Anatomy of the Phillips Curve: Micro Evidence and Macro Implications

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October 25, 2023

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New Keynesian Phillips Curve (NKPC)

$$\pi_t = \kappa(y_t - y_t^\star) + \beta\,\mathbb{E}_t\{\pi_{t+1}\} + u_t \qquad \text{(Output gap-based NKPC)}$$

- Estimates of κ very small for pre-pandemic data.
- Issues involving estimation and interpretation of κ:
  1. Identification: Endogeneity of $y_t - y_t^\star$ due to monetary policy response:
     - Lack of good instruments with aggregate data.
  2. Measurement (1): $y_t^\star$ not directly observable.
  3. Measurement (2): Real marginal cost (not output gap) is the primitive real activity measure.

$$\pi_t = \lambda \widehat{mc}_t^r + \beta\,\mathbb{E}_t\{\pi_{t+1}\} + u_t \qquad \text{(Marginal cost-based NKPC)}$$

- Real marginal cost proportionate to output gap only under very special circumstances.
- The coefficient of proportionality need not to be one.

This paper: Bottom-up approach

Conventional approach: Aggregate then estimate output-based slope of NKPC using aggregate data.

We use high-frequency microdata on prices and costs to estimate slope of marginal cost-based NKPC.

- Estimate firm-level dynamic pass-though regressions to identify the structural parameters that govern firm's pricing decisions and ultimately pin down the slope:
  - Degree of nominal stickiness;
  - Strength of strategic complementarities in price setting.
- Use of firm-level panel data greatly enhances identification power.

Main result: Slope of the marginal cost-based NKPC is economically large.

- 3-10 times larger than estimates of output gap-based NKPC.
- We reconcile with low slope of output-based NKPC.
- Also show how marginal cost-based NKPC captures impact of supply shocks on inflation.

Background Literature

- Estimation of NKPC with aggregate data:

  Roberts (1995), Fuhrer and Moore (1995), Gali and Gertler (1999), Gali, Gertler and Lopez-Salido (2001), Sbordone (2002), Jorgensen and Lansing (2019).

- Estimation of NKPC with panel data:

  McLeay and Tenreyo (2019), Hooper, Mishkin, and Sufi (2019), Rubbo (2020) Hazell, Herreno, Nakamura, and Steinsson (2022).

- Pass-through of marginal cost with strategic complementarities:

  Kimball (1995), Atkeson and Burstein (2008), Amiti, Itskhoki, and Konings (2019), Duprez and Magerman (2021), Wang and Werning (2022).

Plan for the presentation

- Theoretical framework.
- Data.
- Econometric framework.
- Results.

Theoretical Framework

Pricing Behavior

- Imperfectly competitive firm f in industry i face demand function:

$$\mathcal{D}_{ft} := d(P_{ft}, P_{it}, \varphi_{ft}) Y_{it}.$$

- Nominal rigidities à la Calvo with stickiness parameter $\theta \in [0, 1]$

$$P_{ft} = \begin{cases} P^o_{ft} & w.p.\ (1-\theta) \\ P_{ft-1} & w.p.\ \theta \end{cases}$$

- Profit maximization problem for firms setting price at t:

$$\max_{P^o_{ft}} \mathbb{E}_t \left\{ \sum_{\tau=0}^{\infty} \theta^{\tau} \left[\Lambda_{t,\tau} \left(\frac{P^o_{ft}}{P_{t+\tau}} \mathcal{D}_{ft+\tau} - TC(\mathcal{D}_{ft+\tau}) \right) \right] \right\}$$

subject to the sequence of (expected) demand functions $\mathcal{D}_{ft+\tau}$.

