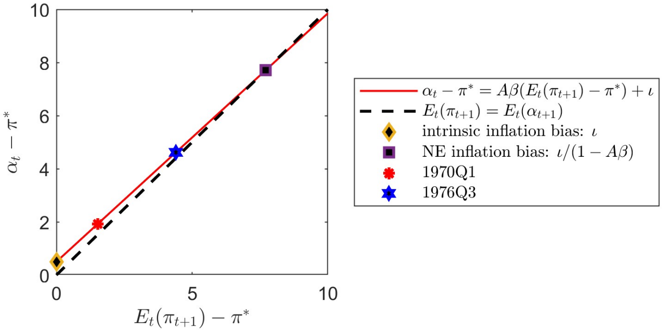
$$\alpha(e) = Ae + B(\varsigma), A = .94, \beta = .995$$

- Intrinsic inflation bias (small)

$$\alpha(e = \beta\pi^*) - \pi^* = 0.5\%.$$

- Nash Eq inflation bias (BIG)

$$\alpha(e = \beta\alpha) - \pi^* = 8\%$$



Optimal opportunistic policy: forward-looking

Opportunistic type chooses α_t that generates $\pi_t = \alpha_t + v_{\pi,t}$

- takes e_t as given but ... understands:
- future payoff depends on future expected inflation $e(h_{t+1})$
- $e(h_{t+1})$ depends on current inflation $h_{t+1} = \{h_t, \pi_t, \varsigma_{t+1}\}$
- manages $e(h_{t+1})$ in a limited manner by controlling π_t

$\alpha_t := \alpha(h_t)$ is sequentially rational if it satisfies the first-order condition

$$
\begin{aligned}
0 &= \int u(\pi_t, e_t, \varsigma_t) \frac{\partial g(\pi_t|\alpha_t)}{\partial \alpha_t} d\pi_t \\
&+ \beta_\alpha(1-q) \int \sum_{\varsigma_{t+1}} \varphi(\varsigma_{t+1}; \varsigma_t) V(h_t, \pi_t, \varsigma_{t+1}) \frac{\partial g(\pi_t|\alpha_t)}{\partial \alpha_t} d\pi_t
\end{aligned} \tag{8}
$$

with

$$
\begin{aligned}
V(h_t) &= \int u(\pi_t, e_t, \varsigma_t) g(\pi_t|\alpha_t) d\pi_t \\
&+ \beta_\alpha(1-q) \int \sum_{\varsigma_{t+1}} \varphi(\varsigma_{t+1}; \varsigma_t) V(h_t, \pi_t, \varsigma_{t+1}) g(\pi_t|\alpha_t) d\pi_t
\end{aligned} \tag{9}
$$

Optimal committed policy plan

At start of his term, choose $\{a(h_t)\}_{t=0}^{\infty}$ to maximize

$$U_0 = E_0 \sum_{t=0}^{\infty} \beta_a^t (1-q)^t \underline{u}\left(a(h_t), e(h_t), \varsigma_t\right)$$

where $\underline{u}\left(a, e, \varsigma\right) \equiv \int u(\pi, x(\pi, e, \varsigma)) g(\pi|a) d\pi$

- "Strategic power" of $\{a(h_t)\}_{t=0}^{\infty}$ on $\{e(h_t)\}_{t=0}^{\infty}$
  - **anchor expectation**: $e(h_t)$ anchored by $\rho(h_t)a(h_{t+1})$
  - **manage perceived alternative**: $\alpha(h_t)$ affected by $e(h_t)$ and $e(h_{t+1})$
  - **build reputation**: $\rho(h_t)$ affected by $a(h_{t-1})$ and $\alpha(h_{t-1})$

Mechanism design approach for within-regime equilibrium

Committed type chooses $\{a_t, \alpha_t, e_t\}_{t=0}^{\infty}$ to maximize

$$U_0 = E_0\{\textstyle\sum_{t=0}^{\infty} \beta_a^t (1-q)^t \, \underline{u}(a_t, e_t, \varsigma_t)\} \tag{10}$$

subject to 3 constraints each period:

1. Rational inflation expectations for private agents

$$e_t = \beta \int \sum \varphi(\varsigma_{t+1};\varsigma_t)\{\rho_t[(1-q)a_{t+1} + qz_{t+1}]g(\pi_t|a_t) \\ +(1-\rho_t)[(1-q)\alpha_{t+1} + qz_{t+1}]g(\pi_t|\alpha_t)\}d\pi_t$$

