INFLATION AND PROFESSIONAL FORECAST DYNAMICS: an evaluation of stickiness, persistence, and volatility

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The results presented here do not necessarily represent the views of the Federal Reserve System or the Federal Open Market Committee

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RESEARCH AGENDA

Research Question

What is the relationship between survey forecasts and inflation?

Inflation process is characterized by ...

- drifting mean / trend component
- time-varying volatility in shocks to trend and gap
- time-varying persistence

Evidence about survey forecasts says ...

- surveys are good at forecasting inflation
- but there are also persistent forecast errors
- consistent with informational frictions in survey formation

QUESTIONS MOTIVATED BY INFORMATION FRICTIONS

1. Does “stickiness” vary over time?

2. How does “stickiness” interact with inflation?

3. Is “stickiness” related to monetary regimes?

THIS PAPER

we combine . . .

1) Stock-Watson-type UC model of inflation

2) Sticky/noisy information in survey forecasts

1) Stock-Watson-type UC model of inflation

$$\pi_t = \tau_t + \varepsilon_t$$

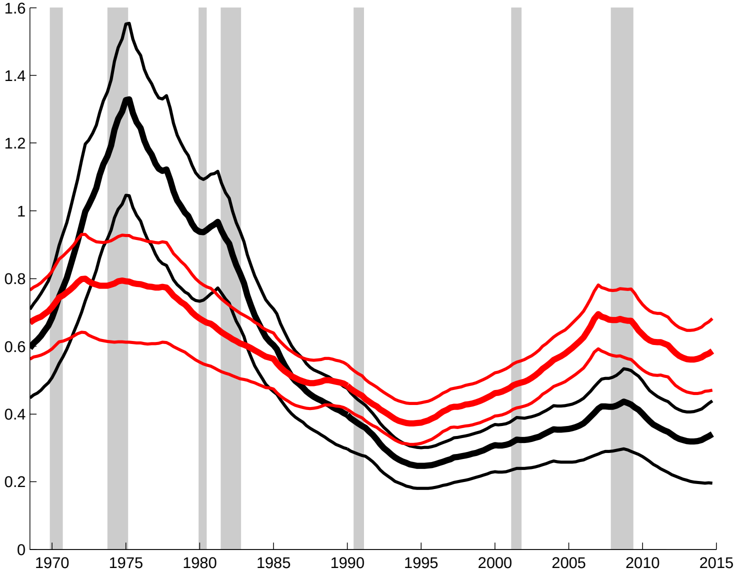
$$\tau_t = \tau_{t-1} + \varsigma_{\eta,t-1}\ \eta_t$$

$$\varepsilon_t = \varsigma_{\nu,t-1}\ \nu_t$$

$$\log \varsigma^2_{l,t} = \log \varsigma^2_{l,t-1} + \sigma_l\ \zeta_{l,t} \qquad \forall\ l = \eta,\ \nu$$

2) Sticky/noisy information in survey forecasts

STOCK-WATSON SV ESTIMATES $\varsigma_{\cdot,t|T}$
Trend SV (black), Gap SV (red)



PROPERTIES OF THE UCSV MODEL FOR INFLATION

1) Filtered Trend is EWMA

$$\boldsymbol{\tau_{t|t} = (1 - K_t)\tau_{t-1|t-1} + K_t \pi_t}$$

where $\boldsymbol{K_t}$ is the Kalman gain for the trend

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where K_t is the Kalman gain for the trend

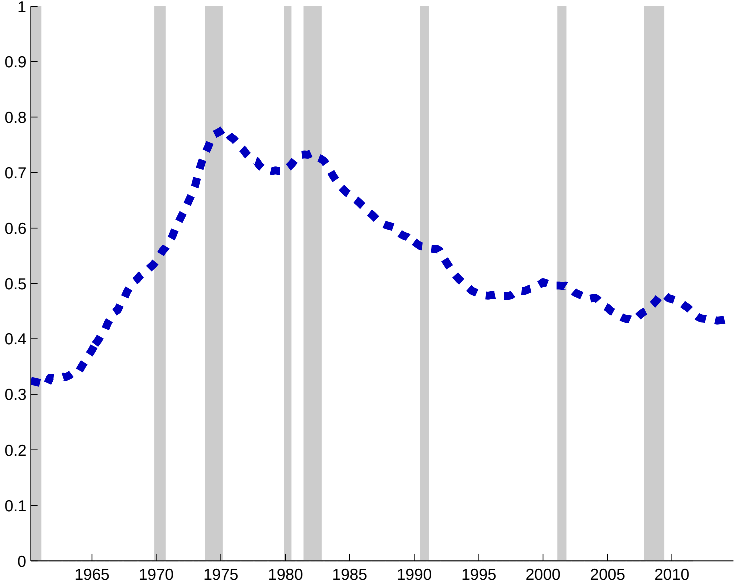
2) IMA representation

$$\Delta\pi_t = (1 - \psi_t L)e_t \qquad e_t = \pi_t - E\left(\pi_t | \pi^{t-1}\right)$$

$$\frac{\partial \pi_{t+\infty}}{\partial e_t} = (1 - \psi_t) = K_t$$

STOCK-WATSON INFLATION PERSISTENCE

Long-run response $\partial \pi_{t+\infty} / \partial e_t = (1 - \psi_t)$



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$$F_t\pi_{t+h} = (1-\lambda)E_t\pi_{t+h} + \lambda F_{t-1}\pi_{t+h}$$

