PHILLIPS CURVE: CROSS-SECTIONAL ESTIMATION

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[1] These slides build heavily on slides for our paper Hazell, Herreno, Nakamura, Steinsson (2021)

Phillips Curve

New Keynesian formalization:

$$\pi_t = \beta E_t \pi_{t+1} - \kappa(u_t - u_t^n) + \nu_t$$

Drivers of inflation:

- Expected inflation: $E_t \pi_{t+1}$
- Measure of "output gap": $u_t - u_t^n$
- Cost-push shocks: ν_t

Object of interest: Slope coefficient κ

- How much does an increase in "demand" affect inflation

Conventional Wisdom

- Volcker disinflation:
    - Tight policy -> high unemployment -> lower inflation
    - Substantial slope of the Phillips curve
- Since 1990:
    - Muted response of inflation to unemployment
    - Great Recession: missing disinflation
    - Late 2010s and 1990s: missing rise in inflation
- Phillips curve is getting flatter or hibernating
    - Perhaps an important flaw in the Keynesian model

Conventional Wisdom

- Assume adaptive expectations: $\beta E_t \pi_{t+1} = \pi_{t-1}$
- In this case,

$$\pi_t = \beta E_t \pi_{t+1} - \kappa(u_t - u_t^n) + \nu_t$$

becomes

$$\Delta\pi_t = -\kappa(u_t - u_t^n) + \nu_t,$$

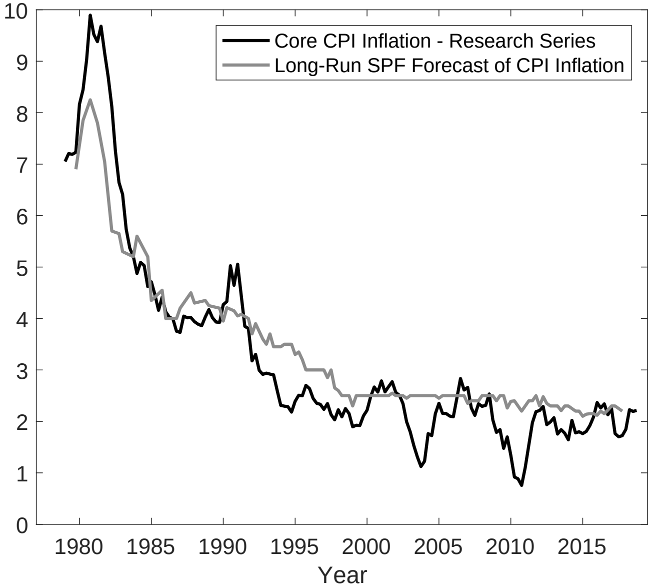
- Stock and Watson (2019):
  - $\Delta\pi_t$: Annual change in 12-month core PCE inflation
  - $u_t - u_t^n$: CBO unemployment gap
  - Refer to κ as “Phillips correlation”

Flattening Phillips Curve

Alternative Explanation

- Volcker disinflation:
    - Sharp regime shift
    - Rapid fall in long-run inflation expectations
    - Rapid fall in inflation
- Since 1990:
    - Long-run inflation expectations have become anchored
    - Consequently, inflation has become more stable
- Apparent "flattening" of Phillips curve due to anchoring of inflationary expectations (Bernanke, 2007; Mishkin, 2007)

Long-Run Inflation Expectations



Can We Tell These Stories Apart?

- Extremely difficult using aggregate evidence
  - Results based on survey or adaptive expectations are very sensitive to details of specification (e.g., which expectation variable)
  - Results based on structural rational expectations specifications also very sensitive to details (partly due to a weak instruments problem)
- Mavroeidis, Plagborg-Moller, Stock 14:

  [T]he Literature has reached a limit on how much can be learned about the New Keynesian Phillips curve from aggregate macroeconomic time series. New identification approaches and new datasets are needed to reach an empirical consensus.

