How Does the Phillips Curve Slope Relate to Repricing Rates?

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The Phillips Curve and Repricing Rates

- Sticky price models: when prices change more frequently, short-run Phillips curve is steeper.
- So far, no direct empirical evidence on this.

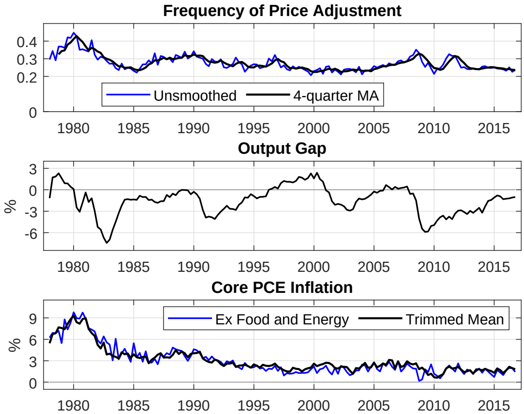
Using repricing rates from Nakamura, Steinsson, Sun, Villar (2018), I find that in the US:

- there is some evidence that the Phillips curve slope depends positively on the frequency of price adjustment.
- the Phillips curve slope is a convex function of the frequency.
- at the same repricing rate, the Phillips curve is much flatter in the data than in a range of models with nominal rigidities.

Relation to the Literature

- Literature on **flattening of the Phillips curve**
  De Veirman (2009), Ball and Mazumder (2011), Blanchard, Cerutti, Summers (2015), Blanchard (2016), Del Negro, Lenza, Primiceri, Tambalotti (2020).
- This paper: Phillips curve often flat, but steep at times.
- Papers **testing endogenous pricing models**: Phillips curve slope depends on determinants of the *unobserved* repricing rate.
  Ball, Mankiw, Romer (1988), DeFina (1991), De Veirman (2009), Ball and Mazumder (2011).
- In the present paper, I use a time series on repricing rates.
- Other papers examine **what drives the repricing rate**:
  Costain, Nakov, Petit (2021), Cotton and Garga (2022),
  De Veirman and Schoenle (2024).
- More frequent repricing => monetary policy has stronger effects on sector-level price indices; weaker effects on real firm-level sales.
  Hong, Klepacz, Pasten, Schoenle (2023).

US Data, 1978Q1-2016Q4



- Median frequency of consumer price adjustment excluding sales from Nakamura e.a. (2018). I express $freq_t$ at a quarterly rate.
- Output gap: percent deviation of real GDP from CBO estimate real potential output.
- Trimmed mean: FRB-Dallas. Dolmas and Koenig (2019), Ball and Mazumder (2020), Verbrugge (2022): trimmed mean & median inflation: better measures of core inflation than ex food and energy.

Link Phillips Curve Slope - Price Adjustment Frequency?

Estimate over 1978Q4-2016Q4:

$$\pi_t = \pi_t^e + \ (a + b \ freq_t) \ (ygap_t + \sum_{j=1}^{5} p_j \ ygap_{t-j}) + \varepsilon_t$$

- π_t: inflation, $freq_t$: price adjustment frequency, $ygap_t$: output gap.
- π_t^e: inflation expectations. Three specifications:
    - Adaptive expectations: $\pi_t^e \ = \beta(L)\pi_t$.
    - Ball-Mazumder (2019) expectations, involving inflation target π^*:

$$\begin{aligned}\pi_t^e \ &= \ I(t \leq 1997) \ [\alpha_1\pi^* + (1-\alpha_1)\gamma(L)\pi_t] \\ &+ I(t \geq 1998) \ [\alpha_2\pi^* + (1-\alpha_2)\gamma(L)\pi_t]\end{aligned}$$

    - Survey (SPF) inflation expectations, e.g. $\pi_t^e \ = \ \pi_{t+1|t}$.

=> test:

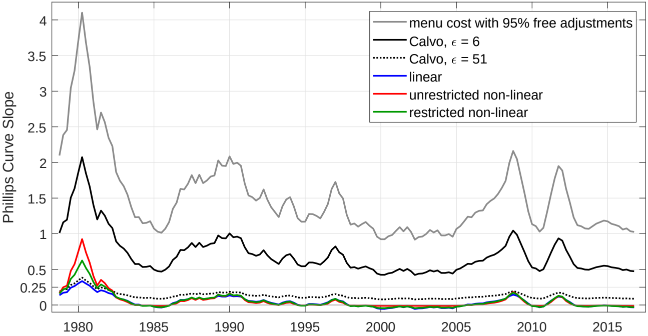
- Significant slope? H_0: $a(1 + \sum_{i=1}^{5} p_i) = 0$ after restricting $b = 0$.
- Does slope depend on frequency? H_0: $b(1 + \sum_{i=1}^{5} p_i) = 0$.

