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)

Inflation: Drivers and Dynamics, Cleveland Fed
Sept. 29-30, 2016

The views expressed here are the authors’ and are not representative of the views of Deutsche Bundesbank, the Eurosystem, the Federal Reserve Bank of New York or of the Federal Reserve System.
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.

⇒ 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).

⇒ **Endogenous** inflation trend affected by economic shocks and policy regime.
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

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

- \( \varphi_t \): a zero mean stationary "short-run component"

\[ \varphi_t = s_t + \mu_t \]

\[ s_t = \rho_s s_{t-1} + \epsilon_t. \]

- \( s_t, \mu_t \): relate to marginal cost and cost-push shocks in NK model.
A Simple Model - ctd.

- True inflation DGP:

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

- \( \Gamma \): 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:

\[
\bar{\pi}_t = \bar{\pi}_{t-1} + k_{t-1}^{-1} \times f_{t-1}
\]

where

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

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

- Intuition:

  \[ \Rightarrow \text{Captures effort to protect against structural change.} \]

  \[ \Rightarrow \text{Large when past forecast errors are of same sign for a few periods.} \]
Learning about the Inflation Trend

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

\[
k_t = \begin{cases} 
  k_{t-1} + 1, & \text{if } |\hat{E}_{t-1}\pi_t - E_{t-1}\pi_t| \leq v \times \text{MSE} \\
  \bar{g}^{-1}, & \text{otherwise.}
\end{cases}
\]

- $E_{t-1}\pi_t$: model-consistent forecast.

- MSE: $\sqrt{E[\pi_t - E_{t-1}\pi_t]^2}$.

⇒ We do not model directly how agents “test” their model.

⇒ 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):

\[
k_t = \begin{cases} 
  k_{t-1} + 1, & \text{if } |\hat{E}_{t-1} \pi_t - E_{t-1} \pi_t| \leq v \times \text{MSE} \\
  \bar{g}^{-1}, & \text{otherwise}.
\end{cases}
\]

- More intuition:

\[
|\hat{E}_{t-1} \pi_t - E_{t-1} \pi_t| = |(1 - \gamma_p)(1 - \Gamma) \bar{\pi}_t| = \left| (1 - \gamma_p)(1 - \Gamma) \left[ \bar{\pi}_0 + \sum_{\tau=0}^{t} k_{\tau}^{-1} f_{\tau} \right] \right|
\]

⇒ 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)
  \[ k_{t-1} \to 0. \]
  ⇒ Sensitivity of long-term expectations to short-term forecast errors decreasing with time:  \( k_{t-1} \to 0. \)

- **Unanchored expectations**: agents doubt the constancy of long-run inflation and put more weight on recent inflation (Constant gain)
  \[ k_{t-1} = \bar{g}. \]
  ⇒ 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:


- Short-term forecasts (consensus):
US: Actual Inflation and Short-Term Survey Forecasts
Estimation: US

- Model in state-space form:

\[ k_t = f_k(\pi_{t-1}, k_{t-1}) \]

\[ \pi_t = f_{\pi}(\pi_{t-1}, k_{t-1}) + A_{\pi} (\pi_{t-1}, k_{t-1}) \xi_{t-1} \]

\[ \xi_t = f_{\xi}(\pi_{t-1}, k_{t-1}) + A_{\xi} (\pi_{t-1}, k_{t-1}) \xi_{t-1} + S \xi u_t \]

- Observation equation:

\[
Y_{t}^{US} = \begin{bmatrix}
\pi_t \\
E_{t}^{SP} \pi_{t+1} \\
E_{t}^{SP} \pi_{t+2} \\
E_{t}^{LIV_1} \left( \frac{1}{2} \sum_{i=1}^{2} \pi_{t+i} \right) \\
E_{t}^{LIV_2} \left( \frac{1}{2} \sum_{i=1}^{2} \pi_{t+i} \right)
\end{bmatrix}
= h_{0,t} + h_{\pi,t} \pi_t + H_t' \xi_t + R_t^{1/2} e_t.
\]
Estimation: US ctd.

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

- Structural parameters:
  \[ \bar{\theta} = (\pi^*, \nu, \bar{g}, \gamma_p, \Gamma, \rho_s, \sigma_s^2, \sigma_\mu^2)' \]

- ... and five i.i.d. observation errors.
Selected Estimated Parameters

- Strong feed-back effects: $\Gamma$ between 0.89 and 0.95.

- Little ‘intrinsic’ inflation persistence: $\gamma_p$ between 0.09 and 0.17.

- Constant gain: $\nu$ such that agents switch for $2\% > \bar{\pi}_t > 3\%$.
  
  - Steady-state inflation rate ($\pi^*$) 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 Blue Chip Economic Indicators 1-10 Years
Adding Consensus Economics 6-10 Years
Adding Survey of Professional Forecasters 1-10 Years
Estimated Gain $k_t^{-1}$
Estimation: Other Countries

Data:


Model’s predictions:

1. “Structural” params: use US posterior dist. as prior for these countries.
   - For $\pi^*$ and obs. errors use same prior distrib. as for the US.

