The Slope of the Phillips Curve: Evidence from U.S. States

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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 $\rightarrow$ high unemployment $\rightarrow$ lower inflation
  - Suggests the Phillips curve is steep
- 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 (or dead)
  - 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,

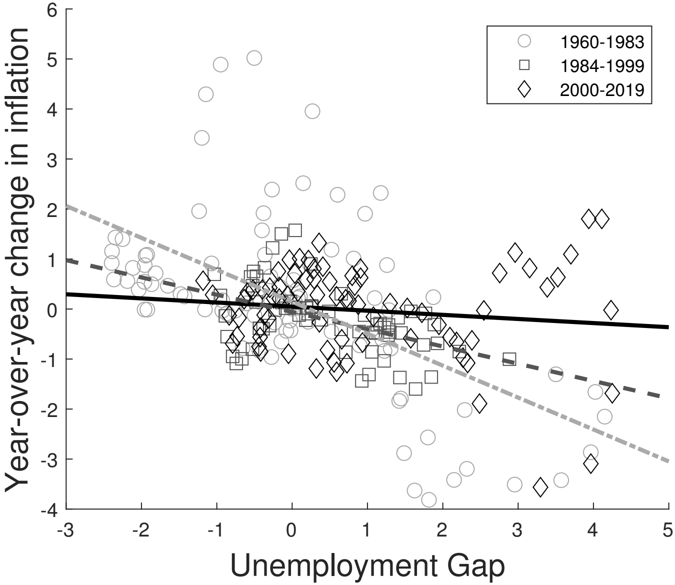
$$\pi_t = \beta E_t \pi_{t+1} - \kappa(u_t - u_t^n) + \nu_t$$

  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”

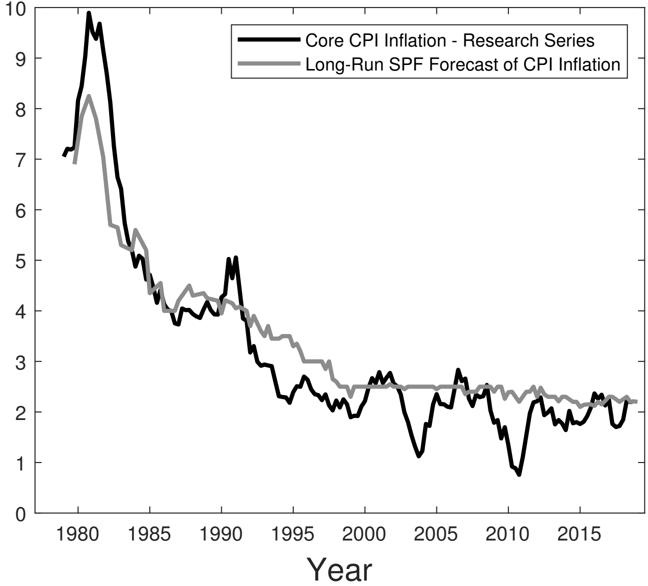
Flattening Phillips Curve



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



Identification Challenges

1. Inflation expectations may covary with unemployment
   - For example: Imperfectly credible regime change
   - Literature seeks to control for inflation expectations
   - Results sensitive to details / weak instruments (Mavroeidis et al. 2014)
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)
- Emphasizes advantages regarding endogeneity of unemployment
  - Monetary policy cannot eliminate regional demand shocks
- We seek to contribute to this literature in several ways

What We Do

- Show that regional estimation eliminates shifting $E_t \pi_{t+\infty}$
  - Absorbed by time fixed effects in panel specification
- Is slope of regional Phillips curve same as aggregate Phillips curve?
  - Provide conditions under which it is (for non-tradeables)
  - Crucial to focus on non-tradeable inflation to avoid downward bias!
- Construct new state-level price indexes back to 1978
  - Based on micro price data underlying US CPI
  - Avoid imputation / match state-level unemployment
- New tradeable demand spillover instrument

Results

- Slope of Phillips curve is small and has always been small (at least since 1978)
- No missing disinflation or missing reinflation since 1990
- Volcker disinflation:
  - Mostly due to fall in long-run expectations
  - Only 2 percentage points due directly to high unemployment
- Flattening of the Phillips curve not quantitatively important (because initial slope was small)

The Power and Problem of Expected Inflation

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

- Current inflation determined by current and future unemployment

- 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

- Assume for simplicity 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

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

- Long-run inflation target major determinant of current inflation
  - Has a coefficient of one
  - Current inflation moves one-for-one with beliefs about long-run inflation target
- Inflation can vary without **any** variation in $\tilde{u}_t$
  - Purely due to changes in $E_t \pi_{t+\infty}$
- Correlation between $E_t \pi_{t+\infty}$ and $\tilde{u}_t$ potentially a source of severe omitted variables bias

