PHILLIPS CURVE: CROSS-SECTIONAL ESTIMATION

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¹These slides build heavily on slides for our paper Hazell, Herreno, Nakamura, Steinsson (2021)
New Keynesian formalization:

\[ \pi_t = \beta E_t \pi_{t+1} - \kappa (u_t - u^n_t) + \nu_t \]

Drivers of inflation:

- Expected inflation: \( E_t \pi_{t+1} \)
- Measure of “output gap”: \( u_t - u^n_t \)
- Cost-push shocks: \( \nu_t \)

Object of interest: Slope coefficient \( \kappa \)

- How much does an increase in “demand” affect inflation
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
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 $\kappa$ as “Phillips correlation”
FLATTENING PHILLIPS CURVE

Year-over-year change in inflation vs. Unemployment Gap

Nakamura, Steinsson (Berkeley)
Phillips Curve
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**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

Core CPI Inflation - Research Series
Long-Run SPF Forecast of CPI Inflation

Year
0 1 2 3 4 5 6 7 8 9 10

Nakamura, Steinsson (Berkeley)
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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:

[The 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 $\nu_t$)
   - 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)
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;

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

\[ \pi_t = \beta E_t \pi_{t+1} - \kappa (u_t - u^n_t) + \nu_t \]

Solve forward:

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

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

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

This is an illusion!
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, \( \kappa \) may be very small
To simplify, one can assume that \( \tilde{u}_t \) follows an AR(1)

This implies \( E_t \tilde{u}_{t+j} = \rho_j \tilde{u}_t \)

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

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 $\pi_t$ and $E_t \pi_{t+1}$?**

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

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

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

- 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 $\pi_t$ and $E_t \pi_{t+1}$ in the data
\[ \pi_t \approx E_t \pi_{t+1} \]

\[ \pi_t - E_t \pi_{t+1} \approx -\kappa (u_t - u^n_t) + \nu_t \]

- 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:

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

- 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 \( \kappa \)
  - 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, \( \lambda \) would be large

- Empirically, \( \lambda \) estimated to be small
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.
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:

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

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

\[ \pi_{Ht}^N = -\psi \tilde{u}_{Ht} - \delta \hat{p}_{Ht}^N + \alpha_i + \gamma_t + \omega_{Ht}^N \]  

where \( \psi = \frac{\kappa}{1 - \beta \rho_u} \) and \( \delta = \frac{\lambda}{1 - \beta \rho_{pN}} \)

- Equation (1) similar to typical regional empirical specification

- But \( \kappa \) and \( \psi \) are not the same!
  - \( \psi \) potentially much larger than \( \kappa \) since \( \tilde{u}_{Ht} \) is persistent
  - Prior regional Phillips curve literature estimates \( \psi \) not \( \kappa \)
  - Helps explain large slope estimates in this literature
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 Phillips curve from model:

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

Reduced form equation similar to prior literature:

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

HHNS present estimates of both \( \kappa \) and \( \psi \)
ESTIMATION OF $\kappa$

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

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

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

where $\eta_{it}$ is an expectations error (and truncation error)

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

- Calibrate $\beta = 0.99$
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
**Tradable 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 $\psi$

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

Same two approaches:

- OLS

- Instrument for $u_{i,t-4}$ with tradeable demand instrument
<table>
<thead>
<tr>
<th></th>
<th>No State Effects</th>
<th>No Time Effects</th>
<th>Lagged u IV</th>
<th>Tradeable Demand IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \psi )</td>
<td>-0.103</td>
<td>0.017</td>
<td>0.112</td>
<td>0.339</td>
</tr>
<tr>
<td></td>
<td>(0.036)</td>
<td>(0.027)</td>
<td>(0.057)</td>
<td>(0.126)</td>
</tr>
<tr>
<td>( \kappa )</td>
<td>-0.0037</td>
<td>0.0003</td>
<td>0.0062</td>
<td>0.0062</td>
</tr>
<tr>
<td></td>
<td>(0.0013)</td>
<td>(0.0019)</td>
<td>(0.0028)</td>
<td>(0.0025)</td>
</tr>
</tbody>
</table>

- State Effects: ✓
- Time Effects: ✓
\textbf{Table:} Has the Phillips Curve Flattened?

<table>
<thead>
<tr>
<th></th>
<th>Lagged u IV</th>
<th>Lagged u IV</th>
<th>Tradeable Demand IV</th>
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<tbody>
<tr>
<td></td>
<td>No Time Fixed Effects</td>
<td>Time Fixed Effects</td>
<td>Time Fixed Effects</td>
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<tr>
<td>Pre-1990</td>
<td>Post-1990</td>
<td>Pre-1990</td>
<td>Post-1990</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.449</td>
<td>0.009</td>
<td></td>
</tr>
<tr>
<td>(0.063)</td>
<td>(0.025)</td>
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<td></td>
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<tr>
<td>$\kappa$</td>
<td>0.0278</td>
<td>0.0002</td>
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<tr>
<td>(0.0025)</td>
<td>(0.0017)</td>
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All specifications include state fixed effects
## Table: Has the Phillips Curve Flattened?

<table>
<thead>
<tr>
<th></th>
<th>Lagged u IV No Time Fixed Effects</th>
<th>Lagged u IV Time Fixed Effects</th>
<th>Tradeable Demand IV Time Fixed Effects</th>
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<tr>
<td></td>
<td>Pre-1990</td>
<td>Post-1990</td>
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<td>(3)</td>
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<td>0.009</td>
<td>0.198</td>
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<td>(0.063)</td>
<td>(0.025)</td>
<td>(0.113)</td>
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<tr>
<td>( \kappa )</td>
<td>0.0278</td>
<td>0.0002</td>
<td>0.0107</td>
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<td>(0.0025)</td>
<td>(0.0017)</td>
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<td>0.0055</td>
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<td>(0.0029)</td>
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</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>$\kappa$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gali (2008)</td>
<td>0.085</td>
</tr>
<tr>
<td>Rotemberg and Woodford (1997)</td>
<td>0.019</td>
</tr>
<tr>
<td>Nakamura and Steinsson (2014)</td>
<td>0.0077</td>
</tr>
<tr>
<td><strong>Our Estimate</strong></td>
<td></td>
</tr>
<tr>
<td>Full Sample IV Estimate</td>
<td>0.0062</td>
</tr>
</tbody>
</table>

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.
Can HHNS’s cross-section estimate of $\kappa$ explain aggregate time-series fluctuations in inflation?

Many have argued:
- Missing disinflation during Great Recession
- Missing reflation 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

Inflation less long-term inflation expectations

Philips Curve Fit
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
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