Does the Slope Depend on the Frequency?

infexp	inflation	Significant Phillips curve slope? slope	stderr	pval	Significant relation to frequency? rel freq	stderr	pval
adaptive	PCE_TM	0.03	0.02	0.11	1.92**	0.62	0.00
adaptive	PCEX	0.07*	0.03	0.02	2.41	1.30	0.07
adaptive	GDPDEF	0.05	0.03	0.15	3.07*	1.22	0.01
adaptive	CPIX	0.06	0.04	0.13	2.51	1.43	0.08
Ball-Mazumder	PCE_TM	0.05**	0.02	0.00	1.52*	0.64	0.02
Ball-Mazumder	PCEX	0.10**	0.03	0.00	2.00	1.15	0.08
Ball-Mazumder	GDPDEF	0.05*	0.02	0.01	0.05	0.47	0.92
Ball-Mazumder	CPIX	0.20**	0.05	0.00	1.39	1.98	0.48
$\pi^e_{t\|t-1}$	GDPDEF	0.06	0.04	0.18	1.25	0.82	0.13
$\pi^e_{t+1\|t}$	GDPDEF	0.05	0.04	0.22	0.85	0.87	0.33

- Wald tests. HAC standard error and p-value. *: significant at 5% level; **: at 1% level.
- Inflation: trimmed mean PCE; PCE ex food & energy; GDP deflator; constant methodology CPI ex food & energy. GDP deflator: control for relative oil price inflation.
- $\pi_{\tau_2|\tau_1}$: SPF forecasts of time-τ_2 inflation formed at τ_1.

Phillips Curve Slopes Varying With Actual Repricing Rate



- Gray line: Phillips curve slope implied by menu cost model with 95% free price adjustments, computed using Auclert e.a. (2024).
- Solid black line: baseline Calvo. With price adjustment probability ω, NKPC slope $\kappa = \Lambda \left[(1-\beta)\left(\omega/(1-\omega)\right) + \beta\left(\omega^2/(1-\omega)\right)\right]$.
- Blue, red, green: empirical Phillips curve slopes, with empirical frequency $freq_t$:
  Red: slope: $\left[c + d\left(freq_t/(1-freq_t)\right) + e\left(freq_t^2/(1-freq_t)\right)\right](1+\sum_{j=1}^{5} p_j)$.
  Green: slope: $f\left[(1-g)\left(freq_t/(1-freq_t)\right) + g\left(freq_t^2/(1-freq_t)\right)\right]\ (1+\sum_{j=1}^{5} p_j)$.

Average of Phillips Curve Slope over Time

	Share free adjustments	ϵ	average slope
Models			
Golosov-Lucas	0	6	10.54
CalvoPlus	75	6	**3.38**
CalvoPlus	90	6	2.01
CalvoPlus	95	6	1.50
Calvo	100	6	0.71
Calvo	100	51	0.13
Empirical			
Unrestr. non-linear			**0.07**
Restr. non-linear			0.05
Linear			0.04

- First column: percent share of free price adjustments. Second: price elasticity of demand. Third: average Phillips curve slope in 1978Q4-2016Q4.
- I use Auclert e.a. (2024) to compute the Phillips curve slopes implied by state-dependent pricing models: Golosov-Lucas (2007) and CalvoPlus/Nakamura and Steinsson (2010).

