Long-run inflation expectations

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Long-run inflation expectations by professional forecasters

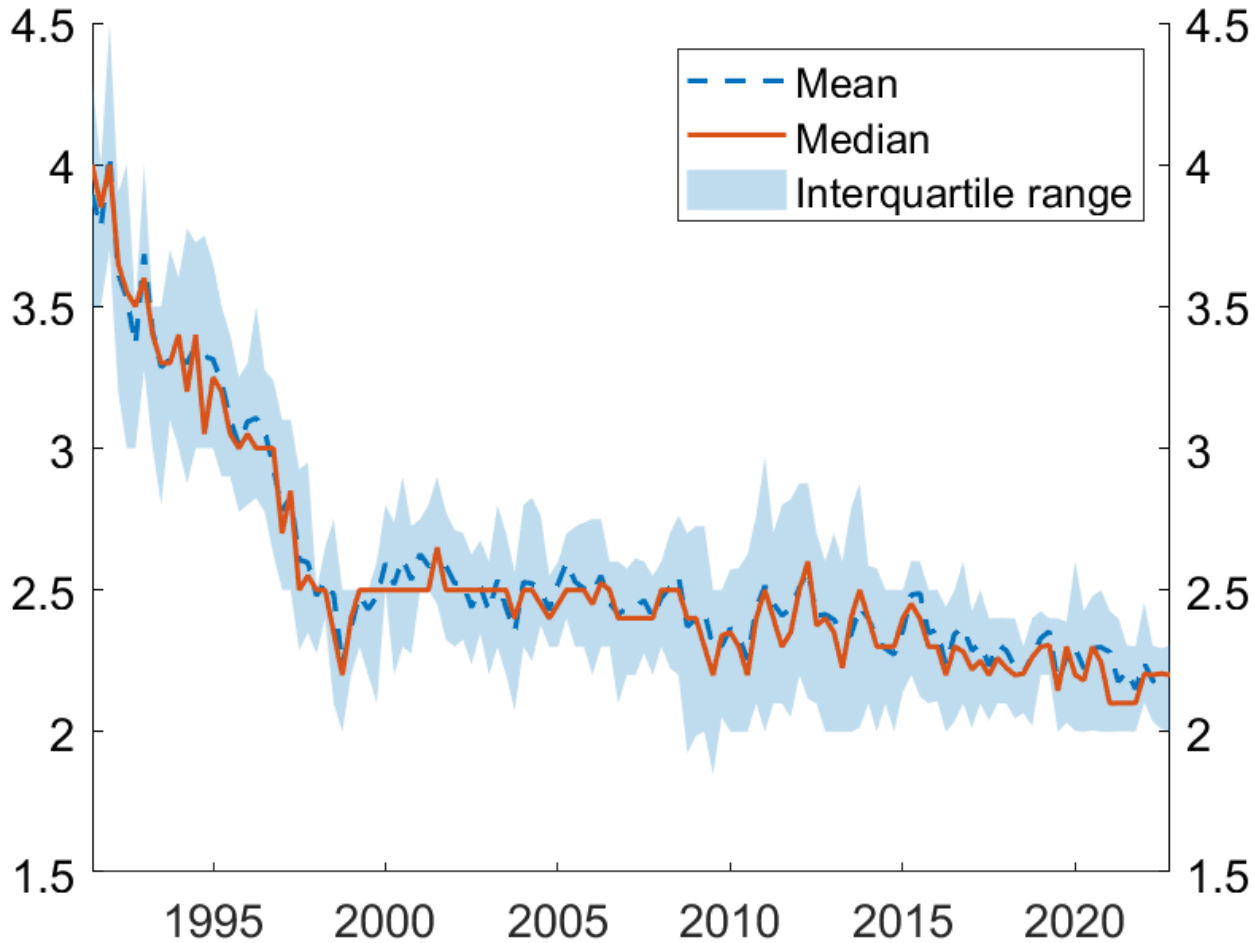

Figure: Long-run CPI inflation expectations, US SPF (1991q4-2023q1)

10Y SPF selection

Looking behind average expectations

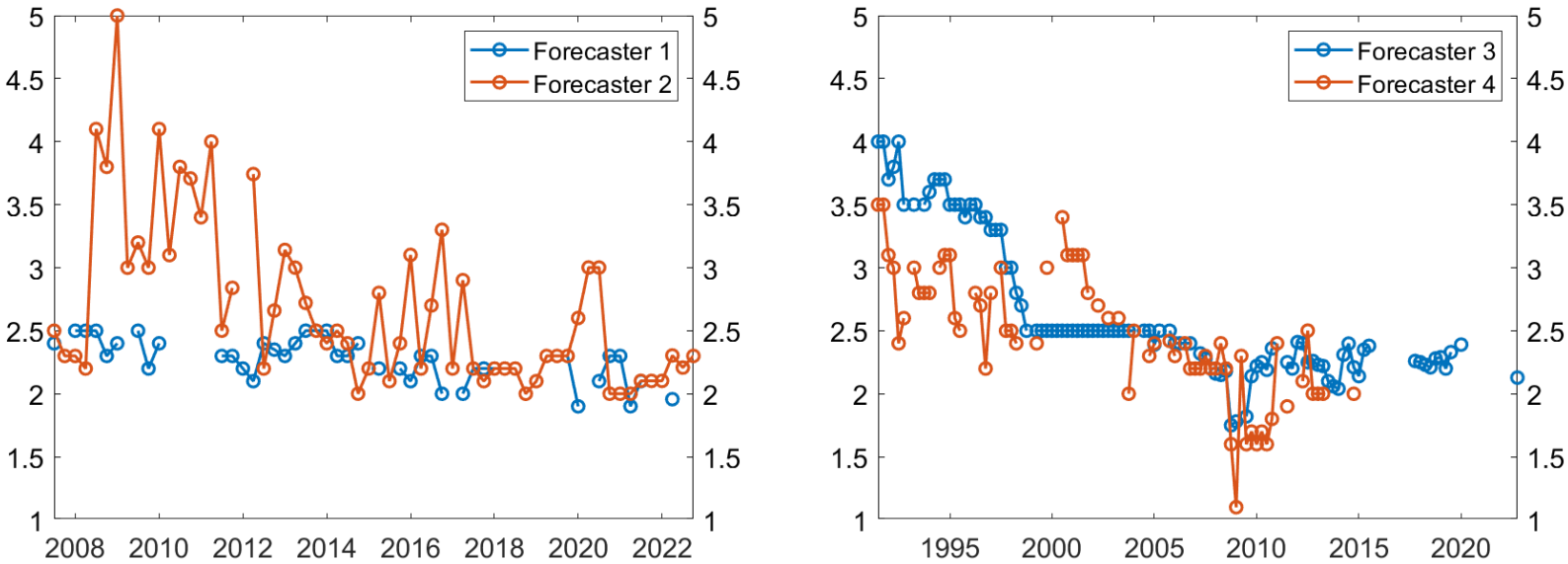

Figure: Long-run inflation expectations by selected forecasters

- Highly heterogeneous patterns $\rightarrow$ wealth of information in the cross-section

This paper

- Model to understand fluctuations in **individual** expectations

  $\rightarrow$ implications for behavior of *average* expectations

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- **Trend-cycle model of inflation** with time-varying parameters
- Forecasters observe **three signals to track trend inflation**:
  1. **Inflation signal**: **trend** + **cycle** + **iid**
  2. **Common signal**: **trend** + **common sentiments**
  3. **Idiosyncratic signal**: **trend** + **idiosyncratic sentiments**

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  3. **Idiosyncratic signal**: **trend** + **idiosyncratic sentiments**
- **Likelihood estimation with SPF panel data to investigate**
  1. The **sensitivity** of expectations to the factors above
  2. What path of inflation is needed to **anchor** SPF expectations

Preview of main findings

1. **Low sensitivity** of expectations to **cyclical inflation**

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2. Information in the **cross-section is critical** to accurately estimate the **sensitivity of expectations**

3. **Coordination of beliefs** around inflation target preserved anchoring despite the low inflation after the Great Recession

4. Dec 2022 SEP inflation inconsistent with anchored expectations and little scope for coordinating beliefs

Related literature

The Model

Forecasting model

Forecasters form expectations believing inflation can be characterized by a **trend-cycle model**:

$$\begin{aligned} \pi_t &= \underbrace{\bar{\pi}_t}_{} + \underbrace{\varepsilon_t}_{} + \underbrace{\sigma_\omega \omega_t}_{} \\ \text{Inflation} &= \text{Trend} + \text{Cycle} + \text{IID} \end{aligned}$$

$$\begin{aligned} \text{Trend}: \quad \bar{\pi}_t &= \bar{\pi}_{t-1} + \sigma_{\lambda,t}\lambda_t \\ \text{Cycle}: \quad \varepsilon_t &= \phi_t \varepsilon_{t-1} + \sigma_{\eta,t}\eta_t \end{aligned}$$

Detailed model equations

Forecasters' information set

- Knowledge of the trend-cycle model
- History of inflation
- Three signals for each forecaster i:
  1. Inflation signal
  2. Common signal:

     $\bar{\pi}_t + \boldsymbol{\alpha(i)} v_{c,t}$ where $v_{c,t} = \rho_c v_{c,t-1} + \boldsymbol{\sigma_{c,t}} \nu_{c,t}, \quad \alpha(i) > 0$
  3. Idiosyncratic signal:

     $\bar{\pi}_t + v_t(i)$ where $v_t(i) = \boldsymbol{\rho(i)} v_{t-1}(i) + \boldsymbol{\sigma_v(i)} \nu_{v,t}(i)$

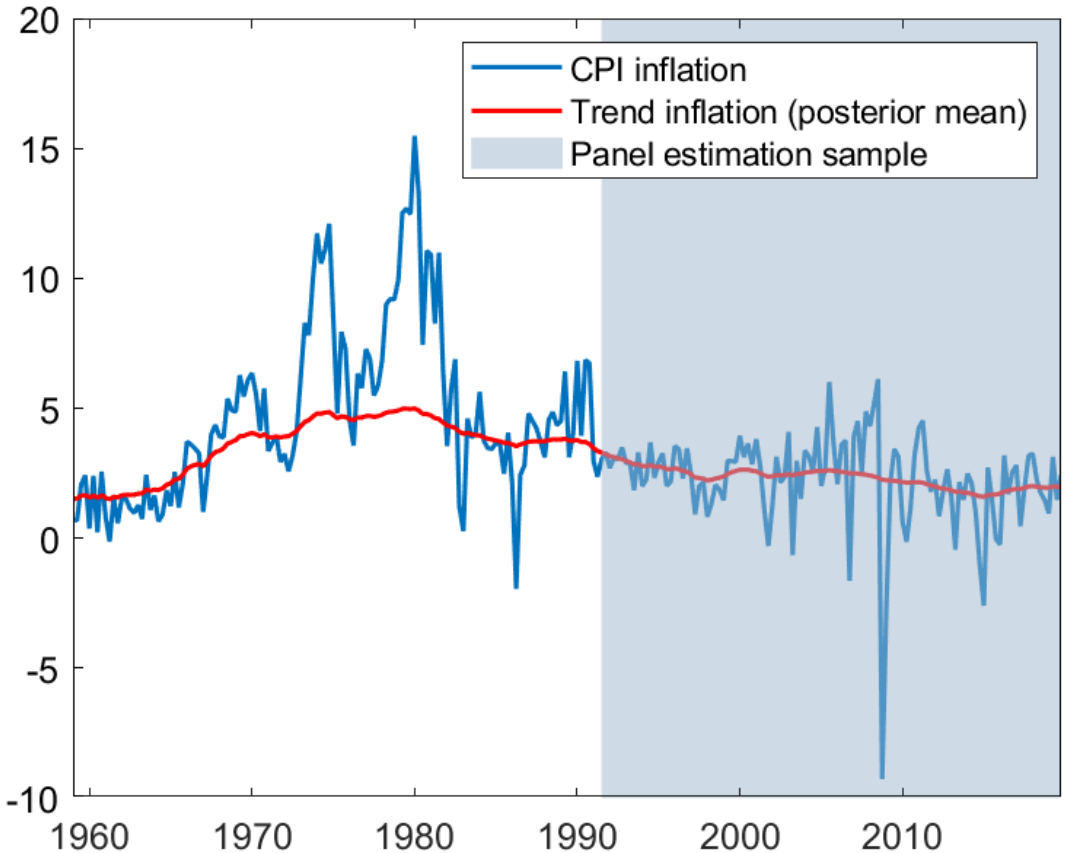
$\Rightarrow$ Forecasters solve a signal-extraction problem Details

