Phillips Curve Estimation: Basics

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Brief History of the Phillips Curve

- Phillips 58 points out empirical relationship between wage inflation and unemployment in UK 1861-1957
- Samuelson-Solow 60 popularize idea in US

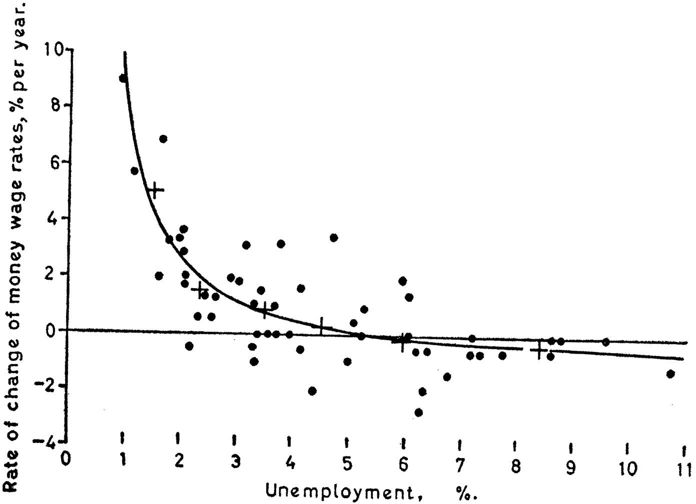


Fig.1. 1861 – 1913

Source: Phillips (1958)

Inflation and Unemployment in the UK

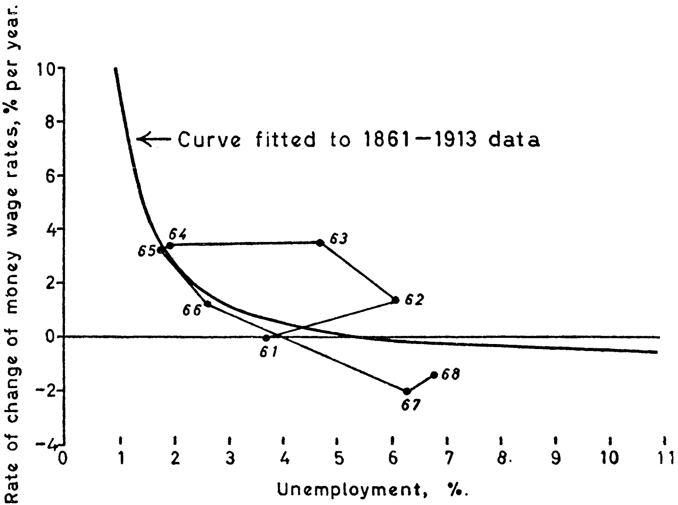


Fig. 2. 1861 − 1868

Source: Phillips (1958)

Inflation and Unemployment in the UK

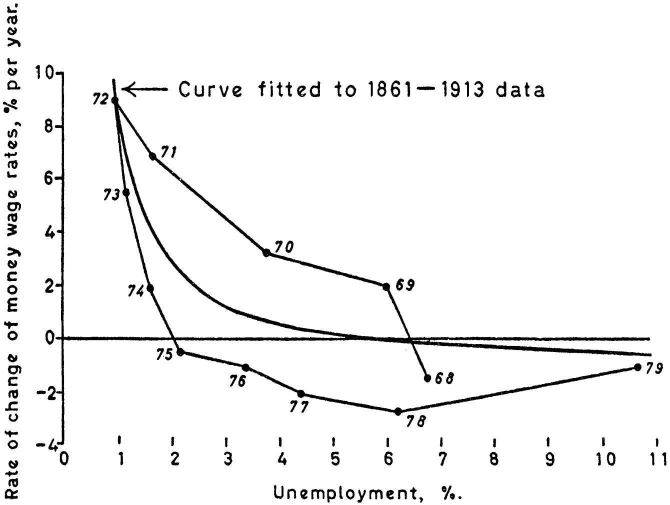


Fig. 3. 1868 —1879

Source: Phillips (1958)

Inflation and Unemployment in the UK

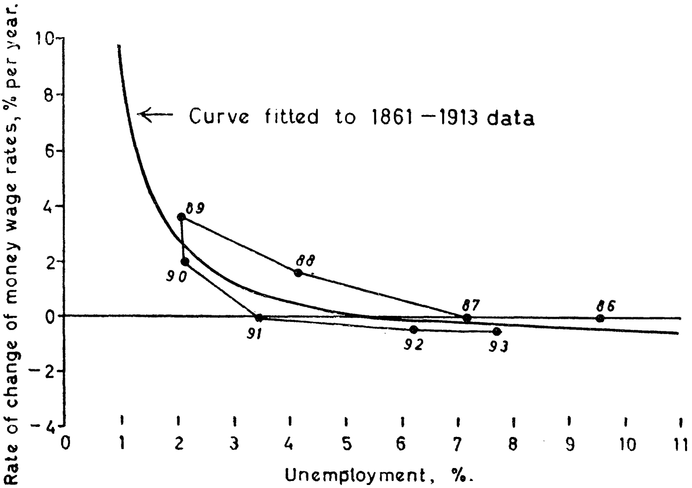


Fig.5. 1886 − 1893

Source: Phillips (1958)

Inflation and Unemployment in the UK

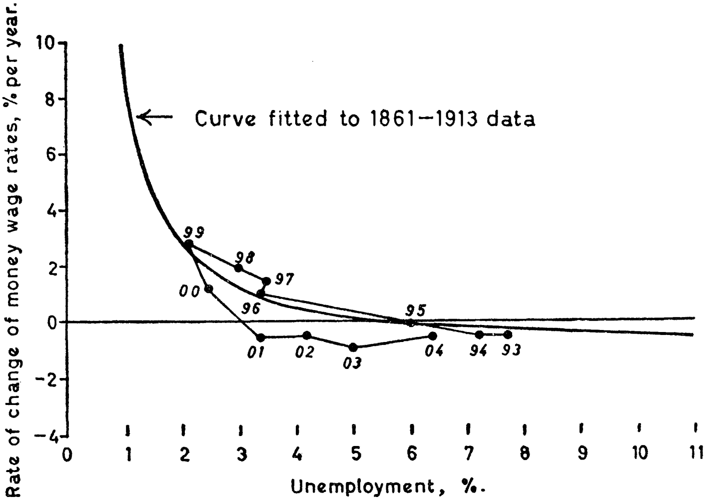


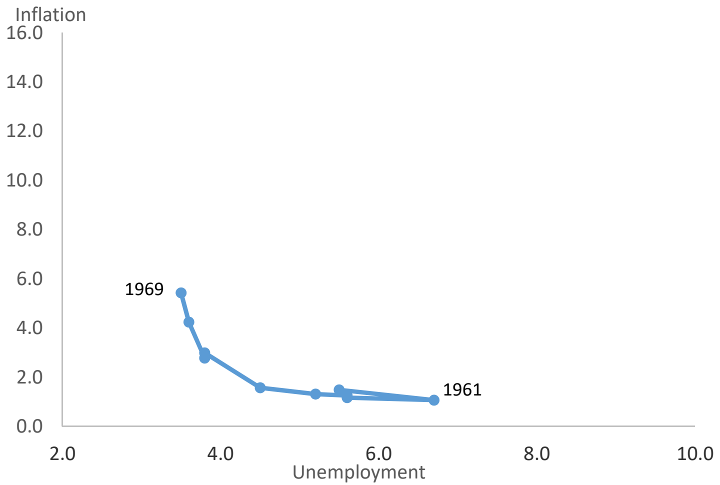
Fig. 6. 1893 – 1904

Source: Phillips (1958)

