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

Elmar Mertens [1] **James M. Nason** [2]

[1]Federal Reserve Board

[2]North Carolina State University

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

June 2016

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?

1) Stock-Watson-type UC model of inflation

2) Sticky/noisy information in survey forecasts

1) Stock-Watson-type UC model of inflation

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

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

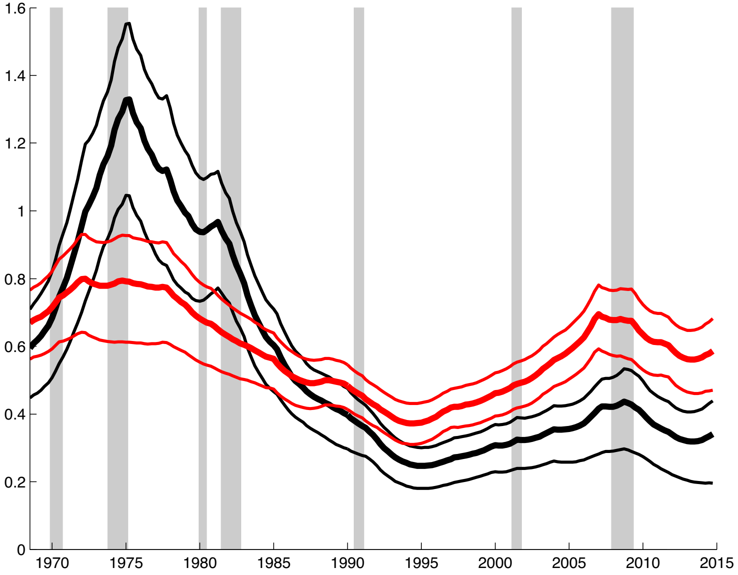
$$\varepsilon_t = \varsigma_{\nu,t-1}\ \nu_t$$

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

2) Sticky/noisy information in survey forecasts

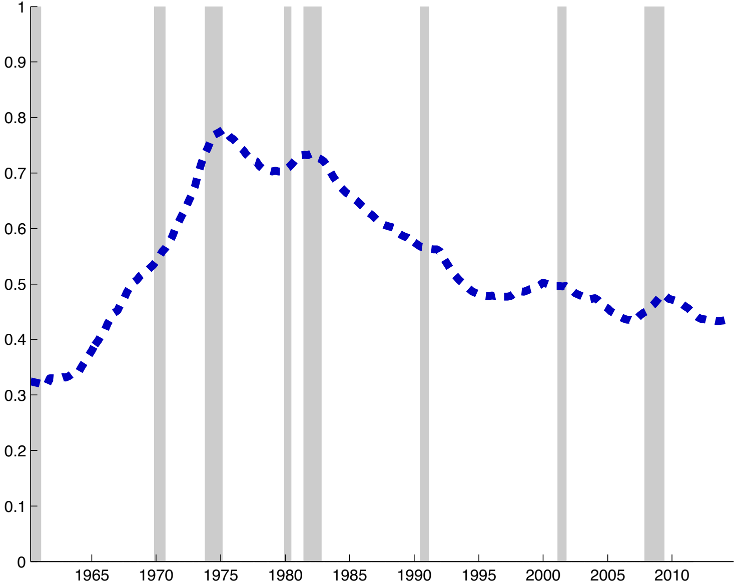
STOCK-WATSON SV ESTIMATES $\varsigma_{\cdot,t|T}$

Trend SV (black), Gap SV (red)



STOCK-WATSON INFLATION PERSISTENCE

Long-run response $\partial\pi_{t+\infty}/\partial e_t = K_t$



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

THIS PAPER

we combine . . .

1) Stock-Watson-type UC model of inflation

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

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

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

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

2) Sticky/noisy information in survey forecasts

1) Stock-Watson-type UC model of inflation

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

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

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

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

2) Sticky/noisy information in survey forecasts

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

STICKY SURVEY FORECASTS
constant SI weight

SI Law of Motion

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

SI Law of Motion

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

Coibion & Gorodnichenko (2015, AER):

"SI" law of motion consistent with ...

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

SI Law of Motion

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

Coibion & Gorodnichenko (2015, AER):

"SI" law of motion consistent with ...

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

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
NEW: time-varying SI weight

SI Law of Motion

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

Coibion & Gorodnichenko (2015, AER):

"SI" law of motion consistent with . . .

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

Implication: Persistent forecast errors

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

1) Stock-Watson-type UC model of inflation

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

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

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

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

2) Sticky/noisy information in survey forecasts

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

... and add new time-varying parameters

1) Stock-Watson-type UC model of inflation

$$\pi_t = \tau_t + \varepsilon_t$$
$$\tau_t = \tau_{t-1} + \varsigma_{\eta,t-1}\,\eta_t$$
$$\varepsilon_t = \theta_{t-1}\,\varepsilon_{t-1} + \varsigma_{\nu,t-1}\,\nu_t$$

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

2) Sticky/noisy information in survey forecasts

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

. . . and add new time-varying parameters

$$\lambda_t = \lambda_{t-1} + \sigma_\lambda\,\zeta_{\lambda,t} \qquad 0 \leq \lambda_t \leq 1$$
$$\theta_t = \theta_{t-1} + \sigma_\theta\,\zeta_{\theta,t} \qquad |\theta_t| \leq 1$$

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?

RELATED LITERATURE

Surveys and fundamentals

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

Inflation models

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

Particle filtering / learning / smoothing

Creal (2012), Shephard (2013), Herbst & Schorfheide (2015), Storvik (2002), Carvalho, Johannes, Lopes, Polsen (2010), Lindsten, Bunch, Särkkä, Schön, and Godsill (2015)

OUR CONTRIBUTIONS AND MAIN RESULT

Our contributions

- Joint state space for inflation and surveys that nests RE and SI
- Multivariate trend cycle decomposition for inflation with time-varying gap persistence
- Particle learning and smoothing combined with Rao-Blackwellization
- Expand on univariate regression results of Coibion and Gorodnichenko (2015, AER)

Main result

Striking comovement between inflation persistence and stickiness of surveys

AGENDA

1. **Nonlinear State Space**
2. **Estimation Strategy**
3. **Results**

AGENDA

1. **Nonlinear State Space**
   - recursive law of motion for SI
   - state vector
   - measurement vector
2. **Estimation Strategy**
3. **Results**

AGENDA

1. **Nonlinear State Space**
   - recursive law of motion for SI
   - state vector
   - measurement vector
2. **Estimation Strategy**
3. **Results**

RECURSIVE SI LAW OF MOTION

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

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

$$\pi_t = \delta_x \, x_t$$

$$x_t = \Theta \, x_{t-1} + \Xi_{t-1} w_t$$

RECURSIVE SI LAW OF MOTION

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

UC model of inflation

$$x_t = \begin{bmatrix} \tau_t & \varepsilon_t \end{bmatrix}'$$

$$\pi_t = \delta_x \, x_t$$

$$x_t = \Theta \, x_{t-1} + \Xi_{t-1} w_t$$

SI forecasts

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

RECURSIVE SI LAW OF MOTION

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

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

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

$$x_t = \Theta \, x_{t-1} + \Xi_{t-1} w_t$$

SI forecasts

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

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

RECURSIVE SI LAW OF MOTION

consider the case of a constant-parameter 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 LAW OF MOTION