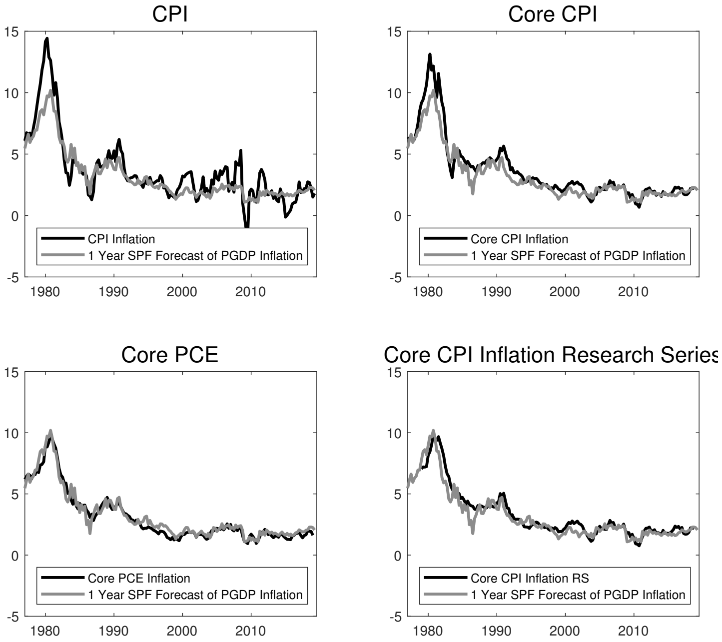
Volcker Disinflation

- Sharp shift in monetary regime
  - Drop in inflation driven by expectations rapidly shifting downward
- But imperfectly credible (Erceg-Levin, 2003, Goodfriend-King, 2005)
  - Induces a recession
  - High unemployment correlated with fall in inflation
  - But not real cause
- Period since late 1990s:
  - Inflationary expectations firmly anchored
  - Collapse in covariance between expectations and unemployment
  - Phillips curve appears to flatten

How Much Did Inflation Gap Vary?

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

- Useful to look at difference between π_t and $E_t \pi_{t+1}$ in the data
- Measurement issue:
  - Before 1983, housing services constructed from house prices and mortgage costs (interest rates)
  - PCE deflator and CPI research series use modern methods back in time (i.e., rents)


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

Small Inflation Gap

- Inflation gap for core inflation is small throughout
- Suggests slope of Phillips curve is small
  - Large variation in unemployment
  - Small variation in inflation gap
- However, sensitive to specification Sensitivity
  - Measure of inflation
  - Measure of inflation expectations
  - Timing of variables
  - Etc.

A Model of the Regional Phillips Curve

Model

- 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 Solved Forward

- Let's solve the regional Phillips curve forward:

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

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

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

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

Non-Rational Expectations

Interpretation of Slope Coefficient

- Regional Phillips curve:

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

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

$$\pi_{Ht}^{N} = -\boldsymbol{\psi} \tilde{u}_{Ht} - \delta \hat{p}_{Ht}^{N} + \gamma_t + \omega_{Ht}^{N} \qquad (1)$$

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

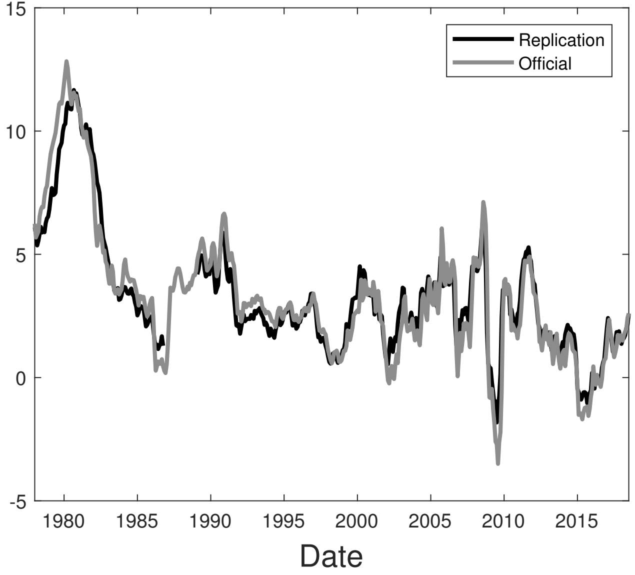
- Equation (1) similar to typical regional empirical specification
- But κ and ψ are not the same!
  - ψ potentially much larger than κ since $\tilde{u}_{Ht}$ is persistent
  - Prior regional Phillips curve literature estimates ψ not κ.
  - Helps explain large slope estimates in this literature