US Macro Policy in the 1960s

- Phillips curve viewed as a menu of options
- Policy makers can lower unemployment if they are willing to tolerate more inflation

Inflation and Unemployment in the US

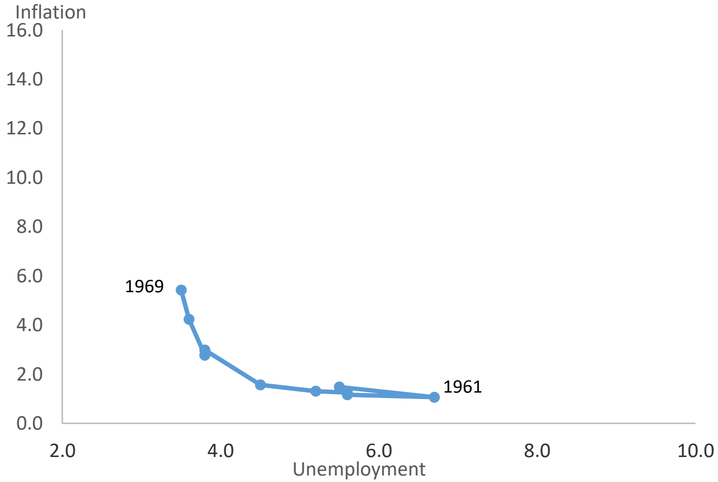


Friedman and Phelps Make a Prediction

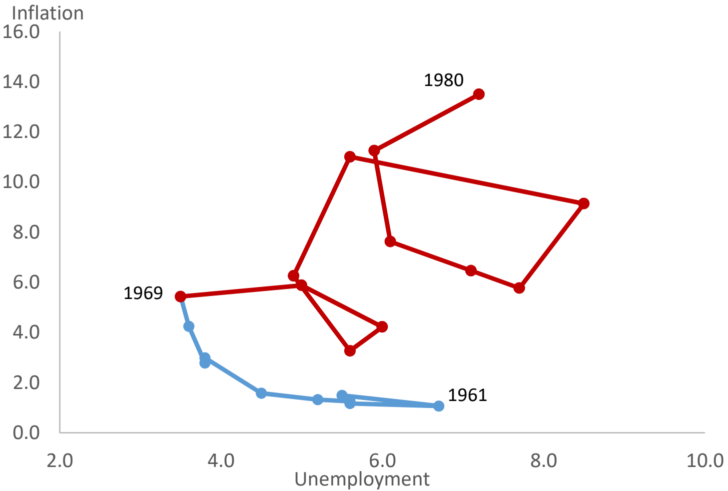
Friedman 68 and Phelps 67:

- Policymakers cannot exploit a stable Phillips curve forever
- Workers will demand wage increases in excess of expected inflation
- As inflation rises, expectations of inflation will rise
- Changes in expected inflation will shift the Phillips curve

Inflation and Unemployment in the US



Friedman and Phelps Were Right!



Modern Phillips Curve

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

- Three drivers of inflation:
  - Expected inflation: $E_t \pi_{t+1}$
  - Output relative to potential: $y_t - y_t^n$
  - Cost-push shocks: η_t
- Specific form above based on Calvo 83 sticky-price assumptions
  Details vary across specifications
  (e.g., sticky information yields $\bar{E}_{t-1}\pi_t$)
- Structural equation originating from firm's price setting decision

Estimating Slope of the Phillips Curve

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

Object of interest: Slope coefficient κ

- How much does an increase in “demand” / “tightness” / “output gap” affect inflation

Estimating Slope of the Phillips Curve

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- How much does an increase in “demand” / “tightness” / “output gap” affect inflation

Tricky identification issues:

- Expected inflation unobserved
- “Natural rate of output” (i.e., supply shocks) unobserved
- Cost push shocks (e.g., variation in desired markups) unobserved

All three may cause omitted variables bias

EXPECTED INFLATION

- Pre Friedman/Phelps Phillips curve: Change in output gap needed to change inflation

$$\pi_t = \mu + \kappa(y_t - y_t^n)$$

- Same is true for accelerationist Phillips curve (i.e., Phillips curve with adaptive expectations)

$$\pi_t = \pi_{t-1} + \kappa(y_t - y_t^n)$$

Expected Inflation

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$$\pi_t = \pi_{t-1} + \kappa(y_t - y_t^n)$$

- Sargent 82: Hyperinflations end abruptly with little or no output cost
Clear violation of aforementioned Phillips curves

German Hyperinflation

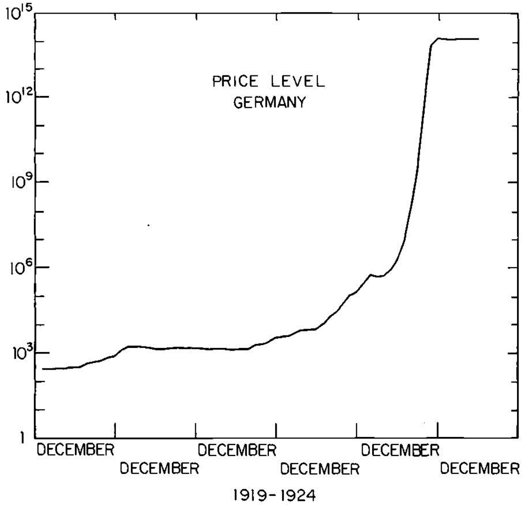


Fig. 2.4 Wholesale prices in Germany.

