The Slope of the Phillips Curve: Evidence from US States

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Theme: Estimate the slope of the Phillips Curve with state-level data to solve the "Phillips Curve Puzzle".

1. Introduction to the Phillips Curve Puzzle
   - Why has the Phillips Curve flattened out?
2. What is this paper's solution to the puzzle? Why does it work?
   - Regional approach: Estimate a state-level Phillips Curve
   - Long Run approach: Estimate a long-run Phillips Curve
3. Theoretical Justification
   - A regional model of the Phillips Curve.
   - Shows that the slope of the regional, long-run Phillips Curve is comparable to the overall Phillips Curve.
4. Empirical analysis
   - Does our regional, long-run approach solve the "Phillips Curve Puzzle"?

Phillips Curve Puzzle

- New Keynesian Phillips Curve measures the relationship between unemployment and inflation.
  - In the 1980's, we observed a strong negative correlation between unemployment and inflation.
    - Contractionary policy tamped down on inflation while unemployment soared.
  - In the Great Recession, unemployment rose, but we saw small changes in inflation.
- What changed in the last 30 years?
  - Has the Phillips Curve flattened?
- Our Solution: Perhaps, nothing changed.
  - Could we have been estimating the slope of the Phillips Curve wrong all along?
  - Identification problems, which have since subsided, misled our estimate in the late 1900's.
  - If we deal with the identification problems, estimates of the curve in the 1980's are in line with estimates today.

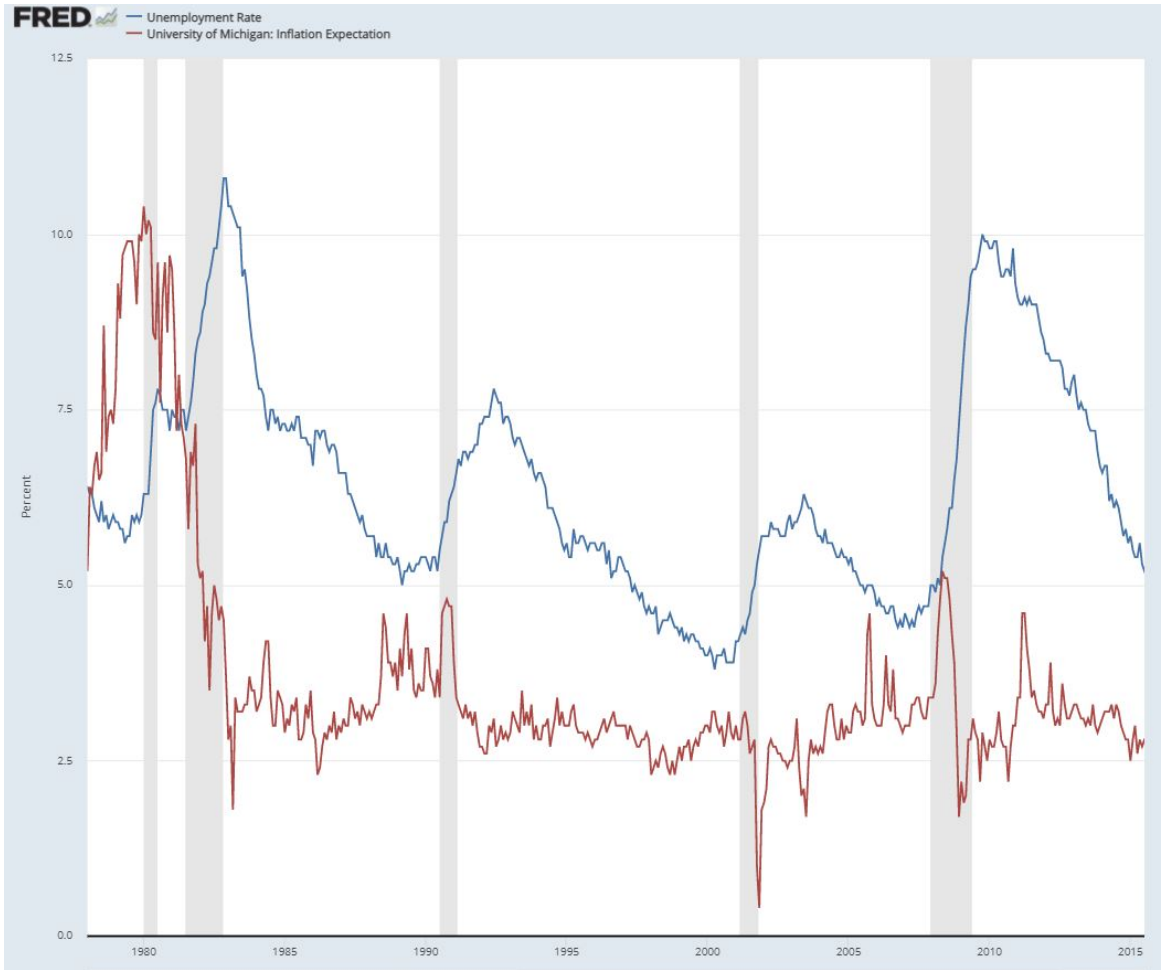
Phillips Curve Puzzle

- What happened to the slope of the Phillips Curve?

