In Search of a Nominal Anchor: What Drives Inflation Expectations?

Carlos Carvalho (PUC-Rio)

Stefano Eusepi (New York Fed)

Emanuel Moench (Deutsche Bundesbank)

Bruce Preston (Melbourne University)

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Motivation

- Successful monetary policymaking relies on **anchored** inflation expectations.
- Yet: do not know much about what drives long-term expectations.
    - Under what conditions are expectations "anchored"?
- In most macro-models **long-term** inflation expectations are:
    - Assumed to be constant; or
    - Assumed to drift exogenously and consistent with policy objectives.
- Yet: Stability of long-run inflation expectations should not be taken for granted — not an inherent feature of the economy.

This Paper

Simple model of inflation and inflation expectations based on learning.

– Price-setting agents act as econometricians: estimate average long-run inflation.

- **Key feature 1**: state-dependent sensitivity of long-run inflation expectations to short-term inflation surprises.

  $\Rightarrow$ Drift in expectations in response to large and persistent surprises.

- **Key feature 2**: with nominal rigidities expected inflation feeds-back current prices (partially self-fulfilling).

  $\Rightarrow$ Endogenous inflation trend affected by economic shocks and policy regime.

This Paper - ctd.

Can such a model explain the evolution of long-term inflation expectations as measured by **survey** forecasts?

1. Estimate the model using only actual inflation and survey-based measures of short-term inflation forecasts (inflation surprises).

2. Evaluate predictions for long-term survey forecasts for US and other countries (Japan, France, Germany, Netherlands, Switzerland, Sweden, Canada, . . .).

3. Run counterfactual simulations to illustrate study the behavior of the endogenous inflation trend.

A Simple Model

- Forecasting model of price-setting agents:

$$\pi_t = (1-\gamma_p)\,\bar{\pi}_t + \gamma_p \pi_{t-1} + \varphi_t.$$

  - $\bar{\pi}_t$: long-run mean of inflation unknown to agents who estimate it from the data

$$\hat{E}_t \lim_{T\to\infty} \pi_T = \bar{\pi}_t.$$

  - φ_t: a zero mean stationary "short-run component"

$$\begin{aligned} \varphi_t &= s_t + \mu_t \\ s_t &= \rho_s s_{t-1} + \epsilon_t. \end{aligned}$$

  - s_t, μ_t: relate to marginal cost and cost-push shocks in NK model.

A Simple Model - ctd.

- True inflation DGP:

$$\pi_t = (1 - \gamma_p)\,\Gamma\bar{\pi}_t + \gamma_p \pi_{t-1} + \varphi_t.$$

- Γ: measures **feed-back** from beliefs to actual inflation.

  $\Rightarrow$ Determines the endogenous drift in inflation.

  $\Rightarrow$ In NK model: feed-back to price-setting decisions.

- $\Gamma < 1$: Agents will eventually learn the true (constant) mean.

Learning about the Inflation Trend

- We assume the following learning algorithm:

$$\bar{\pi}_t = \bar{\pi}_{t-1} + \mathbf{k}_{t-1}^{-1} \times f_{t-1}$$

where

$$f_t = \pi_t - \underbrace{\left[(1-\gamma_p)\,\bar{\pi}_t + \gamma_p \pi_{t-1} + \rho_s s_{t-1}\right]}_{\hat{E}_{t-1}\pi_t}$$

$$k_t = \begin{cases} k_{t-1} + 1, \text{ if } \left|\Phi(past\ \ fcst.errors)\right| < \nu \\ \\ \bar{g}^{-1}, \text{ otherwise.} \end{cases}$$

- Intuition:

$\Rightarrow$ Captures effort to protect against structural change.

$\Rightarrow$ Large when past forecast errors are of same sign for a few periods.

Learning about the Inflation Trend

- In the spirit of Marcet and Nicolini (2003):

$$k_t = \begin{cases} k_{t-1} + 1, \text{ if } \left|\hat{E}_{t-1}\pi_t - \mathbb{E}_{t-1}\pi_t\right| \leq v \times \mathbb{MSE} \\ \\ \bar{g}^{-1}, \text{ otherwise.} \end{cases}$$

- $\mathbb{E}_{t-1}\pi_t$: model-consistent forecast.
- $\mathbb{MSE}$: $\sqrt{\mathbb{E}\left[\pi_t - \mathbb{E}_{t-1}\pi_t\right]^2}$.

$\Rightarrow$ We do not model directly how agents "test" their model.

$\Rightarrow$ Assume they switch if their forecast deviates too much from the model-consistent.

Learning about the Inflation Trend - ctd.

- In the spirit of Marcet and Nicolini (2003):

$$k_t = \begin{cases} k_{t-1} + 1, \text{ if } \left| \hat{E}_{t-1}\pi_t - \mathbb{E}_{t-1}\pi_t \right| \leq v \times \mathbb{MSE} \\ \\ \bar{g}^{-1}, \text{ otherwise.} \end{cases}$$

- More intuition:

$$\begin{aligned} \left| \hat{E}_{t-1}\pi_t - \mathbb{E}_{t-1}\pi_t \right| &= \left| (1-\gamma_p)(1-\Gamma)\,\bar{\pi}_t \right| \\ &= \left| (1-\gamma_p)(1-\Gamma)\left[\bar{\pi}_0 + \sum_{\tau=0}^{t} k_\tau^{-1} f_\tau \right] \right| \end{aligned}$$

$\Rightarrow$ Large when past forecast errors are of same sign for a few periods.

Anchored Expectations?

- **Anchored expectations**: agents learn about a constant long-run mean of inflation (Least Squares)

  $\Rightarrow$ Sensitivity of long-term expectations to short-term forecast errors decreasing with time: $k_t^{-1} \rightarrow 0$.

- **Unanchored expectations**: agents doubt the constancy of long-run inflation and put more weight on recent inflation (Constant gain)

  $\Rightarrow$ Sensitivity of long-term expectations to short-term forecast errors is large and does not change over time: $k_t^{-1} = \bar{g}$.