Source: Sargent (1982)

Expected Inflation

- In Calvo model, perfectly credible, unexpected disinflation can occur without **any** effect on output gap
  - Expected inflation does **all** the work
- Theoretical victory: Potential explanation for Sargent facts

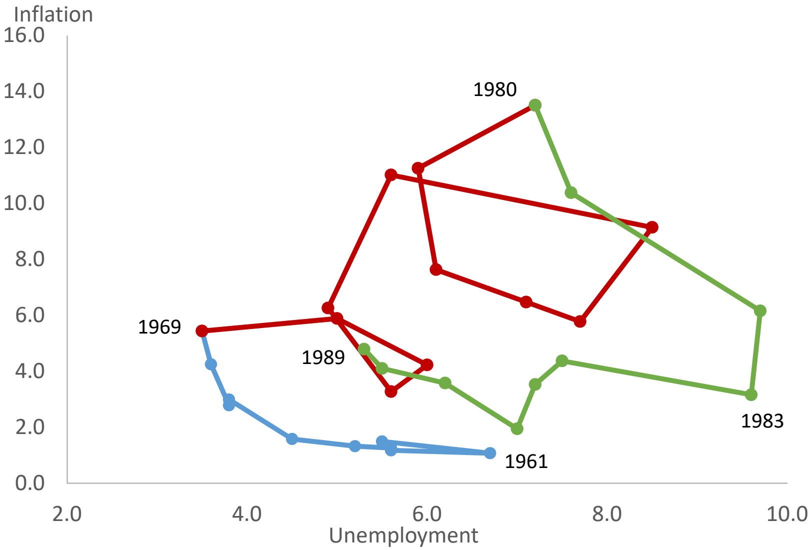
Expected Inflation

- In Calvo model, perfectly credible, unexpected disinflation can occur without **any** effect on output gap
  - Expected inflation does **all** the work
- Theoretical victory: Potential explanation for Sargent facts
- Empirical headache:
  - Movements in inflation potentially completely unrelated to output gap
  - Even if output gap moves during disinflation, not clear what fraction of disinflation was due to shift in expected inflation
- Measurement of expected inflation crucial but hard

SUPPLY SHOCKS

- Estimation of Phillips curve slope also complicated by classic simultaneity problem
- Need to isolate demand variation to estimate slope
- Supply shocks yield “stagflation”
  (i.e., positive correlation between unemployment and inflation)
- Bias slope estimates towards zero (or “wrong” sign)

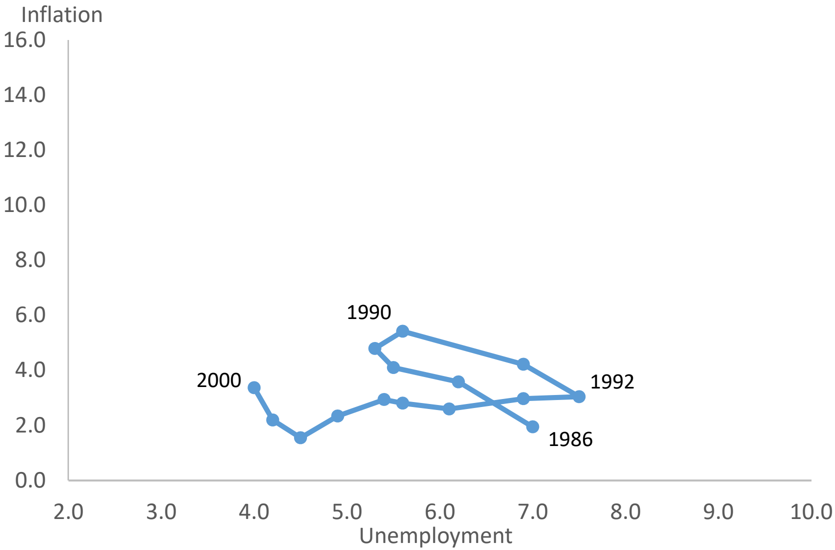
INFLATION EXPECTATIONS + SUPPLY SHOCKS



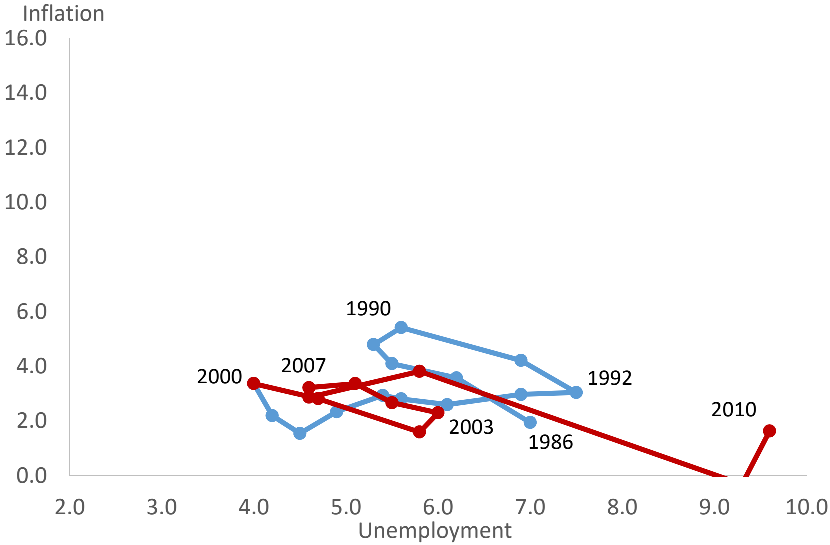
Is the Phillips Curve Dead?

- Phillips curve often pronounced dead
  - Many economists think Phillips curve is an empirical disaster
- Prominent episodes:
  - Missing inflation in late 1990s
  - Missing disinflation in the Great Recession
  - Missing reinflation in the subsequent recovery
  - Missing disinflation in the COVID crisis
- Seems like inflation is always going missing...

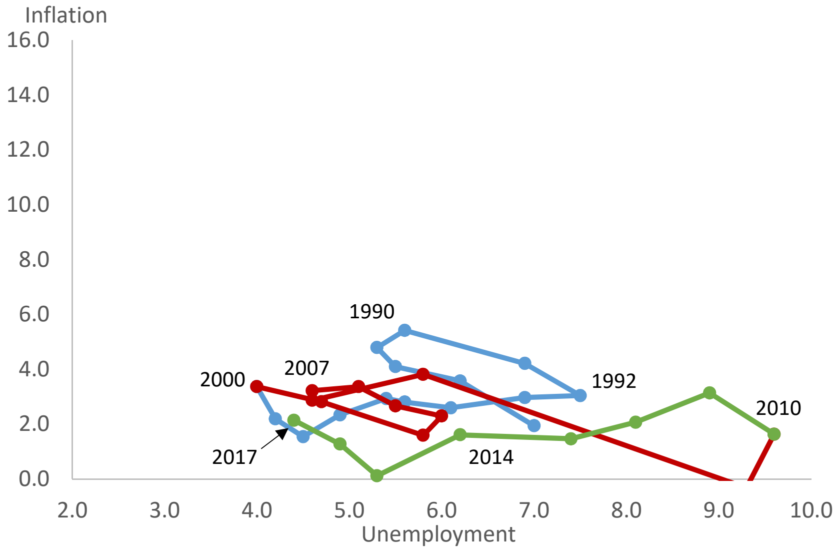
Missing Inflation in Late 1990s



Missing Disinflation in the Great Recession



Missing Reinflation since Great Recession



Atkeson and Ohanian (2001)