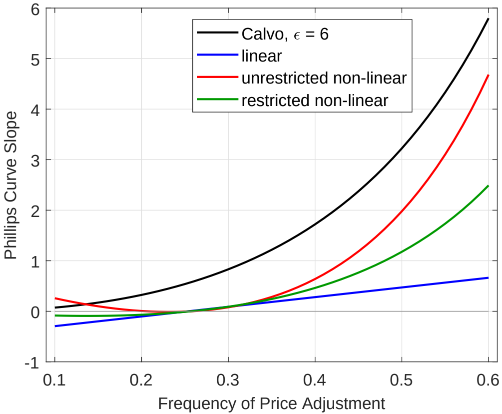
Conclusion

- Positive relation Phillips curve slope - repricing rate:
  - Trend decline in repricing rate caused Phillips curve to flatten.
  - Recent sharp increase in repricing rate in US, France, UK, Germany.
    - Montag, Villar (2022), Dedola, Gautier, Nakov, Santoro, De Veirman, Henkel, Fagandini (2023), Balleer, Link, Menkhoff, Zorn (2024).
  - This would explain findings that Phillips curve recently steepened.
    - Cerrato and Gitti (2024).
- What might explain gap between empirical and theoretical slope?
  - Real rigidities amplify nominal rigidities.
    - Dossche, Heylen, Van den Poel (2010), Klenow and Willis (2016), Beck and Lein (2020), Dedola e.a. (2023), Dedola, Kristoffersen, Züllig (2024), Smets, Tielens, van Hove (2018), Rubbo (2023), Pasten, Schoenle, Weber (2024), Höynck (2024).
  - Monetary policy response to supply shocks: downward bias slope.
    - McLeay and Tenreyro (2019), Bergholt, Furlanetto, Vaccaro-Grange (2023), De Veirman and Nakov (2024).

Empirical vs. Theoretical Phillips Curve Slope

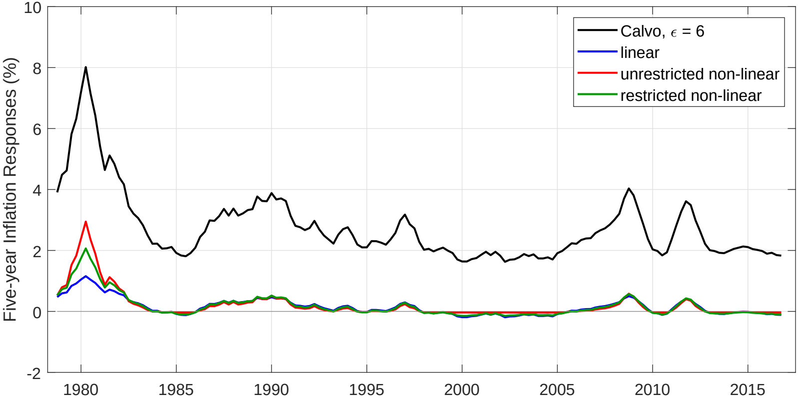
- New Keynesian Phillips Curve: $\pi_t = \beta E_t \pi_{t+1} + \kappa \ ygap_t, with:$
  $\kappa = \left(\frac{(1-\theta)(1-\theta\beta)}{\theta}\right)\left(\frac{1-\alpha}{1-\alpha+\alpha\epsilon}\right)\left(\frac{\phi+\alpha}{1-\alpha}+\sigma\right).$
- Defining price adjustment probability $\omega \equiv 1-\theta$, rewrite:
  $\kappa = \left(\frac{1-\alpha}{1-\alpha+\alpha\epsilon}\right)\left(\frac{\phi+\alpha}{1-\alpha}+\sigma\right)\left[(1-\beta)\left(\frac{\omega}{1-\omega}\right)+\beta\left(\frac{\omega^2}{1-\omega}\right)\right]$
- Replacing ω by empirical frequency $freq_t$, estimate Phillips curve with slope as "unrestricted" non-linear function of frequency:
  $\pi_t = \beta(L)\pi_t + \left[c + d\left(\frac{freq_t}{1-freq_t}\right) + e\left(\frac{freq_t^2}{1-freq_t}\right)\right](ygap_t + \sum_{j=1}^{5} p_j \ ygap_{t-j}) + \varepsilon_t$
- Also estimate with slope as"restricted" non-linear function of frequency:
  $\pi_t = \beta(L)\pi_t + f\left[(1-g)\left(\frac{freq_t}{1-freq_t}\right) + g\left(\frac{freq_t^2}{1-freq_t}\right)\right] \ (ygap_t + \sum_{j=1}^{5} p_j \ ygap_{t-j}) + \varepsilon_t$

How Does the Slope Depend on the Frequency?



- Black line: slope of NKPC as function of probability of price adjustment, with $\epsilon = 6$ and other structural parameters at Smets and Wouters (2007) estimates.
- Blue, red and green lines: empirical Phillips curve slopes, respectively linear, unrestricted non-linear, and restricted non-linear function of the frequency of price adjustment.
- All slopes pertain to response of inflation in annualized terms.

Five-year Inflation Responses to Output



- Output gap 1% for four quarters in a row. Change in inflation from before the spell with positive output gaps to five years after the last quarter with a positive output gap.
- Black lines: Calvo, assume $E_t \pi_{t+1} = \pi_{t-1}$. Blue, red and green lines: empirical. Respectively linear, unrestricted non-linear, and restricted non-linear function of the frequency.