Data: US

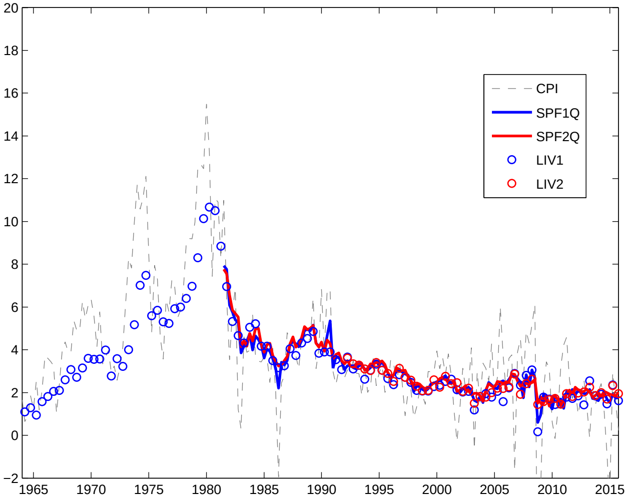
Model is estimated with Bayesian methods using short-term professional survey forecasts and actual inflation.

- **Goal**: evaluate the model's ability to explain long-term inflation forecasts observed in survey data.

Data:

- CPI inflation (quarterly), 1955Q1-2015Q4.
- Short-term forecasts (consensus):
    - 6-months ahead: Livingston survey (semi-annual), 1955Q2-2015Q4.
    - 1- and 2- quarters ahead: Survey of Professional Forecasters (quarterly), 1981Q3-2015Q4.

US: Actual Inflation and Short-Term Survey Forecasts



Estimation: US

- Model in state-space form:

$$
\begin{aligned}
\mathbf{k}_t &= f_k(\bar{\pi}_{t-1}, \mathbf{k}_{t-1}) \\
\bar{\pi}_t &= f_{\bar{\pi}}(\bar{\pi}_{t-1}, \mathbf{k}_{t-1}) + A_{\bar{\pi}}\left(\bar{\pi}_{t-1}, \mathbf{k}_{t-1}\right)\xi_{t-1} \\
\xi_t &= f_{\xi}\left(\bar{\pi}_{t-1}, \mathbf{k}_{t-1}\right) + A_{\xi}\left(\bar{\pi}_{t-1}, \mathbf{k}_{t-1}\right)\xi_{t-1} + S_C \mathbf{u}_t
\end{aligned}
$$

- Observation equation:

$$
Y_t^{US} = \begin{bmatrix} \pi_t \\ \mathbf{E}_t^{SPF} \pi_{t+1} \\ \mathbf{E}_t^{SPF} \pi_{t+2} \\ \mathbf{E}_t^{LIV_1}\left(\frac{1}{2}\sum_{i=1}^{2} \pi_{t+i}\right) \\ \mathbf{E}_t^{LIV_2}\left(\frac{1}{2}\sum_{i=1}^{2} \pi_{t+i}\right) \end{bmatrix} = h_{0,t} + h_{\bar{\pi},t}\bar{\pi}_t + H_t' \xi_t + R_t^{1/2} e_t .
$$

Estimation: US ctd.

- Estimate with Bayesian methods: Marginalized Particle Filter (and Smoother)
  - Filter: Shön, Gustafsson and Nordlund (2004).
  - Smoother: Lindsten and Shön (2011).
- Structural parameters:

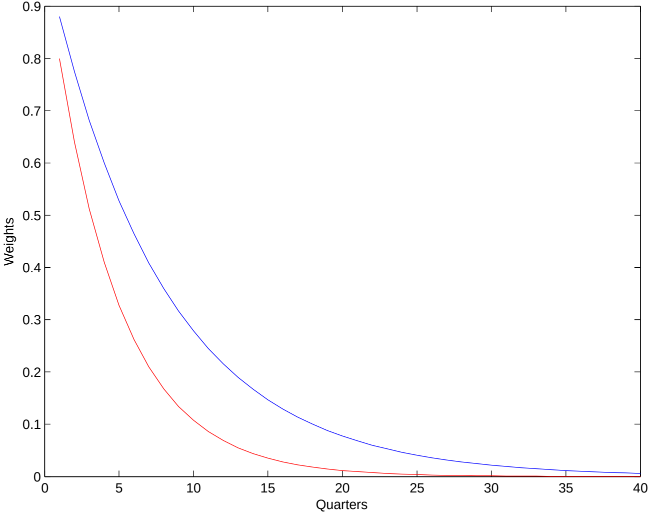
$$\bar{\theta} = \begin{pmatrix} \pi^* & \nu & \bar{g} & \gamma_p & \Gamma & \rho_s & \sigma_s^2 & \sigma_\mu^2 \end{pmatrix}'.$$

- ... and five i.i.d. observation errors.

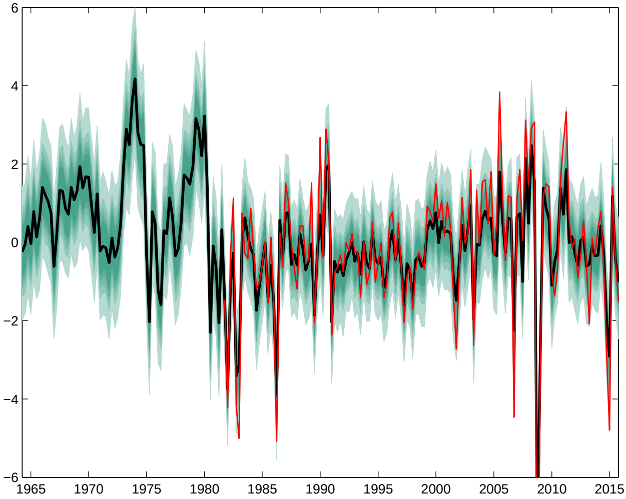
Selected Estimated Parameters

- Strong feed-back effects: Γ between 0.89 and 0.95.
- Little 'intrinsic' inflation persistence: γ_p between 0.09 and 0.17.
- Constant gain: ν such that agents switch for $2\% > \bar{\pi}_t > 3\%$.
  - Steady-state inflation rate (π^*) is (tightly) estimated at 2.5%.
  - Median estimates: parameter distribution does not affect these bands significantly.