2. Sequential rationality conditions for opportunistic type

$$0 = \frac{\partial \underline{u}(\alpha_t, e_t, \varsigma_t)}{\partial \alpha_t} + \beta_\alpha(1-q)\int \sum \varphi(\varsigma_{t+1};\varsigma_t) V_{t+1} \frac{\partial g(\pi_t|\alpha_t)}{\partial \alpha_t} d\pi_t$$

$$V_t = \underline{u}(\alpha_t, e_t, \varsigma_t) + \beta_\alpha(1-q)\int \sum \varphi(\varsigma_{t+1};\varsigma_t) V_{t+1} g(\pi_t|\alpha_t)\, d\pi_t$$

Recursive formulation (Marcet and Marimon 2019)

Committed type chooses $\{a_t, \alpha_t, e_t\}_{t=0}^{\infty}$ to maximize

$$U_0 = E_0\{\sum_{t=0}^{\infty} \beta_a^t \,(1-q)^t \,\underline{u}\,(a_t, e_t, \varsigma_t)\} \tag{11}$$

subject to 3 constraints each period:

1. Rational inflation expectations for private agents

$$\gamma_t : e_t = \beta \int \sum \varphi(\varsigma_{t+1}; \varsigma_t)\{\rho_t[(1-q)a_{t+1} + qz_{t+1}]g(\pi_t|a_t) + (1-\rho_t)[(1-q)\alpha_{t+1} + qz_{t+1}]g(\pi_t|\alpha_t)\}d\pi_t$$

2. Sequential rationality conditions for opportunistic type

$$\phi_t : 0 = \frac{\partial \underline{u}(\alpha_t, e_t, \varsigma_t)}{\partial \alpha_t} + \beta_\alpha(1-q)\int \sum \varphi(\varsigma_{t+1}; \varsigma_t)V_{t+1}\frac{\partial g(\pi_t|\alpha_t)}{\partial \alpha_t}d\pi_t$$

$$\chi_t : V_t = \underline{u}(\alpha_t, e_t, \varsigma_t) + \beta_\alpha(1-q)\int \sum \varphi(\varsigma_{t+1}; \varsigma_t)V_{t+1}g\,(\pi_t|\alpha_t)\,d\pi_t$$

Change of measure

Recursive formulation (Marcet and Marimon 2019)

Within-regime equilibrium is the solution to

$$W(\varsigma,\rho,\mu,y) = \min_{\gamma,\phi,\chi}\max_{a,\alpha,e,V} \underline{u}(a,e,\varsigma) + (\gamma e - \mu\omega) + \phi\frac{\partial \underline{u}(\alpha,e,\varsigma)}{\partial\alpha} + \chi\underline{u}(\alpha,e,\varsigma) + (y-\chi)V + \beta_a(1-q)\int\sum_{\varsigma'}\varphi(\varsigma';\varsigma)W(\varsigma',\rho',\mu',y')g(\pi|a)d\pi \tag{12}$$

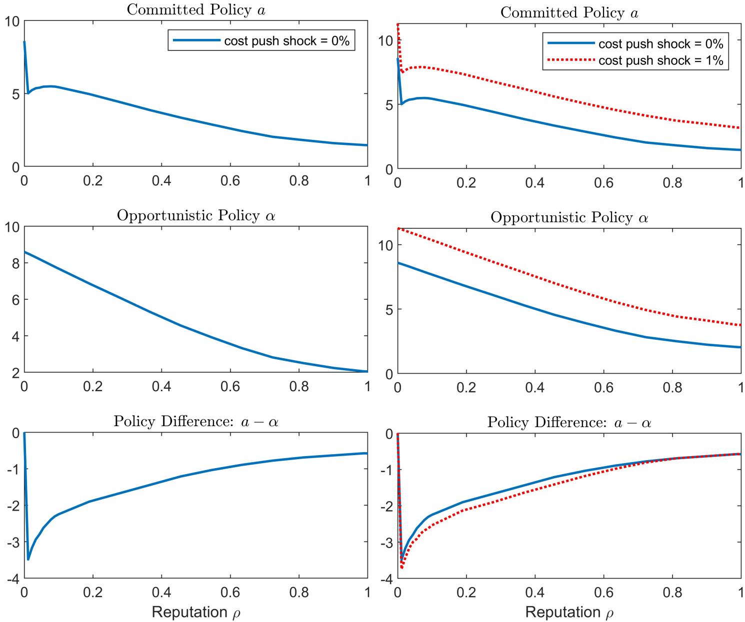
$$\text{with } \omega = (1-q)a + qz + \frac{(1-\rho)}{\rho}[(1-q)\alpha + qz] \tag{13}$$