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. . . and add new time-varying parameters

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... and add new time-varying parameters

$$\lambda_t = \lambda_{t-1} + \sigma_\lambda\ \zeta_{\lambda,t} \qquad 0 \le \lambda_t \le 1$$

$$\theta_t = \theta_{t-1} + \sigma_\theta\ \zeta_{\theta,t} \qquad |\theta_t| \le 1$$

RELATED LITERATURE

Surveys and fundamentals

- Coibion & Gorodnichenko (2014), Nason & Smith (2014)
- Ang, Bekaert, & Wei (2007), Faust & Wright (2013)
- Clark & Davig (2011), Mertens (2015), Jain (2013), Krane (2011)
- Kozicki & Tinsley (2012), Chernov & Mueller (2012), Henzel (2013)

Inflation models

Stock & Watson (2007), Garnier, Mertens & Nelson (2015)
Cogley & Sargent (2005), Cogley, Primiceri, & Sargent (2010)

Particle filters

Creal (2012), Shephard (2013), Herbst & Schorfheide (2015), Storvik (2002), Carvalho, Johannes, Lopes, Polsen (2010)

AGENDA

1. **Sticky Information Model**
2. **Nonlinear State Space**
3. **Results**

SI Law of Motion

$$
\begin{aligned}
F_t\pi_{t+h} &= (1-\lambda)E_t\pi_{t+h} + \lambda F_{t-1}\pi_{t+h} \\
&= (1-\lambda)\sum_{j=0}^{\infty}\lambda^j\, E_{t-j}\pi_{t+h}
\end{aligned}
$$

STICKY SURVEY FORECASTS

constant SI weight

SI Law of Motion

$$F_t\pi_{t+h} = (1-\lambda)E_t\pi_{t+h} + \lambda F_{t-1}\pi_{t+h}$$
$$= (1-\lambda)\sum_{j=0}^{\infty}\lambda^j\, E_{t-j}\pi_{t+h}$$

Implication: Persistent forecast errors

$$(E_t - F_t)\pi_{t+h} = \lambda(E_{t-1} - F_{t-1})\pi_{t+h} + e_t$$

STICKY SURVEY FORECASTS
constant SI weight

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Coibion & Gorodnichenko (2014, forth AER):

"SI" law of motion consistent with ...

- Sticky information (Mankiw & Reis, 2002)
- Noisy information/Rational inattention (Woodford, 2002; Sims, 2003; Mackowiak & Wiederholt, 2009)

STICKY SURVEY FORECASTS
NEW: time-varying SI weight

SI Law of Motion

$$\begin{aligned} F_t\pi_{t+h} &= (1-\lambda_{t-1})E_t\pi_{t+h} + \lambda_{t-1}F_{t-1}\pi_{t+h} \\ &= \sum_{j=0}^{\infty}(1-\lambda_{t-1-j}) \cdot \left(\prod_{l=0}^{j-1}\lambda_{t-1-l}\right) E_{t-j}\pi_{t+h} \end{aligned}$$

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$$(E_t - F_t)\pi_{t+h} = \lambda_{t-1}(E_{t-1} - F_{t-1})\pi_{t+h} + e_t$$

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SW-UC model of inflation

$$\pi_t = \tau_t + \varepsilon_t \qquad \tau_t = \tau_{t-1} + \varsigma_{\eta,t-1}\eta_t \qquad E_{t-1}\varepsilon_t = 0$$

$$E_t\pi_{t+h} = E\left(\pi_{t+1}|\tau^t, \epsilon^t\right) = \tau_t$$

NOISY INFORMATION EXAMPLE

SW-UC model of inflation

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Forecaster i receives noisy signal

$$s_t^i = \tau_t + e_t^i \qquad e_t^i \sim N(0, \sigma_e^2) \qquad F_t^i\pi_{t+h} = E(\tau_t|s^{i,t})$$

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$$E(\tau_t|s^{i,t}) = E(\tau_t|s^{i,t-1}) + \kappa_{t-1}\left(s_t^i - E(s_t^i|s^{i,t-1})\right)$$

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Average Forecast $F_t\pi_{t+h} = \int_i F_t^i\pi_{t+h}\, di$

$$F_t\pi_{t+h} = \kappa_{t-1}E_t\pi_{t+h} + (1-\kappa_{t-1})F_{t-1}\pi_{t+h}$$

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$$F_t\pi_{t+h} = \kappa_{t-1}E_t\pi_{t+h} + (1-\kappa_{t-1})F_{t-1}\pi_{t+h}$$

SI weight λ_t corresponds inversely to Kalman gain κ_t

RECURSIVE SI LAW OF MOTION

consider the case of a constant AR for the inflation gap ...