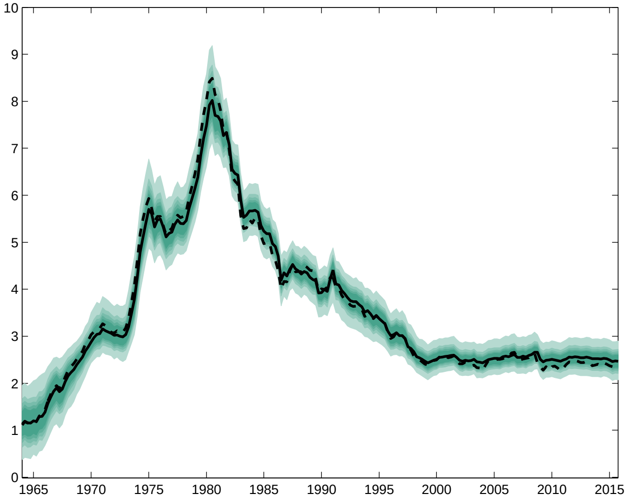
Constant gain: Discounting the past ($g = 0.12, 0.20$)



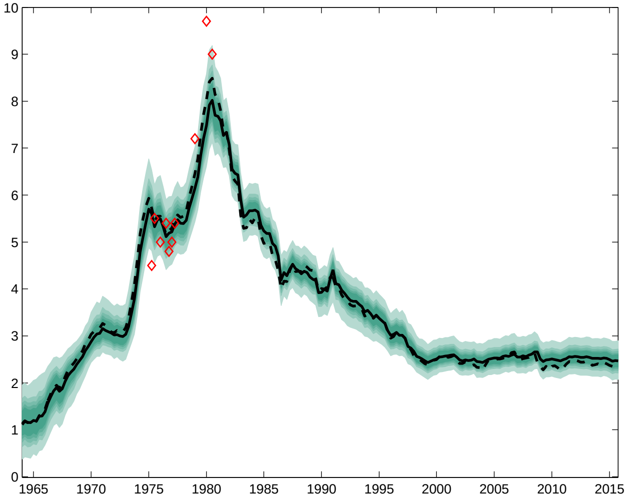
1Q Ahead Forecast Errors: Model-Implied and SPF



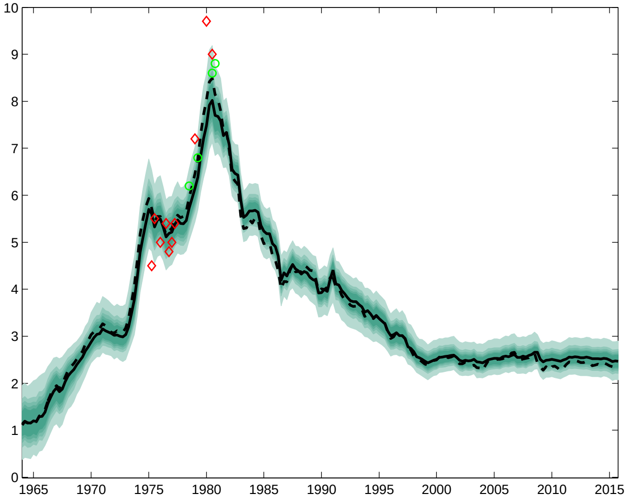
Long-term (6-10 Years) Model-Implied Inflation Forecasts