$$\rho' = b(\pi,a,\alpha,\rho) \tag{14}$$

$$\mu' = \frac{\beta}{\beta_a(1-q)}\rho\gamma \text{ with } \mu_0 = 0 \tag{15}$$

$$y' = \frac{\beta_\alpha}{\beta_a}\frac{1}{g(\pi|a)}\left[\phi\frac{\partial g(\pi|\alpha)}{\partial\alpha} + \chi g(\pi|\alpha)\right] \text{ with } y_0 = 0 \tag{16}$$

Inflation policy as function of ρ: $\beta_\alpha = 0$ case



Linking the theory to the data: $\beta_\alpha = 0$ case

Model inputs

- 3 structural shocks $v_t = (v_\varsigma, v_\rho, v_\pi)$
- 3 state variables $s_t = (\varsigma_t, \rho_t, \mu_t)$
- 3 discrete states $\Theta_t = (\theta_t, \phi_t, \tau_t)$ Def and Trans

Model outputs:

- committed and opportunistic policies $a(s_t)$ and $\alpha(s_t)$
- inflation $\pi_t = \tau_t a(s_t) + (1 - \tau_t)\alpha(s_t) + v_{\pi,t}$
- inflation forecasts at various horizons $E^p(\pi_{t+k}|s_t) = e(s_t, k)$

Data:

- SPF inflation forecasts at various horizons
- Inflation, food and energy price shock

State space model with Markov-switching

$$X_t = [\varsigma_t, \rho_t, \mu_t, \pi_t]' = F(X_{t-1}, v_t | \Theta_t = (\theta_t, \phi_t, \tau_t))$$

$$= \left[\begin{array}{c} \delta_\varsigma \varsigma_{t-1} + v_{\varsigma,t} \\ (1 - \theta_t + \theta_t \phi_t) b(\varsigma_{t-1}, \rho_{t-1}, \mu_{t-1}, \pi_{t-1}) + \theta_t (1 - \phi_t) v_{\rho,t} \\ (1 - \theta_t) m(\varsigma_{t-1}, \rho_{t-1}, \mu_{t-1}) \\ \tau_t a(\varsigma_t, \rho_t, \mu_t) + (1 - \tau_t) \alpha(\varsigma_t, \rho_t, \mu_t) + v_{\pi,t} \end{array} \right]$$

$$Y_t = \left[\begin{array}{c} f_{t+1|t} \\ f_{t+2|t} \\ f_{t+3|t} \\ f_{t+4|t} \\ \frac{1}{40} \sum_{k=1}^{40} f_{t+k|t} \\ \widetilde{\pi}_t \\ \widetilde{\varsigma}_t \end{array} \right] = \left[\begin{array}{c} e(\varsigma_t, \rho_t, \mu_t, 1) + u_{1t} \\ e(\varsigma_t, \rho_t, \mu_t, 2) + u_{2t} \\ e(\varsigma_t, \rho_t, \mu_t, 3) + u_{3t} \\ e(\varsigma_t, \rho_t, \mu_t, 4) + u_{4t} \\ \overline{e}(\varsigma_t, \rho_t, \mu_t, 40) + u_{40,t} \\ \pi_t + u_{\pi t} \\ \varsigma_t + u_{zt} \end{array} \right] = H(X_t, u_t)$$

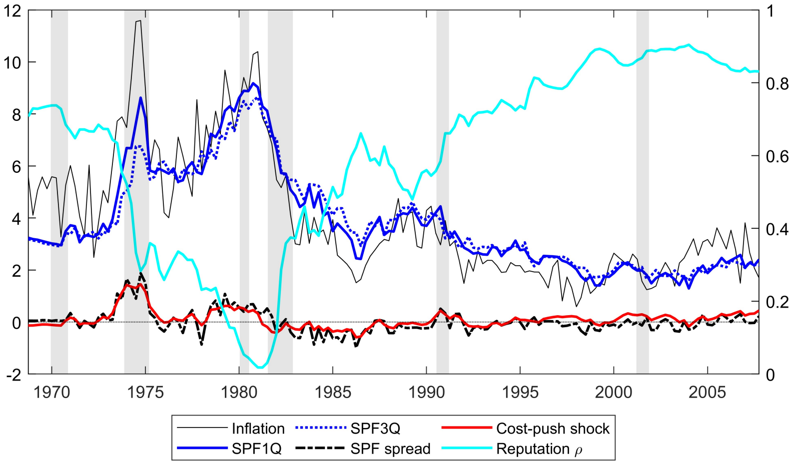
State space model with Markov-switching

$$X_t = [\varsigma_t, \rho_t, \mu_t, \pi_t]' = F(X_{t-1}, v_t | \Theta_t = (\theta_t, \phi_t, \tau_t))$$