UC model of inflation $\quad x_t = \begin{bmatrix} \tau_t & \varepsilon_t \end{bmatrix}'$

$$\pi_t = \delta_x \, x_t \qquad \Rightarrow \qquad E_t \pi_{t+h} = \delta_x E_t x_{t+h}$$

$$x_t = \Theta \, x_{t-1} + \Xi_{t-1} w_t \qquad \Rightarrow \qquad E_t x_{t+h} = \Theta^h \, x_t$$

SI forecasts

$$F_t \pi_{t+h} = (1 - \lambda_{t-1}) E_t \pi_{t+h} + \lambda_{t-1} F_{t-1} \pi_{t+h}$$

$$\Rightarrow \qquad F_t \pi_{t+h} = \delta_x F_t x_{t+h}$$

$$\Rightarrow \qquad F_t x_{t+h} = \Theta^h F_t x_t$$

Recursive SI representation

$$F_t x_t = (1 - \lambda_{t-1}) x_t + \lambda_{t-1} \Theta \, F_{t-1} x_{t-1}$$

AGENDA

1. Sticky Information Model
2. **Nonlinear State Space**
3. Results

SI STATE VECTOR

"Linear" States $\mathcal{S}_t$

$$\begin{bmatrix} x_t \\ F_t x_t \end{bmatrix} = \mathcal{S}_t = \begin{bmatrix} \Theta & 0 \\ (1-\lambda_{t-1})\Theta & \lambda_{t-1}\Theta \end{bmatrix} \mathcal{S}_{t-1} + \begin{bmatrix} B_{t-1} \\ (1-\lambda_{t-1})B_{t-1} \end{bmatrix} w_t$$

"Non-Linear" States $\mathcal{V}_t$

$$\mathcal{V}_t = \begin{bmatrix} \lambda_t \\ \log \varsigma^2_{\eta,t} \\ \log \varsigma^2_{\nu,t} \\ \end{bmatrix} \sim p\left(\mathcal{V}_t | \mathcal{V}_{t-1}\right)$$

"Linear" States $\mathcal{S}_t$

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SI STATE VECTOR

“Linear” States $\mathcal{S}_t$

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Interaction between λ_t and (B_t, Θ_t) and TVP-transition!

“Non-Linear” States $\mathcal{V}_t$

$$\mathcal{V}_t = \begin{bmatrix} \lambda_t \\ \log \varsigma^2_{\eta,t} \\ \log \varsigma^2_{\nu,t} \\ \theta_t \end{bmatrix} \sim p\left(\mathcal{V}_t | \mathcal{V}_{t-1}\right)$$

DATA AND MEASUREMENT VECTOR

Measurement Vector

$$\mathcal{Y}_t = \begin{bmatrix} \pi_t^* \\ \pi_{t,t+1}^{SPF} \\ \vdots \\ \pi_{t,t+5}^{SPF} \end{bmatrix} = \begin{bmatrix} \pi_t \\ F_t \pi_{t+1} \\ \vdots \\ F_t \pi_{t+5} \end{bmatrix} + \begin{bmatrix} \xi_{t,\pi} \\ \xi_{t,t+1} \\ \vdots \\ \xi_{t,t+5} \end{bmatrix} = \mathcal{C}_t \mathcal{S}_t + \xi_t$$

Data

- Real-time measure of realized inflation π_t^*
- SPF surveys for GDP/GNP deflator 1968:Q4 – 2015:Q2
- Forecast horizons up to one year out
- Surveys are collected mid-quarter t, treated as $F_{t-1}(\cdot)$

ESTIMATION STRATEGY

Nonlinear state space with conditional linearity

$$\begin{aligned} \text{Data:} \quad & \mathcal{Y}_t \sim p\left(\mathcal{Y}_t | \mathcal{S}_t, \mathcal{V}_t; \Psi\right) \\ \text{States:} \quad & \mathcal{S}_t \sim p\left(\mathcal{S}_t | \mathcal{S}_{t-1}, \mathcal{V}_{t-1}; \Psi\right) \\ & \mathcal{V}_t \sim p\left(\mathcal{V}_t | \mathcal{V}_{t-1}; \Psi\right) \end{aligned}$$

$$\mathcal{S}_t | (\mathcal{Y}^t, \mathcal{V}^t; \Psi) \sim N\left(\mathcal{S}_{t|t}, \Sigma_{t|t}\right)$$

Previous draft of the paper:

Particle filtering and smoothing
conditional on calibrated Ψ

Revised draft: "Particle Learning"

Online estimation of Ψ
embedded in particle filter and smoother
(see Storvik, 2002; Carvalho et al, 2010)