2. Down-weight foreign country’s Likelihood. Posterior:

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

   - 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

The graph illustrates the Consumer Price Index (CPI) for Japan from 1985 to 2015. The CPI is shown as a dashed line, with short-term forecasts (ST fcsts) indicated by diamonds. The forecasts are divided into two categories: those for more than 1 year (ST fcsts > 1y) and those for less than 1 year (ST fcsts < 1y). The graph provides a visual representation of the inflation trends and forecast projections over the specified period.
Japan: Model-Implied and Obs. 6-11 Years Forecasts

![Graph showing Japan's model-implied and observed forecasts for 6-11 years, with data points and a trend line from 1985 to 2015.](image-url)
Japan: Learning Gain
Germany: Model-Implied and Obs. 6-11 Years Forecasts
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
Spain: Model-Implied and Obs. 6-11 Years Forecasts
Spain: Learning Gain

[Graph showing learning gain over time with data points from 1985 to 2015]
Switzerland: Model-Implied and Obs. 6-11 Years Forecasts
Switzerland: Learning Gain

![Graph showing learning gain over time in Switzerland](image-url)
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 $\alpha$, and with prob $(1 - \alpha)$ is indexed to a weighted average of past inflation and the perceived long-run inflation rate:

$$\bar{\Pi}_t^p = \pi_t^{1-\gamma_p} \bar{\Pi}_{t-1}^\gamma_p.$$
The New Keynesian Phillips Curve - ctd.

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

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

- Aggregating

\[ \pi_t = \gamma_p \pi_{t-1} + (1 - \gamma_p)\bar{\pi}_t + \]

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

- Solving for expectations, the DGP is

\[ \pi_t = \gamma_p \pi_{t-1} + (1 - \gamma_p)\bar{\pi}_t + \frac{(1 - \alpha\beta)(1 - \alpha)}{(1 - \alpha\beta\rho_s)} s_t + \mu_t \]
Lower Bound on Rationality

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

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

Implication: learning mechanism not policy invariant.
Model Summary

\[\pi_t = (1 - \gamma_p) \Gamma \bar{\pi}_t + \gamma_p \pi_{t-1} + \rho_s S_{t-1} + \epsilon_t + \mu_t\]

\[S_t = \rho_s S_{t-1} + \epsilon_t\]

\[\bar{\pi}_{t+1} = \left[1 + k_t^{-1} \times (1 - \gamma_p)(\Gamma - 1)\right] \bar{\pi}_t + k_t^{-1} \times (\epsilon_t + \mu_t)\]

\[k_{t+1} = I(\bar{\pi}_t) \times (k_t + 1) + (1 - I(\bar{\pi}_t)) \times \bar{g}^{-1}\]

where

\[I(\bar{\pi}) = \begin{cases} 
  k_{t-1} + 1, & \text{if } |(1 - \gamma_p)(\Gamma - 1) \bar{\pi}| \leq \nu \times \text{MSE} \\
  0, & \text{otherwise}.
\]
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

\[
\begin{align*}
\bar{\pi}_{t+1} &= \bar{\pi}_t + k_t^{-1} \left( \pi_t - \hat{E}_{t-1} \pi_t \right) \\
&= \left[ 1 + k_t^{-1} (1 - \gamma_p) (\Gamma - 1) \right] \bar{\pi}_t + k_t^{-1} (\epsilon_t + \mu_t).
\end{align*}
\]

- Key differences:
  - Persistence and volatility are time-varying and state-dependent.
  - Innovations to \( \bar{\pi}_t \) depend on inflation forecast errors: \textit{endogenous drift}. 
## US Estimates - Table of Priors and Posteriors

<table>
<thead>
<tr>
<th>Prior</th>
<th>Dist.</th>
<th>Mean</th>
<th>SD</th>
<th>Mode</th>
<th>Mean</th>
<th>SD</th>
<th>5%</th>
<th>Med.</th>
<th>95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$4\pi^*$</td>
<td>Normal</td>
<td>2.5</td>
<td>0.28</td>
<td>2.49</td>
<td>2.53</td>
<td>.20</td>
<td>2.21</td>
<td>2.52</td>
<td>2.89</td>
</tr>
<tr>
<td>$\nu$</td>
<td>Gamma</td>
<td>.05</td>
<td>.04</td>
<td>.02</td>
<td>.03</td>
<td>.01</td>
<td>.01</td>
<td>.03</td>
<td>.05</td>
</tr>
<tr>
<td>$g$</td>
<td>Gamma</td>
<td>.10</td>
<td>.09</td>
<td>.12</td>
<td>.15</td>
<td>.03</td>
<td>.10</td>
<td>.14</td>
<td>.21</td>
</tr>
<tr>
<td>$\Gamma$</td>
<td>Beta</td>
<td>.5</td>
<td>.26</td>
<td>.91</td>
<td>.88</td>
<td>.043</td>
<td>.81</td>
<td>.90</td>
<td>.95</td>
</tr>
<tr>
<td>$\gamma_p$</td>
<td>Beta</td>
<td>.5</td>
<td>.260</td>
<td>.10</td>
<td>.13</td>
<td>.03</td>
<td>.09</td>
<td>.13</td>
<td>.17</td>
</tr>
</tbody>
</table>