Pricing Behavior (cont'd)

- Optimal reset price P^o_{ft} solves the following FONC:

$$\mathbb{E}_t \left\{ \sum_{\tau=0}^{\infty} \theta^\tau \Lambda_{t,\tau} \mathcal{D}_{ft+\tau} \left[\frac{P^o_{ft}}{P_{t+\tau}} - (1 + \mu_{ft+\tau}) \frac{MC^n_{ft+\tau}}{P_{t+\tau}} \right] \right\} = 0$$

with net markup

$$\mu_{ft+\tau} := \ln \left(\frac{\epsilon_{ft+\tau}}{\epsilon_{ft+\tau} - 1} \right)$$

and demand elasticity

$$\epsilon_{ft+\tau} := -\frac{\partial \ln \mathcal{D}_{ft+\tau}}{\partial \ln P^o_{ft}}.$$

Log-linear Formulation

- Log-linearized FOC around steady state:

$$p^o_{ft} = (1-\beta\theta)\mathbb{E}_t\left\{\sum_{\tau=0}^{\infty}(\beta\theta)^{\tau}\left(mc^n_{ft+\tau}+\mu_{ft+\tau}\right)\right\}.$$

- Under general class of models of imperfect competition, log-linearized markup:

$$\mu_{ft}-\mu = -\Gamma\left(p^o_{ft}-p^{-f}_{it}\right)+u^{\mu}_{ft}.$$

u^{μ}_{ft} depends upon demand shock φ_{ft}.

Log-linear Formulation

- Log-linearized FOC around steady state:

$$p^o_{ft} = (1-\beta\theta)\mathbb{E}_t\left\{\sum_{\tau=0}^{\infty}(\beta\theta)^\tau\left(mc^n_{ft+\tau} + \mu_{ft+\tau}\right)\right\}.$$

- Under general class of models of imperfect competition, log-linearized markup:

$$\mu_{ft} - \mu = -\Gamma\left(p^o_{ft} - p^{-f}_{it}\right) + u^\mu_{ft}.$$

  u^μ_{ft} depends upon demand shock φ_{ft}.

- Using μ_{ft} and solving for fixed point, optimal reset price with complementarities:

$$p^o_{ft} = \mu + (1-\beta\theta)\mathbb{E}_t\left\{\sum_{\tau=0}^{\infty}(\beta\theta)^\tau\left((1-\Omega)mc^n_{ft+\tau} + \Omega p^{-f}_{it+\tau}\right)\right\} + u_{ft},$$

$$\Omega := \frac{\Gamma}{1+\Gamma}$$

The Phillips Curve

- Optimal reset price:

$$p^o_{ft} = \mu + (1-\beta\theta)\mathbb{E}_t\left\{\sum_{\tau=0}^{\infty}(\beta\theta)^\tau\left((1-\Omega)mc^n_{ft+\tau} + \Omega p^{-f}_{it+\tau}\right)\right\} + u_{ft}.$$

- Log-linear price index:

$$p_t = (1-\theta)p^o_t + \theta p_{t-1}.$$

- $\Longrightarrow$ New Keynesian Phillips curve (assuming CRS):

$$\pi_t = \lambda\,\widehat{mc}^r_t + \beta\mathbb{E}_t\pi_{t+1} + u_t$$

$$\lambda := \frac{(1-\theta)(1-\beta\theta)}{\theta}(1-\Omega),$$

  and $\widehat{mc}^r_t := mc^n_t - p_t - mc^r$.

- Given calibration of $\beta = .99$, estimates of θ and Ω pin down the slope of NKPC.

Data

Data

- Quarterly micro-data covering manufacturing sector in Belgium across two decades (1999:Q1–2019:Q4).
- Production: firm-product level domestic sales, quantity sold, and prices (unit values) of:
  - *domestic firms* (PRODCOM)
  - *foreign competitors* (Customs declarations)
- Costs: detailed information on total variables costs (VAT + Social Security declarations).
- Almost universal coverage: 80-90% of domestic manufacturing production + foreign importers.
- Price dynamics: Sample almost exactly replicates the official PPI inflation series. ▷ Replication

Firms	Narrow industries	Broader sectors	Average length of firms-industry time-series
5, 118	172	13	12 consecutive years of data

▷ Summary Stats

Measurement

- Under standard production technologies (e.g. Cobb-Douglas, CES):

$$MC^n_{ft} = \mathcal{C}_{it}\mathcal{A}_{ft}Y^{\nu_f}_{ft} \implies MC^n_{ft} = (1+\nu_f)\frac{TVC_{ft}}{Y_{ft}}$$

$\mathcal{C}_{it}$:= Nominal industry cost shifters,

$\mathcal{A}_{ft}$:= Nominal firm cost shifters,

TVC_{ft} := Wage bill + Intermediates cost.