AGENDA

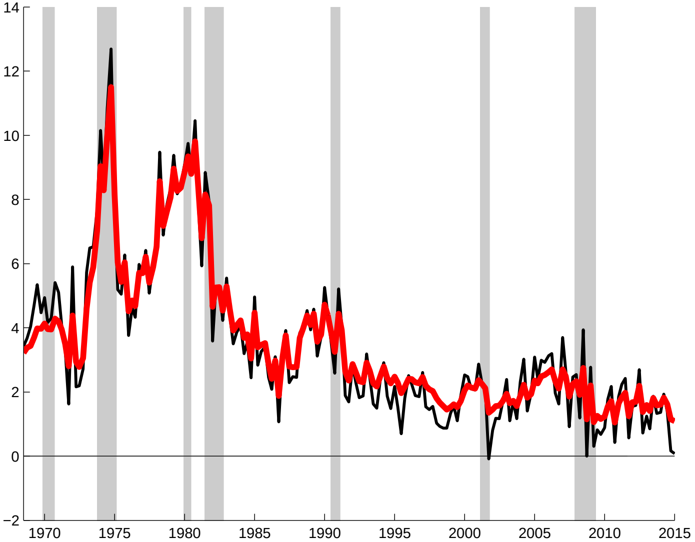
SETUP

- **Joint UC-SI state space**
- **TVP-AR(1) in inflation gap**
- **GDP/GNP deflator, real time 1968:Q3 – 2015:Q1**
- **SPF for $h = 1, \ldots, 5$**
- **Estimated with particle learning**

SI NOWCAST

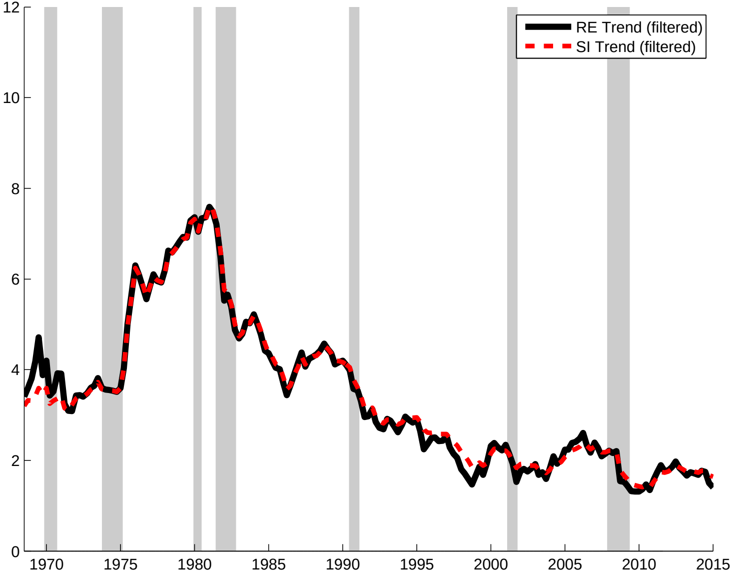
$F_t \pi_t$ (red), inflation π_t (black)