- Are Phillips Curves Useful for Forecasting Inflation?
  - Answer: No
- Methodology:
  - Compare forecasts from Phillips curve models with "naive" no-change model
  - Metric of fit: root mean squared error (RMSE)
  - "Online" estimation using data from January 1959 onward

- Naive model:

$$E_t \pi^{12}_{t+12} = \pi^{12}_t$$

- Original Phillips curve:

$$E_t \pi^{12}_{t+12} = \beta(u_t - \bar{u})$$

- NAIRU Phillips curve:

$$E_t \pi^{12}_{t+12} = \pi^{12}_t + \beta(u_t - \bar{u})$$

- Stock and Watson's (1999) NAIRU Phillips curve:

$$E_t \pi^{12}_{t+12} = \pi^{12}_t + \alpha + \beta(L) u_t + \gamma(L)(\pi_t - \pi_{t-1})$$

(Their nomenclature)

RMSE vs. "Naive" Model

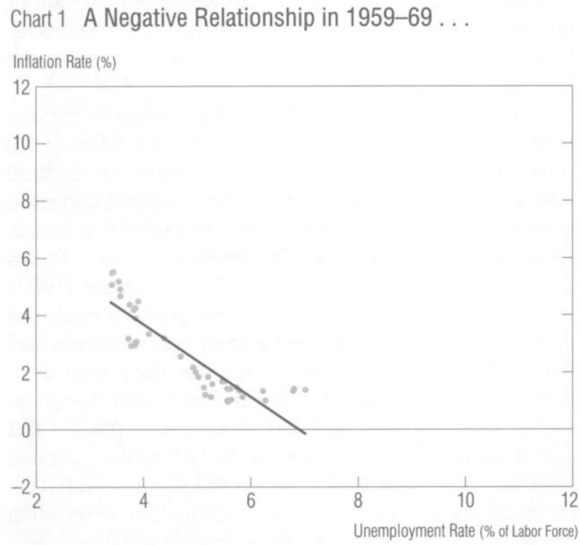
Why Use the NAIRU Phillips Curve?

Ratios of Errors of NAIRU and Naive Model* Forecasts of Inflation for 1984–99, Made With Alternative Indicators and Measures

Inflation Indicator	Inflation Measure†	Range of Ratio of NAIRU/Naive RMSEs**	
		Minimum	Maximum
Unemployment Rate	PCE Deflator	1.02	1.34
	CPI	.99	1.32
	Core CPI	1.06	1.94
Activity Index‡	PCE Deflator	1.04	1.23
	CPI	1.06	1.32
	Core CPI	1.33	1.81

Stock and Watson (1999) NAIRU Phillips curve vs. Naive model with different lag lengths from 1 to 12 for both $\beta(L)$ and $\gamma(L)$.

Why So Hard to Forecast? (in levels)



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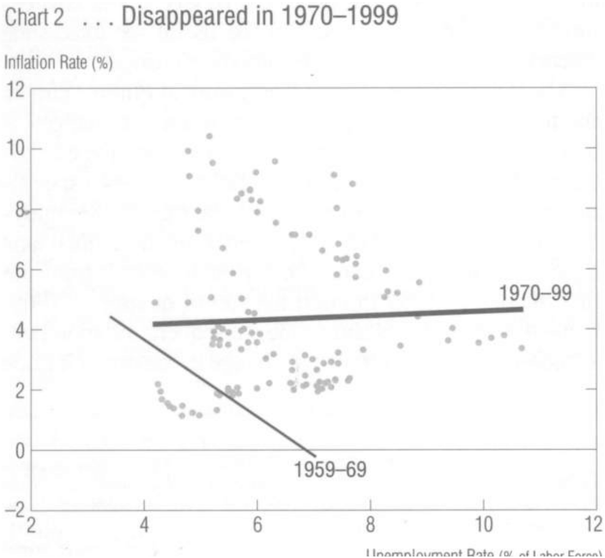
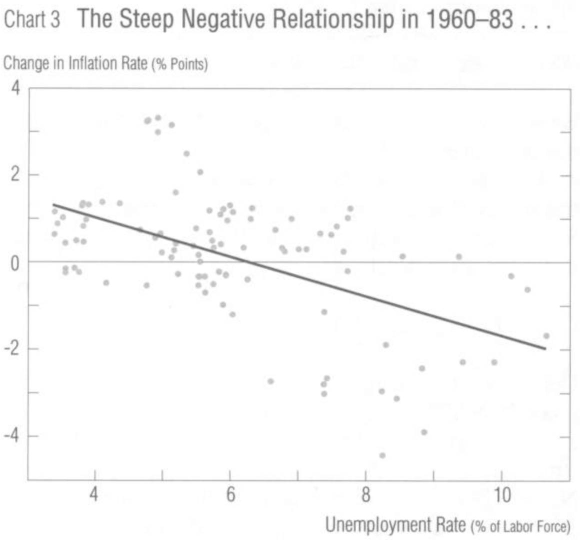
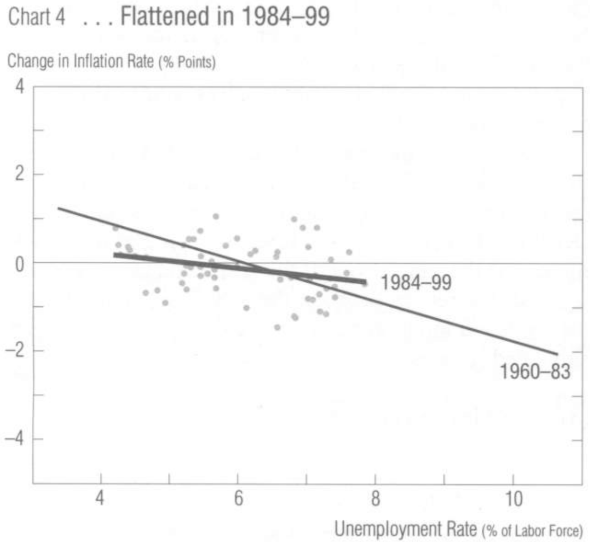


Why So Hard to Forecast? (in changes)



WHY SO HARD TO FORECAST? (IN CHANGES)



Forecasting and the Phillips Curve

- Theory does not suggest that the Phillips curve would necessarily be useful for forecasting
- Phillips curve is a supply curve
- Useful for forecasting only if (when) demand variation is dominant (and inflation expectation stable)
- Clearly not true in 1970s and 1980s
- Same as any other market
  - Supply curve for oil not necessarily useful to forecast price of oil

Three Strands of Phillips Curve Literature

1. Aggregate Variation with Adaptive or Survey Expectations
   - Stock-Watson (2010, 2019), Ball-Mazumder (2011, 2019), Coibion-Gorodnichenko (2015)
2. Aggregate Variation with Rational Expectations
   - Gali-Gertler (1999), Sbordone (2002), Mavroeidis-Plagborg-Muller-Stock (2014)
3. Cross-Sectional Variation
   - Fitzgerald-Nicolini (2014), McLeay-Tenreyro (2019), Hazell-Herreno-Nakamura-Steinsson (2021)

KEY QUESTIONS

- Has the Phillips curve flattened?
- Is there missing disinflation / reinflation?
- Does “anchoring” of inflation expectations explain stability of inflation?
- Is there a stable Phillips curve?