Identification Challenges

1. Inflation expectations may covary with unemployment
   - For example: Imperfectly credible regime change
   - Literature seeks to control for inflation expectations but this is difficult in practice
2. Supply shocks (u_t^n and ν_t)
   - Lead to positive comovement between inflation and unemployment (stagflation)
   - Good monetary policy compounds with by counteracting demand variation, leaving only supply variation (Fitzgerald-Nicolini, 2014, McLeay-Tenreyro 2019)

Can Cross-Sectional Data Help?

- Recent literature estimates "regional Phillips curves"
  - Fitzgerald-Nicolini 14; Kiley 15; Babb-Detmeister 17; McLeay-Tenreyro 19; Hooper-Mishkin-Sufi 19; Fitzgerald-Jones-Kulish-Nicolini 20; Beraja-Hurst-Ospina 19 (wages), Hazell-Herreno-Nakamura-Steinsson 21.
- Major advantages:
  - Fixed effects soak up variation in (common) long-run inflation expectations
  - Fixed effects soak up aggregate supply shocks
  - Shift-share instruments can be used to deal with regional supply shocks
- New challenge:
  - How is the slope of the regional Phillips curve related to the slope of the aggregate Phillips curve?

The Role of the Long-Run Inflation Target

- Let's understand better the central role of long-run inflation expectations:

$$\pi_t = \beta E_t \pi_{t+1} - \kappa(u_t - u_t^n) + \nu_t$$

- Solve forward:

$$\pi_t = -\kappa E_t \sum_{j=0}^{\infty} \beta^j u_{t+j} + \omega_t$$

where $\omega_t = E_t \sum_{j=0}^{\infty} \beta^j (\kappa u_{t+j}^n + \nu_{t+j})$.

- Looks like long-run inflation expectation vanishes due to discounting

- This is an illusion!

The Role of the Long-Run Inflation Target

- Useful to decompose u_{t+j} into permanent and transitory component:

$$\pi_t = -\kappa E_t \sum_{j=0}^{\infty} \beta^j u_{t+j} + \omega_t$$

becomes

$$\pi_t = -\kappa E_t \sum_{j=0}^{\infty} \beta^j \tilde{u}_{t+j} + \frac{\kappa}{1-\beta} E_t u_{t+\infty} + \omega_t$$

where $\tilde{u}_t \equiv u_t - E_t u_{t+\infty}$

- Since $\frac{\kappa}{1-\beta} E_t u_{t+\infty} = E_t \pi_{t+\infty}$, we have

$$\pi_t = -\kappa E_t \sum_{j=0}^{\infty} \beta^j \tilde{u}_{t+j} + E_t \pi_{t+\infty} + \omega_t$$

(Same result with $\beta = 1$)

The Role of the Long-Run Inflation Target

$$\pi_t = -\kappa E_t \sum_{j=0}^{\infty} \beta^j \tilde{u}_{t+j} + E_t \pi_{t+\infty} + \omega_t$$

- Long-run inflation target actually major determinant of current inflation
- Has a coefficient of one!!
- Current inflation moves one-for-one with beliefs about long-run inflation target
- In contrast, κ may be very small

The Role of the Long-Run Inflation Target

- To simplify, one can assume that $\tilde{u}_t$ follows an AR(1)
- This implies $E_t\tilde{u}_{t+j} = \rho_u^j\tilde{u}_t$

$$\pi_t = -\kappa E_t \sum_{j=0}^{\infty} \beta^j \tilde{u}_{t+j} + E_t\pi_{t+\infty} + \omega_t$$

becomes

$$\pi_t = -\psi\tilde{u}_t + E_t\pi_{t+\infty} + \omega_t$$

where $\psi = \kappa/(1-\beta\rho_u)$.