Figure 1: Stock and Watson's Changing Phillips Correlation

Phillips Curve Puzzle

- Unemployment has varied across the last 4 decades, but the inflation gap remained small.
- What is going wrong here?



Phillips Curve Puzzle

- Phillips Curve intuition: High demand drives up wages and prices.

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

  - Inflation is related to **inflation expectations** and the **unemployment gap**.
  - κ is the slope of the Phillips Curve.
- Major identification problems:
  1. Covariation in inflation expectations and unemployment may bias an estimate of κ.
  2. Supply shocks may contaminate an estimate of κ.
     - Supply and demand shocks lead to opposite comovement in inflation and observed unemployment.
- Our solution is a fixed effects approach.
  1. Requires estimation of a long-run Phillips Curve.
  2. Requires estimation of a regional Phillips Curve.

Problem 1: Inflation Expectations

- In the 80's $\text{Cov}(U_t, E_t[\pi_{t+1}]) < 0$ with a large magnitude.
  - The estimated slope of the Phillips Curve may have been exaggerated.
- Theory suggest $E_t\pi_{t+1} - \pi_t$ is explained by κu_t.
  - That the difference between these two variables has been relatively constant suggests that κ has not changed by much.

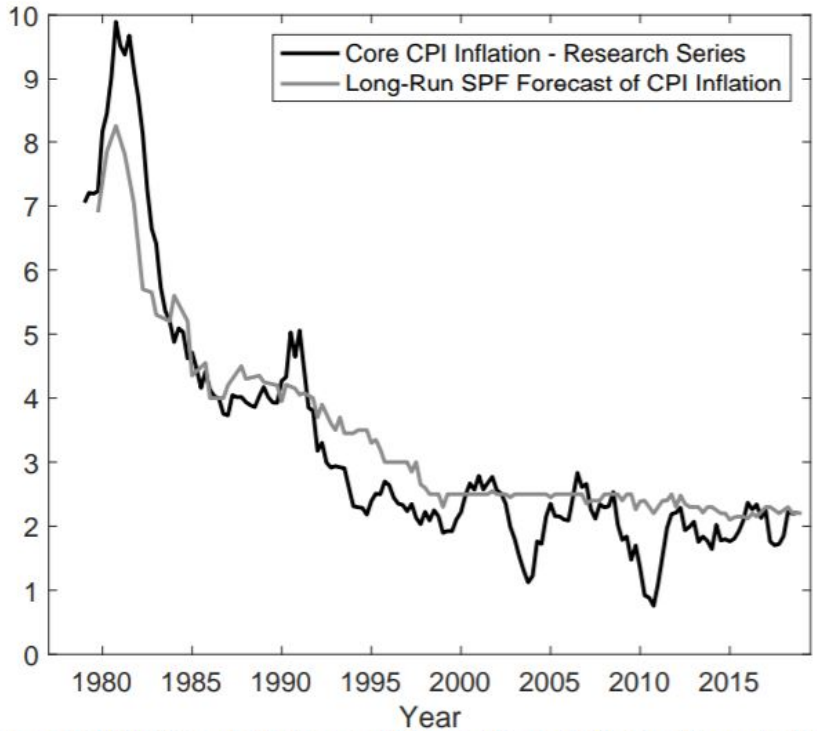


Figure 2: PCE Core Inflation and Long-Term Inflation Expectations

Problem 1: Solve with a long-run approach

- If our estimate of κ is biased from covariance between $E_t\pi_{t+1}$ and u_t, regional fixed effects may provide a solution.
  - Can we difference out inflation expectations?
  - Short run inflation expectations may vary from state to state.
  - But what about expected long-run expected inflation?
- From (1), derive the long-run Phillips Curve.

$$\pi_t = -\kappa E_t \sum_{j=0}^{\infty} \beta^j \tilde{u}_{t+j} - E_t\pi_{t+\infty} + \omega_t \tag{2}$$

  - Inflation expectations show up at the infinite time horizon.
- $E_t\pi_{t+\infty}$ is regionally invariant,
  - Depend on the public's expectations of the policymaker's long-term behavior.
- Implement regional fixed effects and difference out inflation expectations from estimation.