- Use Törnqvist index to construct the following indexes:
  1. Price for multi-product firms (8-digit products $\rightarrow$ 4-digit firm).
  2. Industry prices (4-digit firms $\rightarrow$ 4-digit industry).

Econometric Framework

Econometric Framework

- Under Calvo pricing, observed price is a realization of random variable with distribution:

$$p_{ft} = \begin{cases} p^o_{ft} & w.p.\ 1-\theta \\ p_{ft-1} & w.p.\ \ \theta \end{cases} \qquad \Rightarrow \qquad \mathbb{E}[p_{ft} | p^o_{ft}, p_{ft-1}] = (1-\theta) p^o_{ft} + \theta p_{ft-1}$$

- Regression equation:

$$\begin{aligned} p_{ft} &= (1-\theta) p^o_{ft} + \theta p_{ft-1} + \upsilon_{ft} \\ &= (1-\theta)(1-\beta\theta)\mathbb{E}_t \left\{ \sum_{\tau=0}^{\infty} (\beta\theta)^\tau \left((1-\Omega) mc^n_{ft+\tau} + \Omega p^{-f}_{it+\tau} \right) \right\} + \theta p_{ft-1} + \upsilon_{ft} + (1-\theta) u_{ft} \\ &= (1-\theta)(1-\beta\theta) \sum_{\tau=0}^{\infty} (\beta\theta)^\tau \left((1-\Omega) mc^n_{ft+\tau} + \Omega p^{-f}_{it+\tau} \right) + \theta p_{ft-1} + \underbrace{\upsilon_{ft} + (1-\theta) u_{ft} + \epsilon_{ft}}_{\text{Error term}=\varepsilon_{ft}} \end{aligned}$$

Econometric Framework (Cont'd)

- Mapping to the data:

$$p_{ft} = (1-\theta)\left((1-\Omega)(mc_{ft}^{n})^{\infty} + \Omega(p_{it}^{-f})^{\infty}\right) + \theta p_{ft-1} + \varepsilon_{ft}$$

for $x_t \in \{mc_{ft}^{n}, p_{it}^{-f}\}$:

$$(x_t)^{\infty} = (1-\beta\theta)\sum_{\tau=0}^{\infty}(\beta\theta)^{\tau} x_{t+\tau}$$

- Truncate $(x_t)^{\infty}$ after 8 quarters and include fixed effects:

$$p_{ft} = (1-\theta)\left((1-\Omega)(mc_{ft}^{n})^{8} + \Omega(p_{it}^{-f})^{8}\right) + \theta p_{ft-1} + \varepsilon_{ft}$$

Identification

Baseline specification:

$$p_{ft} = (1-\theta)\left((1-\Omega)(mc_{ft}^{n})^{8} + \Omega(p_{it}^{-f})^{8}\right) + \theta p_{ft-1} + \alpha_{f} + \alpha_{s\times t} + \varepsilon_{ft} \qquad \text{(Model A)}$$

- Fixed effects
  - $\alpha_{s\times t}$:= sector-by-time FE
  - α_{f} := firm FE
- Error term ε_{ft} may contain firm-level demand shocks.
  - Competitors' prices $(p_{it}^{-f})^{8}$ may be correlated with ε_{ft} under oligopoly.
  - Absent constant returns, marginal cost $(mc_{ft}^{n})^{8}$ may also be correlated with ε_{ft}.
- Address endogeneity by instrumenting $(p_{it}^{-f})^{8}$ and $(mc_{ft}^{n})^{8}$ with firm-level supply shifters.

Instruments Set

Building from AIK (2019).

- Competitors' price index:

  Variation in foreign competitors' prices unrelated to domestic demand.

  1. Average of prices that EU competitors charge outside Belgium ($p_{it}^{\star EU}$).
  2. Exchange rates for non-EU competitors ($p_{it}^{\star F}$).

- Marginal cost:

  1. Variation in intermediates costs driven by foreign suppliers' prices ($mc_{ft}^{n\star}$).
  2. Augment with "long" lag of marginal cost (mc_{ft-8}^{n}):
     - Improves precision of estimates in dynamic settings.
     - Valid instrument under weak assumptions (consistent with empirical evidence).

Estimation

- Estimate with non-linear GMM w/ moment conditions:

$$\mathbb{E}\{\boldsymbol{z}_{ft} \cdot \varepsilon_{ft}\} = 0.$$

- Instruments are valid:
  - Hansen-Sargan J-test for over-identifying restrictions.
- Instruments are powerful:
  - Weak instrument tests soundly rejected.