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

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

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

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

SI forecasts

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

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

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

Recursive SI representation

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

TVP-GAP PERSISTENCE AND ANTICIPATED UTILITY

UC model with TVP transition

$$\pi_t = \delta_x x_t$$
$$x_t = \Theta_{t-1}\, x_{t-1} + \Xi_{t-1} w_t$$

Anticipated utility approximations

$$E_t x_{t+h} \approx \Theta_t^h\, x_t$$
$$F_t x_{t+h} \approx \Theta_t^h\, F_t x_t$$
$$F_t x_t \approx (1 - \lambda_{t-1}) x_t + \lambda_{t-1} \Theta_{t-1}\, F_{t-1} x_{t-1}$$

Inflation expectations and forecasts

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

AGENDA

1. **Nonlinear State Space**
   - recursive law of motion for SI
   - state vector
   - measurement vector
2. **Estimation Strategy**
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 $\mathcal{V}_t$

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

SI STATE VECTOR

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

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

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

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

SI STATE VECTOR

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

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

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

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

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

AGENDA

1. **Nonlinear State Space**
   - recursive law of motion for SI
   - state vector
   - measurement vector
2. **Estimation Strategy**
3. **Results**

DATA AND MEASUREMENT VECTOR

Measurement Vector

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

Data

- Real-time measure of realized inflation π_t^*
- SPF surveys for GDP/GNP deflator 1968:Q4 – 2016:Q1
- Forecast horizons up to one year out
- Surveys collected mid-quarter t, treated as $F_{t-1}(\cdot)$

DATA AND MEASUREMENT VECTOR

Measurement Vector

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

Data

- Real-time measure of realized inflation π_t^*
- SPF surveys for GDP/GNP deflator 1968:Q4 – 2016:Q1
- Forecast horizons up to one year out
- **Surveys collected mid-quarter t, treated as $F_{t-1}(\cdot)$**

AGENDA

1. Nonlinear State Space
2. **Estimation Strategy**
3. Results

ESTIMATION STRATEGY

Nonlinear state space with conditional linearity

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

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

ESTIMATION STRATEGY

Nonlinear state space with conditional linearity

$$\text{Data:} \quad \mathcal{Y}_t \sim p\left(\mathcal{Y}_t | \mathcal{S}_t, \mathcal{V}_t; \Psi\right)$$

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

$$\mathcal{V}_t \sim p\left(\mathcal{V}_t | \mathcal{V}_{t-1}; \Psi\right)$$

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

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)

Think of including $\Psi^{(i)}$ in particle swarm, next to $\mathcal{V}_t^{(i)}$, $\mathcal{S}_{t|t}^{(i)}$, ...

Storvik's (2002) idea: track swarm of posteriors

$$\Psi^{(i)} \sim p(\Psi | \mathcal{Y}^t, \mathcal{V}^{t,(i)})$$

- Characterize posteriors by sufficient statistics $s_t^{(i)}$
- Embedded into "particle learning" by Carvalho et al.

Requires analytic posteriors, available in our case

Consider the prior for $\sigma_\lambda^2 = \text{Var}\,(\lambda_t - \lambda_{t-1})$

$$\left(\sigma_\lambda^2\right)^{(i)} \Big| \mathcal{V}_{t-1}^{(i)} \sim IG\left(s_{t-1}^{(i)}\right)$$

$$s_{t-1}^{(i)} = \left[\alpha_{t-1}^{(i)}, \quad \beta_{t-1}^{(i)}, \quad \ldots\right]$$

Think of including $\Psi^{(i)}$ in particle swarm, next to $\mathcal{V}_t^{(i)}$, $\mathcal{S}_{t|t}^{(i)}$, ...

Storvik's (2002) idea: track swarm of posteriors

$$\Psi^{(i)} \sim p(\Psi|\mathcal{Y}^t, \mathcal{V}^{t,(i)})$$

- Characterize posteriors by sufficient statistics $s_t^{(i)}$
- Embedded into "particle learning" by Carvalho et al.

Requires analytic posteriors, available in our case

Consider the posterior for $\sigma_\lambda^2 = \mathrm{Var}\left(\lambda_t - \lambda_{t-1}\right)$

$$\left(\sigma_\lambda^2\right)^{(i)} \Big| \left(\mathcal{V}_t^{(i)}, \mathcal{V}_{t-1}^{(i)}\right) \sim IG\left(s_t^{(i)}\right)$$

$$s_t^{(i)} = \left[\alpha_{t-1}^{(i)} + \frac{1}{2}, \;\; \beta_{t-1}^{(i)} + \frac{1}{2} \cdot \left(\lambda_t^{(i)} - \lambda_{t-1}^{(i)}\right)^2, \;\; \ldots\right]$$

AGENDA

1. Nonlinear State Space
2. Estimation Strategy
3. **Results**

SETUP

- Joint UC-SI state space
- TVP-AR(1) in inflation gap
- GDP/GNP deflator, real time 1968:Q3 – 2015:Q4
- SPF for $h = 1, \ldots, 5$
- Estimated with particle learning

AGENDA

1. Nonlinear State Space
2. Estimation Strategy
3. **Results**
   - Nowcast: RE vs SI
   - Inflation trend and gap
   - Signal embedded in the SPF
   - Non-linear inflation states
   - SI weight λ_t
   - [Scale Parameters]

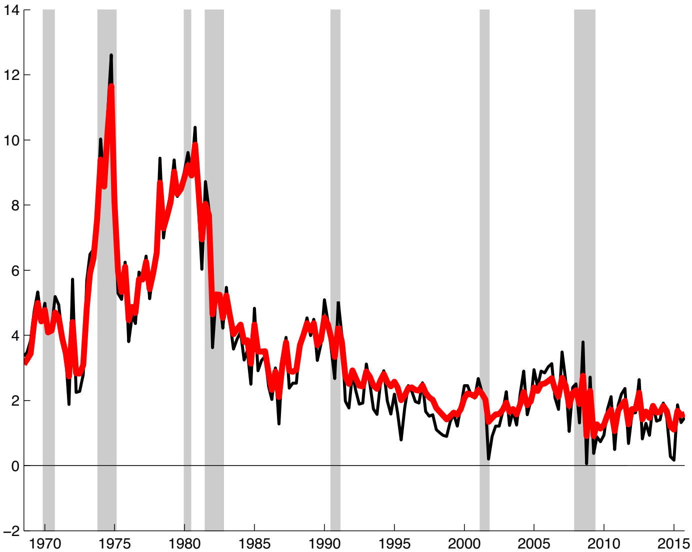
AGENDA

1. Nonlinear State Space
2. Estimation Strategy
3. Results
   - Nowcast: RE vs SI
   - Inflation trend and gap
   - Signal embedded in the SPF
   - Non-linear inflation states
   - SI weight λ_t
   - [Scale Parameters]

