# The Evolution of Inflation Dynamics and the Great Recession

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 Given the high level of unemployment in the recent recession, many economists were surprised that inflation did not fall by more. For example in Williams (2010) (now president of the San Francisco Fed) said:

"The surprise [about inflation] is that it's fallen so little, given the depth and duration of the recent downturn. Based on the experience of past severe recessions, I would have expected inflation to fall by twice as much as it has."

Moreover today many are debating about the likely path of future inflation. Many have argued that deflation is not a risk due to the anchoring of inflation expectations. For example, Bernanke (2010) said:

"Falling into deflation is not a significant risk for the United States at this time, but that is true in part because the public understands that the Federal Reserve will be vigilant and proactive in addressing significant further disinflation."

In light of the debate about the future path of inflation, we examine the accelerationist Phillips curve and the degree of anchoring that exists

# A Simple Phillips Curve

Friedman (1968) presented a theory of the short-run behavior of inflation which states that inflation depends on expected inflation and the gap between unemployment and its nature rate:

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

- Friedman also suggested that expected inflation can be well-proxied by past inflation (accelerationist PC)
- We also follow in the tradition of assuming backward-looking expectations
- Specifically we assume that expected inflation is the average of the past 4 quarters of inflation:

$$\pi_t = \frac{1}{4}(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) + \alpha(u - u^*)_t + \epsilon_t$$

# A Puzzle

- We estimate our Phillips curve equation from 1960 to the beginning of the Great Recession in 2007
- Two measures of quarterly inflation rates are used: total CPI inflation and CPI less food and energy inflation (XFE), with two activity variables: the unemployment gap and the output gap
- The results imply coefficients that are in keeping with Okun's Law and sacrifice ratios that are in keeping with past work
- However a puzzle emerges when we perform dynamic forecasts for 2008-2010
- Inflation should have fallen by more than it actually did:

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A Simple Phillips Curve and a Puzzle

4-Quarter Moving Averages of Dynamic Forecasts of XFE CPI Inflation for 2008 to 2010 (Based on 1960:1-2007:4)



This puzzle can be resolved with two changes to the model-both of which are motivated by models of costly nominal price adjustment from the 1980s and 1990s.

# Measuring Core Inflation

- The standard measure of core inflation is XFE inflation
- Instead we use the weighted median of price changes across industries (produced by Cleveland Fed), since the median inflation rate filters out large relative price changes that cause transitory movements in inflation.
- New result: innovations in median CPI inflation are almost entirely permanent. Specifically, we apply the Stock and Watson (2007) procedure for decomposing inflation into permanent and transitory components.
- We find the transitory shocks to be smaller when inflation is measured by median inflation:

#### Measuring Core Inflation

#### Actual Inflation vs. Permanent Component of Inflation



(a) Median CPI Inflation

(b) XFE CPI Inflation

Movements in median inflation are almost entirely permanent, especially in the last decade, which is a good property of core inflation.

A Phillips Curve With a Time-Varying Slope

## A Phillips Curve With a Time-Varying Slope

- With models costly nominal price adjustment, a higher mean and variance of inflation leads to more frequent price changes, which in turns steepens the Phillips curve by increasing the coefficient α in the model (Ball, Mankiw, and Romer, 1988)
- Therefore we estimate a time-varying slope in the Phillips curve using the following equations (which are estimated with the Kalman filter):

$$\pi_t = \frac{1}{4}(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) + \alpha_t(u - u^*)_t + \epsilon_t$$
  
$$\alpha_t = \alpha_{t-1} + \eta_t$$

• where  $\epsilon \sim N(0, V)$  and  $\eta \sim N(0, Q)$ .  $\alpha_t$  follows a random walk

A Phillips Curve With a Time-Varying Slope

#### Time-Varying $\alpha_t$ from Phillips Curve, 1960:1-2010:4



(a) No Restriction

Our results are fairly robust to estimating the variances freely as well as imposing restrictions.