Problem 2: Contamination from Supply Shocks

- Observed unemployment is a poor proxy for the output gap in the presence of supply shocks.
  - Supply shocks fundamentally alter firm productivity, affecting the natural rate of unemployment.
  - A positive supply shock may accelerate output (and prices) and the natural rate of unemployment.
- We use **demand shocks** to **tradeable goods** as an instrument for unemployment.
  - An increase in demand for oil in California reduces unemployment in Texas.
- Why do we need a regional approach?
  - Demand shocks may affect the natural rate of unemployment because consumers need to work more to satisfy demand.
  - With a regional approach, we isolate shocks in different states.

Identification Problems: Solutions

1. **Problem**: κ is biased because u_t and $E_t\pi_{t+1}$ are correlated.
   - Long-run inflation expectations are regionally invariant.
   - Regional fixed effects difference out long-run inflation expectations.
2. **Problem**: κ is contaminated because we cannot isolate supply and demand side shocks.
   - Demand shocks to tradeable goods are correlated with the regional unemployment gap.
   - A regional framework insulates regional markets from tradeable goods markets in other states.
     - So that tradeable demand shocks are a suitable proxy for the unemployment gap.

- Our Strategy:
  1. Estimate a long-run version of a regional Phillips Curve...
  2. With regional fixed effects...
  3. And an instrumental variable for the unemployment gap.

What's Next?

- Why is it OK to estimate the long-run regional curve instead of the overall curve?
- We construct a **regional model** in which states have **tradeable** and **non-tradeable** goods markets.
  - Tradeable goods are sold in all regions.
  - Nontradeable goods are sold in the region they were produced.
- We extract a **regional Phillips Curve** for the non-tradeable goods market.
  - Slope of regional non-tradeable Phillips Curve is equal to slope of the national Phillips Curve.
- Estimate the **long-run version** of our regional non-tradeable Phillips Curve with fixed effects and an instrument for unemployment.
  - Slope of the long-run regional curve is related to the short-run slope of the overall curve.

Model: Overview

- Consider a two-region, New Keynesian, open economy model with tradeable and non-tradeable sectors.
- In the Home Region:
  1. Home consumers.
  2. Home firms are subject to Calvo-style price rigidities.
     - Firms that produce tradeable goods.
     - Firms that produce non-tradeable goods.
- The Foreign Region is identical to the Home Region.
- Tradeable and non-tradeable goods are priced and sold in different markets.
- A central monetary policy maker sets nominal interest rates.
  - According to time varying inflation target.
  - Time varying inflation target may cause identification problem 1.

Model: Households

- Households maximize lifetime utility.
  - Utility is separable in **leisure** and **consumption**.

$$\text{Max}_{C_{Ht},N_{Ht}} \left\{ E_t \sum_{t=0}^{\infty} \beta^t u(C_{Ht}, N_{Ht}) \right\} \tag{3}$$

- Households demand both tradeable and non-tradeable goods.
  - The composite consumption good is a CES index over a tradeable and non-tradeable goods index.

$$C_{Ht} = \left[\phi_N^{\frac{1}{\eta}} C_{Ht}^{N\,\frac{\eta-1}{\eta}} + \phi_T^{\frac{1}{\eta}} C_{Ht}^{T\,\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{4}$$

  - C_{Ht}^N and C_{Ht}^T are composite tradeable and non-tradeable consumption goods.
    - Subject to demand shocks.

Model: Households

- Households earn wages and firm profits to consume and invest.
- Households supply labor with respect to the real wage.

$$\chi N_{Ht}^{\rho^{-1}} = \frac{W_{Ht}}{P_{Ht}} \tag{5}$$

  - P_{Ht} is the overall price level in the home region and differs from the overall price level in the foreign region.
  - The real wage is measured in "home dollars".
- χ is disutility from labor.
  - Unemployment reflects demand for leisure.

Model: Nominal Rigidities and Price Setting

- Firm output is a function of labor input and a productivity shock.

$$Y_{Ht}^{N}(z) = Z_{Ht}^{N} N_{Ht}^{N}(z) \tag{6}$$

- Firms are subject to Calvo-style price rigidities.
  - A fraction $1 - \alpha$ of firms may reoptimize each period.
  - Firms set prices to maximize discounted sum of expected profits.

$$\sum_{k=0}^{\infty} \alpha^{k} E_{t} \left[M_{Ht,t+k} Y_{H,t+k}^{N}(z) \left(P_{Ht}^{N*}(z) - \frac{\theta}{\theta - 1} S_{H,t+k}^{N}(z) \right) \right] \tag{7}$$

- Productivity shocks carry through to nominal marginal cost, affecting the natural rate of unemployment.