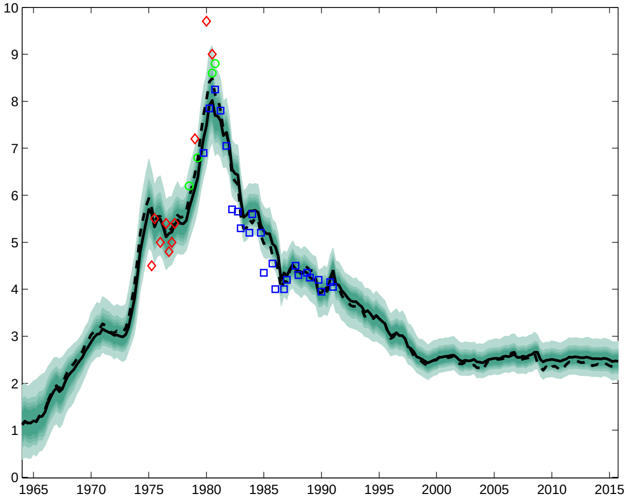
Adding Michigan Survey 6-10 Years



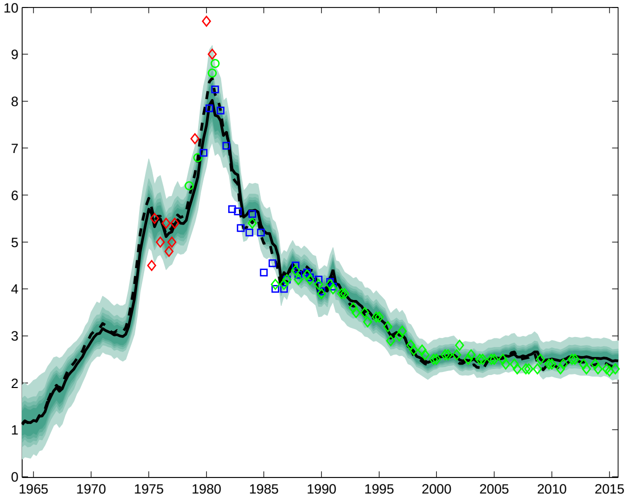
Adding Decision Makers Poll 1-10 Years



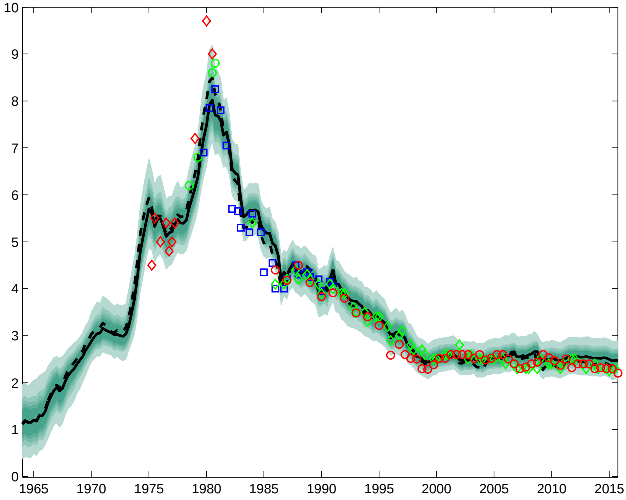
Adding Blue Chip Economic Indicators 1-10 Years



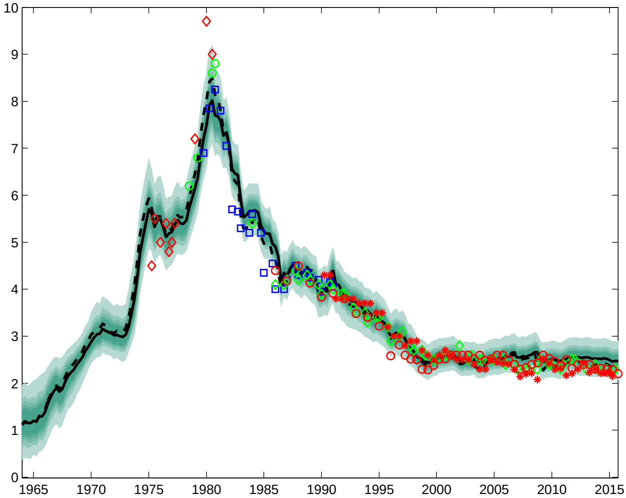
Adding Blue Chip Economic Indicators 6-10 Years



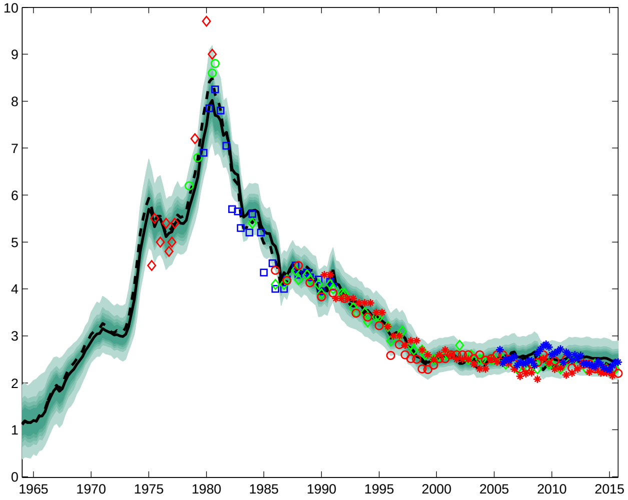
Adding Consensus Economics 6-10 Years



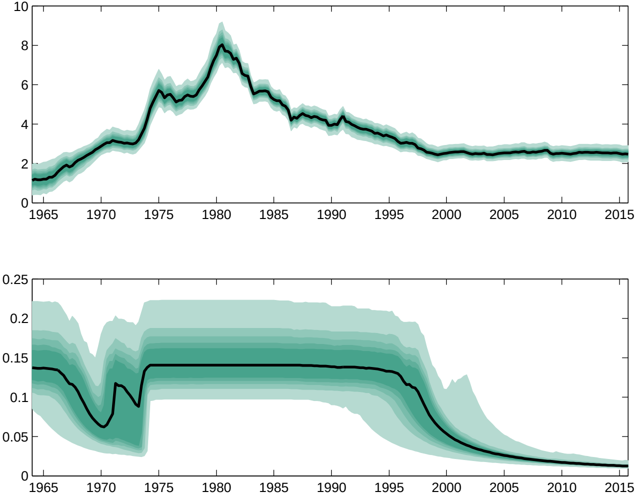
Adding Survey of Professional Forecasters 1-10 Years



Adding Survey of Professional Forecasters 5-10 Years



Estimated Gain k_t^{-1}



Estimation: Other Countries

- **Data**:
  - Consumer Price Indices: late 1950s to 2015Q4.
  - Short-term forecasts from Consensus Economics (1991-2015Q4).

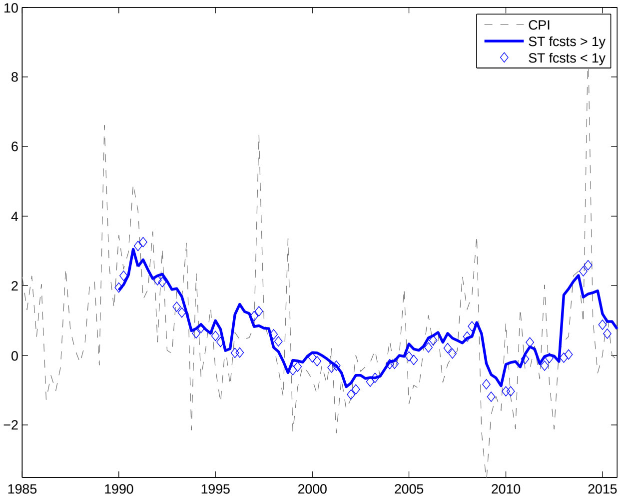
- **Model's predictions**:
  1. "Structural" params: use US posterior dist. as prior for these countries.
     - For π^* and *obs. errors* use same prior distrib. as for the US.
  2. Down-weight foreign country's Likelihood. Posterior:

$$
\begin{aligned}
P^*\left(\theta^* | Y_t^*, Y_t^{US}, \theta^{US}\right) \quad = \quad & 0.05 \ln L(Y_t^* | \theta^{US}, \theta^*) + \\
& \ln\left[L(Y_t^{US} | \theta^{US}) p(\theta^{US})\right] + \\
& \ln p(\theta^*).
\end{aligned}
$$