Flattening Phillips Curve

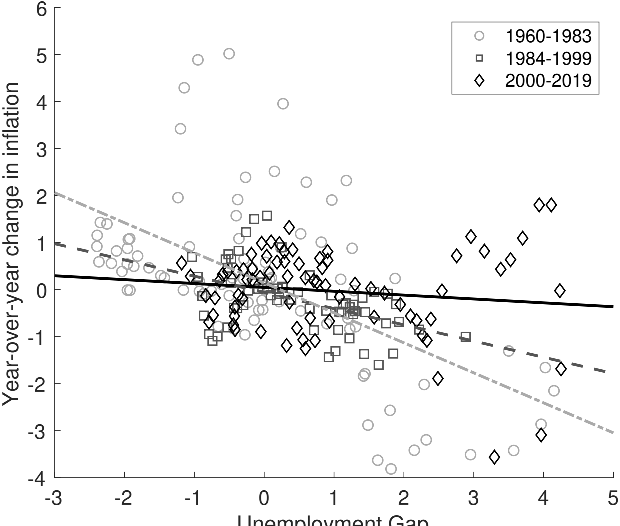


Figure 1: Stock and Watson's Changing Phillips Correlation

Why Might Phillips Curve Have Flattened?

- Inflation fell and prices became more sticky
  (as menu cost model would predict)
- Inflation expectations became better anchored
  - Output gap and change in inflation expectations correlated
    in 1970s and 1980s (biased estimates of Phillips curve slope)
- Some other structural change to the economy

Is There a Stable Phillips Curve?

- To "see" the Phillips curve, must control for:
  - Changes in inflation expectations
  - Supply shocks
- Stock and Watson (2010):
  - The history of the Phillips curve "is one of apparently stable relationships falling apart upon publication."

Ball and Mazumder (2019)

- Empirical specification:

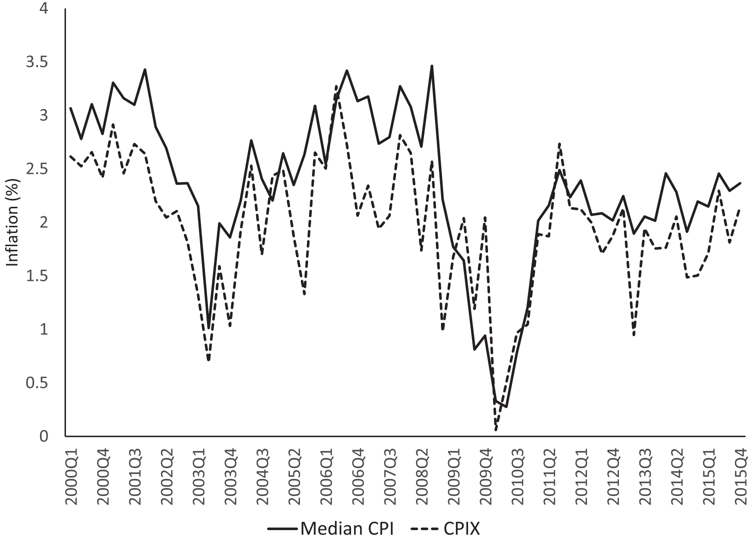
$$\pi_t = \pi_t^e + \alpha(u_t - u_t^*) + \epsilon_t$$

- Focus on post-1985 period
- Use “non-standard series”:
  - Median inflation
  - Long-run inflation expectations
  - Short-term unemployment
- Ignore endogeneity

Median Inflation

- Basic idea to get away from supply shocks
- More common to use core
  - Supply shocks important in food and energy
- Ball and Mankiw (1995):
  - Relative price changes (due to supply shocks) can affect aggregate inflation in a menu cost model
  - Firms in sectors with large shocks will adjust, while others will not
- Ball and Mazumder (2011, 2019): median inflation filters out movements in headline inflation due to large relative price movements in all sectors (not just food and energy)

Median Inflation



Short-Run Unemployment

- Literature uses various different “slack” measures
- Rationale for short-run unemployment:
  - Long-term unemployed are on the margins of the labor force
  - Don’t put pressure on wages
- Largely co-linear with total unemployment prior to Great Recession
- Not so during Great Recession

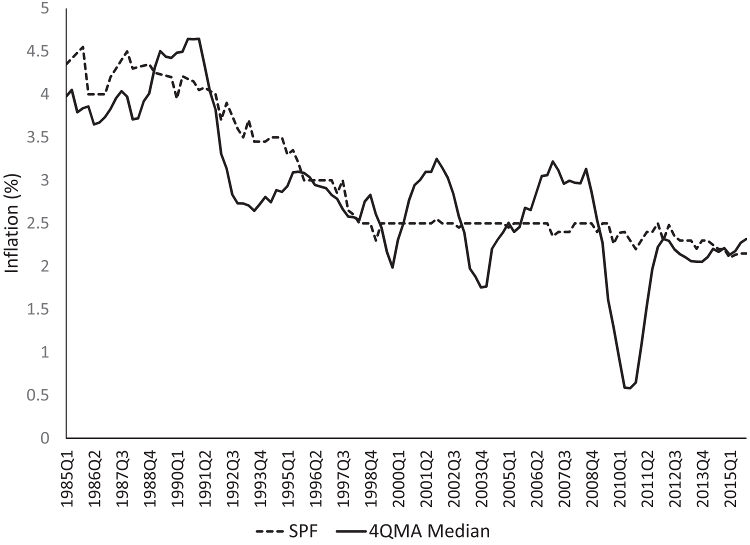
  (smaller rise results in smaller fitted fall in inflation)

Short-Run Unemployment Rate

Long-Run Inflation Expectations?

- Which inflation expectations should be used?
- Ball and Mazumder (2019) use long-run SPF inflation forecasts
- Doesn't New Keynesian model say one should use one-period-ahead inflation expectations?
- Can one just pick whatever one want's?
- We will come back to this (when discussing cross-sectional papers)

Long-Run Inflation Expectations



Phillips Curve Estimation

TABLE 1

An Expectations-Augmented Phillips Curve, 1985–2015

	$\pi_t = \pi_t^e + \alpha(\overline{u}^s_{t-1} - \overline{u}^{s,*}_{t-1}) + \epsilon_t$
α	−0.756
	(0.077)
DW	1.259
SE of Reg.	0.383
$\overline{R}^2$	0.824

Note: OLS with Newey–West (1987) standard errors in parentheses. π_t is median CPI inflation, π_t^e is the average forecast of long-term CPI inflation from the Survey of Professional Forecasters, $\overline{u}^s_{t-1}$ is the average of the short-term unemployment rate from $t-1$ to $t-4$, and $\overline{u}^{s*}_{t-1}$ is the average of the natural rate of short-term unemployment from $t-1$ to $t-4$.