Estimation

Two-step estimation

1. **Estimation of inflation model** Detailed model estimates

   - US CPI inflation
   - Sample: 1959Q1-2019Q4



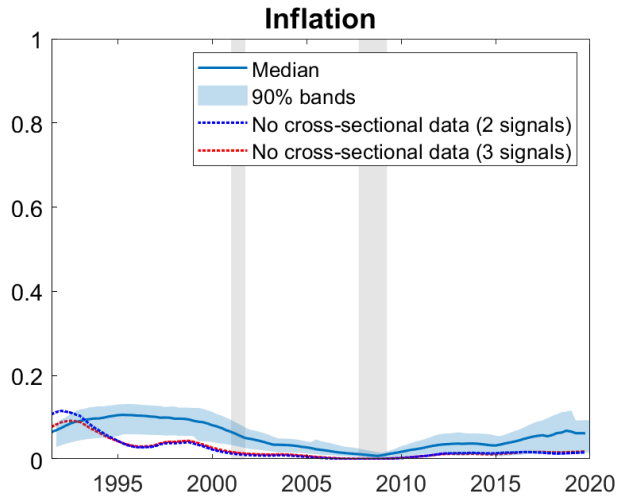
Two-step estimation

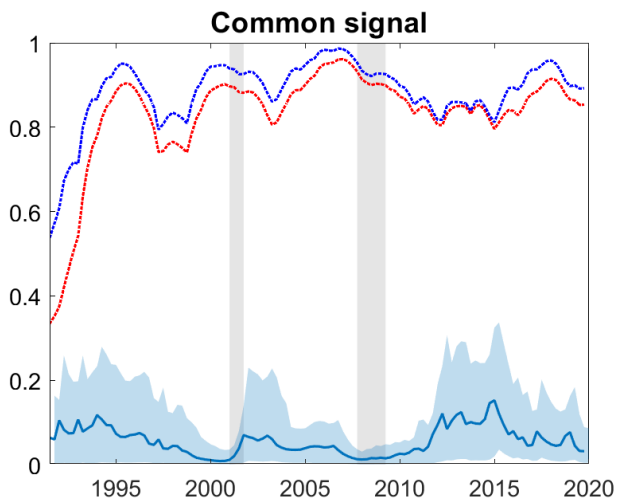
2. **Panel estimation of forecasters' signal-extraction model** given the estimated inflation model from Step 1 Details
   - US CPI inflation
   - estimated cyclical and trend component from Step 1
   - individual SPF long-run CPI inflation expectations

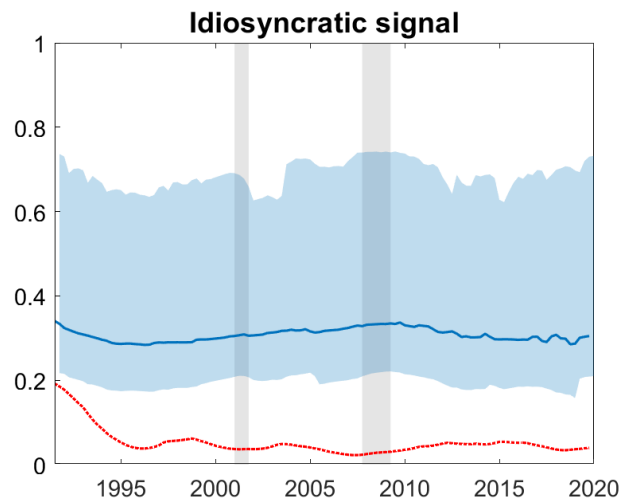
     Proxy: Details on SPF measure
     - until 2010q4: 10Y CPI inflation expectations
     - from 2011q1: 5Y5Y CPI inflation expectations
   - Sample: 1991Q3-2019Q4

Inflation expectations through the lens of the model

Expectations' sensitivity: importance of cross-section







- Information in the **cross-section** key to estimate accurately the sensitivity of SPF expectations IRFs

Historical drivers of long-term inflation expectations

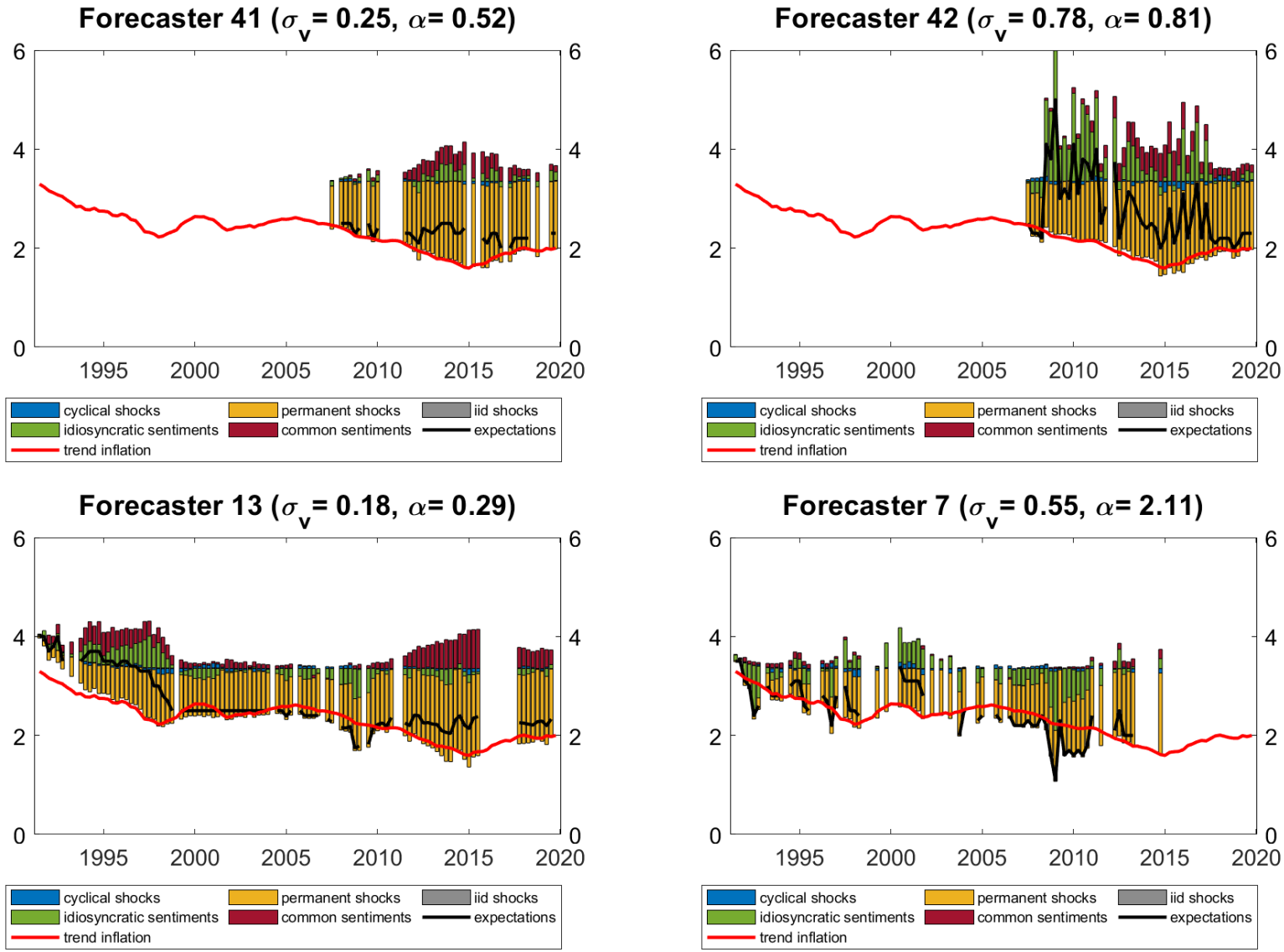


Figure: Historical decomposition of selected forecasters

Historical drivers of average inflation expectations

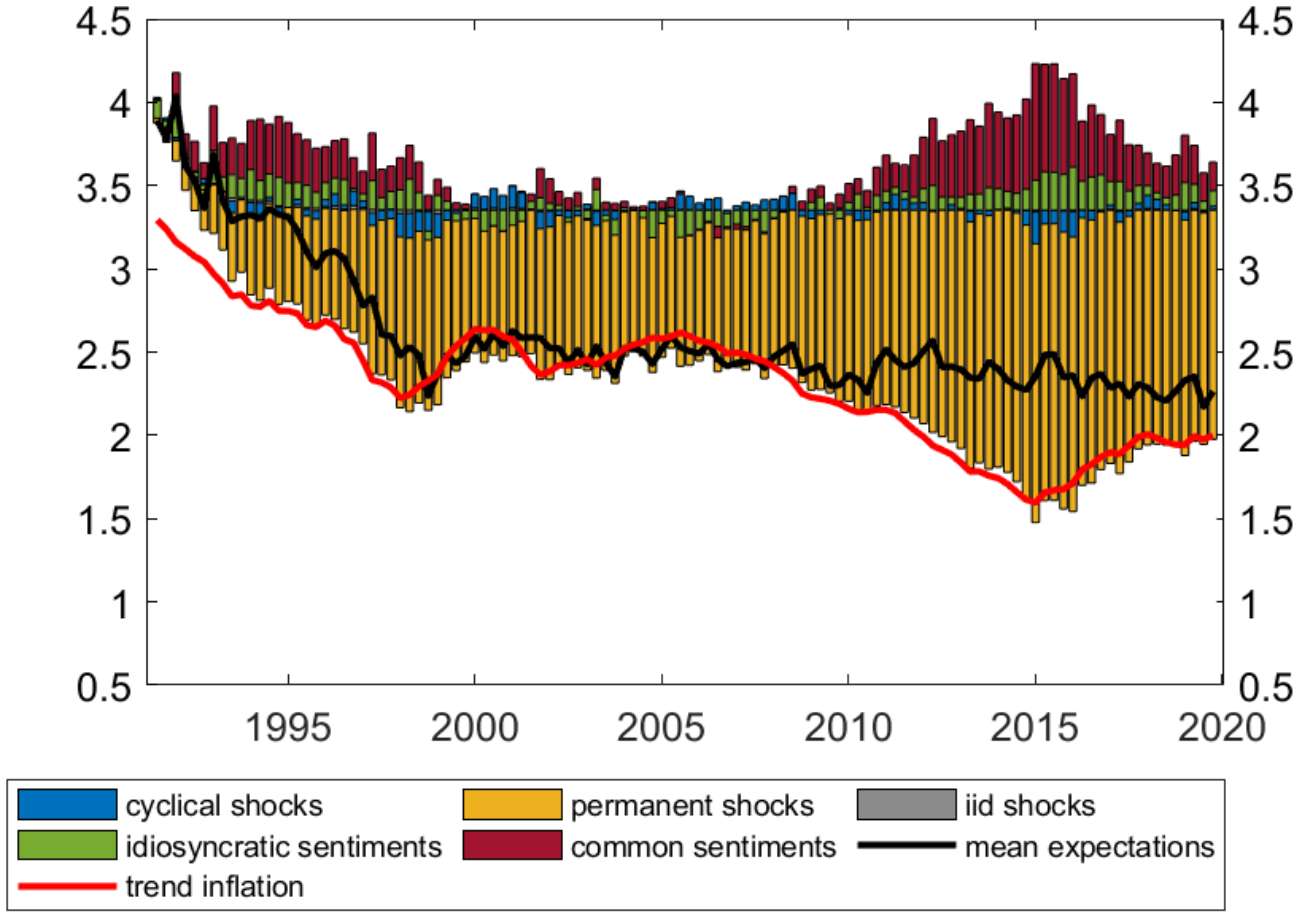


Figure: Historical decomposition of average inflation expectations

- Permanent shocks as primary driver of average expectations
- Coordination of beliefs as stabilization factor of expectations

Anchoring US Inflation Expectations

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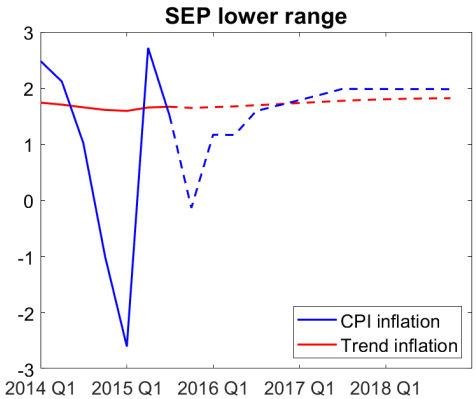
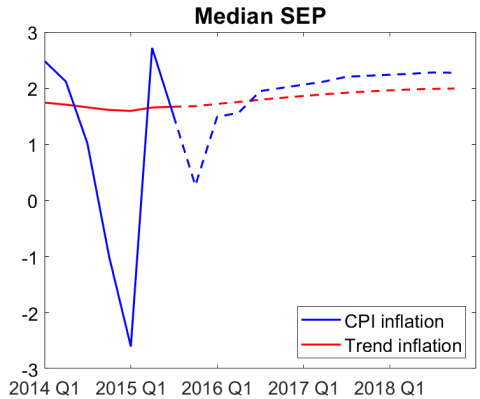
Idea: Will average long term inflation expectations be anchored going forward from any particular date and under what conditions?