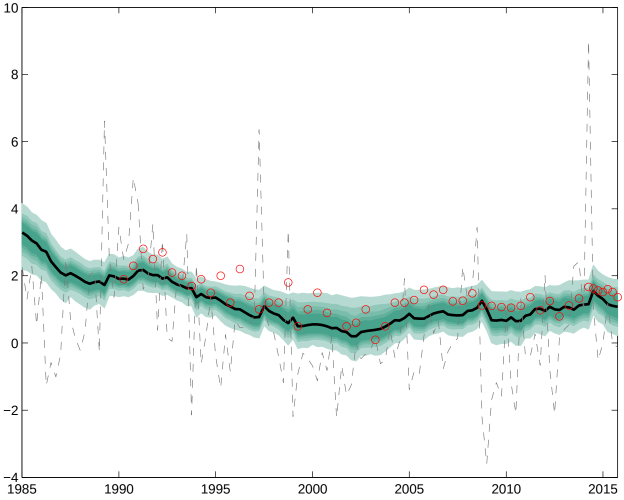
Summary Results: Foreign Countries

1. Model characterizes well the evolution of long-term forecasts.
   - Survey-based forecasts are inside the 95% bands for most of the sample.
2. More stable expectations beginning in the 1990s.
   - Japan and Switzerland: episodes of unanchoring in the past 15 years.
   - Canada, France, Sweden and the Germany: more stable expectations.
3. Beyond inflation surprises: announcement effects?
   - Examples: Sweden and Switzerland?

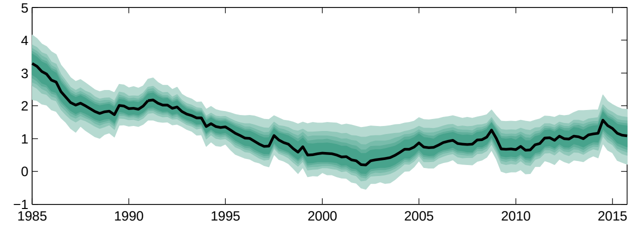
Japan: Consumer Price Inflation and Short-Term Forecasts

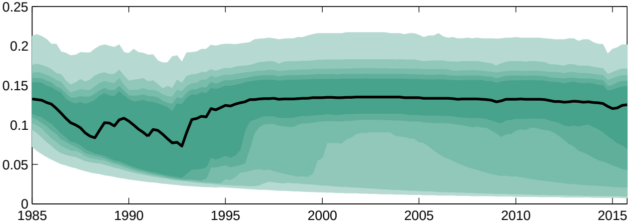


Japan: Model-Implied and Obs. 6-11 Years Forecasts

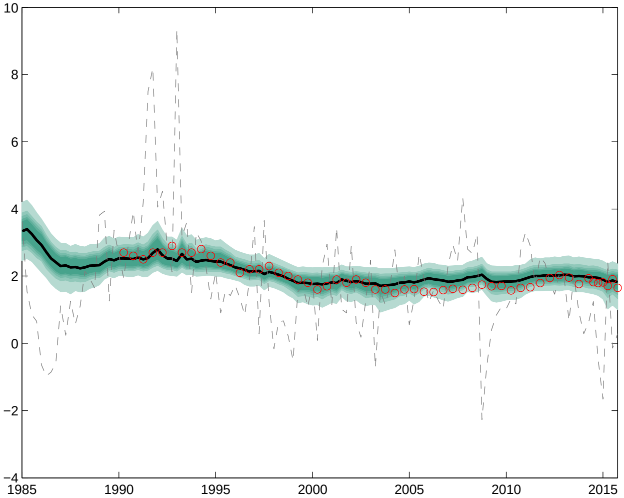


Japan: Learning Gain





Germany: Model-Implied and Obs. 6-11 Years Forecasts



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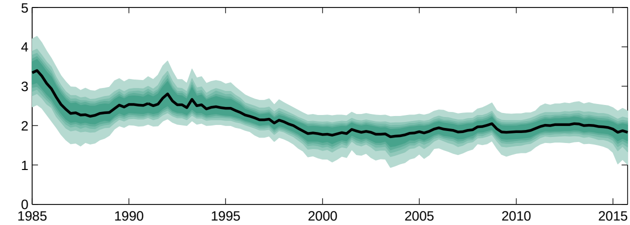
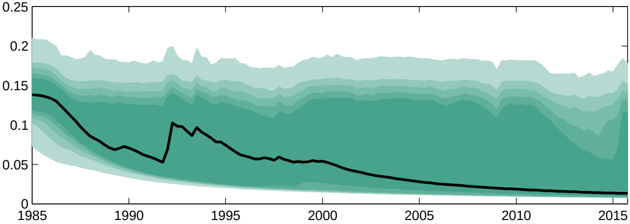
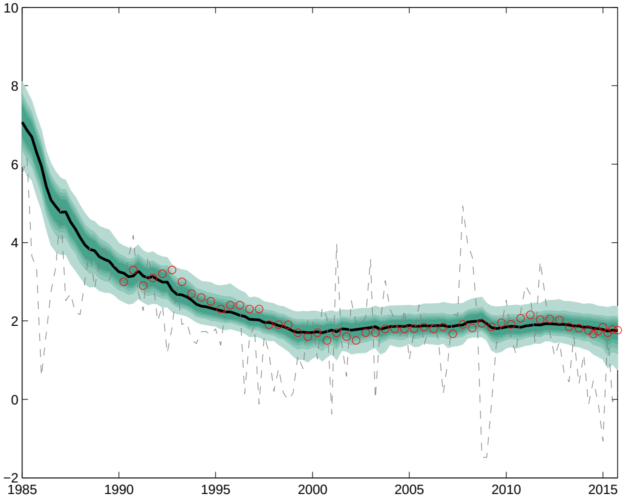
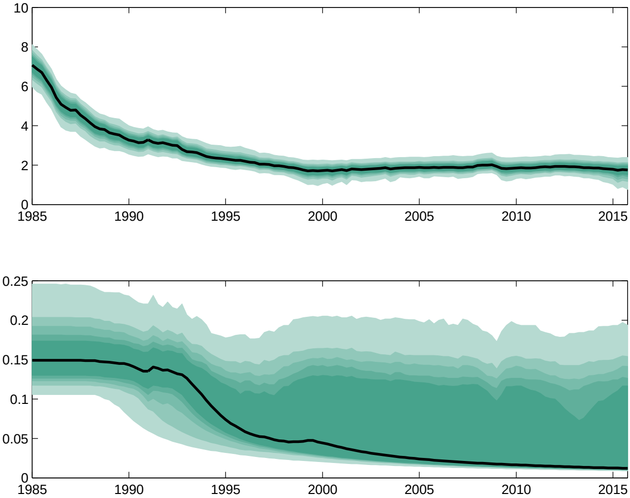