The Role of the Long-Run Inflation Target

$$\pi_t = -\psi \tilde{u}_t + E_t \pi_{t+\infty} + \omega_t$$

- Variation in inflation may be dominated by variation in $E_t \pi_{t+\infty}$
- Variation in inflation may be **completely unrelated** to variation in $\tilde{u}_t$
- Worse still, correlation between $E_t \pi_{t+\infty}$ and $\tilde{u}_t$ potentially a source of severe omitted variables bias

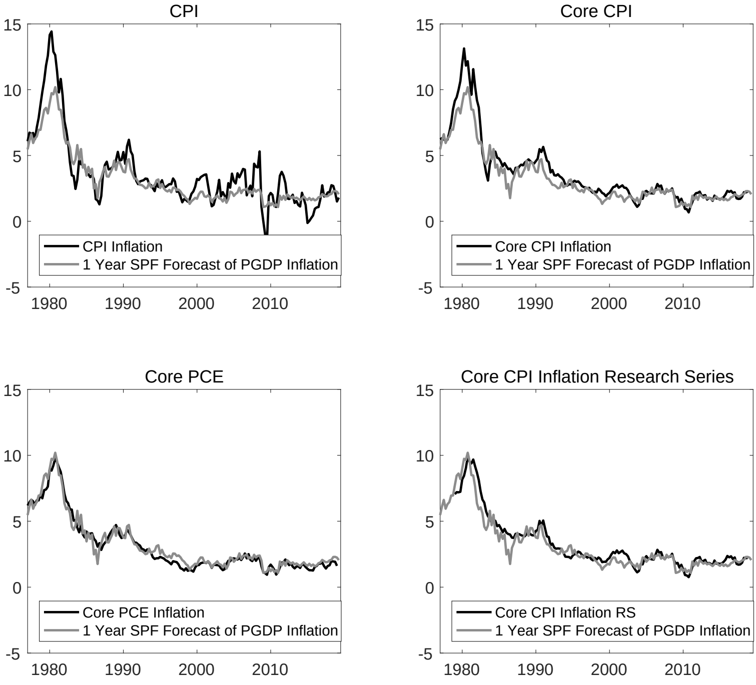
How Different Are π_t and $E_t\pi_{t+1}$?

$$\pi_t = \beta E_t \pi_{t+1} - \kappa(u_t - u_t^n) + \nu_t$$

- This is approximately (if $\beta \approx 1$):

$$\pi_t - E_t \pi_{t+1} \approx -\kappa(u_t - u_t^n) + \nu_t$$

- So, standard analysis aims to explain $\pi_t - E_t \pi_{t+1}$
- But how much is there to explain?
- Let's look at the difference between π_t and $E_t \pi_{t+1}$ in the data


CPI
CPI Inflation
1 Year SPF Forecast of PGDP Inflation
Core CPI
Core CPI Inflation
1 Year SPF Forecast of PGDP Inflation
Core PCE
Core PCE Inflation
1 Year SPF Forecast of PGDP Inflation
Core CPI Inflation Research Series
Core CPI Inflation RS
1 Year SPF Forecast of PGDP Inflation
15
10
5
0
-5
1980
1990
2000
2010

$\pi_t \approx E_t \pi_{t+1}$

$$\pi_t - E_t \pi_{t+1} \approx -\kappa(u_t - u_t^n) + \nu_t$$

- Inflation gap for core inflation is small throughout

  (for core using modern methods)
- Consistent with a flat Phillips curve

However:

- Relies heavily on exact timing of New Keynesian Phillips curve

  (Also subject to other concerns regarding aggregate Phillips curve estimation)

A Model of the Regional Phillips Curve

- Two regions: Home and Foreign
- Tradeable and non-tradeable sector in each region
- No labor mobility between regions
- Perfect labor mobility between sectors within region
- Monetary union

Households and Firms

- Households:
  - Consume and supply labor
  - Nested CES demand over varieties of traded and non-traded goods
  - GHH preferences
- Firms:
  - Linear production function in labor
  - Calvo (1983) type price rigidity