Estimation Results

Model	(A)	(B)	(C)
θ	0.717		
	(0.012)		
Ω	0.375		
	(0.178)		
Firm FE	y		
Sect x time FE	y		
Cragg-Donald F	440		
Kleibergen-Paap F	13.46		
Hansen-Sargan J	5.850		

|▷ IV Robustness

|▷ First Stage

Robustness

- Concern (1): Definition of competitors.
  - Absorb competitors' price index into industry x time FE:

$$p_{ft} = (1-\theta)(1-\Omega)(mc^n_{ft})^8 + \theta p_{ft-1} + \alpha_f + \alpha_{i\times t} + \varepsilon_{ft} \qquad \text{(Model B)}$$

- Concern (2): Approximation of the present value $(mc^n_{ft})^\infty$.
  - Assume marginal cost follows AR(1):

$$p_{ft} = (1-\theta)(1-\Omega)\left(\frac{1-\beta\theta}{1-\beta\theta\rho}\right) mc^n_{ft} + \theta p_{ft-1} + \alpha_f + \alpha_{i\times t} + \varepsilon_{ft} \qquad \text{(Model C)}$$

Estimation Results

Model	(A)	(B)	(C)
θ	0.717	0.688	0.711
	(0.012)	(0.011)	(0.004)
Ω	0.375	0.643	0.490
	(0.178)	(0.058)	(0.051)
ρ			0.749
			(0.030)
Firm FE	y	y	y
Sect x time FE	y		
Ind x time FE		y	y
Cragg-Donald F	440	948	2690
Kleibergen-Paap F	13.46	31.1	15.5
Hansen-Sargan J	5.850	0.314	0.129

|▷ IV Robustness
|▷ First Stage

Estimates of Slope λ of Marginal Cost-based Phillips Curve

Model	(A)	(B)	(C)
λ	0.071	0.052	0.061
	(0.026)	(0.011)	(0.007)

Estimates of output and unemployment gap-based Phillips curves:

- Output gap $\Longrightarrow$ Rotemberg and Woodford (1997): $\kappa = 0.024$
- Unemployment gap $\Longrightarrow$ Hazell, Herreno, Nakamura, Steinsson (2022): $\kappa = 0.0062$

Additional Robustness

- Diminishing returns to scale and macroeconomic complementarities. ▷ Estimates
  - Estimate of short-run returns to scale close to unity.

    $\Longrightarrow$ Baseline with CRS is robust.

- Extension to menu costs.
  - Data appears consistent with Calvo.

▷ Oil and Money IVs

Aggregate Inflation Dynamics

Aggregate Inflation

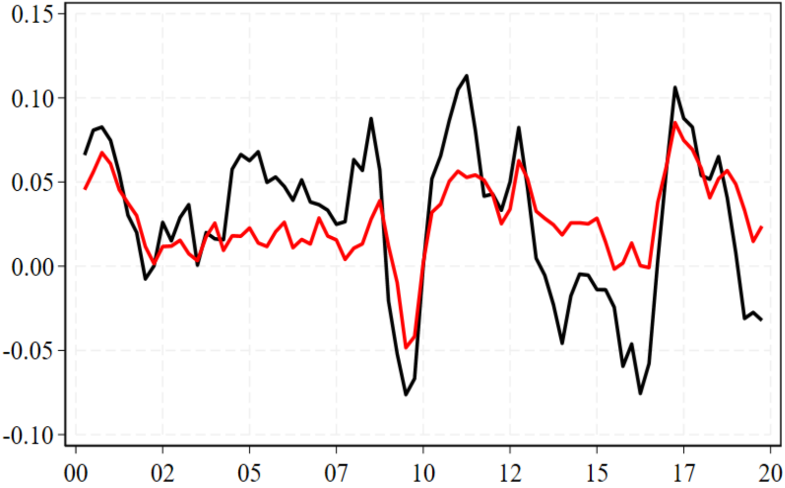
- Assume aggregate nominal marginal cost is random walk (consistently with data).