$$F_t \pi_t = (1 - \lambda_{t-1})\pi_t + \lambda_{t-1} F_{t-1}\pi_t$$



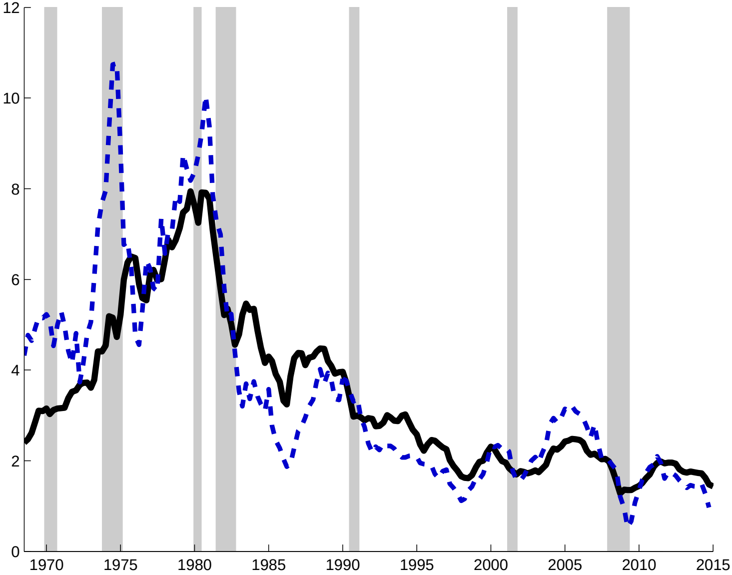
TREND INFLATION

RE (black), SI (red), filtered estimates



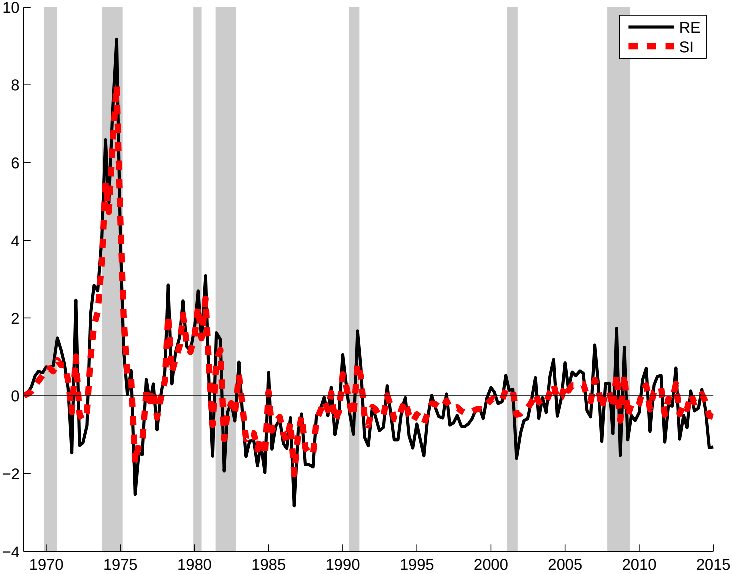
TREND INFLATION: UC-SI VS UC

RE Trends, UC-SI model (black), UC model (blue)



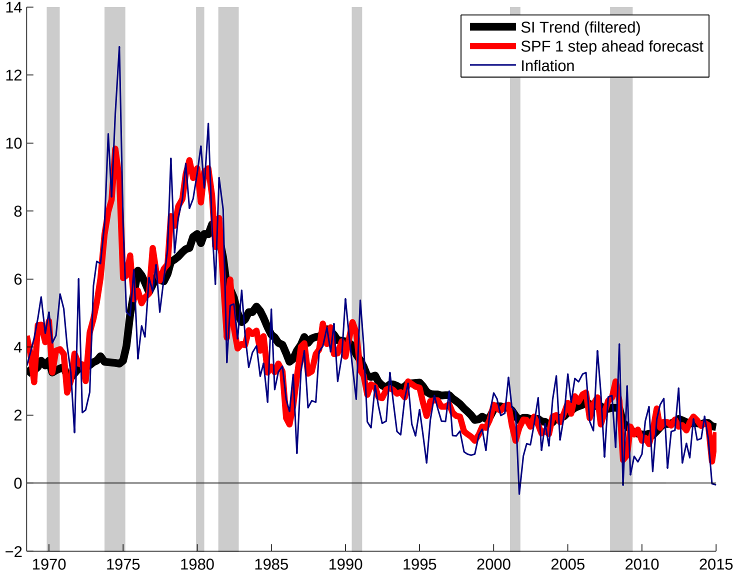
INFLATION GAP

RE (black), SI (red), filtered estimates



SPF AND TREND INFLATION

One-step ahead forecast (red), inflation (blue), SI trend (black)



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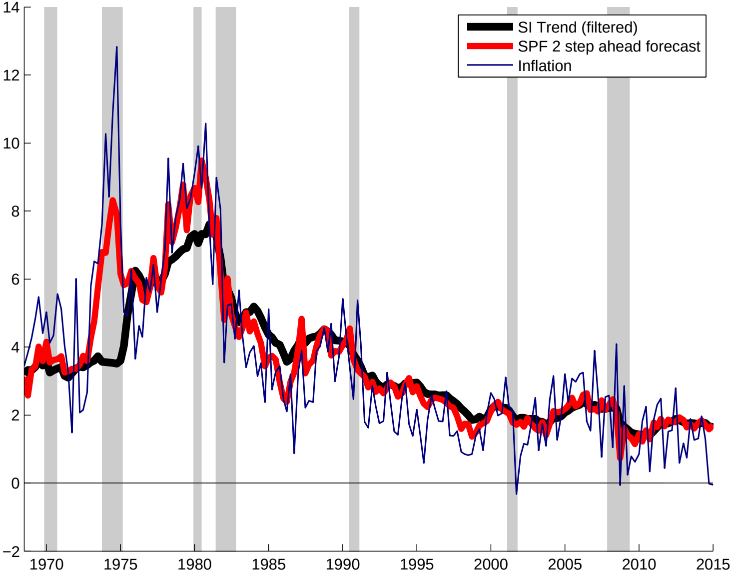
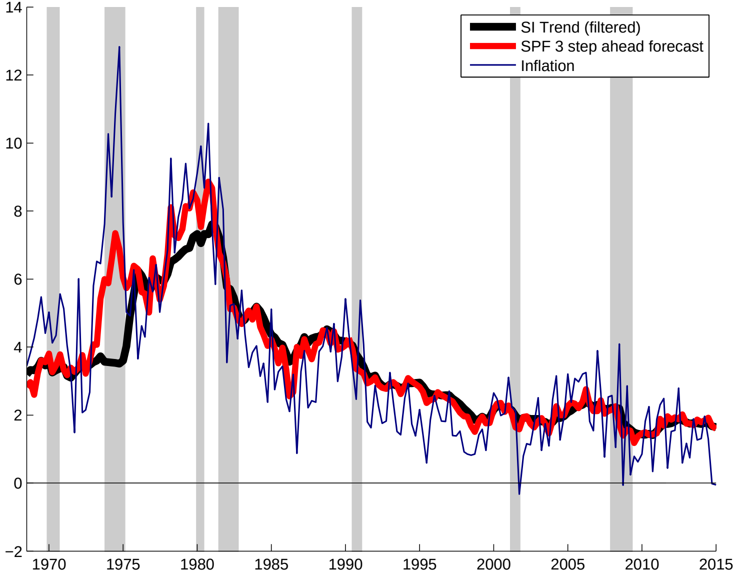