New State-Level Inflation Indexes

State-Level Inflation Indexes

- No existing state-level inflation indexes
  - BEA series reweight industry-series by state's industry composition
  - BLS city-level CPI series rely on regional and aggregate imputation
  - Scanner price data have a short sample period
- We construct state-level CPI series from BLS micro-data
  - Sample period 1978 - 2018, quarterly
  - Free of cross-state imputations
  - Separate indexes for tradeables vs. non-tradeables
  - Analyze housing separately (more on this later)

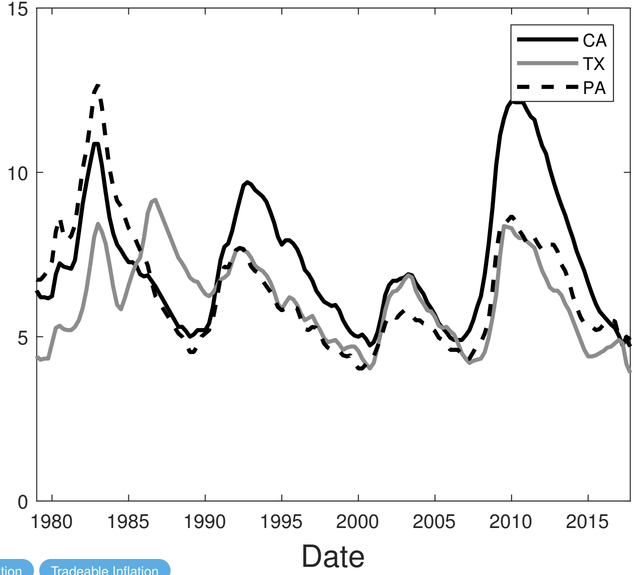
Aggregate Non-Shelter CPI Inflation



Employment Data

- 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



Non-Tradeable Inflation
Tradeable Inflation

Results

Phillips Curve Slope

- Regional Phillips curve from our 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:

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

- We 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)

- We can now estimate κ 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 Details

- Focus on non-tradeable inflation over four quarters,
  Divide κ estimate by 4 due to this time aggregation
- Truncate present sum of $\tilde{u}_t$ at 20 quarters
- Split sample IV procedure to avoid dropping data
  - Estimate first stage on sample ending in 2013
  - Estimate second stage on sample ending in 2018 (Chodorow-Reich & Wieland 2020)

ESTIMATION OF ψ

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

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		
	(0.036)	(0.027)		
κ	-0.0037	0.0003		
	(0.0013)	(0.0019)		
State Effects		✓	✓	✓
Time Effects			✓	✓

Estimates of λ | Estimates as β Varies | First Stage Estimates

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	
	(0.036)	(0.027)	(0.057)	
κ	-0.0037	0.0003	0.0062	
	(0.0013)	(0.0019)	(0.0028)	
State Effects		✓	✓	✓
Time Effects			✓	✓

Estimates of λ | Estimates as β Varies | First Stage Estimates

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			✓	✓

Estimates of λ | Estimates as β Varies | First Stage Estimates

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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	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		
	(0.063)	(0.025)	(0.113)	(0.057)		
κ	0.0278	0.0002	0.0107	0.0050		
	(0.0025)	(0.0017)	(0.0080)	(0.0038)		

All specifications include state fixed 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	0.198	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

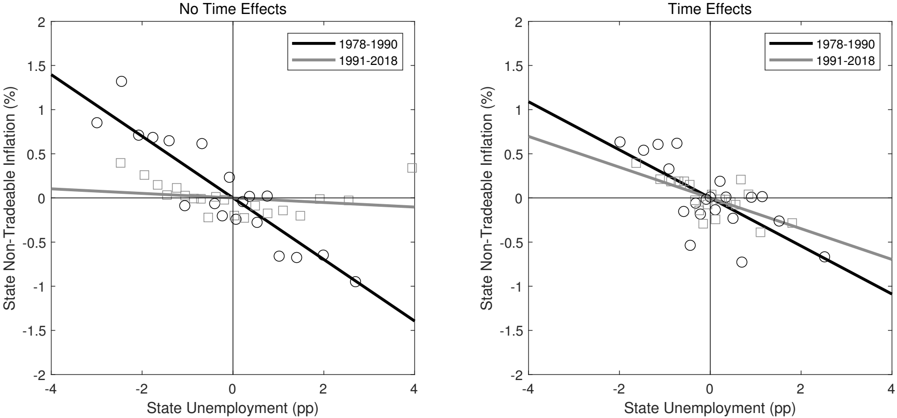


FIGURE: Scatterplots—Non-Tradeable Inflation and Unemployment

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

Missing Disinflation?