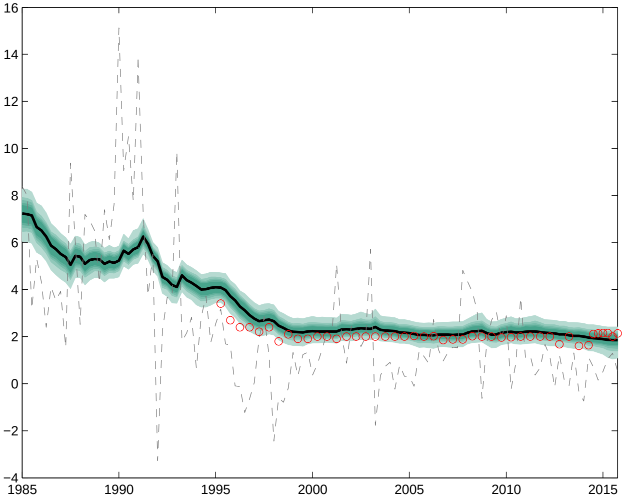
France: Model-Implied and Obs. 6-11 Years Forecasts



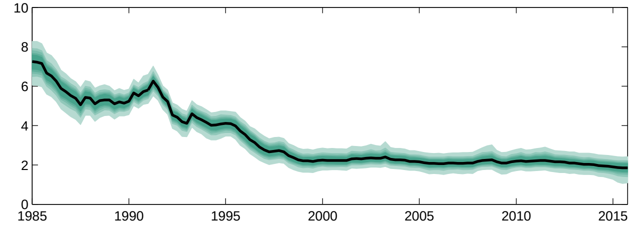
France: Learning Gain

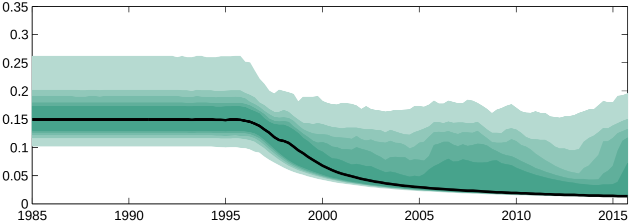


Sweden: Model-Implied and Obs. 6-11 Years Forecasts

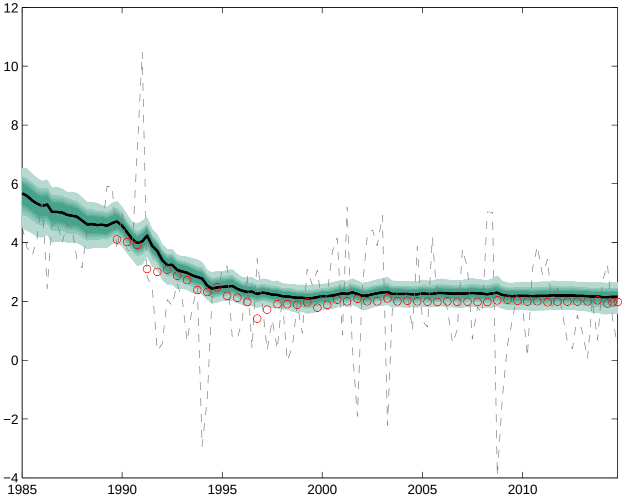


Sweden: Learning Gain

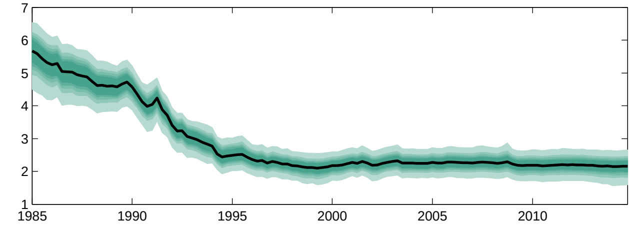


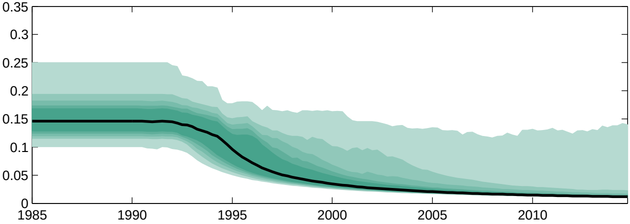


Canada: Model-Implied and Obs. 6-11 Years Forecasts

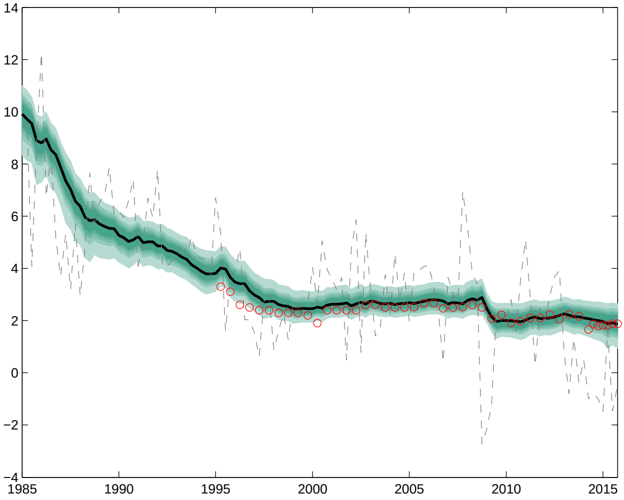


Canada: Learning Gain

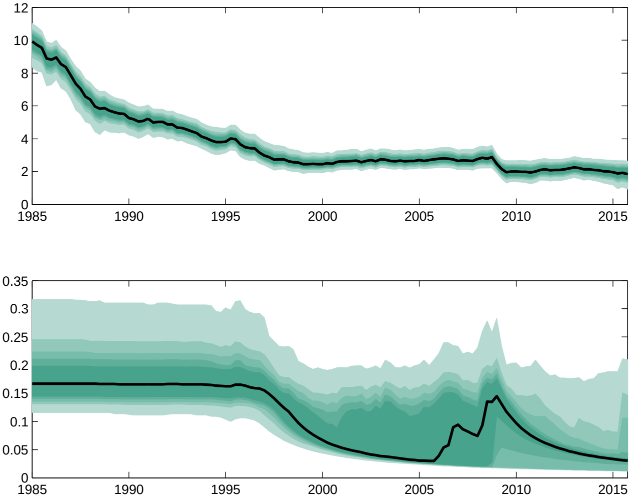




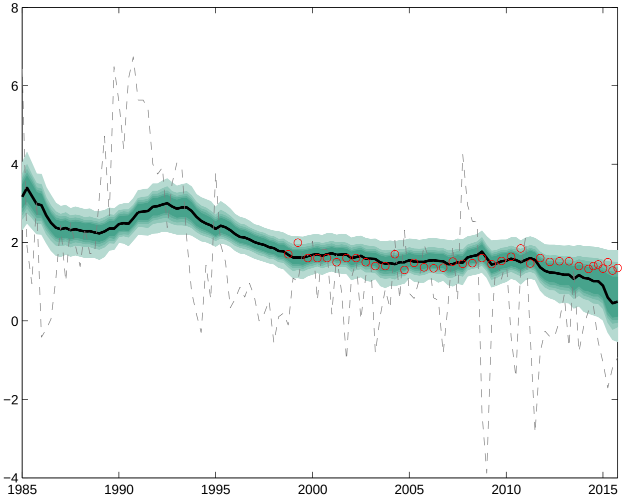
Spain: Model-Implied and Obs. 6-11 Years Forecasts



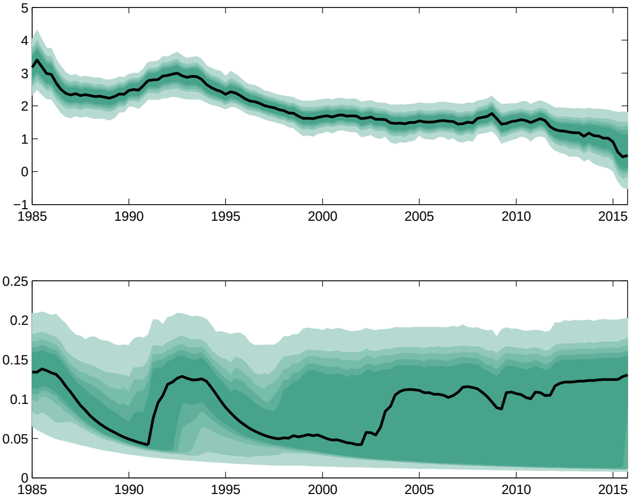
Spain: Learning Gain



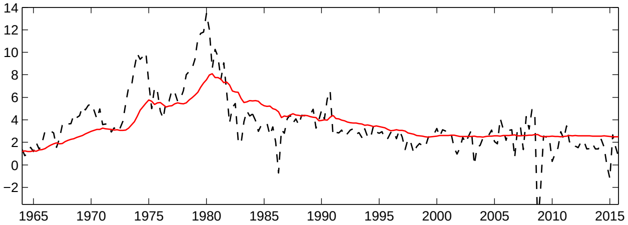