Good Fit!

(a)
Inflation (%)
6
5
4
3
2
1
0
1985Q1
1986Q1
1987Q1
1988Q1
1989Q1
1990Q1
1991Q1
1992Q1
1993Q1
1994Q1
1995Q1
1996Q1
1997Q1
1998Q1
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2004Q1
2005Q1
2006Q1
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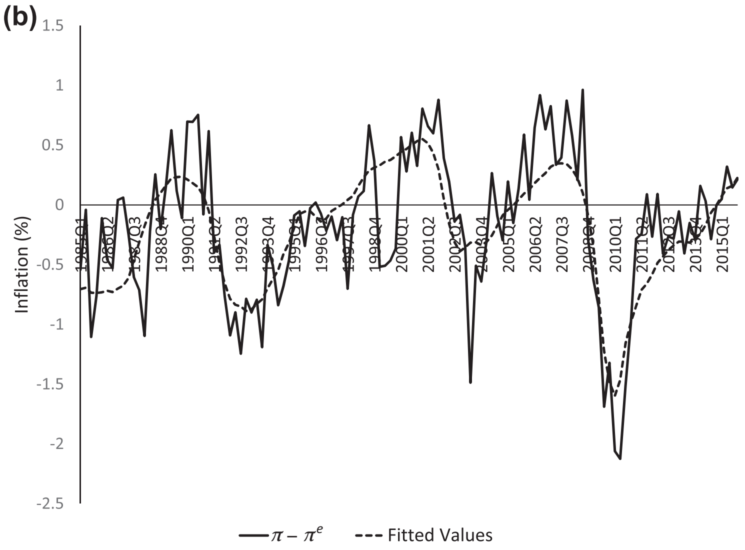
2009Q1
2010Q1
2011Q1
2012Q1
2013Q1
2014Q1
2015Q1
π
Fitted Values

Good Fit!



(b)
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
Inflation (%)
1985Q1
1986Q2
1987Q3
1988Q4
1990Q1
1991Q2
1992Q3
1993Q4
1995Q1
1996Q2
1997Q3
1998Q4
2000Q1
2001Q2
2002Q3
2003Q4
2005Q1
2006Q2
2007Q3
2008Q4
2010Q1
2011Q2
2012Q3
2013Q4
2015Q1
$\pi - \pi^e$
Fitted Values

Stable Across Sub-periods

TABLE 2

Stability of the Expectations-Augmented Phillips Curve

	$\pi_t = \pi_t^e + \alpha(\overline{u}_{t-1}^s - \overline{u}_{t-1}^{s,*}) + \epsilon_t$ 1985Q1–1997Q4	1998Q1–2007Q4	2008Q1–2015Q4
α	−0.702	−0.781	−0.795
	(0.094)	(0.228)	(0.109)
DW	1.492	1.043	1.286
SE of Reg.	0.361	0.436	0.353
$\overline{R}^2$	0.764	0.316	0.755
p-Value for stability		0.813	

Note: OLS with Newey–West (1987) standard errors in parentheses. π_t is median CPI inflation, π_t^e is the average forecast of long-term CPI inflation from the Survey of Professional Forecasters, $\overline{u}_{t-1}^s$ is the average of the short-term unemployment rate from $t-1$ to $t-4$, and $\overline{u}_{t-1}^{s*}$ is the average of the natural rate of short-term unemployment from $t-1$ to $t-4$. The reported p-value is for a Wald test of the hypothesis that α is equal in the three subsamples.

Have Expectations Become More Anchored?

- Anchored Expectations:

$$\pi_t^e = 2.5 + \epsilon_t$$

- Backward-Looking Expectations:

$$\pi_t^e = \frac{1}{1-\gamma^{40}}[(1-\gamma)\pi_{t-1} + \gamma(1-\gamma)\pi_{t-2} + ... + \gamma^{39}(1-\gamma)\pi_{t-40}] + \epsilon_t$$

- Nested Specification:
  - Weighted average with weight λ
- Ball-Mazumder estimate this allowing for a break in λ
- Estimated break date is 1998Q1

Anchoring of Expectations

TABLE 4

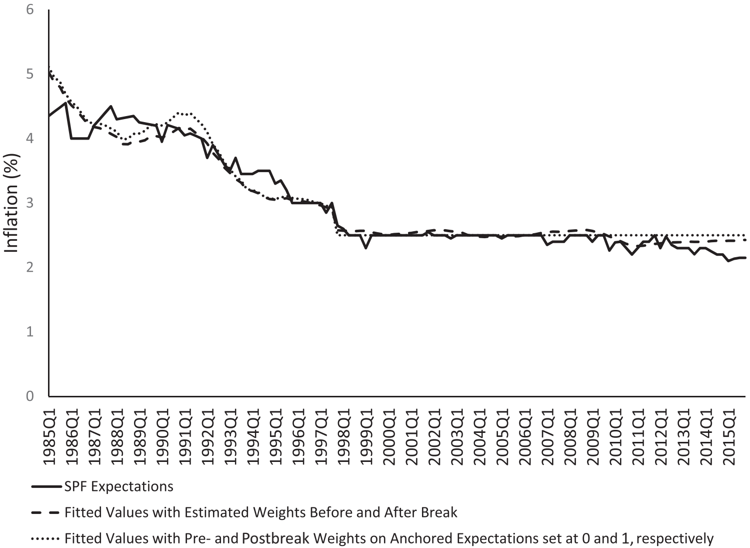
Anchored vs. Backward-Looking Expectations

$$\pi_t^e = \lambda 2.5 + (1-\lambda)\frac{1}{1-\gamma^{40}}[(1-\gamma)\pi_{t-1} + \gamma(1-\gamma)\pi_{t-2} + \ldots + \gamma^{39}(1-\gamma)\pi_{t-40}] + \epsilon_t$$