SI NOWCAST

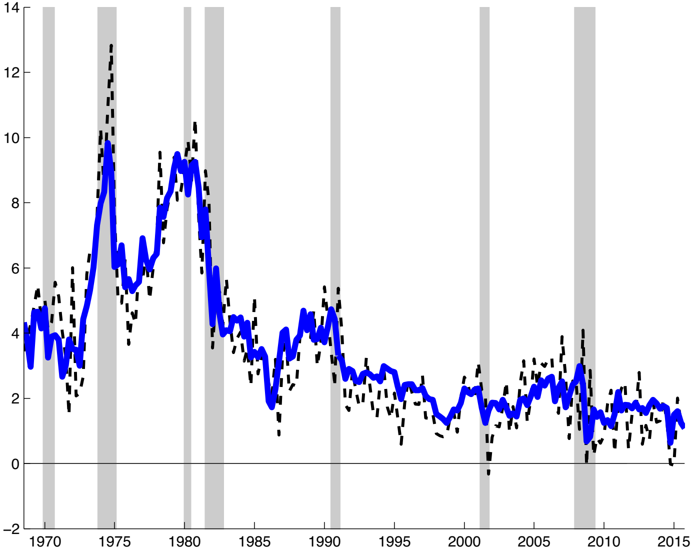
$F_t\pi_t$ (red), inflation π_t (black)

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



SPF NOWCAST AND DATA

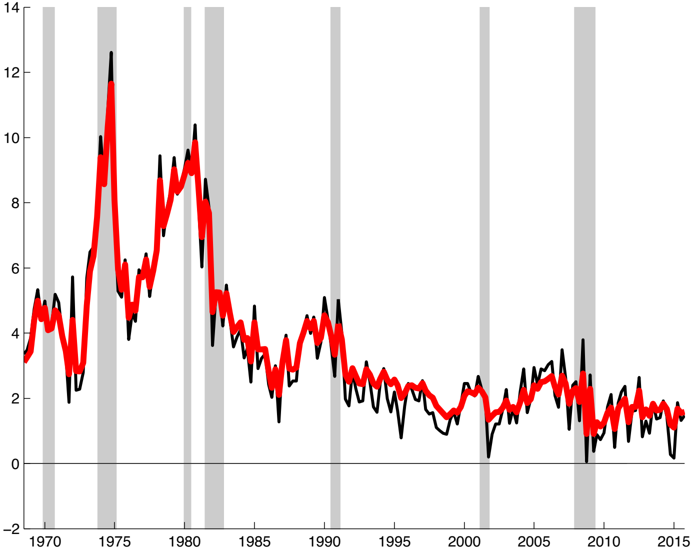
$\pi_{t,t}^{SPF}$ (blue), inflation π_t^* (black)



SI NOWCAST

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

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



EWMA TRENDS AND SI

Local-level trend is EWMA of π_t $E_{t-1}\varepsilon_t = 0$

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

where K_t is the Kalman gain for the trend

SI trend is EWMA of τ_t

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

SI nowcast is nearly an EWMA of π_t

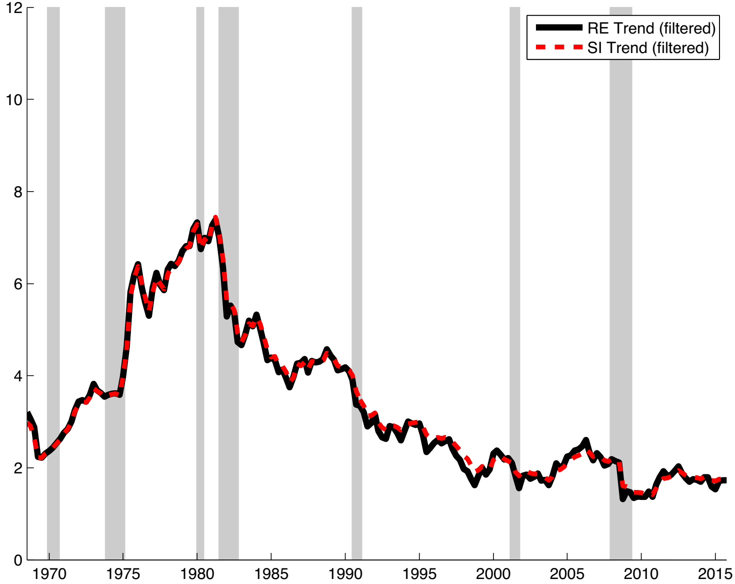
$$F_t\pi_t = (1 - \lambda_{t-1})\pi_t + \lambda_{t-1}F_{t-1}\pi_t$$

AGENDA

1. Nonlinear State Space
2. Estimation Strategy
3. Results
   - Nowcast: RE vs SI
   - Inflation trend and gap
   - Signal embedded in the SPF
   - Non-linear inflation states
   - SI weight λ_t
   - [Scale Parameters]