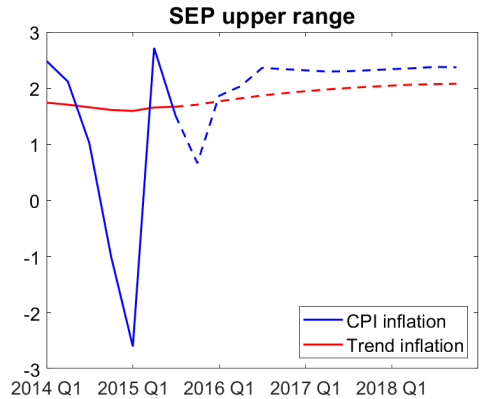
Counterfactual exercises:

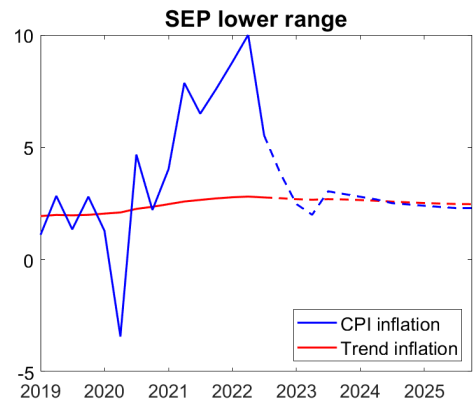
1. December 2015: Inflation persistently below target for years
2. December 2022: More than one year very high inflation

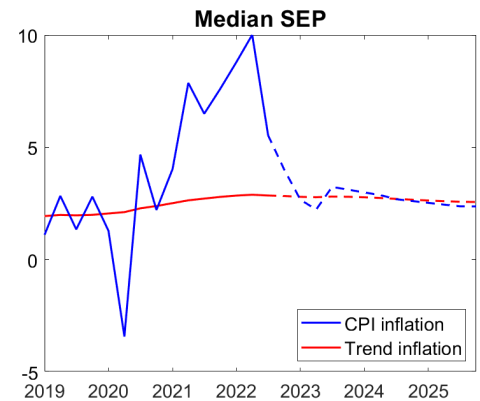
SEP inflation paths

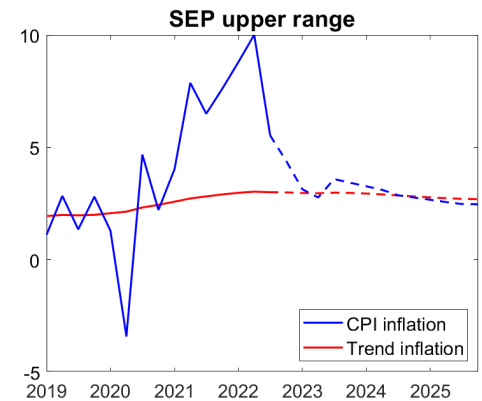








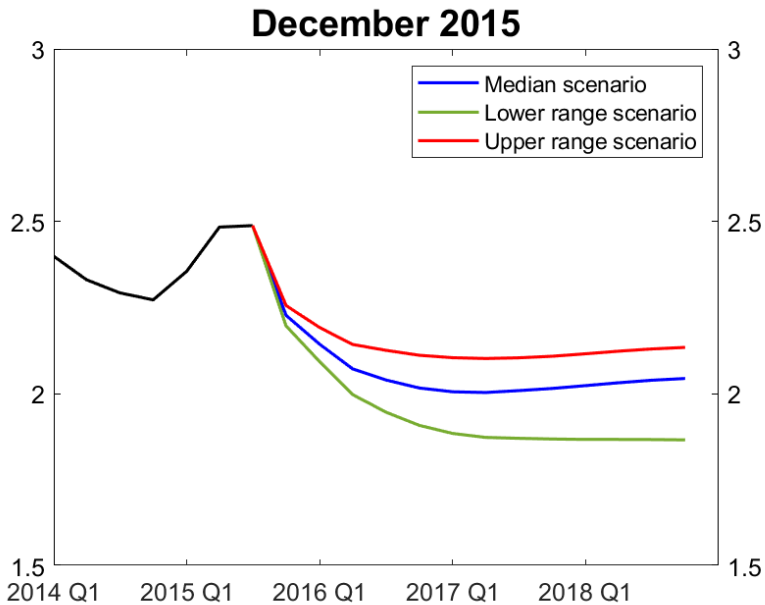


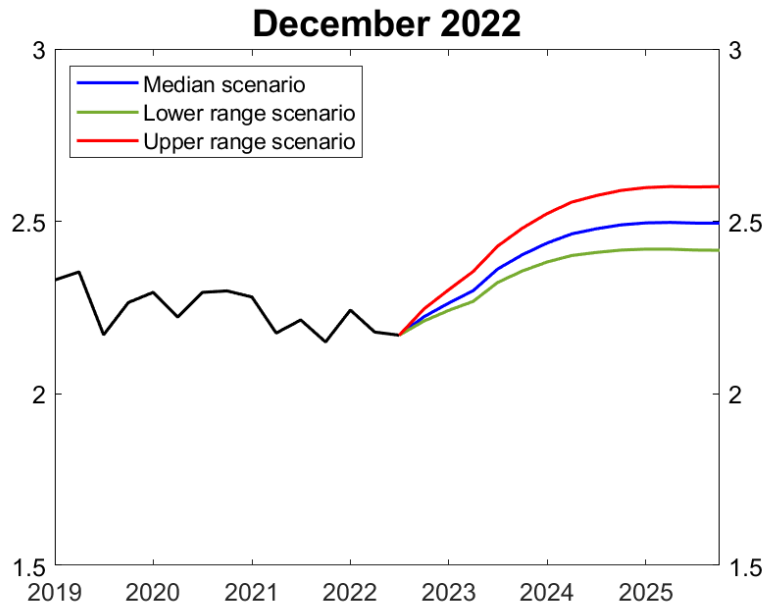


- For each of these SEP scenarios, we estimate trend inflation
- Ask the model to predict the path of average expectations

Extended sample estimation

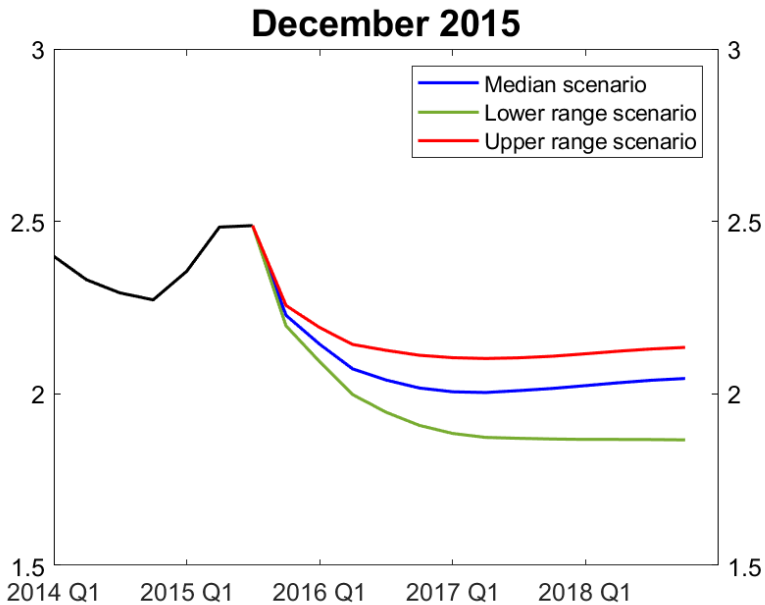
Expectations under SEP inflation paths

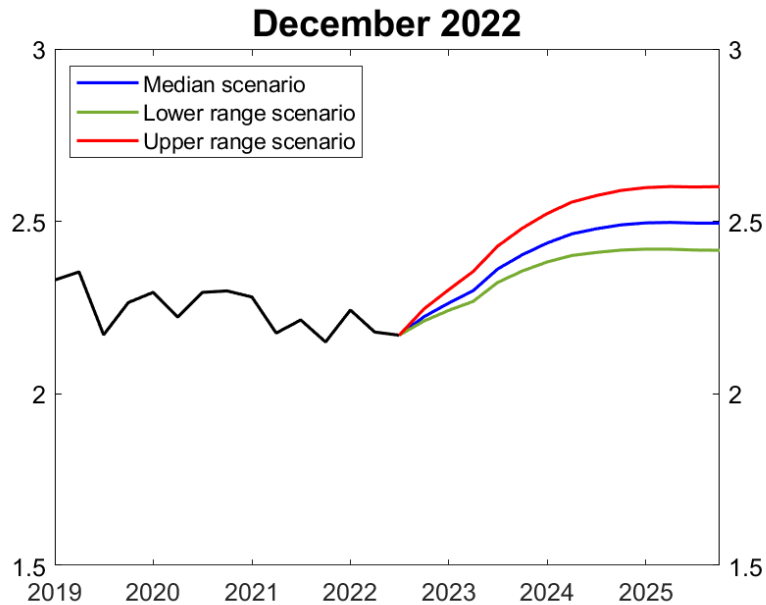




- Dec 15: SEP inflation paths too shallow $\Rightarrow$ anchoring fails
- Dec 22: SEP inflation paths inconsistent with anchoring

Expectations under SEP inflation paths





- Dec 15: SEP inflation paths too shallow $\Rightarrow$ anchoring fails
- Dec 22: SEP inflation paths inconsistent with anchoring in the absence of central bank's communications
- Caveat: no role for sentiment shocks

Keeping long-run expectations stable

1. Target a path of stable average expectations
2. Guess a path for trend inflation $\bar{\pi}_t$
3. Given the path of average expectations and trend inflation, we ask the model what path of inflation is consistent

   Assumption: Individual sentiments are set to zero
4. Estimate trend of the inflation path from 3. to verify the guess

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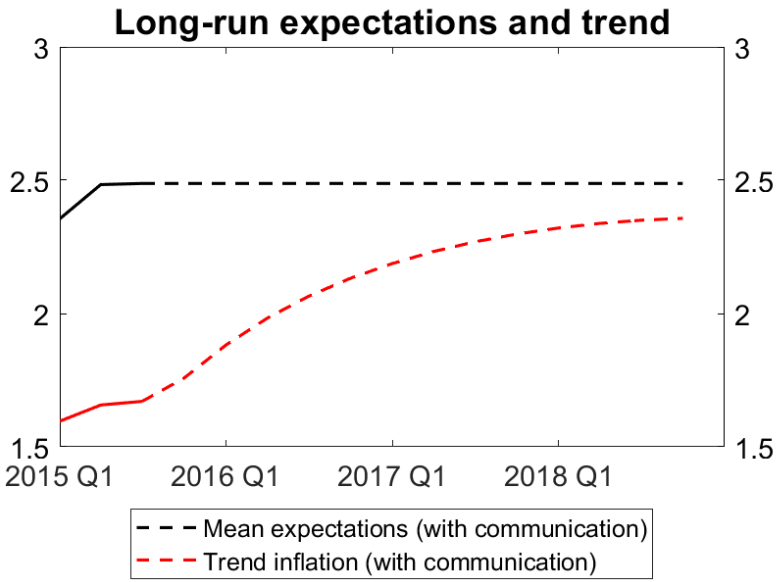
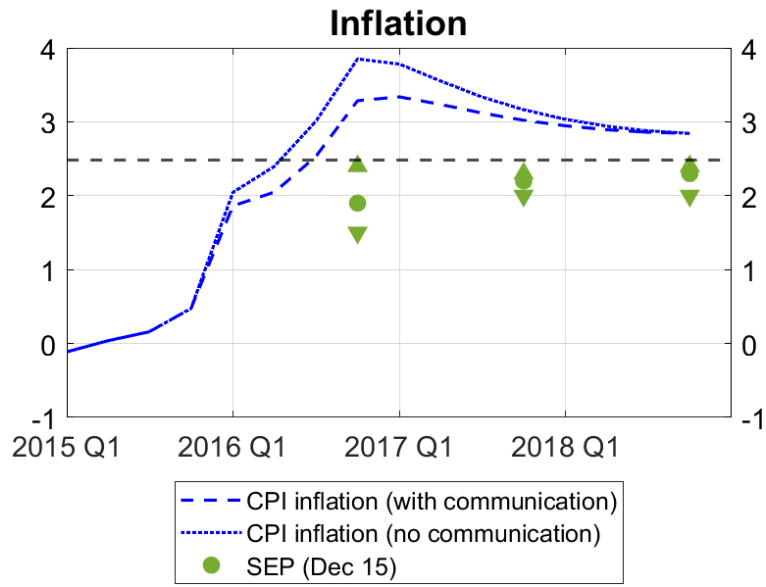
Two cases:

- Perfect communication: All three signals active
- No communication: Common signal inactive

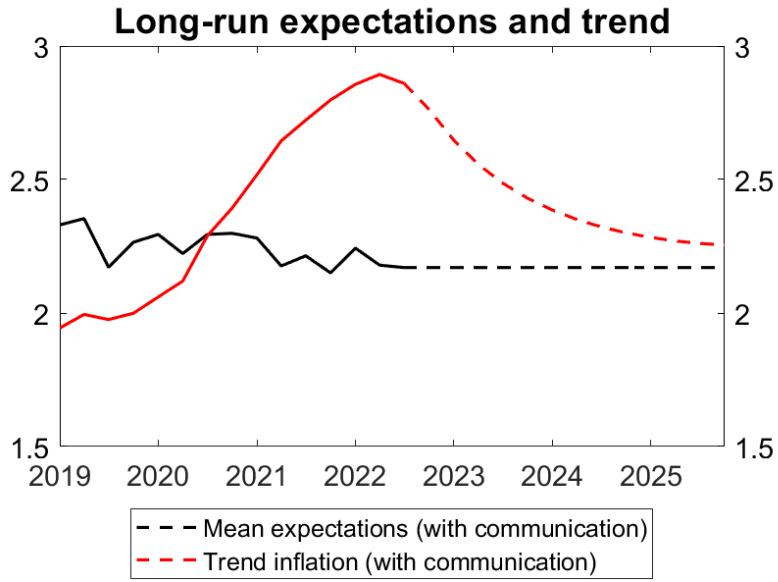
Stable US inflation expectations: December 2015

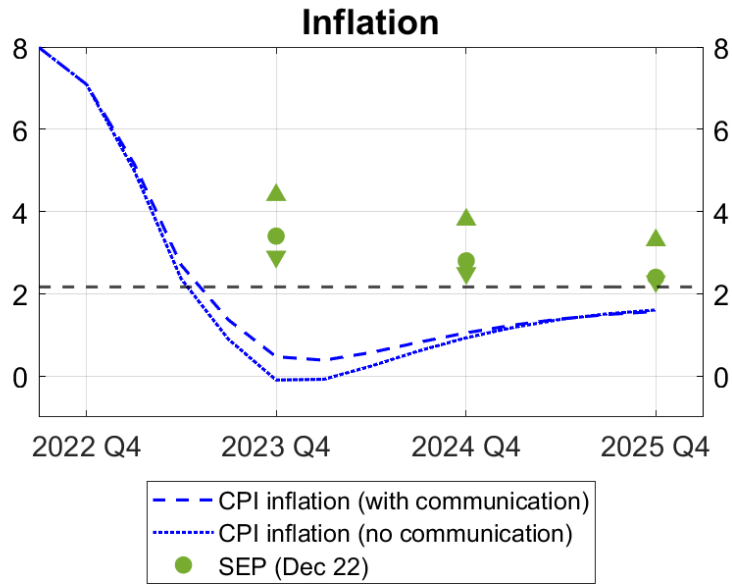




- Perfect communication: median SEP not enough for stabilization
- Imperfect communication: even higher inflation overshoot needed

Stable US inflation expectations: December 2022





- Significant undershooting of SEP inflation path
- Small role of communication based on Dec 22 model estimates

Role of $\sigma_{c,t}$

Concluding Remarks

This paper: How to use panel survey data to assess

- the sensitivity of long-run inflation expectations
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Key take-aways:

- **Low sensitivity** of expectations to **cyclical inflation**
- Information in the **cross-section is critical** to accurately estimate the **sensitivity of expectations**
- **Coordination of beliefs** around inflation target preserved anchoring despite the low inflation after the Great Recession
- Dec 2022 SEP inflation inconsistent with anchored expectations and little scope for coordinating beliefs

Thank you!

Appendix

Long-run inflation expectations by professional forecasters

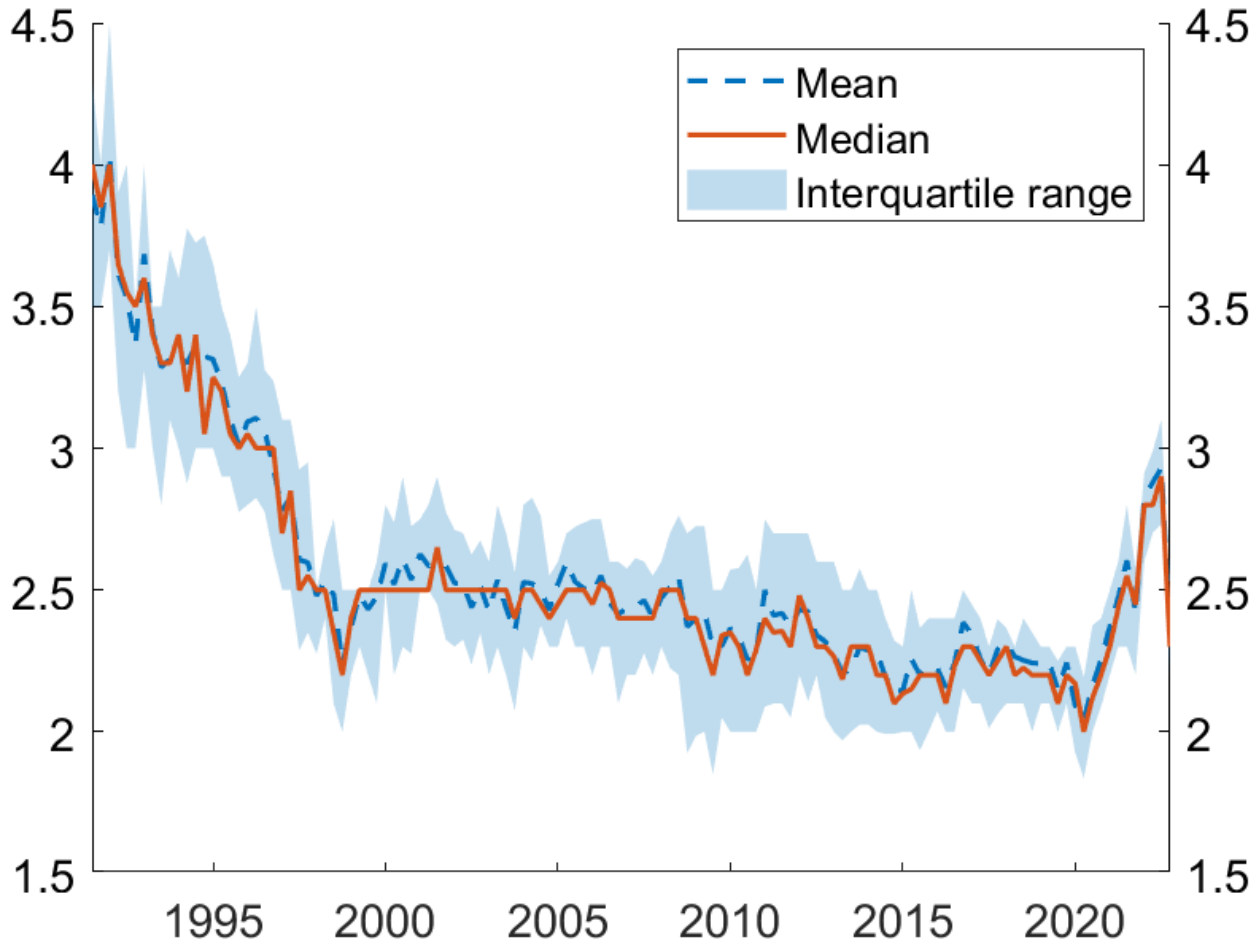

Figure: 10Y CPI inflation expectations, US SPF (1991q4-2023q1)

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Related Literature

- Modelling the dynamics of inflation and inflation expectations
  Chan et al. (2018), Henzel (2013), Mertens (2016), Mertens and Nason (2020), Nason and Smith (2021), Stock and Watson (2007)
- Role of central bank communications in aggregate dynamics
  Nakamura and Steinsson (2018), Gürkaynak et al. (2005), Campbell et al. (2012)
- (Professionals) survey data and expectations formation
  Clements et al. (2023), Patton and Timmermann (2010), Andrade et al. (2016), Coibion and Gorodnichenko (2015), Bianchi et al. (2023), Kohlhas and Walther (2021), Bordalo et al. (2020)
- Anchoring of inflation expectations
  1. Average long-run inflation forecasts stable and close to target
     Carvalho et al. (2020), Beechey et al. (2011), Orphanides and Williams (2005)
  2. Long-run expectations do not respond much to incoming data
     Corsello et al. (2021), Dräger and Lamla (2014), Barlevy et al. (2021), Gürkaynak et al. (2007)
  3. Defined based on higher order moments of inflation expectations
     Reis (2021), Grishchenko et al. (2019) back

Inflation model

The model of inflation, π_t is:

$$\begin{aligned} \pi_t &= \bar{\pi}_t + \varepsilon_t + \sigma_\omega \omega_t \\ \bar{\pi}_t &= \bar{\pi}_{t-1} + \sigma_{\lambda,t} \lambda_t \\ \varepsilon_t &= \phi_t \varepsilon_{t-1} + \sigma_{\eta,t} \eta_t \end{aligned}$$

where ω_t, λ_t, and η_t are i.i.d. $\mathcal{N}(0,1)$.

$$\begin{aligned} \ln(\sigma^2_{\eta,t}) &= \ln(\sigma^2_{\eta,t-1}) + \gamma_\eta \omega_{\eta,t} \\ \ln(\sigma^2_{\lambda,t}) &= \ln(\sigma^2_{\lambda,t-1}) + \gamma_\lambda \omega_{\lambda,t}, \end{aligned}$$

where $\omega_{\eta,t}$ and $\omega_{\lambda,t}$ are i.i.d. $\mathcal{N}(0,1)$.

$$\phi_t = \phi_{t-1} + \gamma_\phi \omega_{\phi,t},$$

where $\omega_{\phi,t}$ is distributed $\mathcal{N}(0,1)$ and $\phi_t \in (0,1)$. back

Forecasters' long-run inflation expectations

Forecasters state-space model can be written as

$$\xi_t(i) = \mathbf{\Phi_t}(\boldsymbol{i})\xi_{t-1}(i) + \mathbf{R_t}(\mathbf{i})e_t(i) \quad (1)$$

$$s_t(i) = \mathbf{D}(\mathbf{i})\xi_t(i) + \mathbf{\Psi} u_t \quad (2)$$

where

$$\begin{aligned} \xi_t(i) &= [\varepsilon_t, \bar{\pi}_t, v_{c,t}, v_t(i)]' \\ e_t(i) &= [\eta_t, \lambda_t, \nu_{c,t}, \nu_t(i)]' \\ s_t(i) &= [s_{1,t}, s_{2,t}(i), s_{3,t}(i)]' \end{aligned}$$

$\Rightarrow$ Forecasters update expectations about states using Bayes rule

$$\xi_{t|t}(i) \equiv \mathbb{E}\left(\xi_t(i)|s_t(i), \pi^{t-1}\right) = \left(\mathbf{I}_4 - \mathbf{K}_t(i)\,\mathbf{D}(\mathbf{i})\right)\xi_{t|t-1}(i) + \mathbf{K}_t(i)\,s_t(i)$$

where $\mathbf{K}_t(i)$ denotes Kalman gain. ◂ back

Kalman filter derivation

The Kalman filter recursion is given by:

$$
\begin{aligned}
\xi_{t|t-1}(i) &= \mathbf{\Phi_t(i)}\xi_{t-1|t-1}(i) \\
P_{t|t-1}(i) &= \mathbf{\Phi_t(i)}P_{t-1|t-1}(i)\,\mathbf{\Phi_t(i)}' + \mathbf{R}_t(i)\mathbf{R}_t(i)' \\
s_{t|t-1}(i) &= \mathbf{D(i)}\xi_{t|t-1}(i) \\
F_{t|t-1}(i) &= \mathbf{D(i)}P_{t|t-1}(i)\,\mathbf{D(i)}' + \Psi\Psi' \\
\xi_{t|t}(i) &= \xi_{t|t-1}(i) + \underbrace{P_{t|t-1}(i)\mathbf{D(i)}'\left[F_{t|t-1}(i)\right]^{-1}}_{K_t(i)}\left[s_t(i) - \mathbf{D(i)}\xi_{t|t-1}(i)\right] \\
P_{t|t}(i) &= P_{t|t-1}(i) - P_{t|t-1}(i)\,\mathbf{D(i)}'\left[F_{t|t-1}(i)\right]^{-1}\mathbf{D(i)}P_{t|t-1}(i)
\end{aligned}
$$