Model: Monetary Policy

- The Central Bank operates a common monetary policy rule for both regions.

$$\hat{r}_t^n = \rho_\pi(\pi_t - \bar{\pi}_t) - \rho_u(\hat{u}_t - \bar{u}_t) + \epsilon_{rt} \tag{8}$$

- The interest rate rule balances time-varying inflation and unemployment targets, $\bar{\pi}_t$ and $\bar{u}_t$.

$$\bar{u}_t = \frac{(1-\beta)\bar{\pi}_t}{\kappa} \tag{9}$$

- Time-varying targets ensure that:
  1. Inflation expectations are non-zero at the infinite-time horizon.
  2. Inflation and unemployment deviate from their inflation-free steady-state values.
  3. Expected unemployment does not equal the natural rate of unemployment.

Model: Inflation and Unemployment

- Inflation, π_t, is a population weighted sum of inflation in the home and foreign regions.

$$\pi_{Ht} = p_{Ht} - p_{H,t+1} \tag{10}$$
$$\pi_{Ft} = p_{Ft} - p_{F,t+1} \tag{11}$$

- Economy-wide unemployment is a population weighted average of unemployment in the home and foreign regions.

$$u_{Ht} = 1 - N_{Ht} \tag{12}$$
$$u_{Ft} = 1 - N_{Ft} \tag{13}$$

Model: Regional and Aggregate Phillips Curve

- We extract the overall Phillips Curve and regional Phillips Curve for nontradeable goods.

$$\pi_t = \beta E_t \pi_{t+1} - \kappa \hat{u}_t + \nu_t \tag{14}$$

$$\pi^N_{Ht} = \beta E_t \pi_{H,t+1} - \kappa \hat{u}_{Ht} - \lambda \hat{p}^N_{Ht} + \nu^N_{Ht} \tag{15}$$

- They share the same slope.
  - We seamlessly transform from firms' marginal cost to wage to unemployment.
  - Household preferences are additively separable in leisure and consumption.
- The regional nontradeable curve includes a term for the relative price of nontradeable goods.
  - Nontradeable marginal costs are deflated by the nontradeable price level.
  - Whereas wage is deflated by the overall regional price level.
- Note: Regional tradeable Phillips Curve has a smaller slope than nontradeable curve.
  - A portion of the tradeable market is unresponsive to regional unemployment.

Empirical Methodology: Putting the model into practice

- How can we use (15) to solve our identification problems?
  - Can we difference out inflation expectations?
    - Short-run inflation expectations vary region-to-region depending on economic circumstance.
  - Solution: Use a long-run version of (15).
    - $E_t \pi_{t+\infty}$ depends on expectations of the LR behavior of the monetary regime and is consistent across regions.
- Up next: Manipulate a long-run version of (15) in order to apply regional and time fixed effects.
  - Afterwards, construct an instrument for unemployment using shocks to demand for tradeable goods.

Empirical Methodology: A long-run approach

- Iterate (15) to obtain the long-run nontradeable Phillips Curve for goods produced at home.

$$\pi^N_{Ht} = -E_t \sum_{j=0}^{\infty} \beta^j (\kappa \tilde{u}_{H,t+j} + \lambda \hat{p}^N_{H,t+j}) + E_t \pi_{t+\infty} + \omega^N_{Ht} \quad (16)$$

  - We can remove $E_t \pi_{t+\infty}$ and include fixed effects.
- (16) contains expected unemployment and prices at the infinite time horizon.
  - Truncate infinite expectations at $t = T$.
  - Replace expected future values with realized values.
  - Include a term for expectational errors.

$$\pi^N_{it} = \alpha_i + \gamma_t - \kappa \sum_{j=0}^{T} \beta^j u_{i,t+j} - \lambda \sum_{j=0}^{T} \beta^j \hat{p}^N_{i,t,j} + \tilde{\omega}^N_{it} + \eta^N_{it} \quad (17)$$

Empirical Methodology: Contamination from shocks

- What is the issue with supply shocks?
  - Productivity shocks and future unemployment are correlated.
- We can take two alternate approaches.
  1. Instrument for future unemployment with lagged unemployment.
     - Assumes that supply shocks are not systematically related to boom-bust cycles within states.
     - When Texas experiences a boom relative to California, this is not correlated with improvements in technology in Texas relative to California.
  2. Instrument for unemployment with tradeable demand shocks.