Phillips Curves

- Regional Phillips Curve for Non-Tradeables:

$$\pi_{Ht}^{N} = \beta E_t \pi_{H,t+1}^{N} - \kappa \hat{u}_{Ht} - \lambda \hat{p}_{Ht}^{N} + \nu_{Ht}^{N}$$

- Aggregate Phillips Curve:

$$\pi_t = \beta E_t \pi_{t+1} - \kappa \hat{u}_t + \nu_t$$

where $\hat{u}_{Ht} = -\hat{n}_{Ht}$ and $\hat{u}_t = -\hat{n}_t$

- Important result: Same slope κ
  - This is true for non-tradeable regional Phillips curve
  - Not for overall regional Phillips curve (traded goods priced nationally)
  - Relies on GHH preferences

Regional Phillips Curve for Non-Tradeables

$$\pi^N_{Ht} = \beta E_t \pi^N_{H,t+1} - \kappa \hat{u}_{Ht} - \lambda \hat{p}^N_{Ht} + \nu^N_{Ht}$$

- Extra term: $\lambda \hat{p}^N_{Ht}$. Theoretically important!
- Common critique:
  - Even in multi-region RBC model, regional demand shock would result in an increase in relative price of local goods
- Extra term implies that this model nests multi-region RBC model
- If prices were flexible, λ would be large
- Empirically, λ estimated to be small

Regional Phillips Curve Solved Forward

- Let's solve the regional Phillips curve forward:

$$\pi_{Ht}^{N} = -\kappa E_t \sum_{j=0}^{\infty} \beta^j \tilde{u}_{H,t+j} - \lambda E_t \sum_{j=0}^{\infty} \beta^j \hat{p}_{H,t+j}^{N} + E_t \pi_{t+\infty} + \omega_{Ht}^{N},$$

- Long-run inflation expectations are constant across regions and can be replaced with time and state fixed effects:

$$\pi_{Ht}^{N} = -\kappa E_t \sum_{j=0}^{\infty} \beta^j \tilde{u}_{H,t+j} - \lambda E_t \sum_{j=0}^{\infty} \beta^j \hat{p}_{H,t+j}^{N} + \alpha_i + \gamma_t + \omega_{Ht}^{N},$$

- Panel specification "differences out" long-run inflation expectations

Common Across Regions?

$$\pi_{Ht}^N = -\kappa E_t \sum_{j=0}^{\infty} \beta^j \tilde{u}_{H,t+j} - \lambda E_t \sum_{j=0}^{\infty} \beta^j \hat{p}_{H,t+j}^N + E_t \pi_{t+\infty} + \omega_{Ht}^N,$$

- Can't long-run inflation expectation differ across regions?
  - Prices are rising in New York relative to Kansas
  - Balassa-Samuelson effects
- Constant differences captured by state fixed effects
- Non-constant differences in **long-run** inflation expectations will be in error term
  - Small part of total variation (arguably)
  - A concern if correlated with instruments

Interpretation of Slope Coefficient

- Regional Phillips curve:

$$\pi^N_{Ht} = -\boldsymbol{\kappa} E_t \sum_{j=0}^{\infty} \beta^j \tilde{u}_{H,t+j} - \lambda E_t \sum_{j=0}^{\infty} \beta^j \hat{p}^N_{H,t+j} + \alpha_i + \gamma_t + \omega^N_{Ht},$$

- Suppose we assume that $\tilde{u}_{Ht}$ and $\hat{p}^N_{Ht}$ follow AR(1) processes:

$$\pi^N_{Ht} = -\boldsymbol{\psi} \tilde{u}_{Ht} - \delta \hat{p}^N_{Ht} + \alpha_i + \gamma_t + \omega^N_{Ht} \tag{1}$$