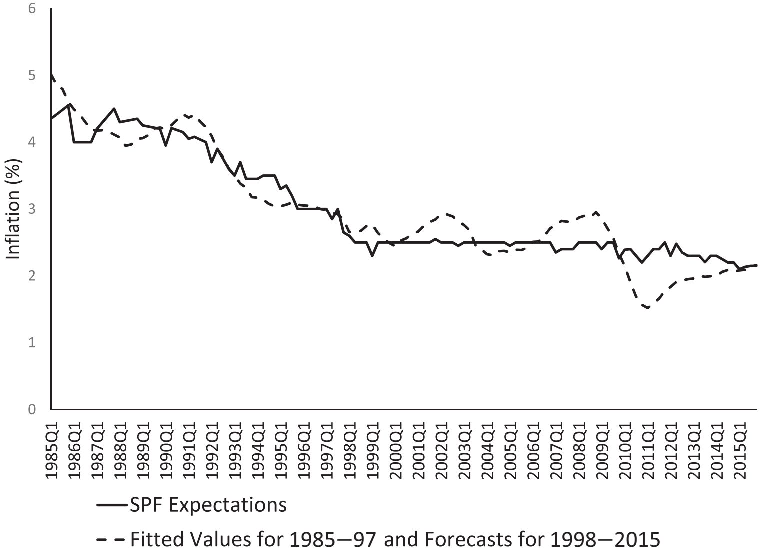
	1985Q1–2015Q4 (with 1998Q1 Break in λ)	
$\lambda^{prebreak}$	0.067	0
	(0.046)	
$\lambda^{postbreak}$	0.773	1
	(0.066)	
γ	0.875	0.859
	(0.018)	(0.017)
DW	0.357	0.312
SE of Reg.	0.189	0.203
$\overline{R}^2$	0.940	0.930

Note: NLLS with Newey–West (1987) standard errors in parentheses. π_t^e is the average forecast of long-term CPI inflation from the Survey of Professional Forecasters, and π_t is median CPI inflation. The break date of 1998Q1 is the quarter that produces the largest Wald statistic for the hypothesis that $\lambda^{prebreak} = \lambda^{postbreak}$.

Anchoring of Expectations



Counterfactual with No Anchoring



Coibion-Gorodnichenko 15

- Focus on “missing disinflation” during Great Recession
- Argue that population explanations insufficient
  - Anchored inflationary expectations
  - Movements in natural rate
  - Flattening of the Phillips curve
- New explanation:
  - Household inflation expectations rose in 2009-2013
  - If firm’s expectation the same, this can explain missing disinflation

Coibion-Gorodnichenko 15

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

Baseline assumptions:

- Output gap measure: Unemployment rate

$$y_t - y_t^n = u_t$$

  (Ignore natural rate u_t^n)

- Expectations of inflation: backward looking

$$E_t \pi_{t+1} = \frac{1}{4}(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4})$$

  (Ignore discounting: $\beta = 1$)

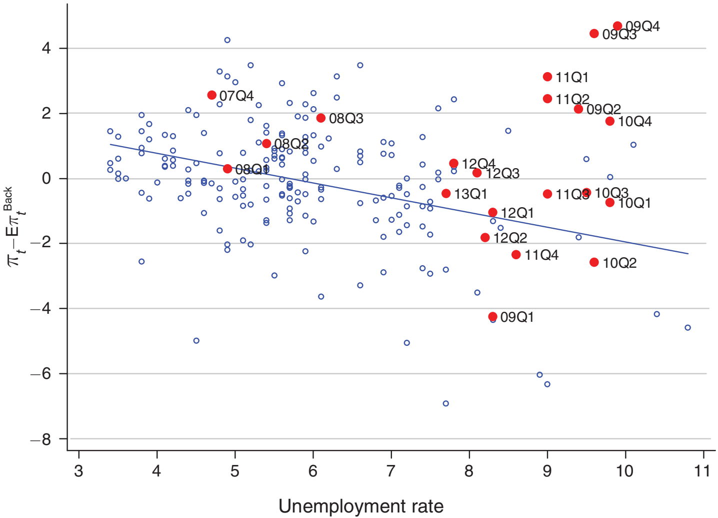
Coibion-Gorodnichenko 15

$$\pi_t - E\pi_{t+1}^{\text{Back}} = \kappa u_t + \eta_t$$

- Estimate by OLS for sample 1960Q1-2007Q4
  - Implicitly assuming that $\eta_t \perp u_t$ (i.e., ignoring supply shocks)
- Consider alternative specifications later
- See whether Great Recession "sticks out"

Missing Disinflation: CPI

Panel A. CPI inflation and US unemployment



Source: Coibion and Gorodnichenko (2015)

Missing Disinflation

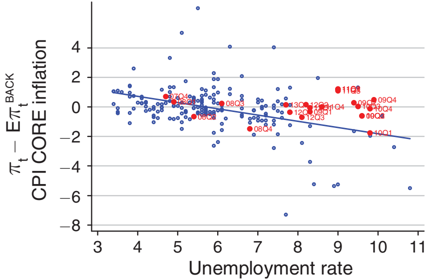
Panel B. CPI inflation and predicted inflation from the Phillips Curve

Figure 1. The Missing Disinflation

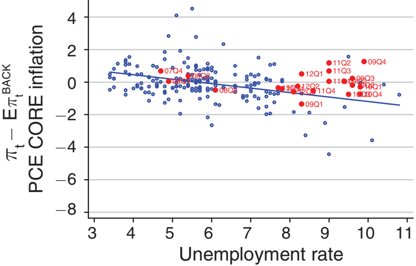
Source: Coibion and Gorodnichenko (2015)

Missing Disinflation: Core CPI/PCE

Panel C. Core CPI inflation



Panel D. Core PCE inflation



Source: Coibion and Gorodnichenko (2015)

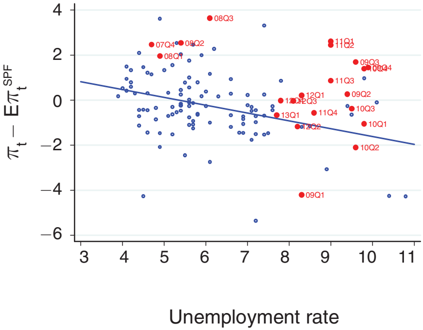
Alternative specifications

- Survey expectations
- CBO estimates of natural rate
- Oil shocks

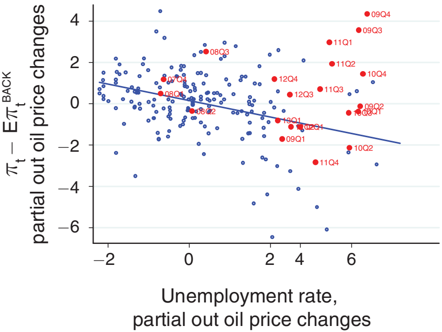
Help address alternative explanations:

- Anchoring of inflation expectations
- Movements in natural rate
- Role of supply shocks

