Anchored Inflation Expectations and the Slope of the Phillips Curve[1]

Peter Lihn Jørgensen
Copenhagen Business School

Kevin J. Lansing
FRB San Francisco

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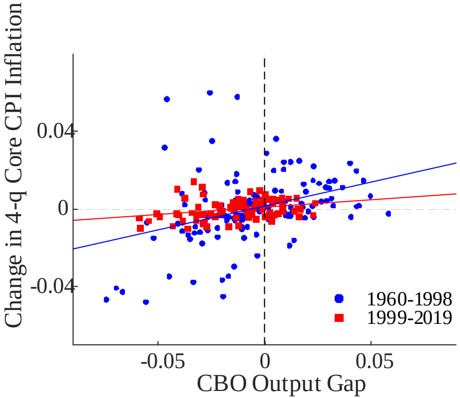
[1] Any opinions expressed here do not necessarily reflect the views of the Federal Reserve Bank of San Francisco or the Board of Governors of the Federal Reserve System.

The "flattening" of the Phillips Curve

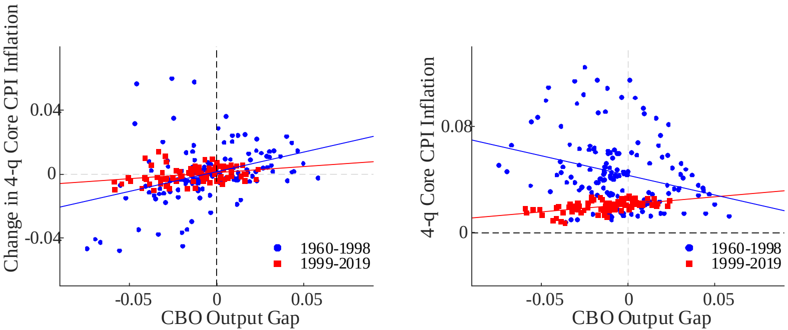
"The relationship between slack in the economy...and inflation was a strong one 50 years ago...and that has gone away"

Fed Chair Jerome Powell July 11, 2019.



Has the Phillips Curve become "flatter"?

- Depends on what we mean by "the Phillips Curve"
  - NKPC: $\pi_t = \widetilde{E}_t \boldsymbol{\pi}_{t+1} + \kappa y_t + u_t$
  - Left panel: $\pi_t = \boldsymbol{\pi}_{t-1} + \kappa y_t + u_t$ (backward-looking)
  - Right panel: $\pi_t = \overline{\boldsymbol{\pi}} + \kappa y_t + u_t$ ("original")



Key moments of US inflation data

Moments of U.S. inflation

	1960.q1-1998.q4	1999.q1-2019.q2	1999.q1-2007.q3
$Corr\left(\pi_t, y_t\right)$	–0.10	0.36	0.28
$Corr\left(\Delta\pi_t, y_t\right)$	0.14	0.03	0.07
$Corr\left(\pi_t, \pi_{t-1}\right)$	0.75	0.20	0.20
$Std.Dev\left(4\pi_t\right)$	2.91	0.80	0.77

Note: π_t is quarterly core CPI inflation and y_t is the CBO output gap

- $Corr\left(\Delta\pi_t, y_t\right) \downarrow$ but $Corr\left(\pi_t, y_t\right) \uparrow$
    - similar results for alternative measures of inflation or alternative gap variables

Theories of the "flatter" Phillips Curve

- New Keynesian Phillips Curve (NKPC):

$$\pi_t = \widetilde{E}_t \pi_{t+1} + \kappa y_t + u_t, \qquad u_t \sim N\left(0, \sigma_u^2\right),$$

1. **The PC has become structurally flatter** $\Rightarrow \kappa \downarrow$
   (Ball & Mazumder 2011; IMF 2013; Blanchard, et al. 2015)
2. **Monetary policy has blurred the statistical correlation between** π_t **and** y_t $\Rightarrow Corr\left(y_t, u_t\right) < 0$
   (Bullard 2018; McLeay & Tenreyro 2020)

   All else equal, #1 and #2 imply $Corr\left(\pi_t, y_t\right) \downarrow$
   $\Rightarrow$ but the opposite has happened in the data!