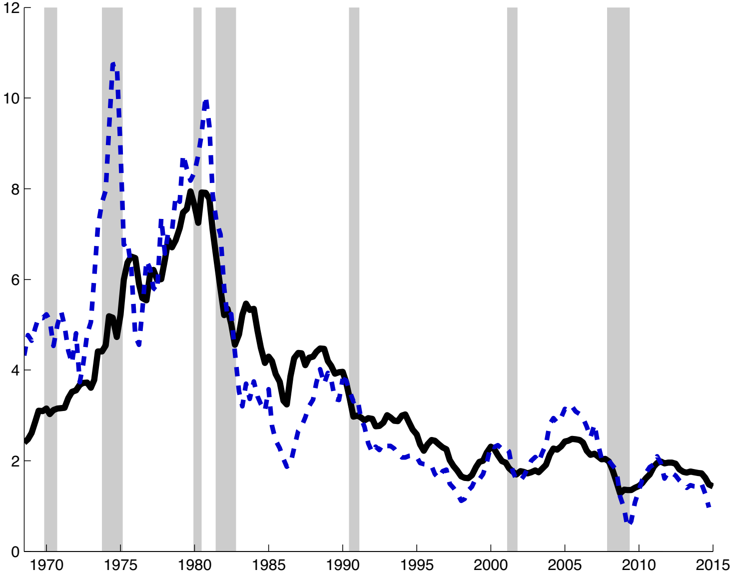
TREND INFLATION

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



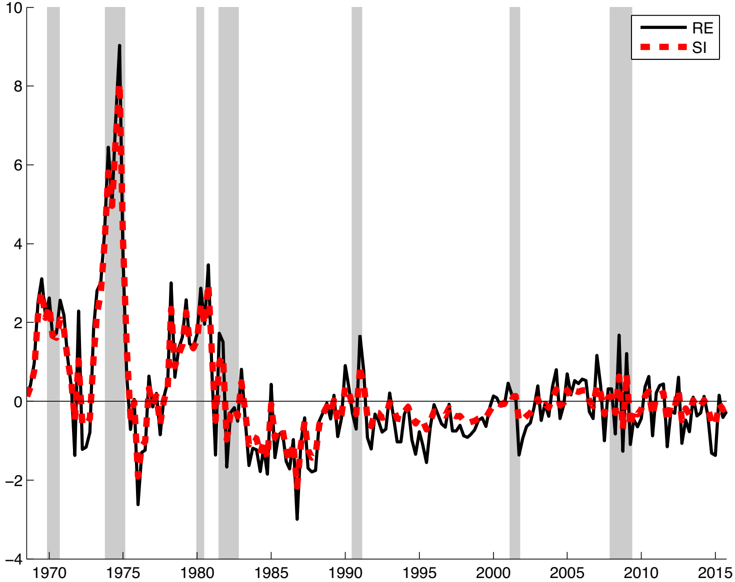
TREND INFLATION: UC-SI VS UC

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



INFLATION GAP

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

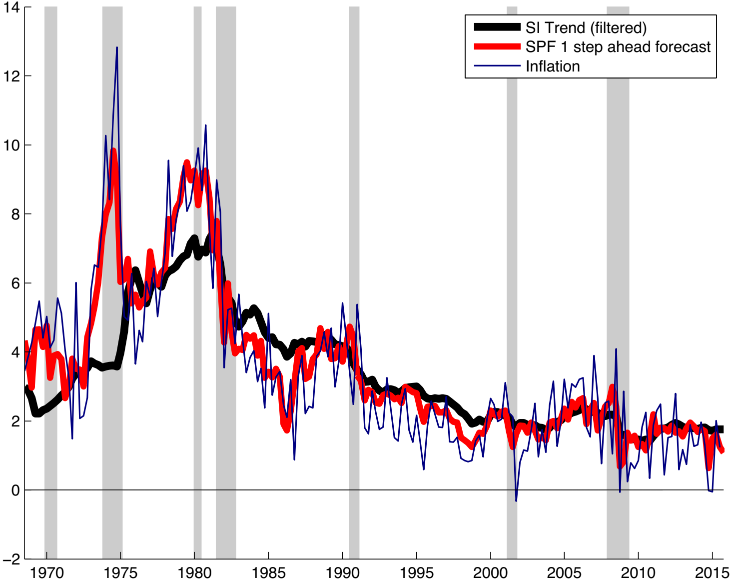


AGENDA

1. Nonlinear State Space
2. Estimation Strategy
3. Results
   - Nowcast: RE vs SI
   - Inflation trend and gap
   - Signal embedded in the SPF
   - Non-linear inflation states
   - SI weight λ_t
   - [Scale Parameters]