Panel E. SPF inflation (CPI) forecasts

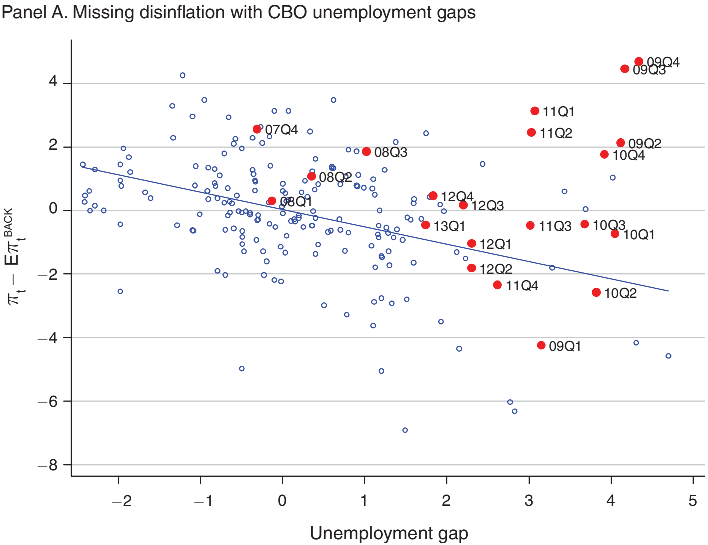


Panel F. Controlling for oil prices



Source: Coibion and Gorodnichenko (2015) – SPF forecast over next four quarters.

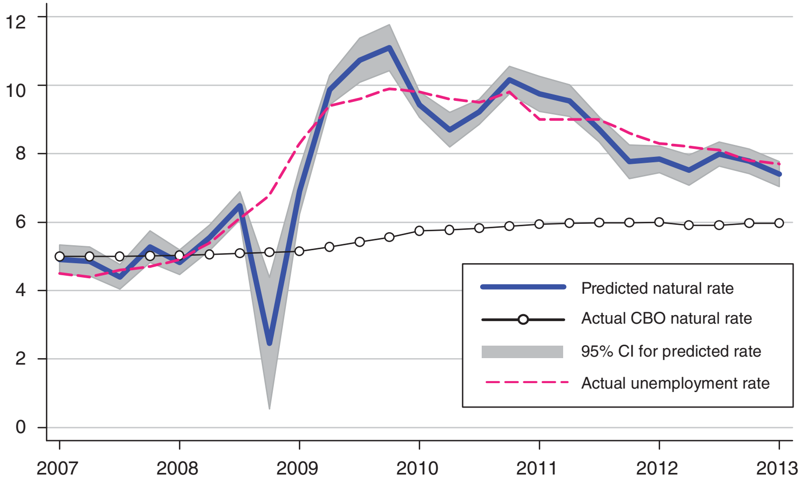
Missing Disinflation: Natural Rate



Source: Coibion and Gorodnichenko (2015)

Missing Disinflation: Natural Rate

Panel B. Changes in natural rate of unemployment needed to explain missing disinflation



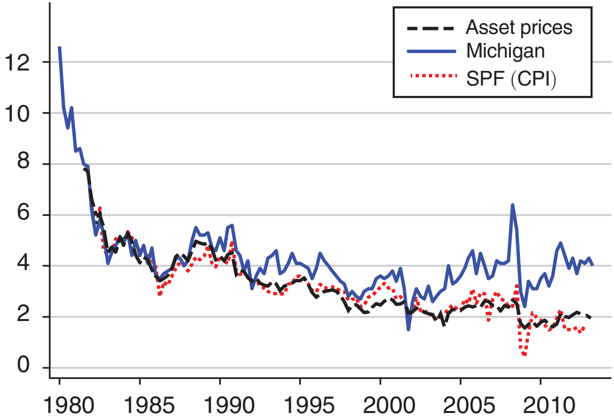
Source: Coibion and Gorodnichenko (2015)

New Explanation

- Expectations typically measured by SPF forecasts
- But is this the way to go?
- Perhaps firm expectations exhibit similar biases to household expectations
- Show that household expectations (Michigan survey) have quite different properties from SPF
  - Overreact to gasoline prices

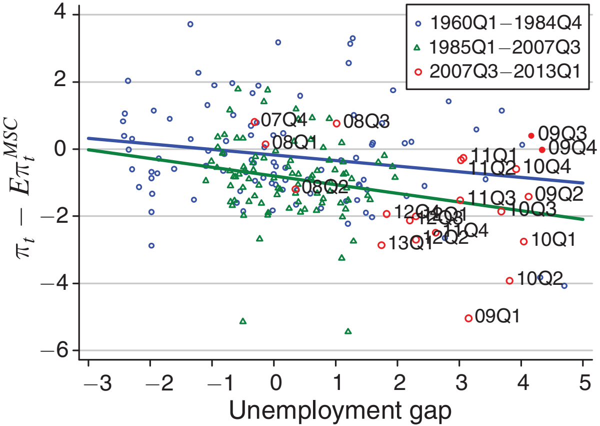
Household Expectations vs. SPF Forecasts

Panel A. Inflation expectations
for different economic agent



Source: Coibion and Gorodnichenko (2015)

Panel B. Phillips Curve with household inflation expectations



Source: Coibion and Gorodnichenko (2015)

Inflation Expectations

Three differences versus SPF:

- No evidence of flattening
- Flatter throughout
- No evidence of missing disinflation!

Stock and Watson (2019)

- Large variation across sectors in correlation between inflation and cyclical component of real activity
- Stronger correlation for well-measured, domestic components
- In particular **housing**
- Median inflation measure used by Ball-Mazumder 19 ends up placing a lot of weigh on housing

Measurement of Housing

- Inflation measure for owner-occupied housing changed in 1983
  - pre-83: Changes in house prices and mortgage costs (interest rates)
  - post-83: Changes in rents
- Makes a BIG difference for properties of CPI
- CPI Research Series uses modern methodology back in time (as do PCE and GDP deflators)

What if We Use Old Method for Recent Period?

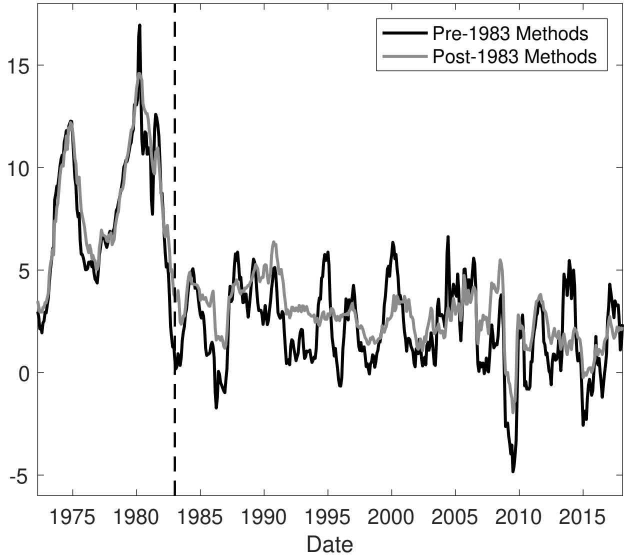


Figure B.1: CPI Inflation Using Pre- and Post-1983 Housing Methodology