   Alternative theory:

3. **Inflation expectations have become more firmly anchored**
   (Mishkin 2007; Bernanke 2007, 2010; Stock 2011; Blanchard 2016; Hazell et. al. 2020)

This paper

- We estimate a NKPC on US data that allows for changes in the degree of anchoring of expected inflation
  1. Expectations have become much better anchored over the Great Moderation
  2. The structural slope coefficient κ has been stable since 1960
  3. There is no "missing disinflation" puzzle or "missing inflation" puzzle

- In a simple New Keynesian model with endogenous anchoring:
  1. An increase in the Taylor rule coefficient on inflation serves to endogenously anchor agents' subjective inflation expectations
  2. Improved anchoring implies $Corr\left(\Delta\pi_t, y_t\right)\downarrow$ but $Corr\left(\pi_t, y_t\right)\uparrow$
  3. It also implies $Std.Dev\left(\pi_t\right)\downarrow$ and $Corr\left(\pi_t, \pi_{t-1}\right)\downarrow$

Formalizing anchoring

- Motivated by survey evidence (Coibion & Gorodnichenko 2015), we postulate:

$$\widetilde{E}_t \pi_{t+1} = \widetilde{E}_{t-1} \pi_t + \lambda_\pi (\pi_t - \widetilde{E}_{t-1} \pi_t),$$

  where λ_π = gain parameter

- λ_π is an inverse measure of the degree of anchoring
  - *"I use the term 'anchored' to mean relatively insensitive to incoming data"* – Bernanke (2007)
- Optimal forecast rule if agents employ an unobserved components time series model to forecast inflation along the lines of Stock & Watson (2007, 2010)
  - A "signal extraction" forecast rule

NKPC estimation: Has the structural slope declined?

- Substitute forecast rule into NKPC and solve for π_t:

$$\pi_t = \widetilde{E}_{t-1}\pi_t \; + \; \frac{\kappa}{1-\lambda_\pi} y_t \; + \frac{1}{1-\lambda_\pi} u_t,$$

where $\widetilde{E}_{t-1}\pi_t = \widetilde{E}_{t-2}\pi_{t-1} + \lambda_\pi(\pi_{t-1} - \widetilde{E}_{t-2}\pi_{t-1})$

- Estimate κ and λ_π
    - Generalized IV using lagged variables as instruments (Gali & Gertler 1999)
    - Using data for core CPI inflation and the CBO output gap from 1960.q1 to 2019.q2.
    - Including current and lagged oil price inflation as regressors
    - Instruments: Two lags of core CPI inflation and oil price inflation and one lag of the CBO output gap and wage inflation

- Split data into three subsamples.

NKPC estimation: Results (1/2)

Three "Great" Eras

	Great Inflation 1960.q1 to 1983.q4	Great Moderation 1984.q1 to 2007.q3	Great Recession 2007.q4 to 2019.q2
	A. Signal-extraction: $\widetilde{E}_t \pi_{t+1} = \widetilde{E}_{t-1}\pi_t + \lambda_\pi(\pi_t - \widetilde{E}_{t-1}\pi_t)$		
$\widehat{\kappa}$	0.066***	0.042***	0.063***
	(0.115)	(0.015)	(0.013)
$\widehat{\lambda}_\pi$	0.280***	0.119**	0.008
	(0.021)	(0.059)	(0.010)

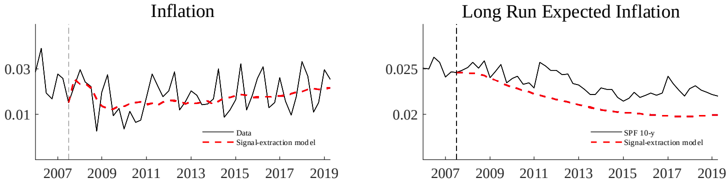
Notes: The asterisks ***, ** and * denote significance at the 1, 5, and 10% levels, respectively. The estimation uses quarterly inflation rates (not annualized). Newey-West standard errors are shown in parentheses