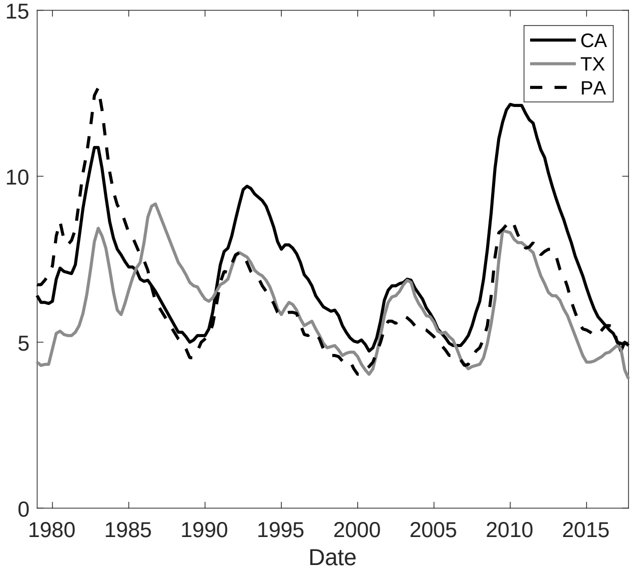
$$\text{where} \qquad \psi = \frac{\kappa}{1 - \beta\rho_u} \qquad \text{and} \qquad \delta = \frac{\lambda}{1 - \beta\rho_{pN}}$$

- Equation (1) similar to typical regional empirical specification
- But κ and ψ are not the same!
  - ψ potentially much larger than κ since $\tilde{u}_{Ht}$ is persistent
  - Prior regional Phillips curve literature estimates ψ not κ.
  - Helps explain large slope estimates in this literature

DATA

- New state-level inflation indexes (Hazell-Herreno-Nakamura-Steinsson 21)
  - Sample period 1978 - 2018, quarterly
  - Based on BLS CPI micro data
  - Free of cross-state imputations
  - Separate indexes for tradeables vs. non-tradeables
- Analyze housing separately
- Measure of slack: State unemployment rates
- Tradeable demand spillover instrument:
  - State-industry employment shares
  - 2-digit SIC for 1975-2000
  - 3-digit NAICS from 1990-2018

Regional Business Cycles



Phillips Curve Slope

- Regional Phillips curve from model:

$$\pi_{it}^N = \alpha_i + \gamma_t - \boldsymbol{\kappa} E_t \sum_{j=0}^{\infty} \beta^j u_{i,t+j} - \lambda E_t \sum_{j=0}^{\infty} \beta^j \hat{p}_{i,t+j}^N + \omega_{it}$$

- Reduced form equation similar to prior literature:

$$\pi_{it}^N = \alpha_i + \gamma_t - \boldsymbol{\psi} u_{i,t-4} - \delta p_{i,t-4}^N + \varepsilon_{it}$$

- HHNS present estimates of both $\boldsymbol{\kappa}$ and $\boldsymbol{\psi}$

Estimation of κ

$$\pi_{it}^N = \alpha_i + \gamma_t - \boldsymbol{\kappa} E_t \sum_{j=0}^{\infty} \beta^j u_{i,t+j} - \lambda E_t \sum_{j=0}^{\infty} \beta^j \hat{p}_{i,t+j}^N + \omega_{it}$$

- Replace expectations with realized values and expectation error and truncate the infinite sums:

$$\pi_{it}^N = \alpha_i + \gamma_t - \boldsymbol{\kappa} \sum_{j=0}^{T} \beta^j u_{i,t+j} - \lambda \sum_{j=0}^{T} \beta^j \hat{p}_{i,t+j}^N + \omega_{it} + \eta_{it}$$

  where η_{it} is an expectations error (and truncation error)

- κ can now be estimated using an IV regression (i.e., GMM)

- Calibrate $\beta = 0.99$

Identification

Two Approaches:

1. Use lagged unemployment and relative prices as instruments
   - Unemployment may reflect supply shocks
   - Time fixed effects capture national supply shocks
   - Identifying assumption: No relative change in restaurant technology in Texas vs. Illinois when Texas experiences a recession relative to Illinois
2. Tradeable demand instrument