- Aggregate inflation can be expressed as:

$$\underbrace{\pi_t}_{\text{Data}} = \underbrace{\tilde{\lambda}\left(mc_t^n - p_{t-1}\right) + \alpha}_{\text{Model}} + u_t,$$

with $\tilde{\lambda} := \tilde{\lambda}(\theta, \Omega)$ analytical function.

Year-over-year Aggregate Inflation



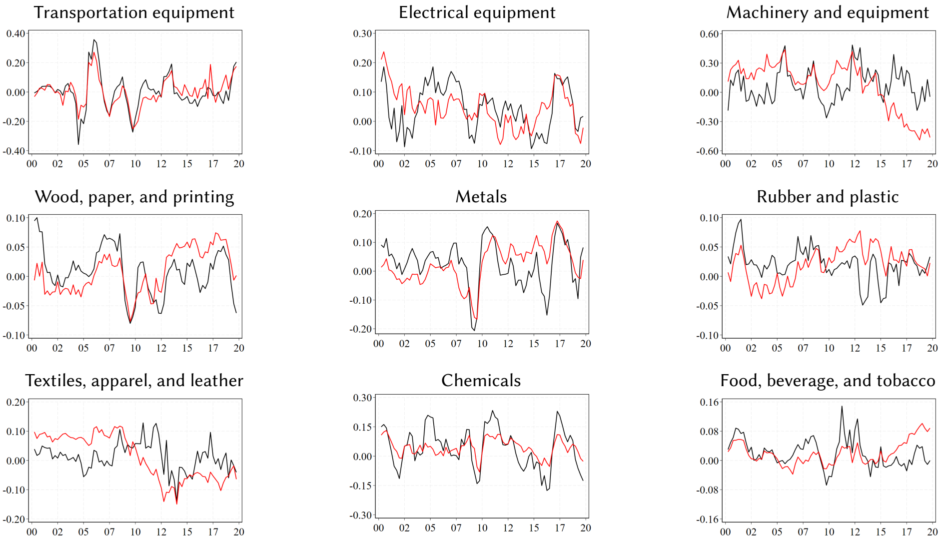
— Data

— Model

$R^2 = 0.5$

Corr $= 0.7$

Year-over-year Sectoral Inflation



Reconciliation with the conventional NKPC

Output Elasticity of Real Marginal Cost

- Marginal cost: $mc_{ft} = (w_{it} - p_t) - mpn_{ft}$

- In general equilibrium with flexible wages:

$$mc_{ft} = \sigma^w y_{it} - mpn_{ft}$$

- Firm output: $y_{ft} = y_{it} + (\varepsilon^d_{ft}, \varepsilon^s_{ft})$

  $\varepsilon^d_{ft}, \varepsilon^s_{ft}$ are firm-level supply and demand shocks.

- Real marginal cost (in log deviation from steady steady) is:

$$\widehat{mc}_{ft} = \sigma^y (y_{ft} - y^\star_{ft}) - \sigma^w \varepsilon^d_{ft}$$

  $y^\star_{ft}$:= Natural output with flexible prices.
  σ^y := Elasticity of mc wrt the firm output gap.

Output Gap-based Slope

- Output gap-based PC slope:

$$\kappa = \frac{(1-\beta\theta)(1-\theta)}{\theta}(1-\Omega)\cdot\sigma^{y} = \lambda\cdot\sigma^{y}$$

- Nominal marginal cost:

$$mc_{ft}^{n} = \sigma^{y} y_{ft}^{n} + \alpha_{f} + \alpha_{s\times t} - \sigma^{y} y_{ft}^{\star} - \sigma^{w}\varepsilon_{ft}^{d}$$

- Using expression above, substitute for mc_{ft}^{n} in baseline model and assume AR(1) for y_{ft}^{n}:

$$p_{ft} = (1-\theta)(1-\Omega)\Psi\cdot\sigma^{y} y_{ft}^{n} + (1-\theta)\Omega p_{it}^{-f} + \theta p_{ft-1} + \alpha_{f} + \alpha_{s\times t} + \varepsilon_{ft}^{y}$$

where $\Psi := \frac{1-\beta\theta}{1-\beta\theta\rho^{y}}$

ε_{ft}^{y} includes $(1-\sigma^{w})\varepsilon_{ft}^{d} - \sigma^{y} y_{ft}^{\star}$