- Can our 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) Table
  - About four time larger than for non-shelter

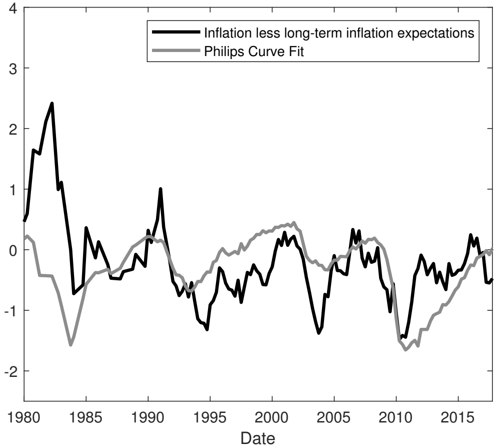


FIGURE: Aggregate Phillips Curve and Housing: Predicted vs. Fit

Results Excluding Rent Fit by Sub-Sample

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

Conclusions

- Slope of the Phillips curve is small and has been small since 1978
- Apparent flattening in time series due to anchoring of expectations
  - No time fixed effects: Factor 100 flattening
  - With time fixed effects: Factor 2 flattening
- Volcker disinflation:
  - Mostly due to fall in long-run expectations
  - Only 2 percentage points due directly to high unemployment

Appendix

Relaxing Rational Expectations

If expectations are non-rational but obey the law of iterated expectations:

$$\pi^N_{Ht} = -\psi \tilde{u}_{Ht} + F_t \pi^N_{H,t+\infty}$$

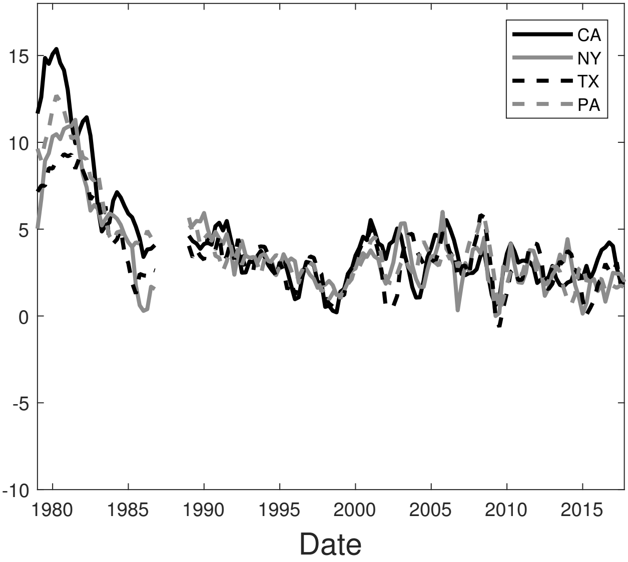
with

$$\psi = \frac{\kappa}{1 - \rho^F_u \beta}$$

- ρ^F_u is **subjective belief** of unemployment AR(1) coefficient
- $F_t \pi^N_{H,t+\infty}$ is **subjective forecast** of inflation target
- If $\rho^F_u < \rho_u$, Phillips curve is less forward looking (Coibion-Gorodnichenko 2012, 2015)