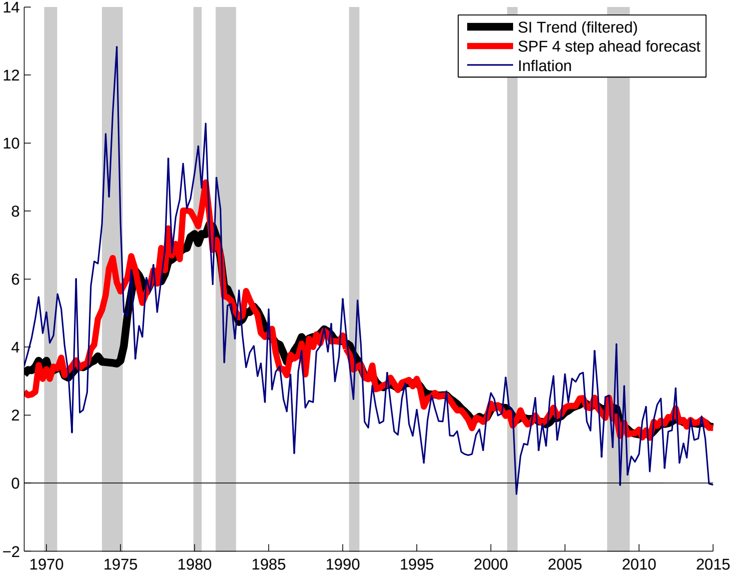
SPF AND TREND INFLATION

Three-steps ahead forecast (red), inflation (blue), SI trend (black)



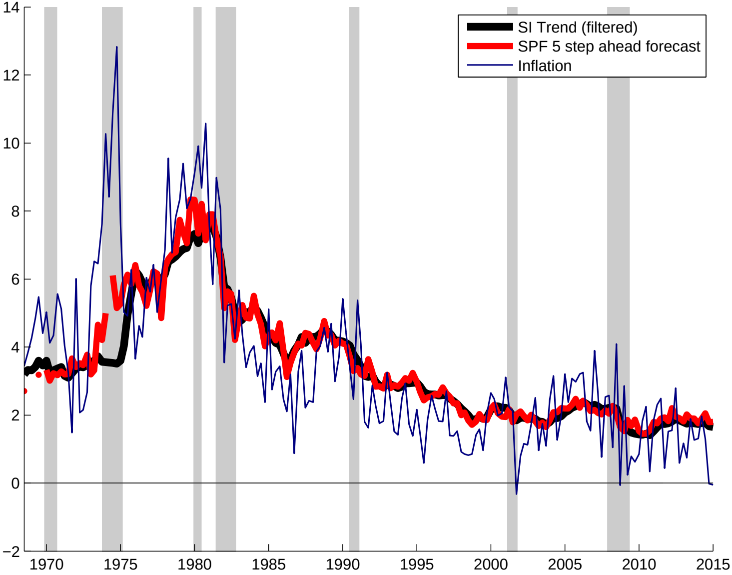
SPF AND TREND INFLATION

Four-steps ahead forecast (red), inflation (blue), SI trend (black)

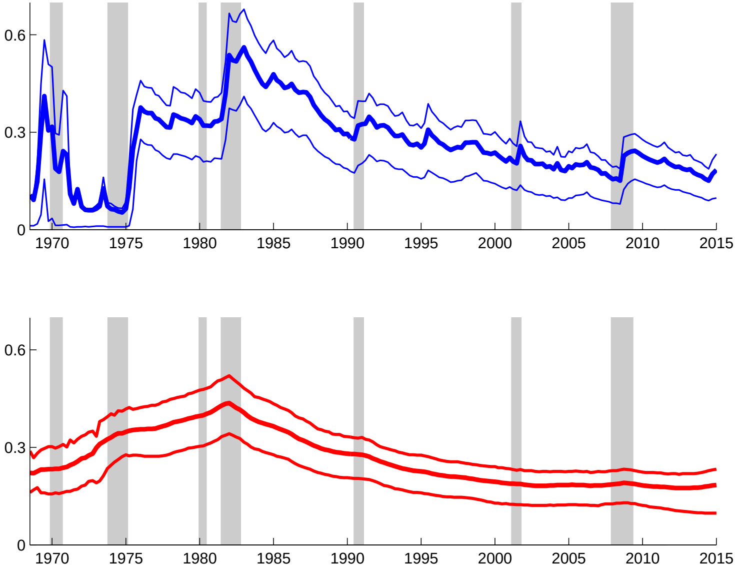


SPF AND TREND INFLATION

Five-steps ahead forecast (red), inflation (blue), SI trend (black)