NKPC estimation: Results (2/2)

	Great Inflation 1960.q1 to 1983.q4	Great Moderation 1984.q1 to 2007.q3	Great Recession 2007.q4 to 2019.q2
	B. Survey Data: $\widetilde{E}_t \pi_{t+1} = \widetilde{E}^s_t \pi_{t+h}$		
		1-q SPF	
$\widehat{\kappa}$		0.006	0.026***
		(0.020)	(0.011)
		5-y MSC	
$\widehat{\kappa}$		0.024**	0.070***
		(0.011)	(0.015)
		10-y SPF	
$\widehat{\kappa}$		0.041***	0.065***
		(0.010)	(0.019)

Resolving the inflation puzzles

- Estimate model on 1999.q1-2007.q3 subsample.
  - $\widehat{\lambda}_\pi = 0.024$, $\widehat{\kappa} = 0.048^{***}$
- Out-of-sample forecast: Compute (median) projected paths for π_t and $\widetilde{E}_t \pi_{t+1}$ from 2007.q4 to 2019.q2, conditional on y_t=CBO output gap.



- No "missing disinflation" during Great Recession.
- No "missing inflation" during subsequent recovery.

Endogenous anchoring in New Keynesian model (1/4)

- How does a shift towards a more hawkish monetary policy affect the PC relationship?
- Counterfactual prediction of RE models: $Corr\left(\pi_t, y_t\right) \downarrow$ (Bullard 2018; McLeay and Tenreyro 2020)
- We show that an endogenous anchoring mechanism can overturn this counterfactual prediction

Endogenous anchoring in New Keynesian model (2/4)

Phillips curve:

$$\pi_t = \beta \widetilde{E}_t \pi_{t+1} + \kappa y_t + u_t, \qquad u_t \sim N(0, \sigma_u^2).$$

IS curve:

$$y_t = \widetilde{E}_t y_{t+1} - \alpha(i_t - \widetilde{E}_t \pi_{t+1}) + v_t, \qquad v_t \sim N\left(0, \sigma_v^2\right),$$

Taylor-type policy rule:

$$i_t = \mu_\pi \widetilde{E}_t \pi_{t+1} + \mu_y \widetilde{E}_t y_{t+1},$$

Subjective forecast rules:

$$\begin{aligned} \widetilde{E}_t \pi_{t+1} &= \widetilde{E}_{t-1} \pi_t + \lambda_\pi(\pi_t - \widetilde{E}_{t-1} \pi_t), \\ \widetilde{E}_t y_{t+1} &= \widetilde{E}_{t-1} y_t + \lambda_y(y_t - \widetilde{E}_{t-1} y_t). \end{aligned}$$

How does anchoring affect the original PC slope?

- Consider simplified model with $\lambda_y \to 0$ and $\widetilde{E}_{t-2}\pi_{t-1} \simeq 0$. Implies:

$$Cov(\pi_t, y_t) \simeq -\frac{\alpha(\mu_\pi - 1)\widehat{\beta}(1-\lambda_\pi)^2\lambda_\pi^2}{(1-\widehat{\beta}\lambda_\pi)^2} Var(\pi_{t-1}) + \frac{(1-\beta\lambda_\pi)\kappa}{(1-\widehat{\beta}\lambda_\pi)^2}\sigma_v - \frac{\alpha(\mu_\pi - 1)\lambda_\pi}{(1-\widehat{\beta}\lambda_\pi)^2}\sigma_u,$$

where $\widehat{\beta} = \beta - \kappa\alpha(\mu_\pi - 1) > 0$.

1. Lagged inflation π_{t-1} induces **negative** co-movement
2. Demand shocks v_t induce **positive** co-movement.
3. Cost-push shocks u_t induce **negative** co-movement

For $\lambda_\pi \to$ 0, first and third terms go to zero and $\frac{Cov(\pi_t, y_t)}{Var(y_t)} \to \kappa$

Can anchoring explain the shifting relative slopes?