Switzerland: Model-Implied and Obs. 6-11 Years Forecasts

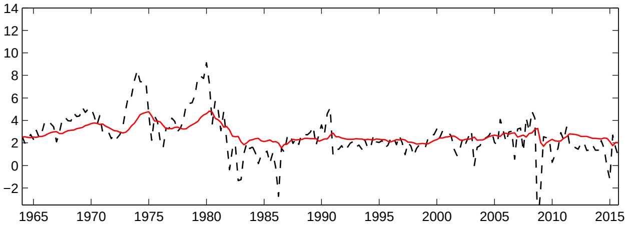


Switzerland: Learning Gain

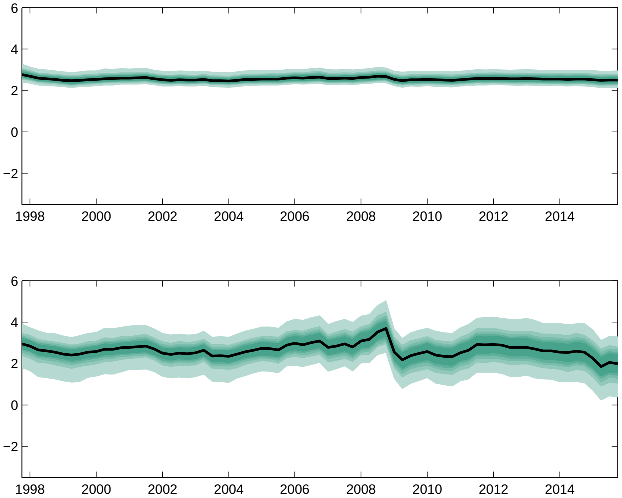


Counterfactuals (US Economy): No Feedbacks





Counterfactuals (US Economy): Constant gain



Conclusion

- Simple learning model which links long-term inflation expectations to short-term forecast errors.
- In model inflation and inflation expectations can become unmoored in response to large and persistence short-term forecast errors.
- Model describes long-term survey forecasts of inflation very well for number of countries even using only posterior distribution for the US.
- In our model short-term forecast errors are treated as exogenous...
- ...but in full general equilibrium model they depend on policy regime.