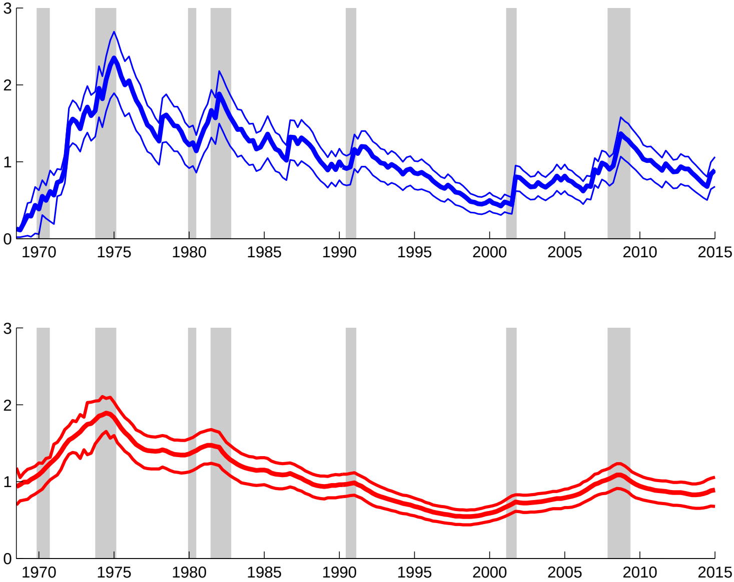


STOCHASTIC VOLATILITY IN TREND SHOCKS
top: filtered, bottom: smoothed



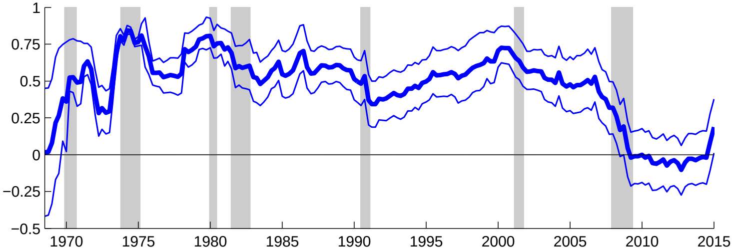
STOCHASTIC VOLATILITY IN GAP SHOCKS

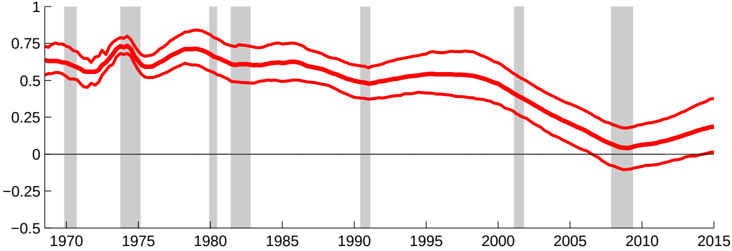
top: filtered, bottom: smoothed



GAP AR COEFFICIENT θ_t

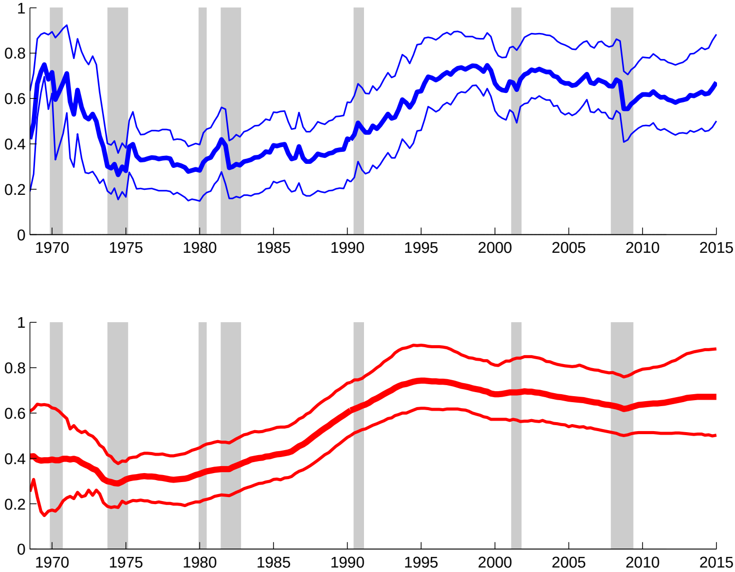
top: filtered, bottom: smoothed





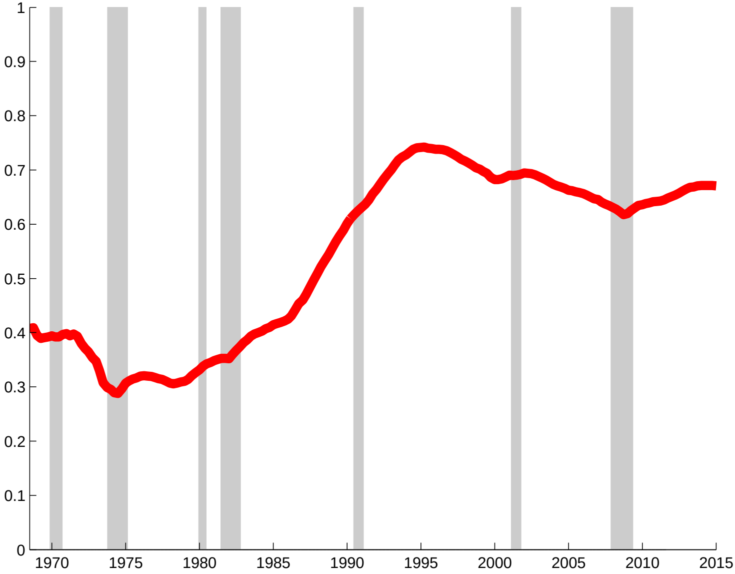
SI WEIGHT λ_t

top: filtered, bottom: smoothed



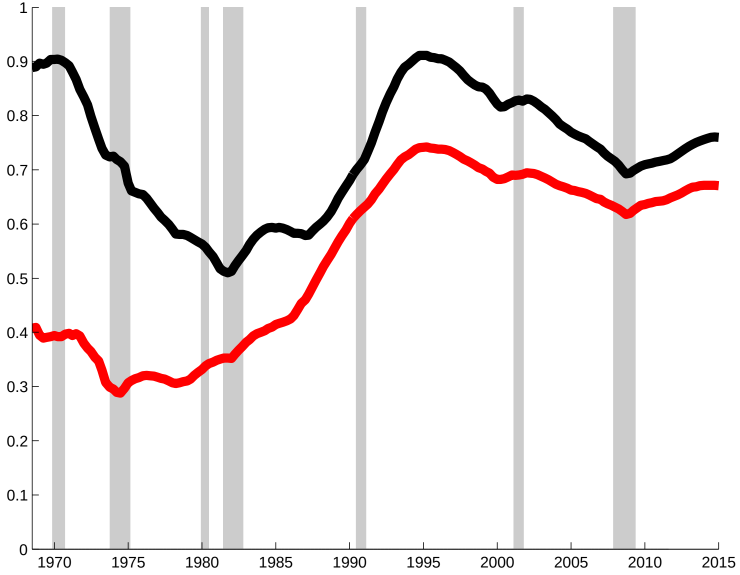
SI WEIGHT AND MODEL SPECIFICATION

λ_t: TVP-AR(1) in red



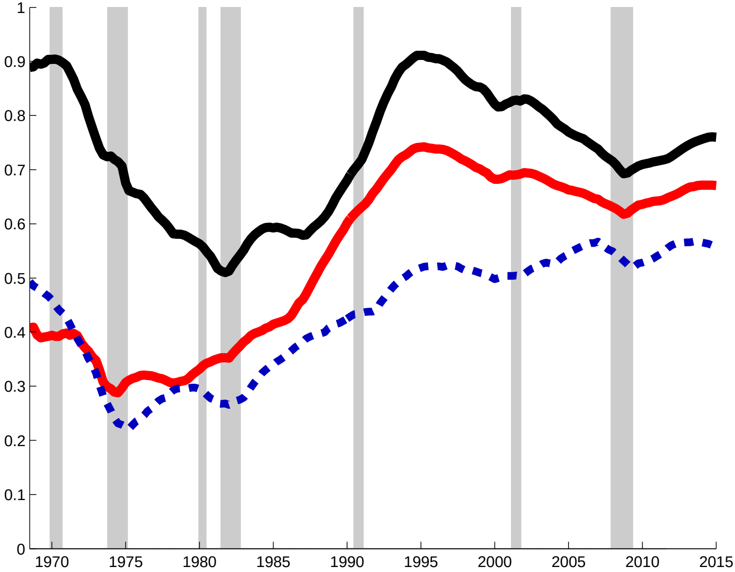
SI WEIGHT AND MODEL SPECIFICATION

λ_t: TVP-AR(1) in red, Const-AR with $\theta = 0$ in black



SI WEIGHT AND (ONE MINUS) INFLATION PERSISTENCE

Blue: IMA coefficient ψ_t from $\Delta\pi_t = (1 - \psi_t L)e_t$



QUESTIONS ...
and answers

1. **Does "stickiness" vary over time?**

   Yes! Surveys have been quite sticky over the last couple of decades, but they were much less sticky before the mid-1980s.

2. **How does "stickiness" interact with inflation?**

   Stickiness seems to rise with falling inflation persistence and decreasing trend volatility.

3. **Is "stickiness" related to monetary regimes?**

   For future research: Stickiness seems to coincide with "well anchored" inflation expectations.