Then, re-arrange the Kalman equation as follows:

$$
\begin{aligned}
\xi_{t|t}(i) &= \xi_{t|t-1}(i) + K_t(i)\left[s_t(i) - D(i)\xi_{t|t-1}(i)\right] \\
&= \left[\mathbf{I}_4 - K_t(i)\,D(i)\right]\Phi_t(i)\xi_{t-1|t-1}(i) + K_t(i)\,s_t(i) \\
&= \left[\mathbf{I}_4 - K_t(i)\,D(i)\right]\Phi_t(i)\xi_{t-1|t-1}(i) + K_t(i)\left[D(i)\xi_t(i) + \Psi u_t\right] \\
&= \left[\mathbf{I}_4 - K_t(i)\,D(i)\right]\Phi_t(i)\xi_{t-1|t-1}(i) \\
&\quad + K_t(i)\left[D(i)(\Phi_t(i)\xi_{t-1}(i) + R_t(i)e_t(i)) + \Psi u_t\right]
\end{aligned}
$$

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Estimation of inflation model

Data: US CPI inflation, quarter-on-quarter annualized growth rates

Sample: 1959Q1-2019Q4

Parameters:

	Prior				Posterior
	Shape	Scale	Mean	[5%, 95%]	Mean
γ_η^2	5	0.04	0.01	[0.004,0.02]	0.0497
γ_λ^2	5	0.04	0.01	[0.004,0.02]	0.0104
γ_ϕ^2	5	0.004	0.001	[0.0004,0.002]	0.0014
σ_ω^2	3	0.2	0.1	[0.032,0.245]	0.1520

Table: Prior and posterior for parameters distributed as Inverse Gamma (Shape,Scale)

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Estimation of inflation model (cont)

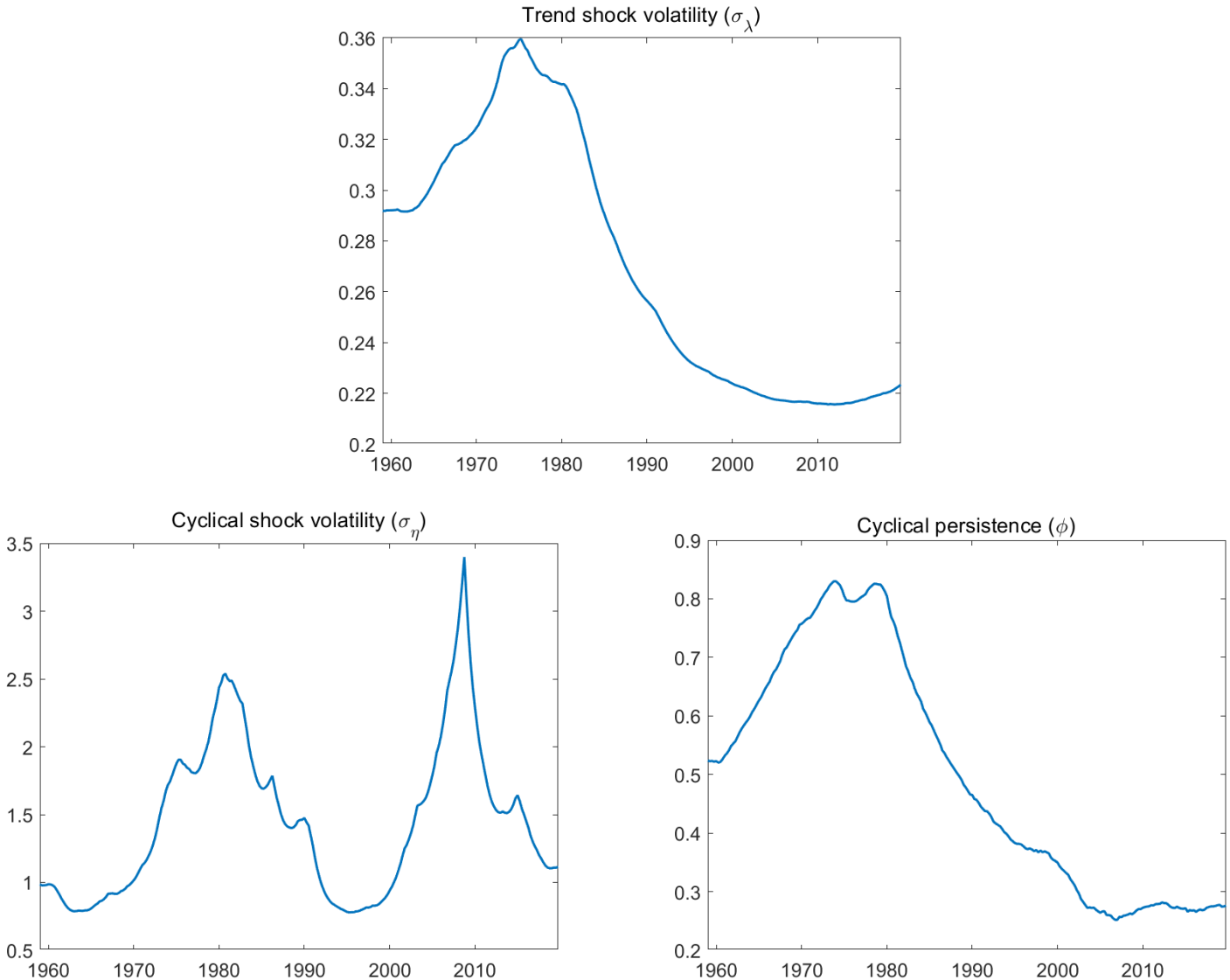

Figure: Time-varying parameter estimates (posterior means)

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Estimation of forecaster panel model

Transition equation:

$$\begin{bmatrix} \xi_t \\ \overrightarrow{\xi}_{t|t} \\ \omega_t \end{bmatrix} = \widetilde{\mathbf{\Phi}}_t \begin{bmatrix} \xi_{t-1} \\ \overrightarrow{\xi}_{t-1|t-1} \\ 0 \end{bmatrix} + \widetilde{\mathbf{R}}_t \begin{bmatrix} \eta_t \\ \lambda_t \\ \nu_{c,t} \\ \overrightarrow{\nu_{v,t}} \\ \omega_t \end{bmatrix}$$

- ξ_t: Inflation model and belief processes, i.e. $\xi_t = \begin{bmatrix} \varepsilon_t & \bar{\pi}_t & \nu_{c,t} & \overrightarrow{\nu_t} \end{bmatrix}'$
- $\overrightarrow{\xi}_{t|t}$: vector of individual forecasters' expectations $\xi_{t|t}(i)$ Link

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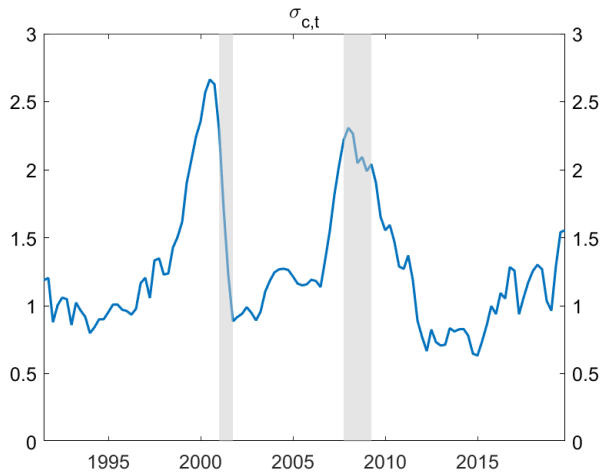
Estimation of forecaster panel model

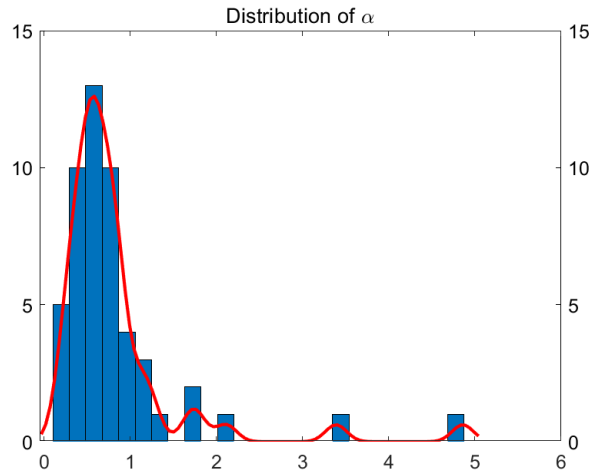
Measurement equation:

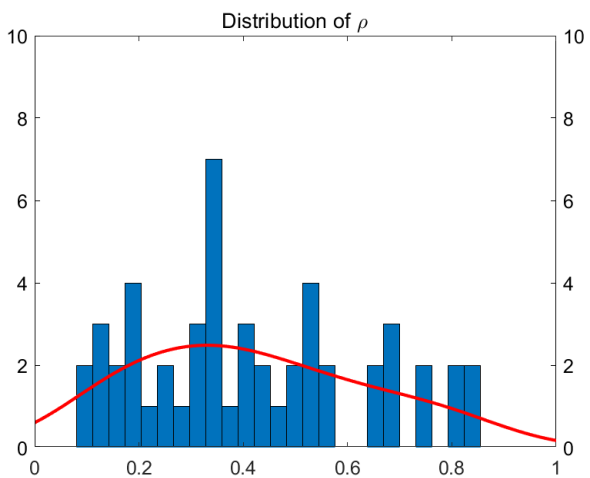
$$\begin{bmatrix} \pi_t^{cpi} \\ \varepsilon_t^{est} \\ \bar{\pi}_t^{est} \\ \mathbb{E}_t \pi_t^{long}(1) \\ \mathbb{E}_t \pi_t^{long}(2) \\ \vdots \\ \mathbb{E}_t \pi_t^{long}(N) \end{bmatrix} = \begin{bmatrix} \mathbf{D_{CPI}} & \mathbf{0}_{1\times k} & \mathbf{0}_{1\times k} & \cdots & \mathbf{0}_{1\times k} & \sigma_\omega \\ \mathbf{1}_1 & \mathbf{0}_{1\times k} & \mathbf{0}_{1\times k} & \cdots & \mathbf{0}_{1\times k} & 0 \\ \mathbf{1}_2 & \mathbf{0}_{1\times k} & \mathbf{0}_{1\times k} & \cdots & \mathbf{0}_{1\times k} & 0 \\ \mathbf{0}_{1\times k} & \mathbf{1}_2 & \mathbf{0}_{1\times k} & \cdots & \mathbf{0}_{1\times k} & 0 \\ \mathbf{0}_{1\times k} & \mathbf{0}_{1\times k} & \mathbf{1}_2 & \cdots & \mathbf{0}_{1\times k} & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ \mathbf{0}_{1\times k} & \mathbf{0}_{1\times k} & \mathbf{0}_{1\times k} & \cdots & \mathbf{1}_2 & 0 \end{bmatrix} \begin{bmatrix} \xi_t \\ \xi_{t|t}(1) \\ \xi_{t|t}(2) \\ \vdots \\ \xi_{t|t}(N) \\ \omega_t \end{bmatrix},$$

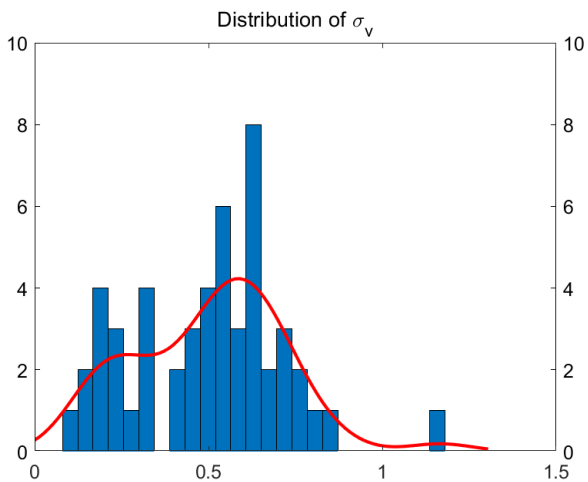
where $\mathbf{D_{CPI}}$ is a zero row vector of length N+k-1 with elements 1 and 2 equal to 1 and k=4. $\mathbf{1}_n$ denotes the $1 \times n$ row vector with elements all equal to zero except the n-th one which is equal to one. back