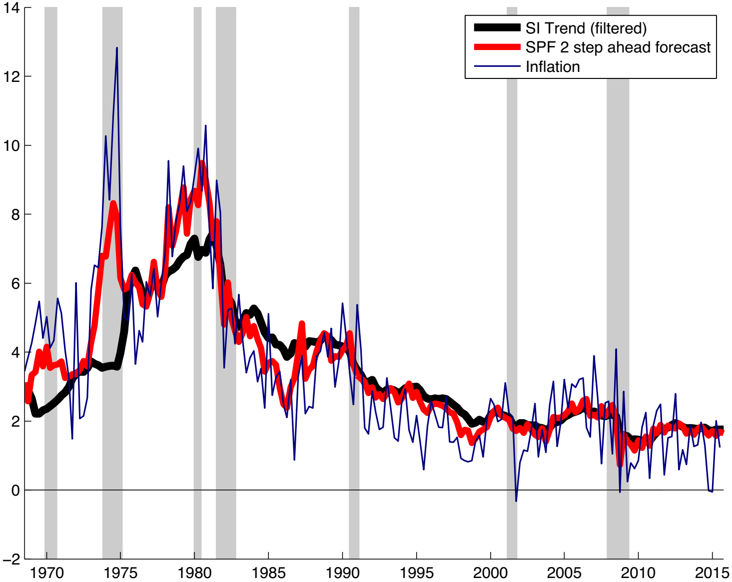
SPF AND TREND INFLATION

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



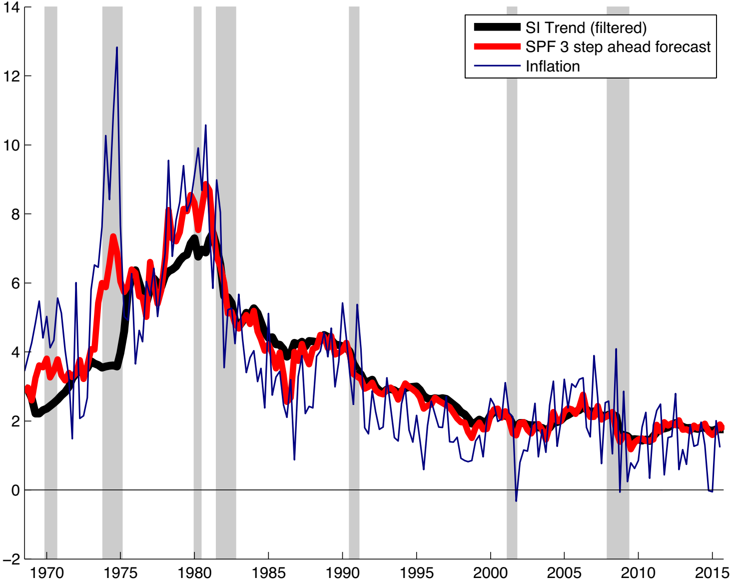
SPF AND TREND INFLATION

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



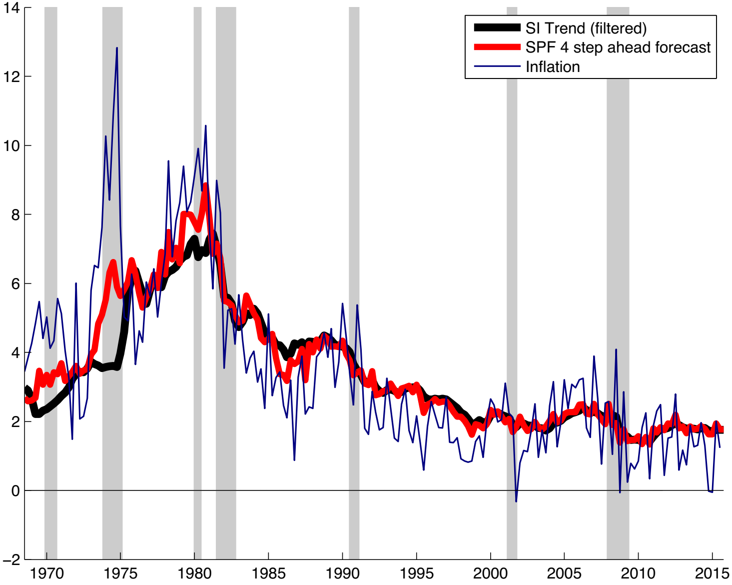
SPF AND TREND INFLATION

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



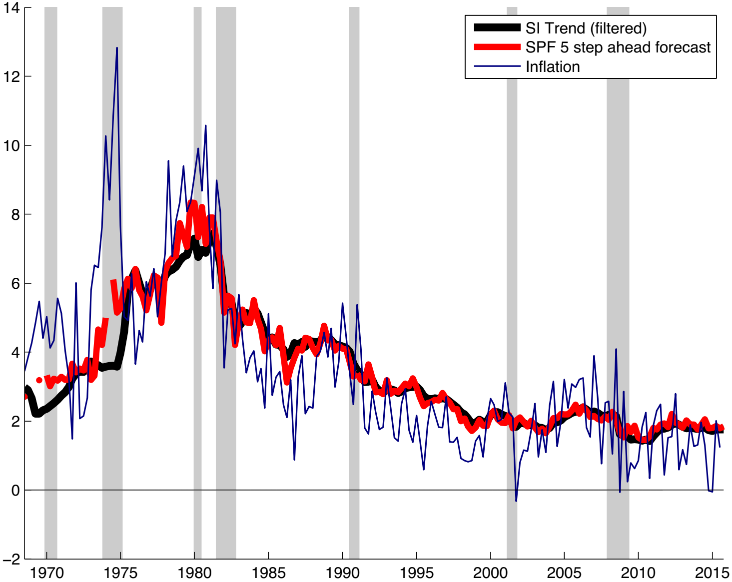
SPF AND TREND INFLATION

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



SPF AND TREND INFLATION

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

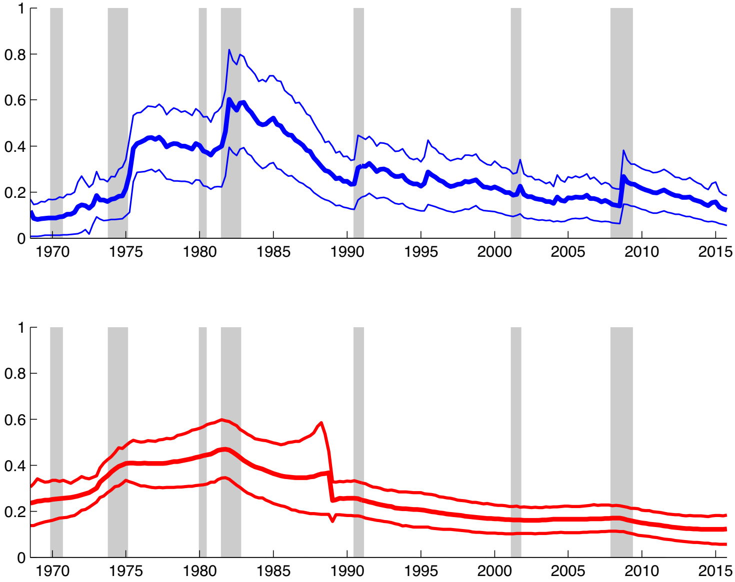


AGENDA

1. Nonlinear State Space
2. Estimation Strategy
3. Results
   - Nowcast: RE vs SI
   - Inflation trend and gap
   - Signal embedded in the SPF
   - Non-linear inflation states
   - SI weight λ_t
   - [Scale Parameters]

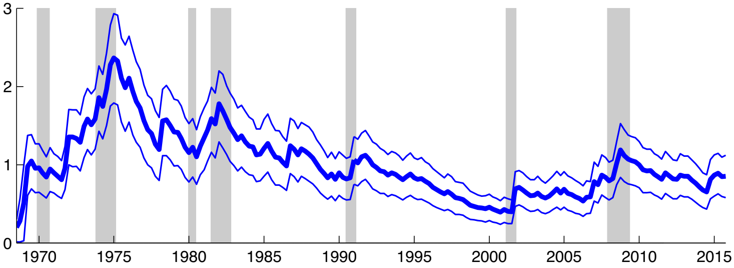
STOCHASTIC VOLATILITY IN TREND SHOCKS

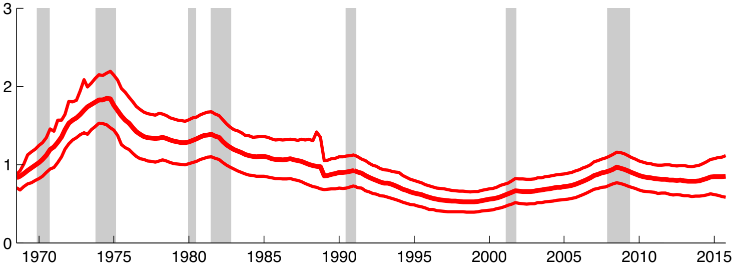
top: filtered, bottom: smoothed



STOCHASTIC VOLATILITY IN GAP SHOCKS

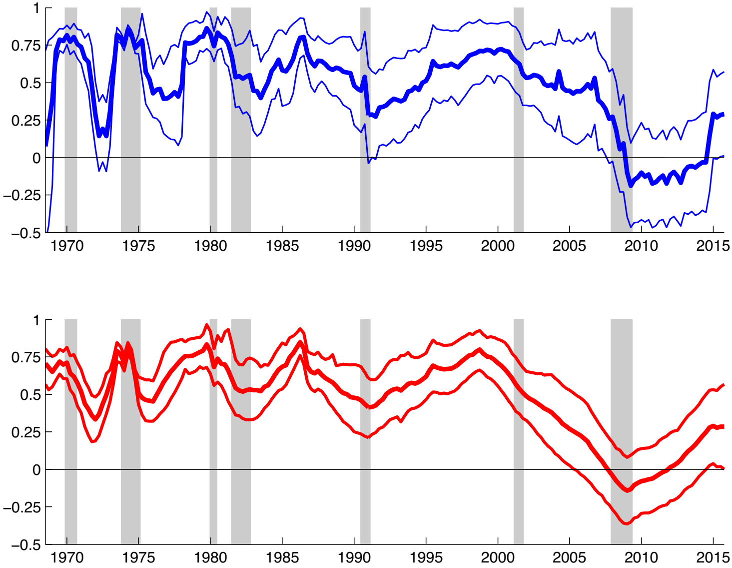
top: filtered, bottom: smoothed





GAP AR COEFFICIENT θ_t

top: filtered, bottom: smoothed

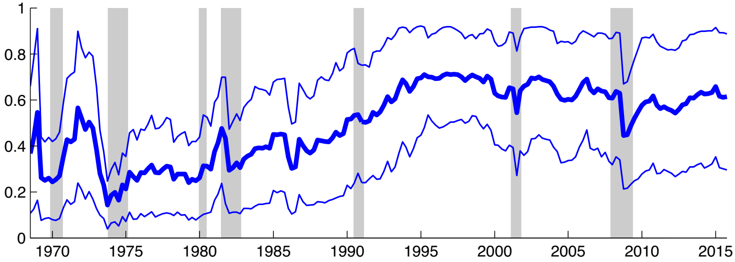


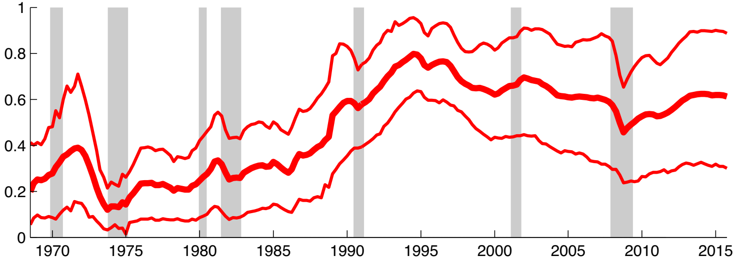
AGENDA

1. Nonlinear State Space
2. Estimation Strategy
3. **Results**
   - Nowcast: RE vs SI
   - Inflation trend and gap
   - Signal embedded in the SPF
   - Non-linear inflation states
   - SI weight λ_t
   - [Scale Parameters]