Tradeable Demand Spillover Instrument

$$\text{Tradable Demand}_{i,t} = \sum_{x \in T} \bar{S}_{x,i} \times \Delta \log S_{-i,x,t}$$

- $\bar{S}_{x,i}$: Average employment share of industry x in state i over time
- $\log S_{-i,x,t}$: National employment share of industry x at time t

- Identifying assumption: supply shocks not simultaneously correlated with **both** shifts $\Delta \log S_{-i,x,t}$ **and** shares $\bar{S}_{x,i}$
- Intuition:
  - Oil boom increases labor demand and wages in Texas
  - "Demand shock" for Texan restaurants
  - Oil boom does not differentially affect production technology for restaurants in Texas

Estimation of ψ

$$\pi_{it}^{N} = \alpha_i + \gamma_t - \psi u_{i,t-4} - \delta p_{i,t-4}^{N} + \varepsilon_{it}$$

Same two approaches:

- OLS
- Instrument for $u_{i,t-4}$ with tradeable demand instrument

TABLE: Full Sample

	No State Effects	No Time Effects	Lagged u IV	Tradeable Demand IV
	(1)	(2)	(3)	(4)
ψ	-0.103	0.017	0.112	0.339
	(0.036)	(0.027)	(0.057)	(0.126)
κ	-0.0037	0.0003	0.0062	0.0062
	(0.0013)	(0.0019)	(0.0028)	(0.0025)
State Effects		✓	✓	✓
Time Effects			✓	✓

TABLE: Has the Phillips Curve Flattened?

	Lagged u IV No Time Fixed Effects		Lagged u IV Time Fixed Effects		Tradeable Demand IV Time Fixed Effects	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
	(1)	(2)	(3)	(4)	(5)	(6)
ψ	0.449	0.009				
	(0.063)	(0.025)				
κ	0.0278	0.0002				
	(0.0025)	(0.0017)				

All specifications include state fixed effects

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	Lagged u IV No Time Fixed Effects		Lagged u IV Time Fixed Effects		Tradeable Demand IV Time Fixed Effects	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
	(1)	(2)	(3)	(4)	(5)	(6)
ψ	0.449	0.009	0.198	0.090	0.422	0.332
	(0.063)	(0.025)	(0.113)	(0.057)	(0.232)	(0.157)
κ	0.0278	0.0002	0.0107	0.0050	0.0109	0.0055
	(0.0025)	(0.0017)	(0.0080)	(0.0038)	(0.0048)	(0.0029)

All specifications include state fixed effects

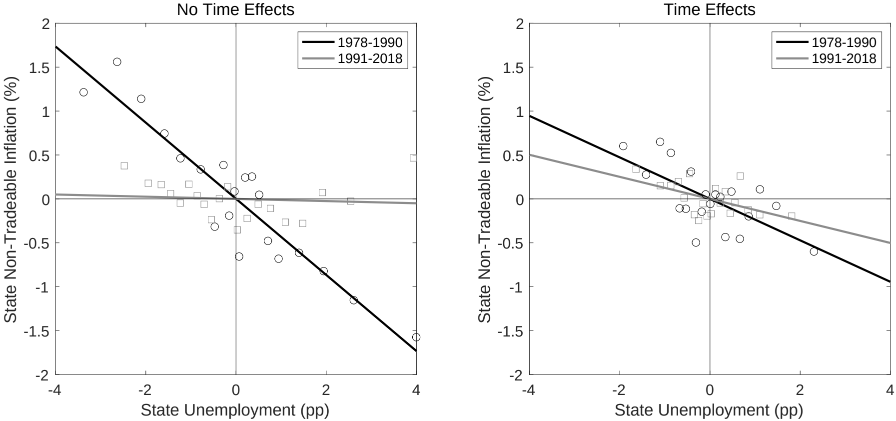

FIGURE: Scatterplots—Non-Tradeable Inflation and Unemployment

Main Conclusions

- Slope of Phillips curve small
  - $\kappa = 0.0062$ implies that even a 5 percentage point increase in unemployment decreases inflation by only 2 percentage points (if inflation expectations remain unchanged)
- Apparent "flattening" mainly due to anchoring of expectations
  - No time fixed effects: Factor >100 flattening
  - With time fixed effects: Factor 2 flattening
  - Interpretation: Time fixed effects absorb movements in long-run inflation expectations