A Phillips Curve With a Time-Varying Slope

#### Given these results, we also estimate a constant $\alpha$ :

	(a) Unemployment Gap		(b) Output Gap	
$\pi_t$ measure:	MEDIAN CPI	XFE CPI	MEDIAN CPI	XFE CPI
1960:1-1972:4				
Coefficient for $\alpha$		-0.231		0.135
S.E.		(0.103)		(0.056)
$\overline{R}^{2}$		0.729		0.733
S.E. of Regression		0.992		0.985
1973:1-1984:4				
Coefficient for $\alpha$	-0.660	-0.688	0.368	0.371
S.E.	(0.171)	(0.184)	(0.095)	(0.103)
$\overline{R}^2$	0.526	0.402	0.527	0.391
S.E. of Regression	2.243	2.408	2.240	2.429
1985:1-2007:4				
Coefficient for $\alpha$	-0.200	-0.246	0.113	0.136
S.E.	(0.054)	(0.067)	(0.029)	(0.037)
$\overline{R}^2$	0.700	0.762	0.703	0.763
S.E. of Regression	0.425	0.529	0.423	0.528
1985:1-2010:4				
Coefficient for $\alpha$	-0.168	-0.136	0.114	0.092
S.E.	(0.031)	(0.039)	(0.019)	(0.024)
$\overline{R}^2$	0.781	0.764	0.793	0.769
S.E. of Regression	0.448	0.570	0.436	0.564

We then use the regression estimated for 1985-2007 to compute dynamic forecasts for 2008-2010  $\,$ 

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## The Great Recession

Forecasts for median inflation are close to the actual values for 2008-2010: the puzzle is solved since there is no missing deflation. I.e. inflation fell by approximately as much as it should have

4-Quarter Moving Averages of Dynamic Forecasts of Median CPI Inflation for 2008 to 2010



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4-Quarter Moving Averages of Dynamic Forecasts of XFE CPI Inflation for 2008 to  $2010\,$ 



The measurement of core inflation here is crucial if we compare the median and XFE forecasts: XFE implies that inflation should have fallen more than it did

## Anchored Expectations?

- So far we have assumed expectations depend on past inflation rates
- However many argue that expectations have become "anchored," which means they do not respond strongly to past inflation
- We examine this issue further by distinguishing between shock anchoring and level anchoring

Anchored Expectations

## Shock Anchoring:

- For 1960-1972 and 1973-1984 we find that the Phillips curve fits better where expectations are proxied with lagged total inflation (which includes shocks), but the model fits better with lagged core inflation after 1985 (see Table 3 in paper)
- The 1985-2010 results are also true if we use *SPF4Q* as our dependent variable
- This suggests that since 1985 expectations have been fully shock-anchored

Level Anchoring: To test for level anchoring we estimate:

$$\pi_t^e = \delta_t 2.5 + (1 - \delta_t) \frac{1}{4} (\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) + \epsilon_t$$

using SPF4Q as our measure of  $\pi^e$ . We then take our basic Phillips curve:

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

and substitute in the new expression for expectations, leaving us with the following model:

$$\pi_t = \delta_t 2.5 + (1 - \delta_t) \frac{1}{4} (\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) + \alpha (u - u_t^*) + \epsilon_t$$

which we also estimate with median inflation.

Anchored Expectations

### Level Anchoring: $\delta_t$



## Should We Expect Deflation in the Near Future?

Forecasts of Inflation for 2011-2013 (4-Quarter Moving Averages)



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However a caveat is in order with the previous result:

- We assume that expectations do not change in the future, but it is possible that expectations may become less anchored
  - $\circ~$  The figure shows that actual inflation stays below 1% for several years, yet expectations remain tied to 2.5%
  - Price setters may learn that inflation is stuck below 2.5% and adjust their expectations downward
- Other researchers have argued that 10-year ahead inflation forecasts should be used instead of 4-quarter ahead forecasts, which might make it plausible for inflation to remained anchored even if actual inflation remains below expected inflation.
  - But sticky-price models underlying the PC suggest it is shorter-term expectations that matter

#### Conclusion

## Conclusion

- We find that a simple accelerationist Phillips curve fits U.S. inflation data from 1960 to 2010 well under two conditions that are motivated by models of costly price adjustment: (1) core inflation measured by the median inflation rate; (2) slope of the PC changes with the level and variance of inflation.
- We also find evidence of a change in the Phillips curve since the 1990s: inflation expectations have become partially anchored at a level of 2.5%.
- If this anchoring is maintained, then deflation is likely to be avoided in the near future. However if low inflation leads to the de-anchoring of expectations, then deflation may yet still occur.
- We also show in the paper that the period of 2008-2010 provides fresh evidence against the New Keynesian Phillips curve