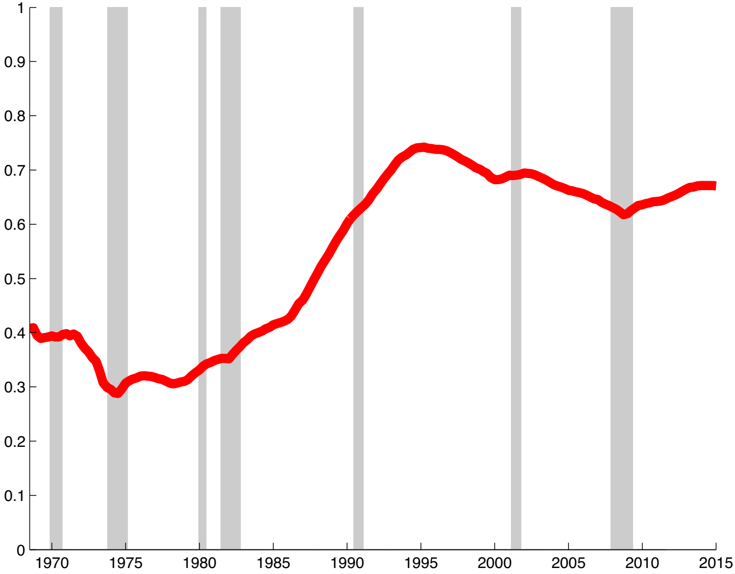
SI WEIGHT λ_t

top: filtered, bottom: smoothed



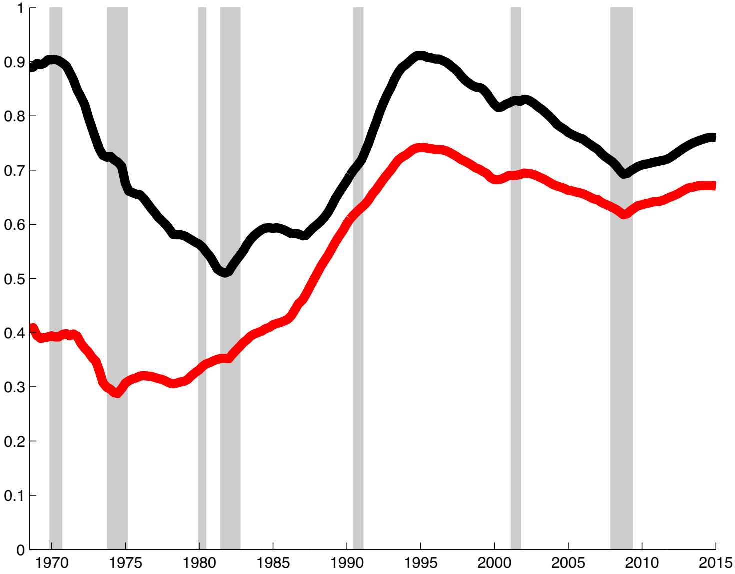


SI WEIGHT AND MODEL SPECIFICATION
λ_t: TVP-AR(1) in red



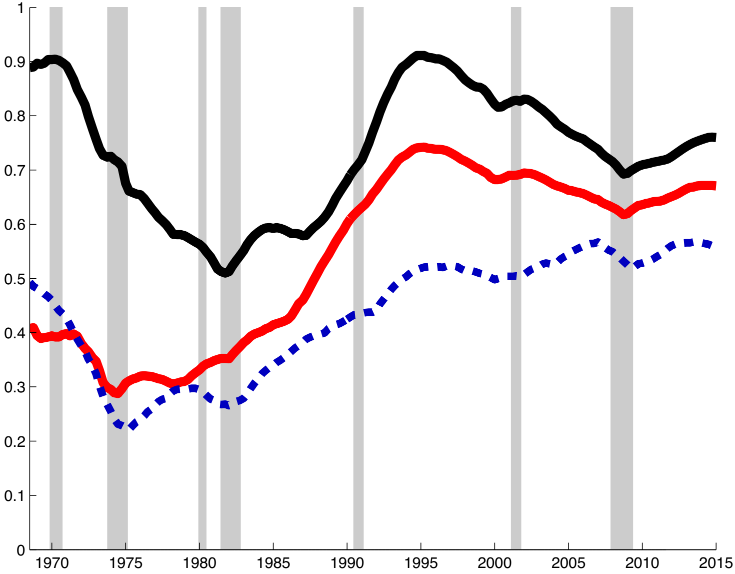
SI WEIGHT AND MODEL SPECIFICATION

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 $\Delta\pi_t = (1 - \psi_t L)e_t$

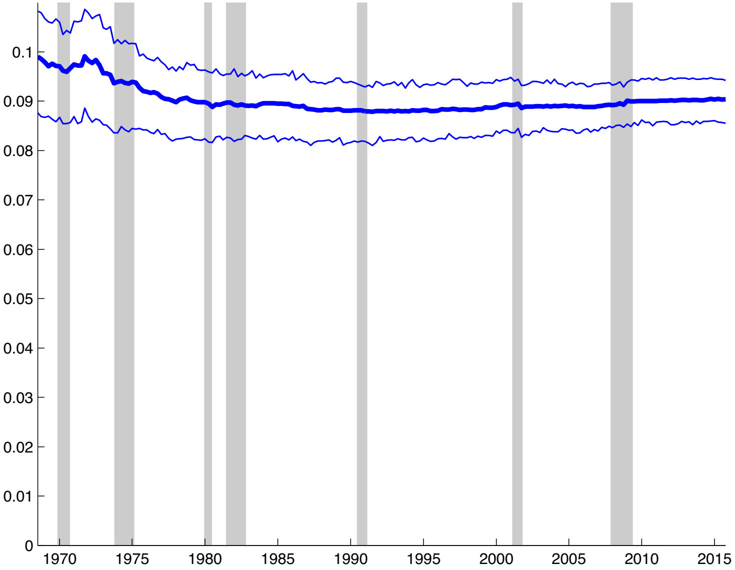


AGENDA

1. Nonlinear State Space
2. Estimation Strategy
3. Results
   - Nowcast: RE vs SI
   - Inflation trend and gap
   - Signal embedded in the SPF
   - Non-linear inflation states
   - SI weight λ_t
   - [Scale Parameters]