Empirical Methodology: Tradeable demand shocks

- Why are tradeable demand shocks are a valid proxy for unemployment in our fixed effects regression?
  - They differentially affect states' unemployment levels.
    - Increase in demand for oil in California reduces unemployment in Texas by more than it reduces unemployment in Vermont.
  - Beyond the unemployment channel, they shouldn't differentially affect nontradeable sectors.
    - Costs everywhere may rise as a result of higher oil prices, but increases are constant across states.

$$\text{Tradeable Demand}_{it} = \sum_{x} \bar{S}_{x,i} \times \Delta_{3y} \log S_{-i,x,t} \tag{18}$$

- $\bar{S}_{x,i}$: employment share of industry x, excluding state i.
- $\Delta_{3y} \log S_{-i,x,t}$: three-year growth in employment in industry x, excluding state i.

Empirical Results: Has the Phillips Curve Flattened?

Table 2: Has the Phillips Curve Flattened?

	Lagged Unempl. IV Without Time Fixed Effect		Lagged Unempl. IV With Time Fixed Effect		Tradeable Demand IV With Time Fixed Effect	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: Estimates of κ from equation (17)					
κ	0.0278	0.0002	0.0107	0.0050	0.0109	0.0055
	(0.0025)	(0.0017)	(0.0080)	(0.0040)	(0.0062)	(0.0028)
	Panel B: Estimates of ψ from equation (19)					
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)

Empirical Results: Role of inflation expectations

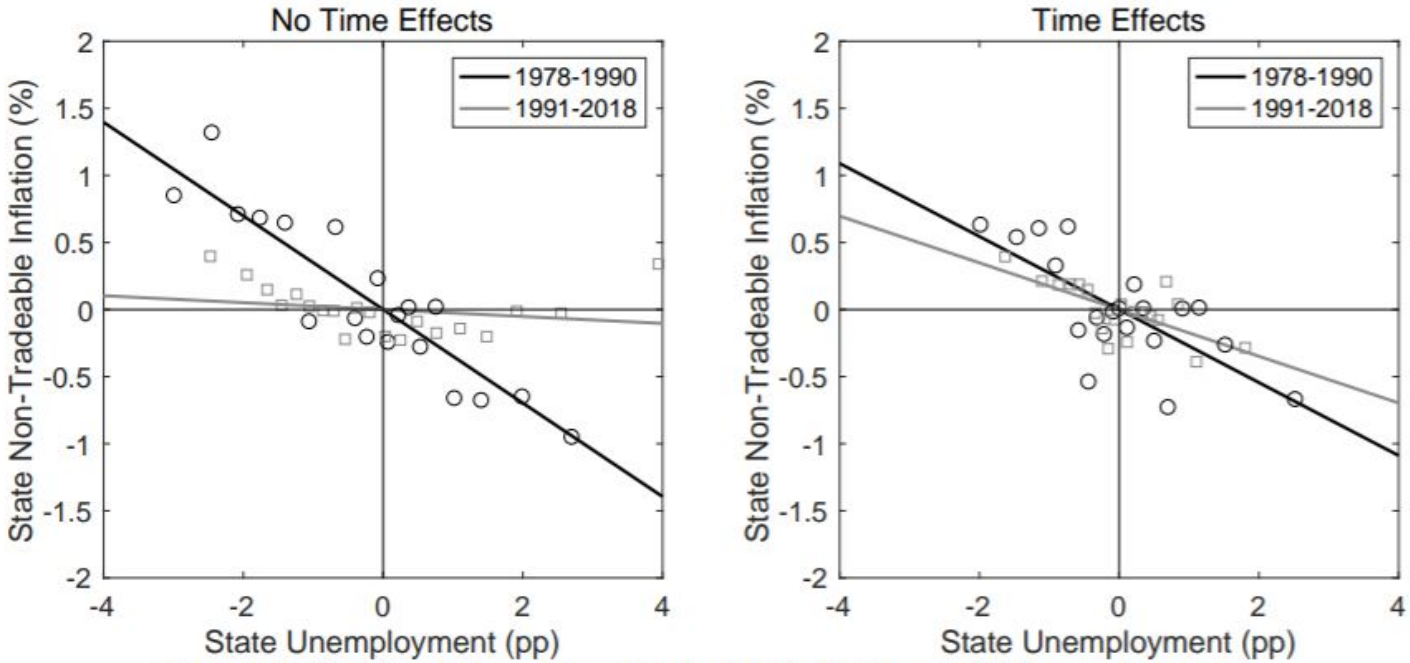


Figure 5: Scatterplots—Non-Tradeable Inflation and Unemployment