Estimation of forecaster panel model









Notes: $\ln \sigma^2_{c,t} \backsim \mathcal{N}\left(\ln \sigma^2_{c,t-1}, .25\right)$, $\alpha(i) \sim$ IG(3,1), ρ_c, $\rho(i) \sim$ Beta(0.5,0.2), $\sigma_v(i) \sim$ IG(3,1)

$\rho_c \sim$ Beta(0.5,0.2) $\rightarrow$ Estimate of 0.99

◂ back

US Survey of Professional Forecasters: Data overview

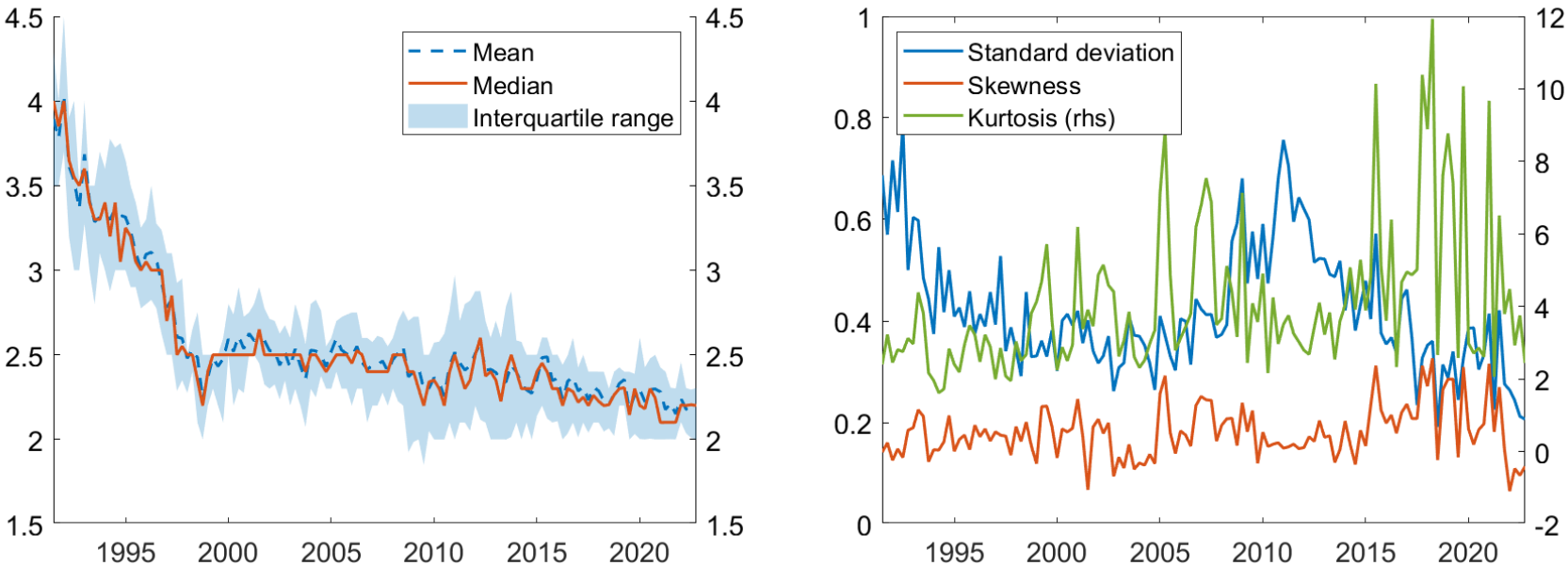


Figure: Time series summary of long-run CPI inflation expectations

Selection of forecasters:

At least 32 forecasts → unbalanced panel of 51 forecasters

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Selection of forecasters

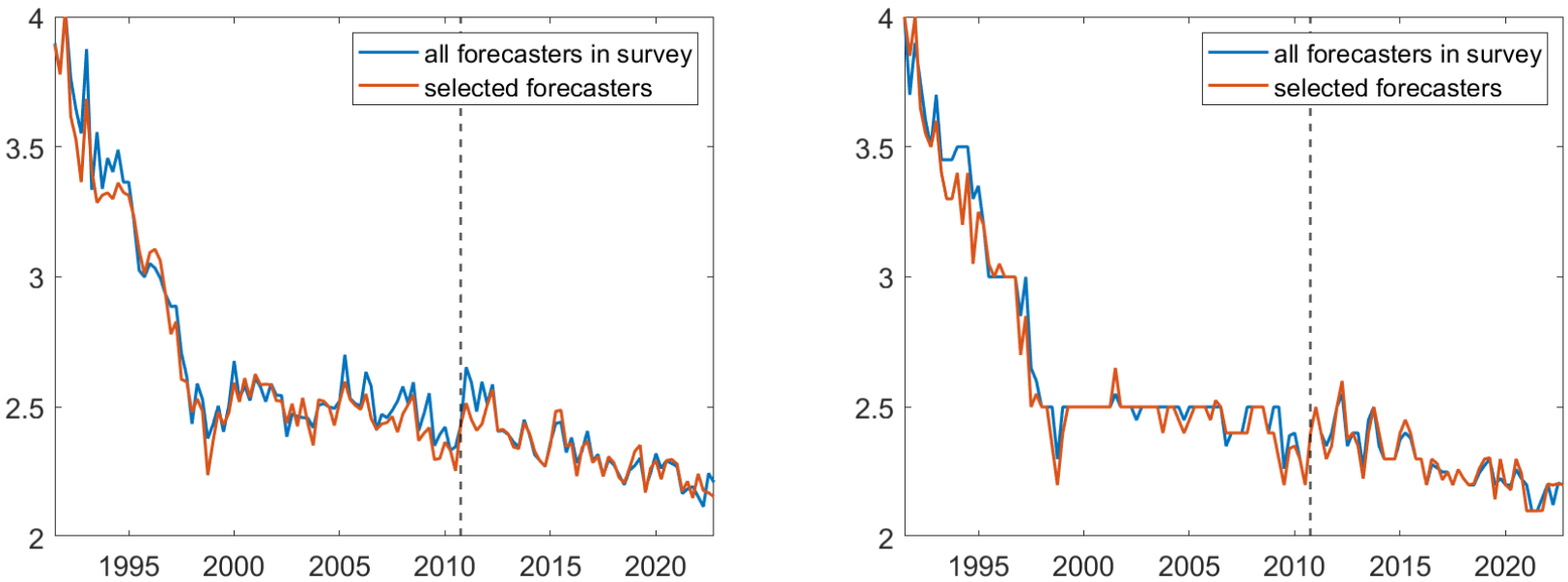

Figure: Time series of inflation expectations: mean(lhs) and median (rhs)

Note: Dashed vertical line indicates 2011Q1 before which we use 10Y and afterwards 5Y5Y expectations.

◂ back to intro ◂ back to estimation

Selection of forecasters (cont)