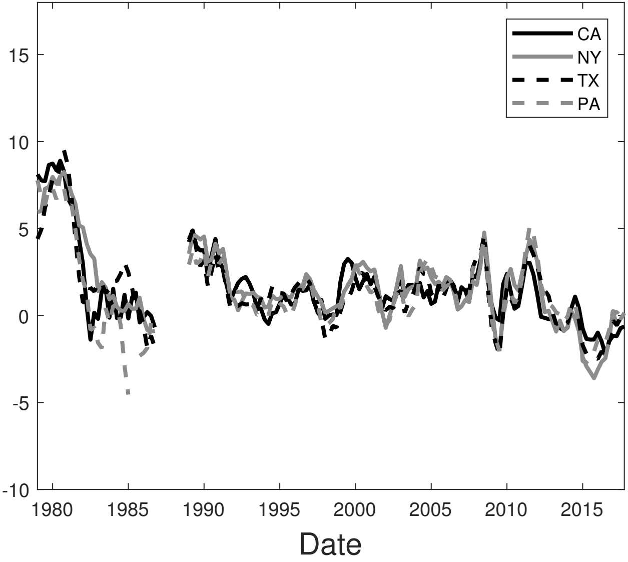
Back

Non-Tradeable Inflation By State



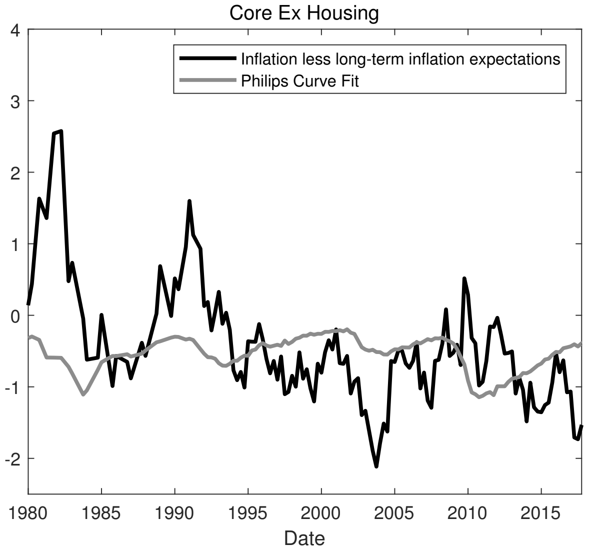
Back

Tradeable Inflation By State



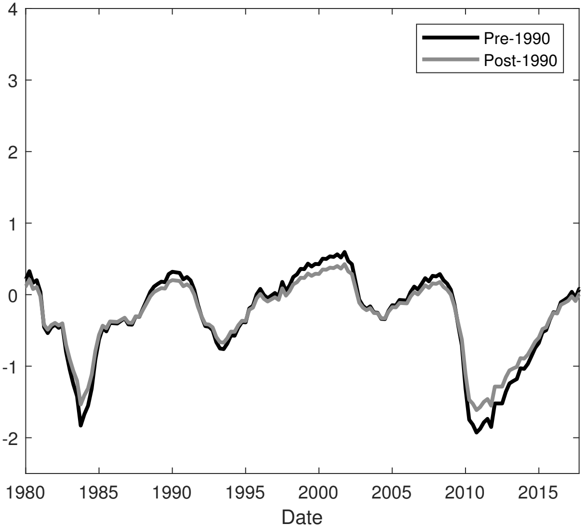
Back

Phillips Curve Fit Excluding Rent



Back

Phillips Curve Fit Excluding Rent



Back

TABLE: Slope of the Regional Phillips Curve: Rents

	No Fixed Effects	No Time Effects	Baseline
	(1)	(2)	(3)
ψ	0.268	0.356	0.603
	(0.041)	(0.044)	(0.124)
κ	0.0074	0.0179	0.0243
	(0.0006)	(0.0014)	(0.0053)
State Effects		✓	✓
Time Effects			✓

Back

TABLE: Slope of the Aggregate Phillips Curve

	Pre-1990	Post-1990
	(1)	(2)
Core CPI	0.796	0.111
	(0.120)	(0.027)
Median CPI	0.386	0.250
	(0.136)	(0.032)
Shelter CPI	1.624	0.396
	(0.350)	(0.050)
PCE	0.416	0.034
	(0.078)	(0.021)
Core less Shelter CPI	0.221	-0.084
	(0.103)	(0.028)
Core CPI RS	0.182	0.150
	(0.108)	(0.028)

TABLE: Estimates of λ

	No State Effects	No Time Effects	OLS	Tradeable Demand IV
	(1)	(2)	(3)	(4)
λ	0.0010	0.0022	0.0029	0.0020
	(0.0001)	(0.0002)	(0.0009)	(0.0007)
State Effects		✓	✓	✓
Time Effects			✓	✓

Return

TABLE: First Stage Regressions

	Present Value of Unemployment			
Lagged Unemployment	7.029	3.661	5.477	
	(0.635)	(0.474)	(0.510)	
Lagged Tradeable Demand				-4.465
				(0.594)
Lagged Relative Price	0.181	-0.178	0.259	0.833
	(0.160)	(0.202)	(0.565)	(0.516)
State Effects		✓	✓	✓
Time Effects			✓	✓

Return

TABLE: Estimate of κ as Calibrated Value of β Varies

	$\beta = 0.99$	$\beta = 0.95$	$\beta = 0.90$
κ	0.0062	0.0084	0.0116
	(0.0025)	(0.0033)	(0.0046)
State Effects	✓	✓	✓
Time Effects	✓	✓	✓

Return