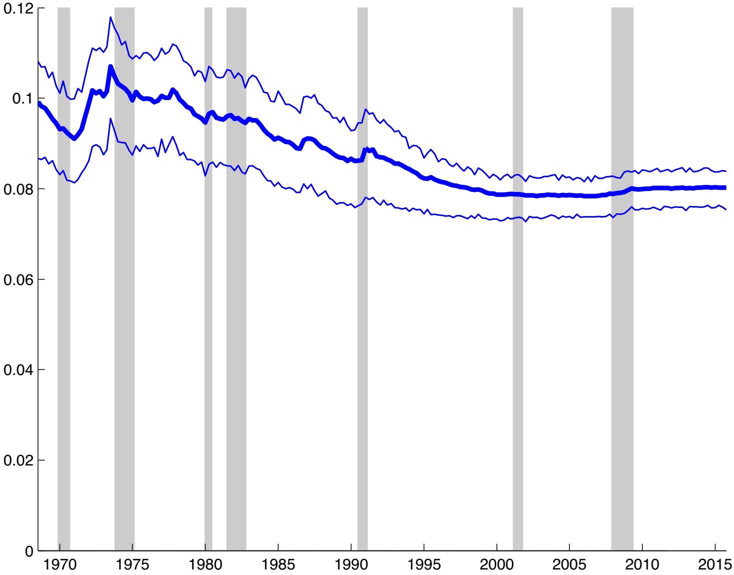
VOLATILITY OF λ_t SHOCKS

Estimates of time-invariant parameter, updated with particle learning



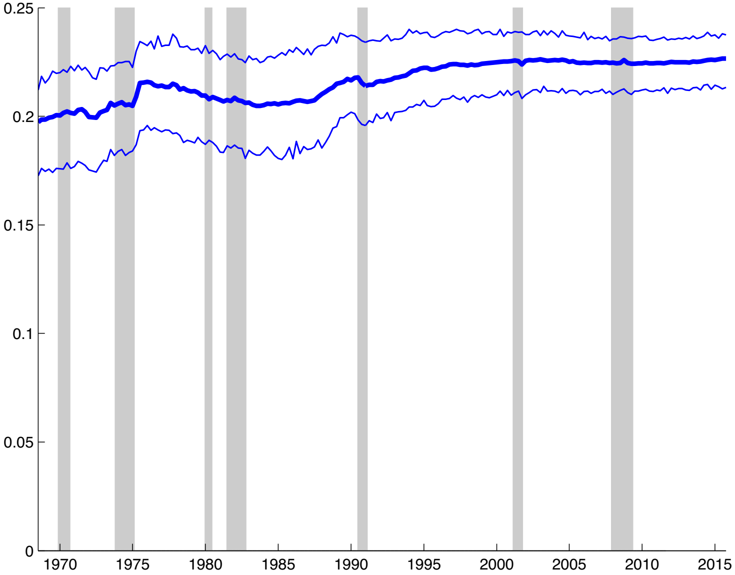
VOLATILITY OF θ_t SHOCKS

Estimates of time-invariant parameter, updated with particle learning



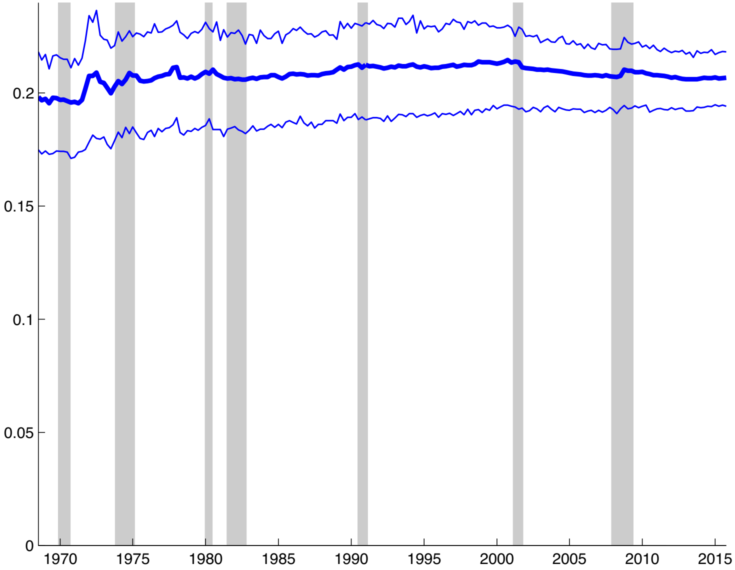
VOLATILITY OF SHOCKS TO TREND LOG-VARIANCE

Estimates of time-invariant parameter, updated with particle learning



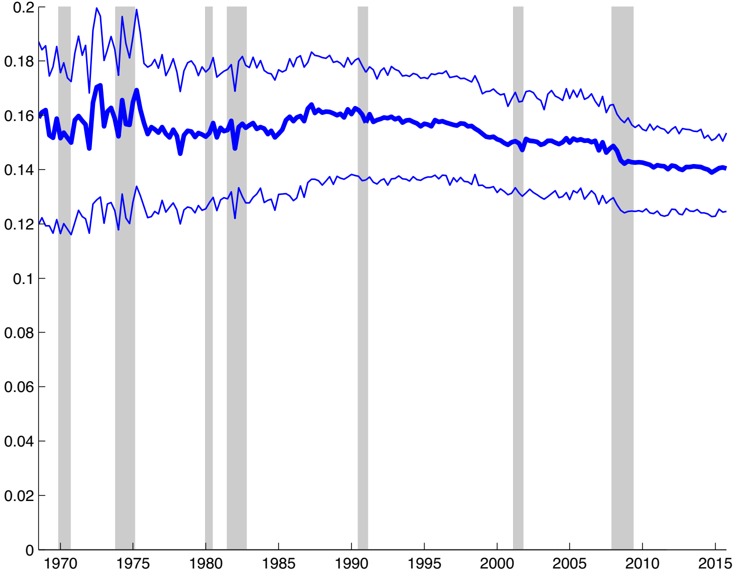
VOLATILITY OF SHOCKS TO GAP LOG-VARIANCE