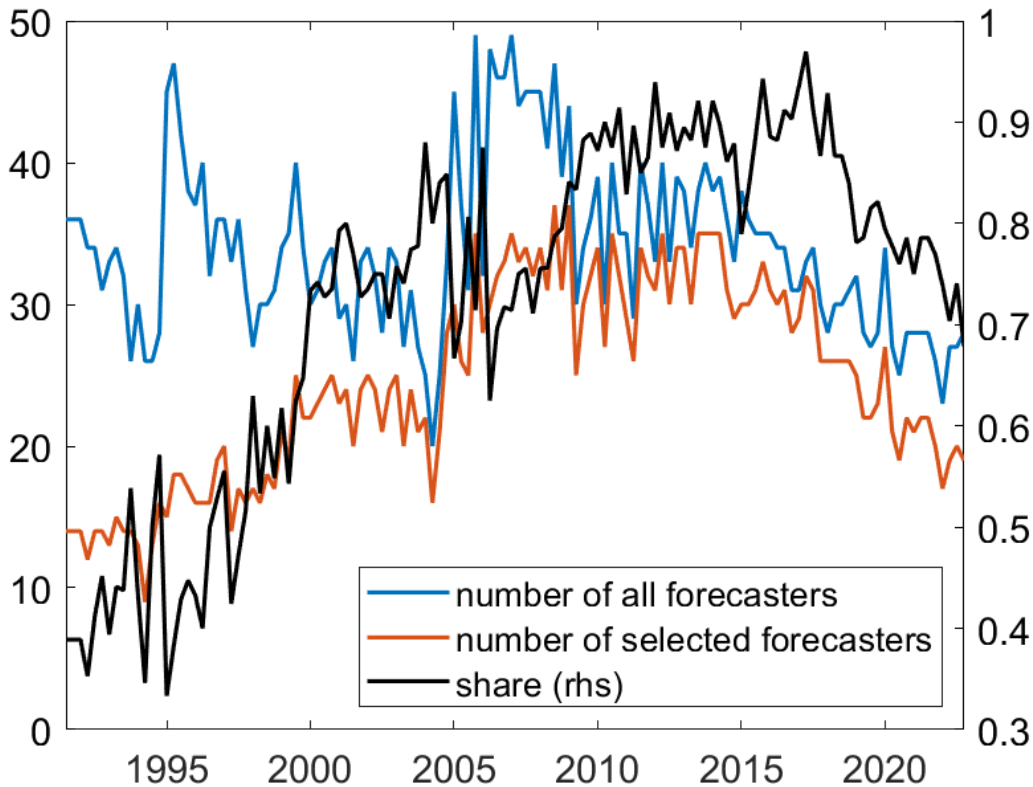

Figure: Number of total and selected forecasters in the US SPF survey

back to estimation

Response of inflation expectations to shocks

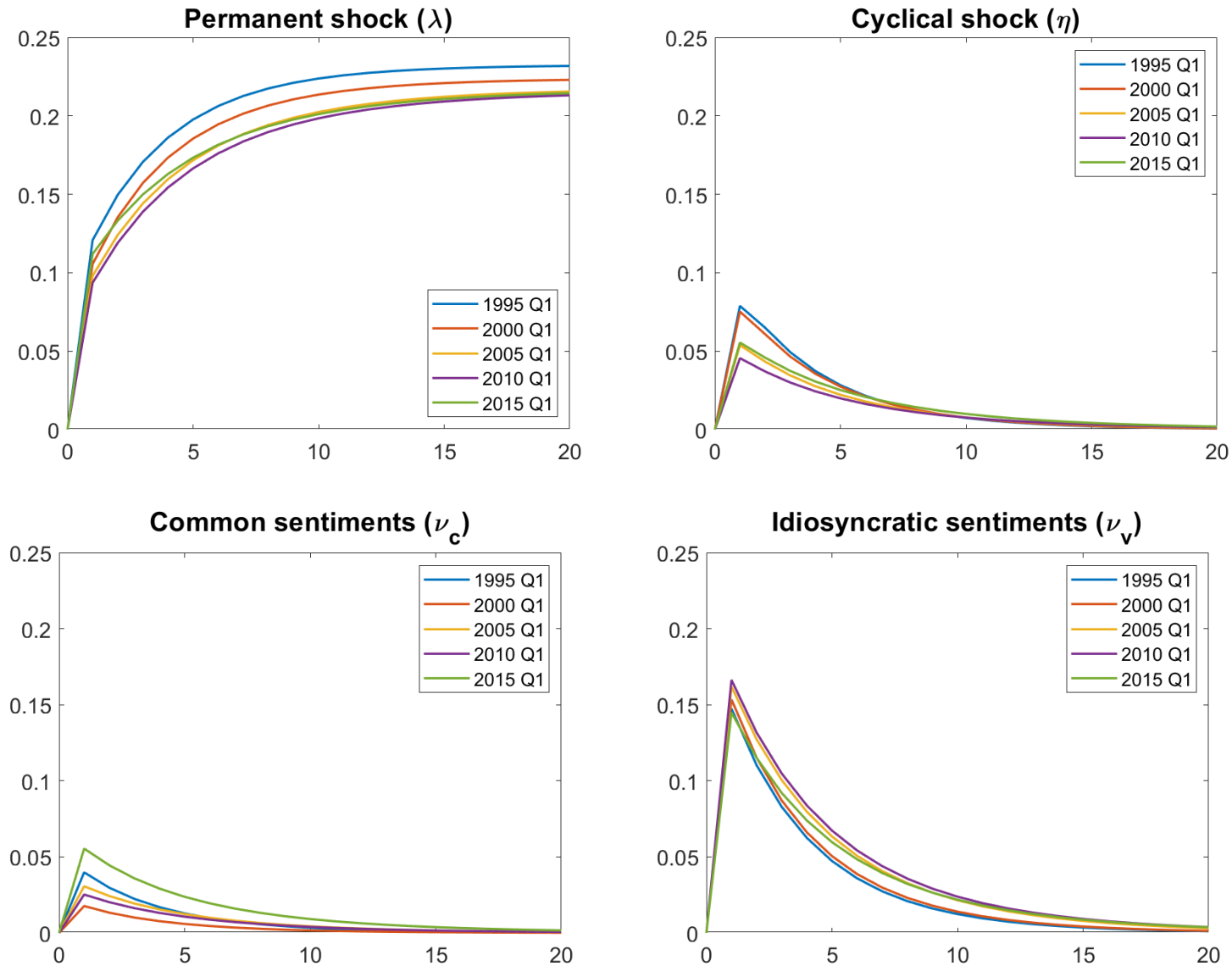

Figure: Impulse response functions to one standard deviation shocks

Response of inflation to shocks

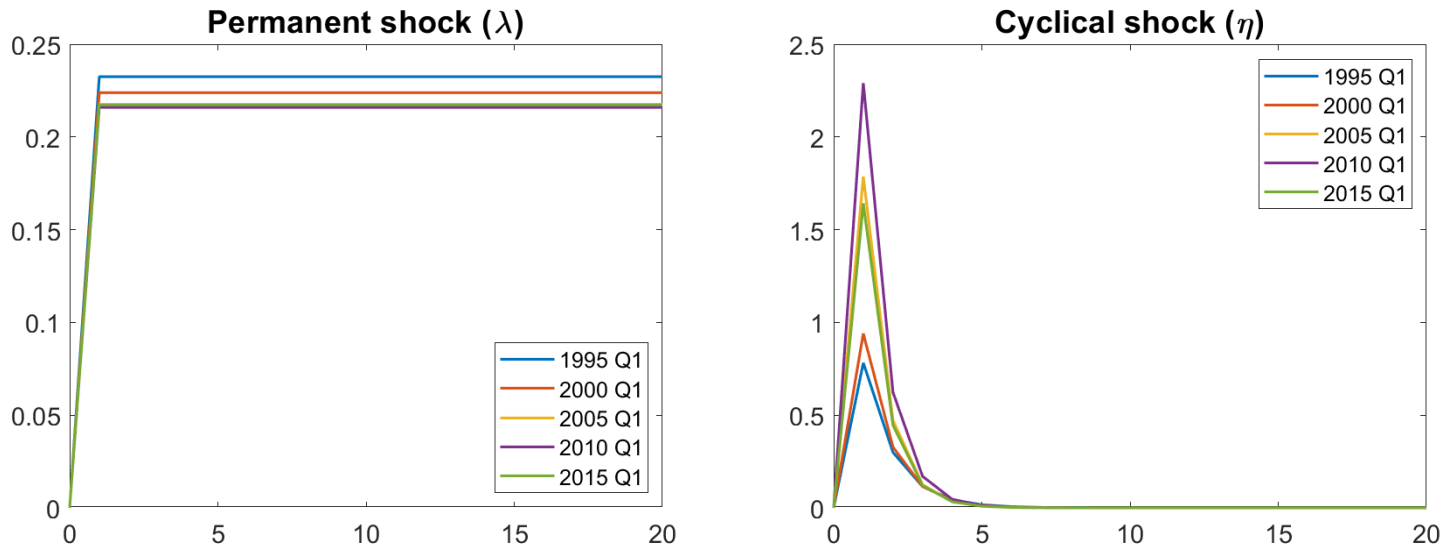

Figure: Impulse response functions to one standard deviation shocks

back

Extended panel estimation

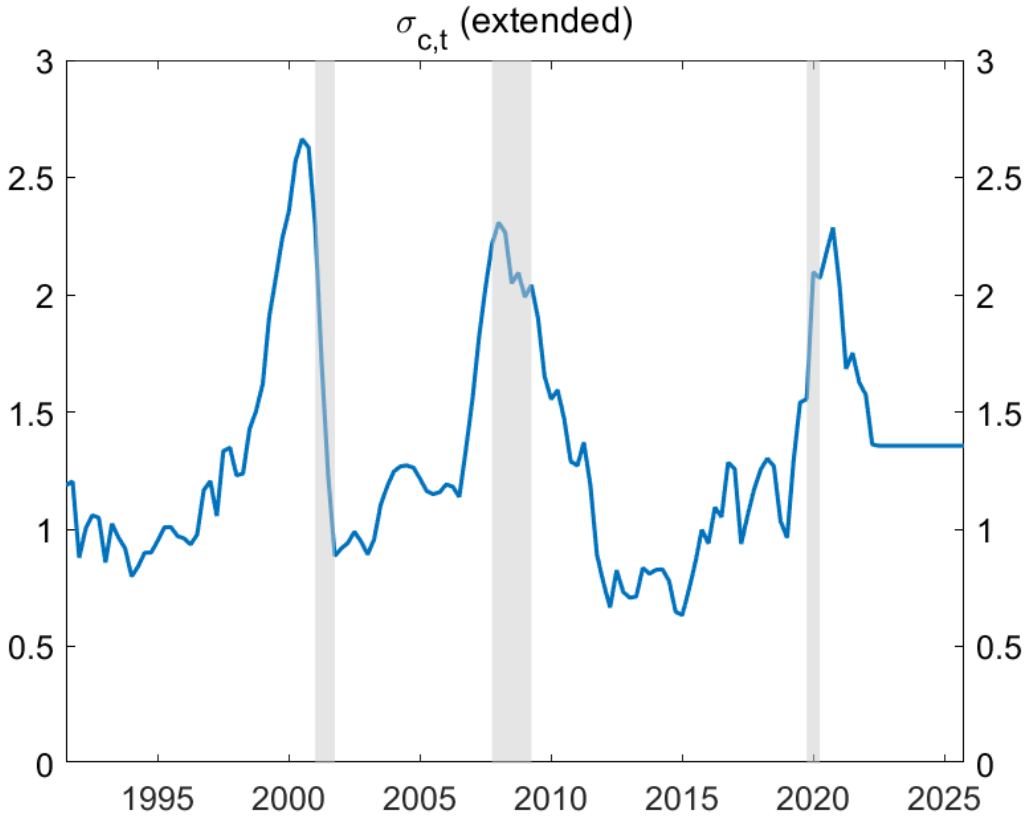

Figure: Extended estimate of $\sigma_{c,t}$

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Extended panel estimation (cont)

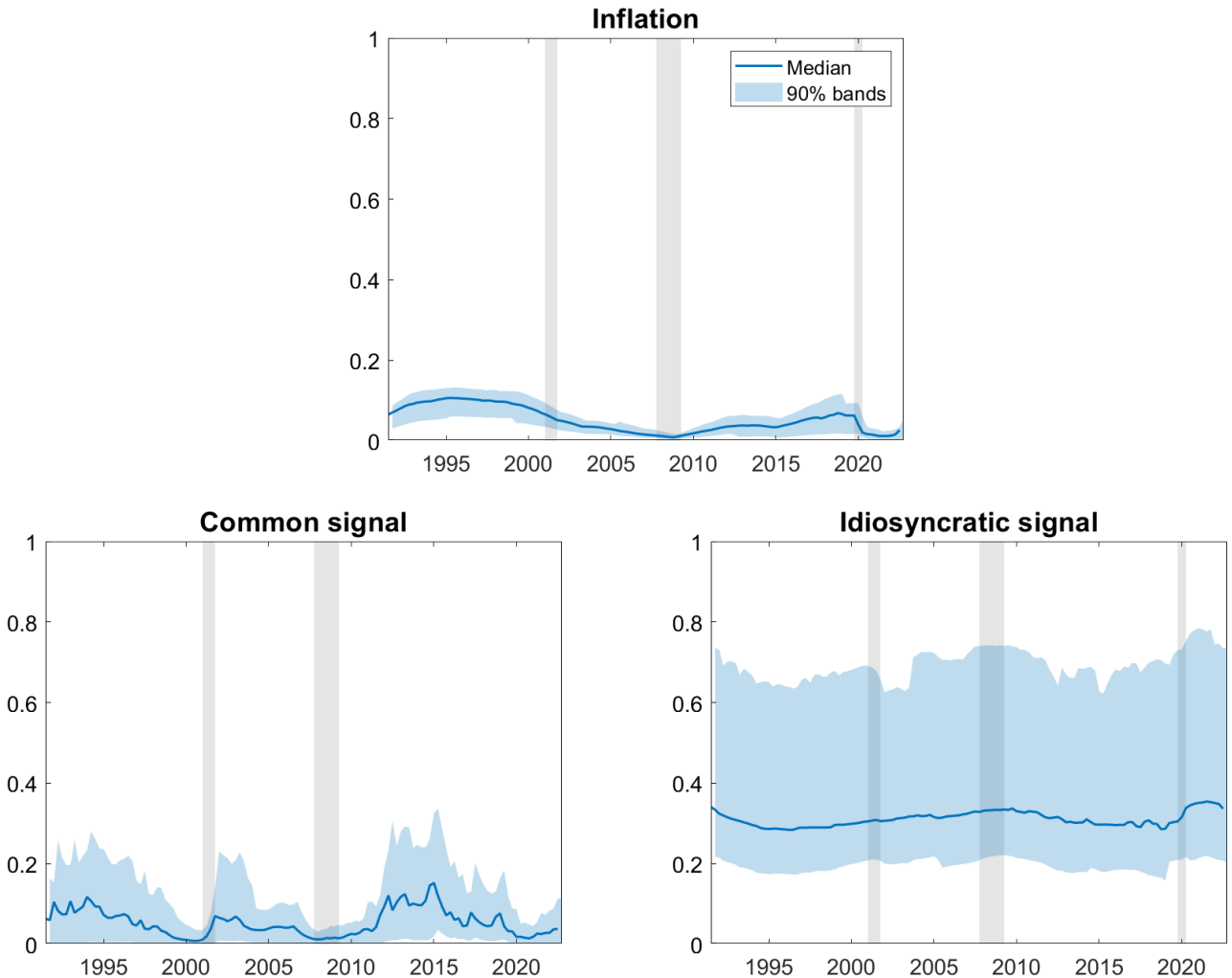

Figure: Kalman gains for extended sample

Extended panel estimation (cont)

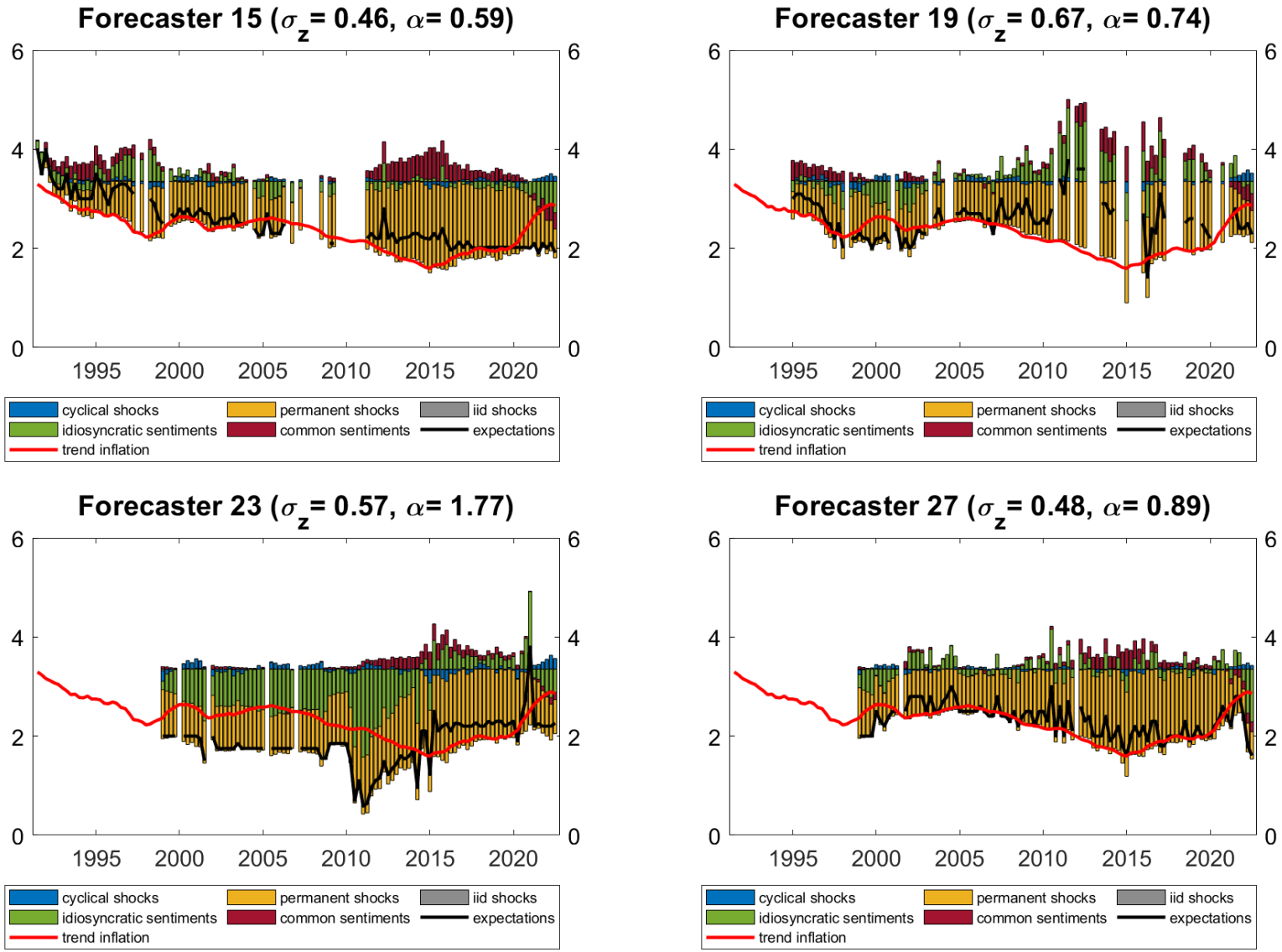

Figure: Historical decomposition of selected forecasters (extension)