TABLE: HHNS Estimates Compared to Prior Work

	κ
Gali (2008)	0.085
Rotemberg and Woodford (1997)	0.019
Nakamura and Steinsson (2014)	0.0077
Our Estimate	
Full Sample IV Estimate	0.0062

Note: HHNS adjust prior estimates by the elasticity of output with respect to employment in the model in these papers. For Nakamura and Steinsson (2014), HHNS use the calibration with GHH preferences.

Missing Disinflation?

- Can HHNS's cross-section estimate of κ explain aggregate time-series fluctuations in inflation?
- Many have argued:
  - Missing disinflation during Great Recession
  - Missing reinflation during late 2010s and late 1990s
- Are cross-sectional estimates of Phillips curve steeper than time-series estimates?

Aggregate Implication

- Plot RHS and LHS of

$$\pi_t - E_t\pi_{t+\infty} = -\kappa\zeta\tilde{u}_t + \omega_t$$

  assuming no supply shocks $\omega_t = 0$

- Scaling factor: $\zeta = 6.16$ (s.e. 1.80)

$$\sum_{j=0}^{T} \beta^j \tilde{u}_{t+j} = \zeta\tilde{u}_t + \alpha + \epsilon_t.$$

- Aggregate includes housing
  - Estimate aggregate Phillips curve for shelter
  - Data from American Community Survey for 2001-2017
  - $\kappa = 0.0243$ (s.e. 0.0053)
  - About four time larger than for non-shelter

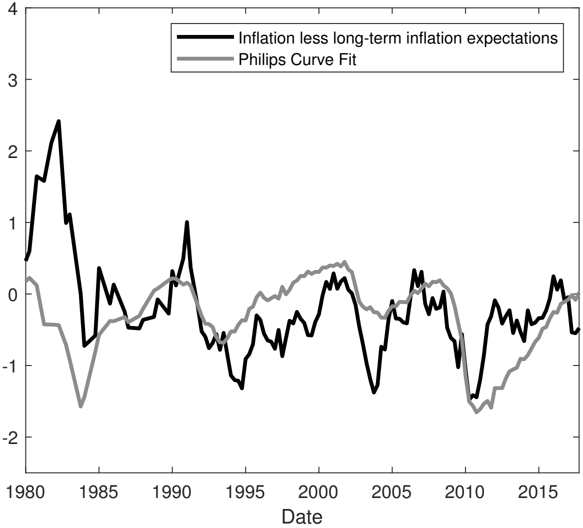

FIGURE: Aggregate Phillips Curve

Has Phillips Curve "Broken Down" Recently?

- Post-1990: Predictions fit data reasonably well
  - Essentially no missing disinflation or missing reinflation
- Pre-1990: Data deviates substantially from predictions
  - Actual inflation gap much higher than predicted
  - Natural Explanation: Adverse supply shocks
- Opposite of conventional wisdom

The Elephant in the Room

- Key determinant of inflation: $E_t \pi_{t+\infty}$
- But how does the monetary authority change $E_t \pi_{t+\infty}$
  - Fundamentally hard!!
  - How does it convince people that what it says is credible?
  - Answering this is not a strong suit of economists (need more research)
- Sometimes beliefs do change rapidly
  (e.g., Volcker disinflation, ends of hyperinflations)

How Does One Change Long-Run Beliefs?

- Volcker tightened policy dramatically
  - Caused massive recession
  - Didn't get fired
- Perhaps this was crucial in changing beliefs about long-run monetary regime
- Fundamentally different from view that inflation fell due to steep Phillips curve