Estimates of time-invariant parameter, updated with particle learning



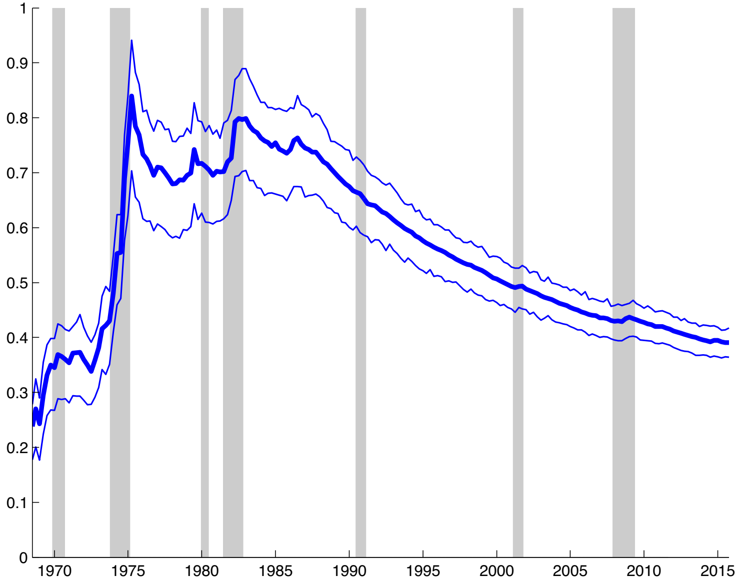
MEASUREMENT ERROR VARIANCE: INFLATION

Estimates of time-invariant parameter, updated with particle learning



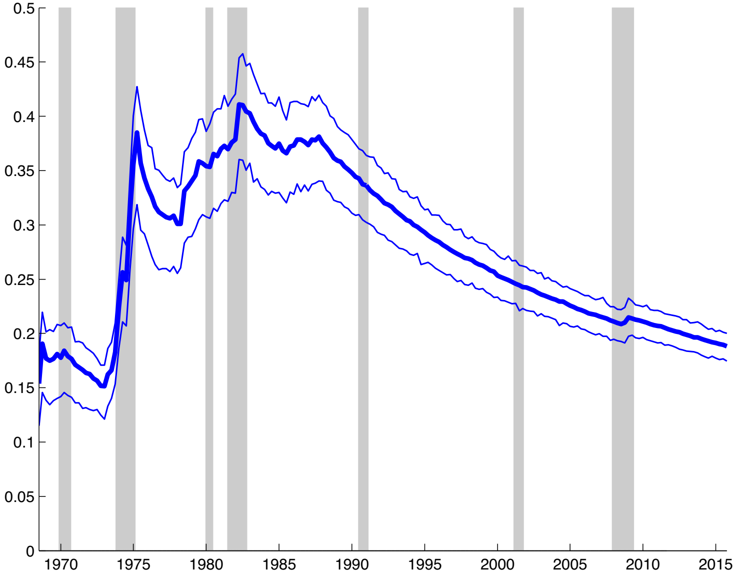
MEASUREMENT ERROR VARIANCE: SPF-NOWCAST

Estimates of time-invariant parameter, updated with particle learning



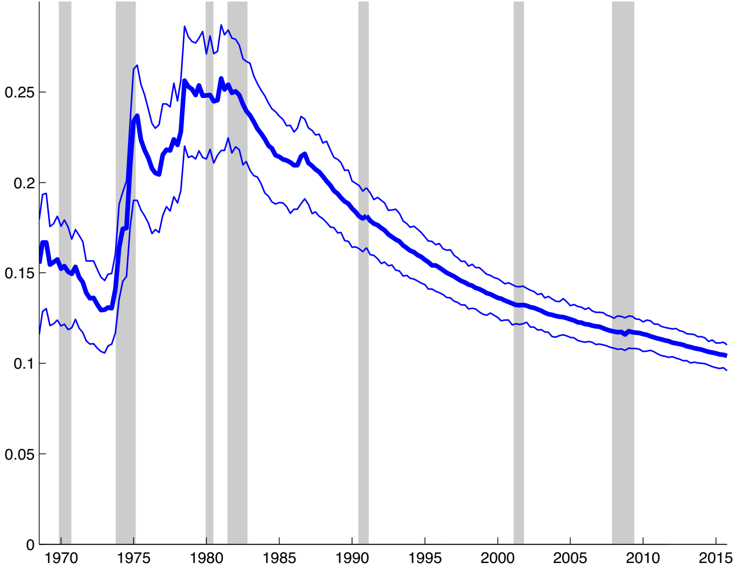
MEASUREMENT ERROR VARIANCE: SPF-Q1

Estimates of time-invariant parameter, updated with particle learning



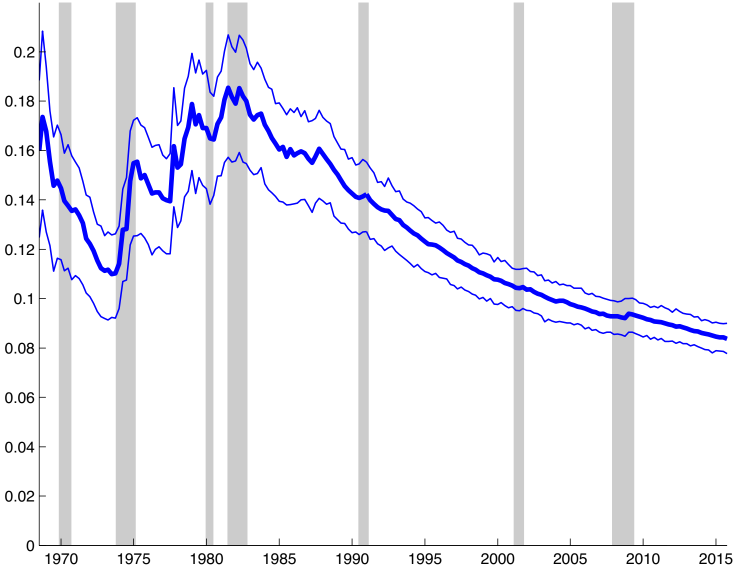
MEASUREMENT ERROR VARIANCE: SPF-Q2

Estimates of time-invariant parameter, updated with particle learning



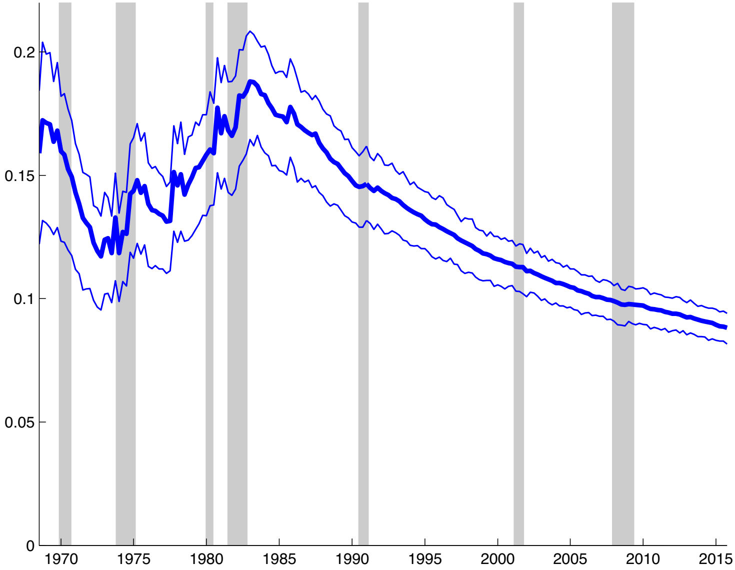
MEASUREMENT ERROR VARIANCE: SPF-Q3

Estimates of time-invariant parameter, updated with particle learning



MEASUREMENT ERROR VARIANCE: SPF-Q4

Estimates of time-invariant parameter, updated with particle learning



FOOD FOR THOUGHT

- Surveys have been sticky over the last couple of decades
- Sticky surveys should not be discarded:
  they are (at least) informative about the trend
- Still, trend inflation should lead the survey trend
  (which could be ominous given inflation data seen in recent years)
- For future work: Sequencing of transition of persistence and stickiness from one "regime" to another

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.

OUR CONTRIBUTIONS AND MAIN RESULT

Our contributions

- Joint state space for inflation and surveys that nests RE and SI
- Multivariate trend cycle decomposition for inflation with time-varying gap persistence
- Particle learning and smoothing combined with Rao-Blackwellization
- Expand on univariate regression results of Coibion and Gorodnichenko (2015, AER)

Main result

Striking comovement between inflation persistence and stickiness of surveys