The New Keynesian Phillips Curve

- Firm i maximizes the present discounted value of profits

$$E_t \sum_{T=t}^{\infty} \alpha^{T-t} Q_{t,T} \left[Y_T(i) \left(\frac{P_t(i)}{P_T} - MC_T \right) \right],$$

where $Q_{t,T}$ is the discount factor, MC_t is the real marginal cost and

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\theta_{p,t}} Y_t$$

the demand the firm faces with time-varying elasticity $\theta_{p,t}$.

- Each period the firm's price is reset optimally with probability α, and with prob $(1-\alpha)$ is indexed to a weighted average of past inflation and the perceived long-run inflation rate:

$$\bar{\Pi}_t^p = \bar{\pi}_t^{1-\gamma_p} \pi_{t-1}^{\gamma_p}.$$

The New Keynesian Phillips Curve - ctd.

- Optimal price in a model with Calvo pricing and indexation to past inflation and estimated inflation mean

$$\hat{p}_t^* = \hat{E}_t \sum_{T=t}^{\infty} (\alpha\beta)^{T-t} \left[(1-\alpha\beta)\,\varphi_T + \alpha\beta\left(\pi_{T+1} - \gamma_p \pi_T - (1-\gamma_p)\bar{\pi}_t\right)\right]$$

- Aggregating

$$\begin{aligned} \pi_t &= \gamma_p \pi_{t-1} + (1-\gamma_p)\bar{\pi}_t + \\ & \quad \hat{E}_t \sum_{T=t}^{\infty} (\alpha\beta)^{T-t} \left[\kappa\varphi_T + (1-\alpha)\,\beta\left(\pi_{T+1} - \gamma_p \pi_T - (1-\gamma_p)\bar{\pi}_t\right)\right] \end{aligned}$$

- Soving for expectations, the DGP is

$$\pi_t = \gamma_p \pi_{t-1} + (1-\gamma_p)\Gamma\bar{\pi}_t + \frac{(1-\alpha\beta)(1-\alpha)}{(1-\alpha\beta\rho_s)} s_t + \mu_t$$

Lower Bound on Rationality

1. Parameters ν and $\bar{g}$ such that agents eventually learn.
   - Here $\bar{\pi}_t \to \pi$.

2. For given ν, $\bar{g}$ nearly optimal if no individual agent has strong incentives to deviate .
   - Key role of feed-back effects (Γ high enough).

Implication: learning mechanism not policy invariant.

Model Summary

$$\begin{aligned}
\pi_t &= (1-\gamma_p)\,\Gamma\bar{\pi}_t + \gamma_p \pi_{t-1} + \rho_s s_{t-1} + \epsilon_t + \mu_t \\
s_t &= \rho_s s_{t-1} + \epsilon_t \\
\bar{\pi}_{t+1} &= \left[1 + k_t^{-1} \times (1-\gamma_p)\,(\Gamma - 1)\right] \bar{\pi}_t + k_t^{-1} \times (\epsilon_t + \mu_t) \\
k_{t+1} &= I(\bar{\pi}_t) \times (k_t + 1) + (1 - I(\bar{\pi}_t)) \times \bar{g}^{-1}
\end{aligned}$$

where

$$I(\bar{\pi}) = \begin{cases} k_{t-1} + 1, \text{ if } \left|(1-\gamma_p)\,(\Gamma-1)\,\bar{\pi}\right| \leq v \times \mathbb{MSE} \\ \mathbf{0}, \text{ otherwise.} \end{cases}$$

Comparing to Model with Exogenous Inflation Drift

- Popular approach both in reduced-form and DSGE models

$$\bar{\pi}_{t+1} = \rho_{\bar{\pi}} \bar{\pi}_t + e_t ; \rho_{\bar{\pi}} \approx 1.$$

- To compare, our model implies

$$\begin{aligned} \bar{\pi}_{t+1} &= \bar{\pi}_t + k_t^{-1} \left(\pi_t - \hat{E}_{t-1} \pi_t \right) \\ &= \underbrace{\left[1 + k_t^{-1} \left(1 - \gamma_p \right) \left(\Gamma - 1 \right) \right]}_{\rho_{\bar{\pi},t}} \bar{\pi}_t + \underbrace{k_t^{-1} \left(\epsilon_t + \mu_t \right)}_{\tilde{e}_t}. \end{aligned}$$

- Key differences:
  - Persistence and volatility are time-varying and state-dependent.
  - Innovations to $\bar{\pi}_t$ depend on inflation forecast errors: *endogenous drift.*

US Estimates - Table of Priors and Posteriors

	Prior				Posterior				
	Dist.	Mean	SD	Mode	Mean	SD	5%	Med.	95%
$4\pi^*$	Normal	2.5	0.28	2.49	2.53	.20	2.21	2.52	2.89
ν	Gamma	.05	.04	.02	.03	.01	.01	.03	.05
g	Gamma	.10	.09	.12	.15	.03	.10	.14	.21
Γ	Beta	.5	.26	.91	.88	.043	.81	.90	.95
γ_p	Beta	.5	.260	.10	.13	.03	.09	.13	.17