$$= \begin{bmatrix} \delta_\varsigma \varsigma_{t-1} + v_{\varsigma,t} \\ (1-\theta_t+\theta_t\phi_t) b(\varsigma_{t-1}, \rho_{t-1}, \mu_{t-1}, \pi_{t-1}) + \theta_t(1-\phi_t) v_{\rho,t} \\ (1-\theta_t) m(\varsigma_{t-1}, \rho_{t-1}, \mu_{t-1}) \\ \tau_t a(\varsigma_t, \rho_t, \mu_t) + (1-\tau_t)\alpha(\varsigma_t, \rho_t, \mu_t) + v_{\pi,t} \end{bmatrix}$$

$$Y_t = \begin{bmatrix} f_{t+1|t} \\ f_{t+2|t} \\ f_{t+3|t} \\ f_{t+4|t} \\ \frac{1}{40}\sum_{k=1}^{40} f_{t+k|t} \\ \widetilde{\pi}_t \\ \widetilde{\varsigma}_t \end{bmatrix} = \begin{bmatrix} e(\varsigma_t, \rho_t, \mu_t, 1) + u_{1t} \\ e(\varsigma_t, \rho_t, \mu_t, 2) + u_{2t} \\ e(\varsigma_t, \rho_t, \mu_t, 3) + u_{3t} \\ e(\varsigma_t, \rho_t, \mu_t, 4) + u_{4t} \\ \overline{e}(\varsigma_t, \rho_t, \mu_t, 40) + u_{40,t} \\ \pi_t + u_{\pi t} \\ \varsigma_t + u_{zt} \end{bmatrix} = H(X_t, u_t)$$

Extracting states: term structure intuition about SPF



- SPF1Q more sensitive to temporary price shocks
- SPF3Q better reflects reputation

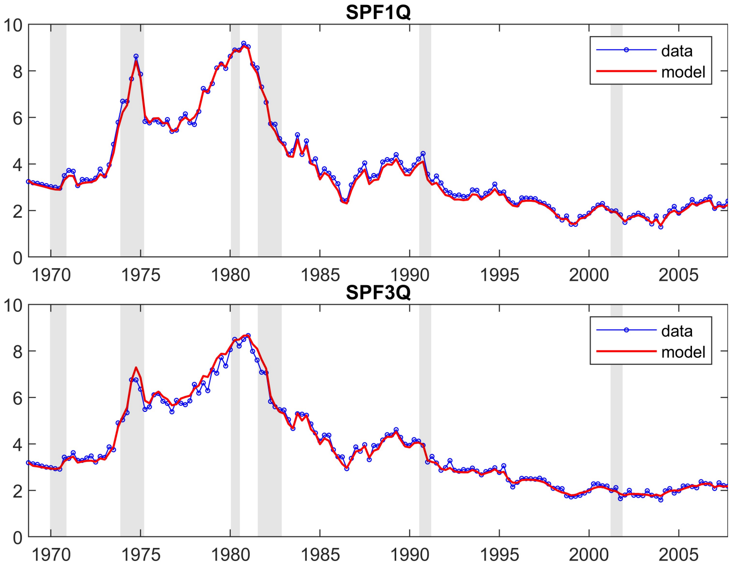
Calibration of parameters

β, β_a	Discount factor (private, committed type)	0.995
q	Replacement probability	0.03
κ	PC output slope	0.08
π^*	Inflation target	1.5%
ϑ_x	Output weight	0.1
x^*	Output target	1.73%
δ_ς	Persistence of cost-push shock	0.7
$\sigma_{v,\varsigma}$	Std of cost-push innovation	0.7%
$\sigma_{v,\pi}$	Std of implementation error v_π	1.2%
δ_ρ	prob of reputation inheritance	0.9
$\overline{\rho}$	mean of reputation draw	0.1
σ_ρ	std of reputation draw	0.05