Extended panel estimation (cont)

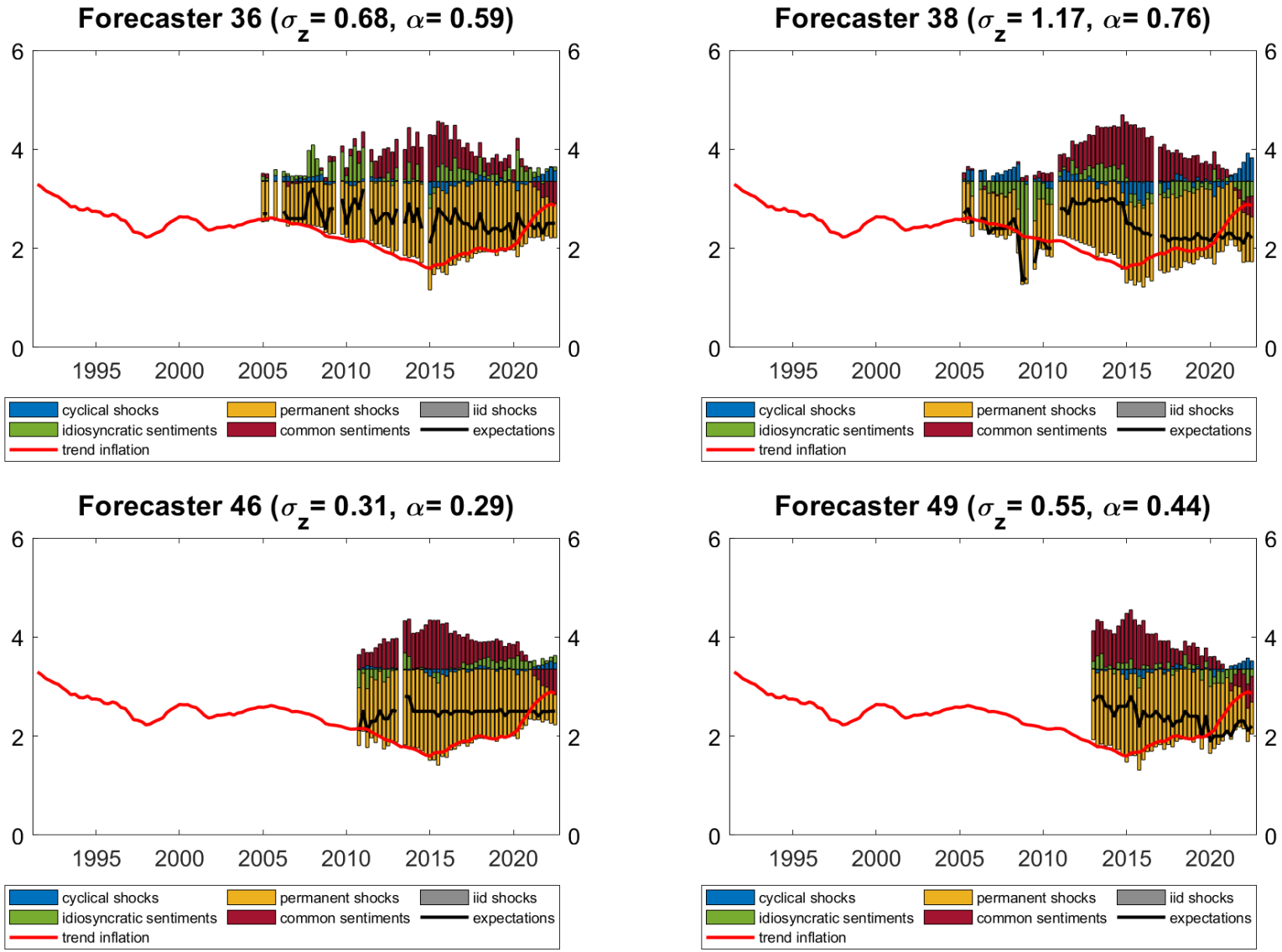

Figure: Historical decomposition of selected forecasters (extension)

Extended panel estimation (cont)

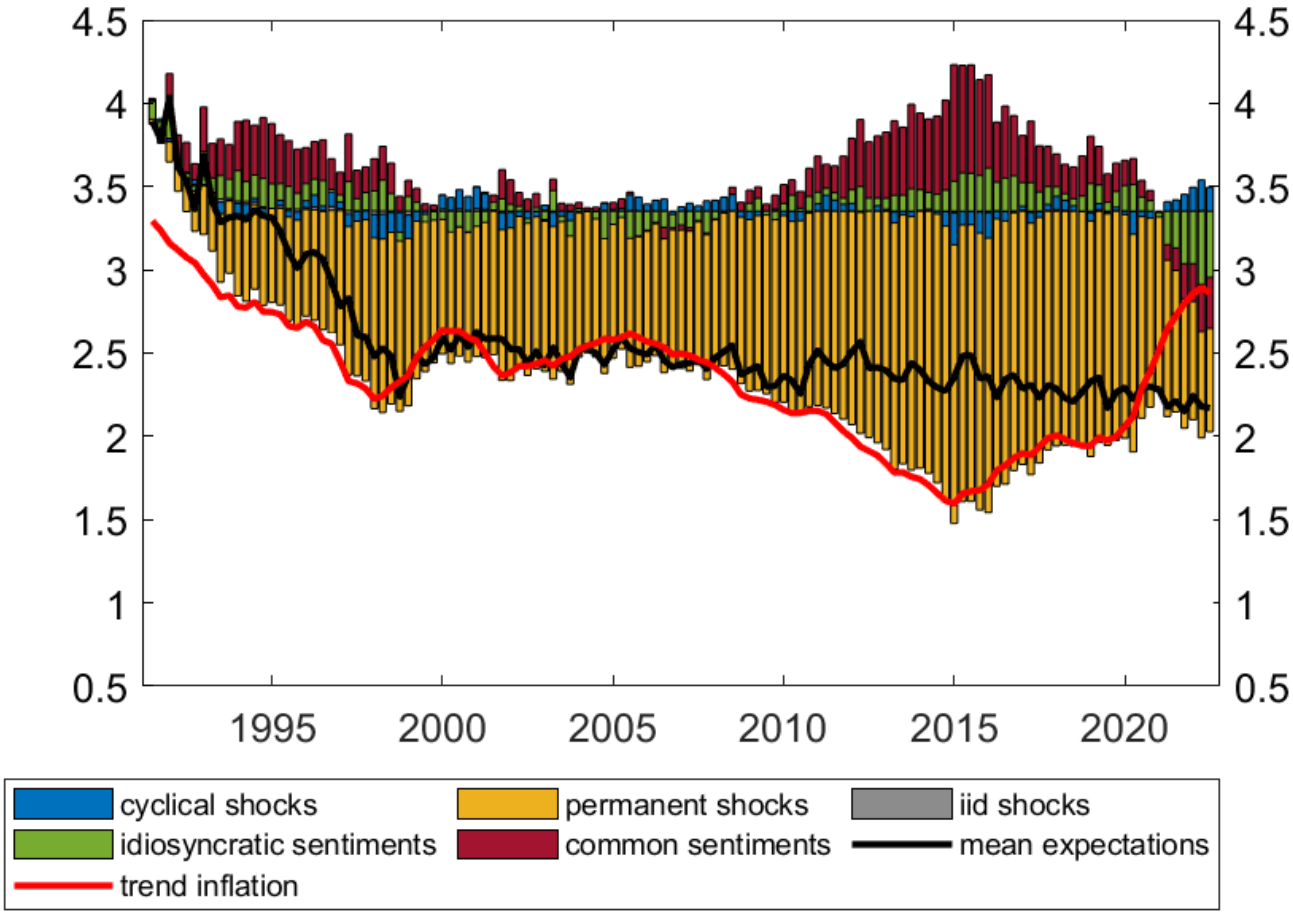

Figure: Historical decomposition of average inflation expectations (extension)

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Stable US inflation expectations: Dec 2022

- More aggressive communication $\rightarrow$ lower $\sigma_{c,t}$?

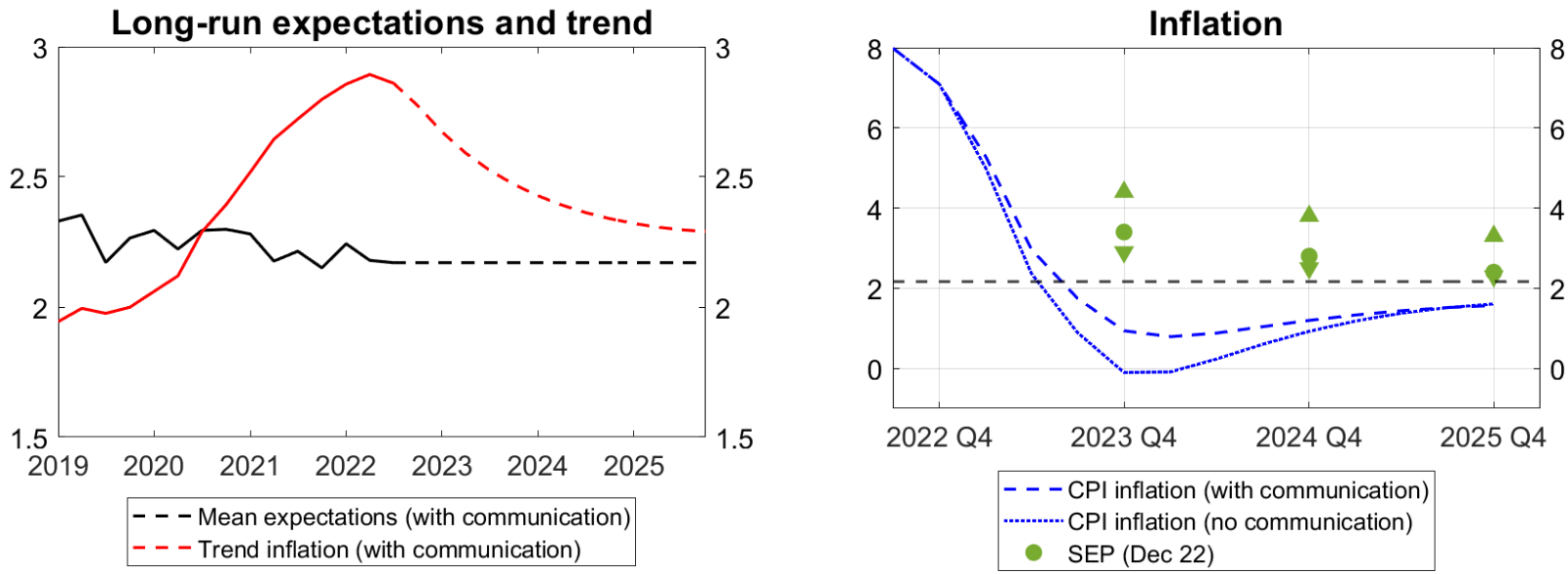

Figure: Inflation path consistent with stable average long-term inflation expectations, $\sigma_{c,t}$ value from Dec 2015

back

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