- Yes. Note the following definitional relationship:

$$\frac{Cov\left(\Delta\pi_t, y_t\right)}{Var\left(y_t\right)} - \frac{Cov\left(\pi_t, y_t\right)}{Var\left(y_t\right)} = -\frac{Cov\left(\pi_{t-1}, y_t\right)}{Var\left(y_t\right)}$$

- Poor anchoring implies $Cov\left(\pi_{t-1}, y_t\right) < 0$
    - Intuition: $\pi_{t-1} \uparrow \Rightarrow \widetilde{E}_t \pi_{t+1} \uparrow \Rightarrow \pi_t \uparrow \Rightarrow i_t \uparrow \Rightarrow y_t \downarrow$
- Improved anchoring, i.e. $\lambda_\pi \downarrow$, *weakens* this negative co-movement force
    - This will serve to "flatten" the backward-looking PC relative to the original PC
    - Indeed, in US data, $Cov\left(\pi_{t-1}, y_t\right)$ has gone from negative to positive

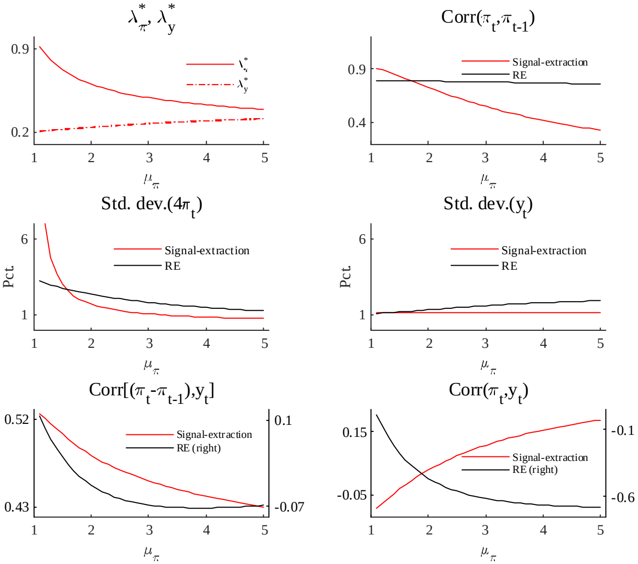
Unique fixed point learning equilibrium

- Without anchoring, $\mu_\pi \uparrow \Rightarrow Corr(\pi_t, y_t) \downarrow$
- Introduce *endogenous* anchoring mechanism
- Unique fixed point learning equilibrium:
  - Agents use unobserved components models to forecast inflation and the output gap
    $\Rightarrow$ signal-extraction forecast rules are perceived optimal!
  - λ_π^* is endogenously (and uniquely) pinned down by the coefficient $Corr(\triangle\pi_t, \triangle\pi_{t-1})$
  - Endogenous anchoring mechanism:
    $\mu_\pi \uparrow \Rightarrow Corr(\triangle\pi_t, \triangle\pi_{t-1}) \downarrow \Rightarrow \lambda_\pi^* \downarrow \Rightarrow Corr(\pi_t, y_t) \uparrow$

Endogenous anchoring in New Keynesian model (3/4)

- Key question: How will $\mu_\pi \uparrow$ affect $Corr\left(\Delta\pi_t, y_t\right)$ and $Corr\left(\pi_t, y_t\right)$ with endogenous anchoring?
- Exercise: Compute these moments for different values of the policy rule coefficient μ_π
  - Signal-extraction model vs. RE version of the model
  - Standard calibration (see paper for details)

Endogenous anchoring in New Keynesian model (4/4)



Conclusion

- U.S. inflation expectations have become much better anchored over the Great Moderation period.
- Accounting for improved anchoring, estimated NKPC slope parameter κ is statistically significant and stable from 1960 to 2019.
- Out-of-sample forecasts resolve inflation puzzles.
- In a simple NK model, a stronger Taylor rule response to inflation helps to:
  1. Endogenously anchor $\widetilde{E}_t \pi_{t+1}$.
  2. Flatten backward-looking PC.
  3. Resurrect the original PC.
  4. Reduce inflation volatility.
  5. Lower inflation persistence.