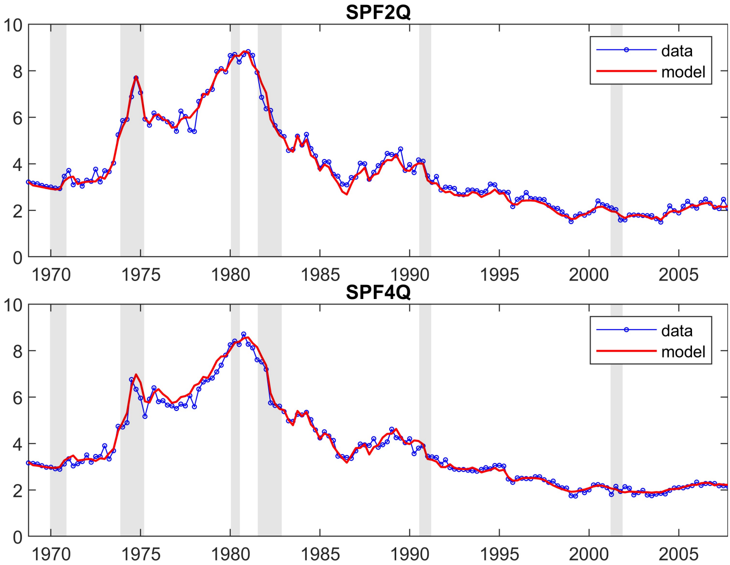
- Implies $A = 0.94$, $\iota = 0.5\%$, NE bias$= 8\%$

Calibration

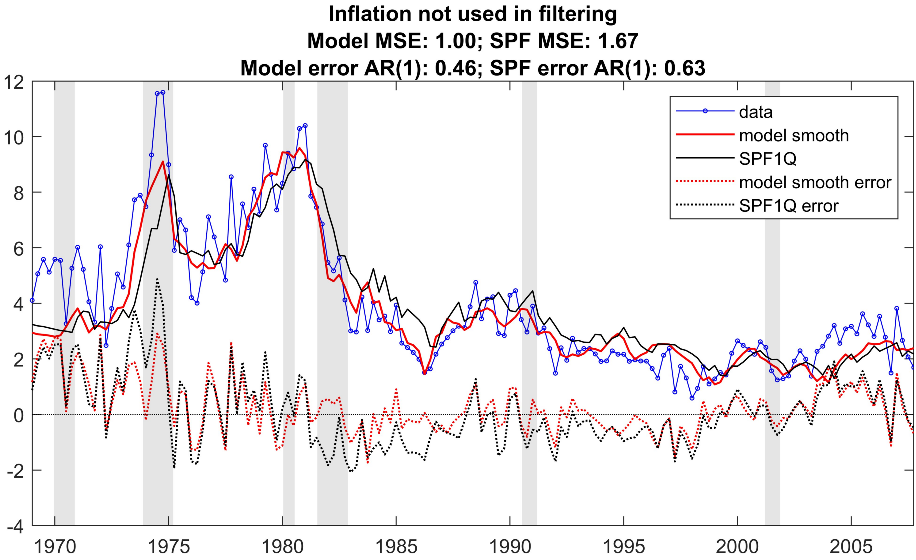
Fitting SPFs



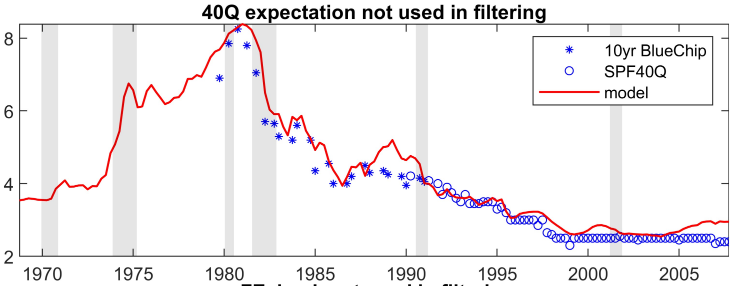
Untargeted: SPF2Q and SPF4Q

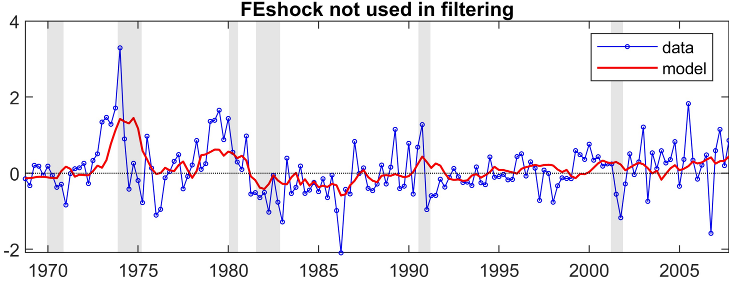


Untargeted: Inflation filtered result long



Untargeted: SPF40Q, Food and Energy Price Shock long





Forecast revision responds to forecast error

Forecast error (FE) in our model:

$$\pi_{t-1} - E_{t-1}\pi_{t-1} = \begin{cases} (1-\rho_{t-1})(a_{t-1}-\alpha_{t-1}) + v_{\pi,t-1} & \text{if committed} \\ -\rho_{t-1}(a_{t-1}-\alpha_{t-1}) + v_{\pi,t-1} & \text{if opportunistic} \end{cases}$$

FE is a noisy signal of policymaker type:

$$\begin{aligned} \pi_{t-1} - E_{t-1}\pi_{t-1} &< 0 \Rightarrow \Delta\rho_t = \rho_t - \rho_{t-1} > 0 \\ \pi_{t-1} - E_{t-1}\pi_{t-1} &> 0 \Rightarrow \Delta\rho_t = \rho_t - \rho_{t-1} < 0 \end{aligned}$$

with signal-to-noise ratio $\propto |a_{t-1} - \alpha_{t-1}|$

- Lower $\rho_{t-1} \Rightarrow \uparrow |a_{t-1} - \alpha_{t-1}| \Rightarrow$ larger $|\Delta\rho_t|$ and Forecast Revision
- Higher $\varsigma_{t-1} \Rightarrow \uparrow |a_{t-1} - \alpha_{t-1}| \Rightarrow$ larger $|\Delta\rho_t|$ and Forecast Revision

Forecast revision responds more at lower ρ

$$E_t\pi_{t+h} - E_{t-1}\pi_{t+h} = \alpha + \beta FE_{t-1} + \gamma \mathbf{1}_{\text{low } \rho_{t-1}} \times FE_{t-1} + \lambda v_{\varsigma,t} + \varepsilon_t$$

- $\mathbf{1}_{\text{low } \rho_{t-1}} = 1$ if $E_{t-1}\pi_{t+40Q} >$ its 75th percentile
- $\varsigma_t = \delta\varsigma_{t-1} + v_{\varsigma,t}$ proxy

	h=0Q	h=1Q	h=2Q	h=3Q
β	0.124***	0.091***	0.072***	0.073***
	(0.006)	(0.003)	(0.001)	(0.002)
γ	**0.226****	**0.241*****	**0.134***	**0.049**
	(0.034)	(0.003)	(0.068)	(0.518)
λ	0.252***	0.129***	0.039	0.085**
	(0.000)	(0.000)	(0.257)	(0.042)
N	200	200	200	200

Forecast revision responds more at higher ς

$$E_t\pi_{t+h} - E_{t-1}\pi_{t+h} = \alpha + \beta FE_{t-1} + \gamma \mathbf{1}_{\text{high } \varsigma_{t-1}} \times FE_{t-1} + \lambda v_{\varsigma,t} + \varepsilon_t$$

- $\mathbf{1}_{\text{high } \varsigma_{t-1}} = 1$ if $\varsigma_{t-1} >$ its 75th percentile
- $\varsigma_t = \delta\varsigma_{t-1} + v_{\varsigma,t}$

	h=0Q	h=1Q	h=2Q	h=3Q
β	0.129***	0.081***	0.062**	0.082***
	(0.000)	(0.001)	(0.018)	(0.002)
γ	**0.158***	**0.205*****	**0.122****	**0.017**
	(0.059)	(0.002)	(0.036)	(0.792)
λ	0.237***	0.113***	0.029	0.083**
	(0.000)	(0.004)	(0.408)	(0.049)
N	202	202	202	202

Summary and conclusions

- A theory for interaction b/w inflation expectation and policy
    - Private agents learns type and form expectations of future policy
    - Committed policymaker manages expectations
    - Opportunistic policymaker responds to expectations
    - Interplay between agents learning and optimal policies
- New theoretical and numerical approaches
    - Dynamic game with expectations linkages across periods
    - Equilibrium via mechanism design approach
    - Recursive formulation
    - Model-consistent nonlinear Kalman filter with Markov-switching
- Looking forward
    - Long horizon opportunistic type
    - Term structure of interest rates
    - **Other applications**

What about signaling?