Identification of the Output Gap-based Slope

$$p_{ft} = (1-\theta)(1-\Omega)\Psi \cdot \sigma^y y^n_{ft} + (1-\theta)\Omega p^{-f}_{it} + \theta p_{ft-1} + \alpha_f + \alpha_{s\times t} + \varepsilon^y_{ft}$$

- Calibrate θ and Ω to baseline estimates and estimate $\rho^y = 0.73$.
  - σ^y is identified from coefficient on y^n_{ft}.
  - But need instrument uncorrelated with both firm-level demand shocks and aggregate supply shocks (which move y^n_{ft} and enter the composite error term ε^y_{ft})

- Construct "Bartik-"style aggregate demand instrument based on money shocks:

  1. Estimate industry sensitivities to aggregate shock (loadings):

  $$y^n_{ft} = \alpha_f + \zeta_i \cdot MS_{t-1} + \varepsilon^m_{ft}$$

  2. Instrument y^n_{ft} combining industry loadings with aggregate money shock variation:

  $$y^{IV}_{ft} := \hat{\zeta}_i \cdot MS_{t-1}$$

Estimates of Elasticity σ^y and Output-based Slope κ

	(1)	(2)	(3)
σ^y	0.295	0.225	0.277
	(0.229)	(0.301)	(0.393)
Firm FE	y	y	y
Sect x time FE	y		
Time FE		y	
Cragg-Donald F	632	763	838
Kleibergen-Paap F	32	20	16
$\kappa = \lambda \cdot \sigma^y$	0.0209	0.0159	0.0196

|▷ Robustness

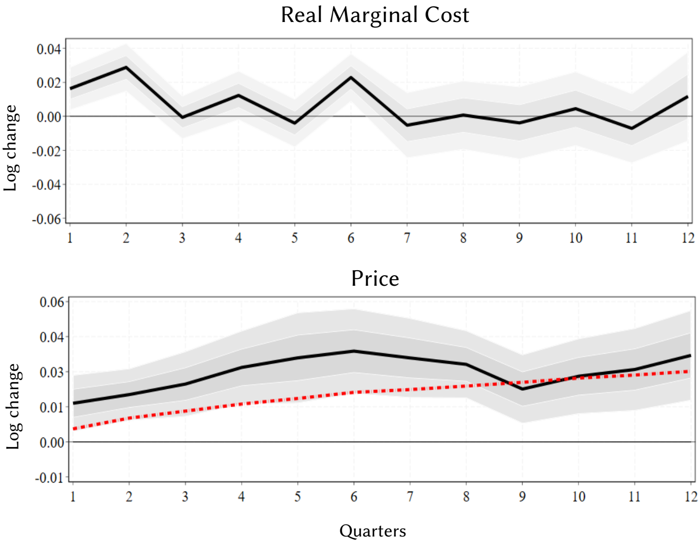
|▷ $\rho^y = 1$

Inflationary Effects of Supply Shocks

Supply Shocks, Marginal Cost, and Inflation

- Difficulties using output gap-based PC for supply shocks:
  - Output gap may be poor proxy for marginal cost with supply shocks.
  - Supply shocks can have much larger impact on MC than on potential output:
    (Lorenzoni Werning 23, Gagliardone Gertler 23)
    - If employment and primary commodities (e.g. oil) are complements.
    - Wage rigidity.
- Marginal cost-based PC useful for tracing impact of supply shocks on inflation.
- Illustrate with example of oil shocks:
  - Trace out impact of oil shock on real marginal costs and prices.
  - Compare marginal cost-based PC vs data.
  - Oil shock: surprise in oil prices around OPEC meetings (Kanzig 21).

Effects of an Oil Shock



— Jorda projection

- - Model

$$\pi_t = \lambda \widehat{mc}_t^r + \beta \mathbb{E}_t \pi_{t+1}$$
$$= \lambda \sum_{\tau=0}^{\infty} \beta^\tau \mathbb{E}_t \widehat{mc}_{t+\tau}^r$$

Implications of Menu Costs

Extension to Menu Costs

- Fixed cost to adjust:

$$\Longrightarrow p_{ft} = \begin{cases} p^{o}_{ft} & \text{if } \; p_{ft-1} \notin [\underline{p}_{ft}, \bar{p}_{ft}] \\ p_{ft-1} & \text{if } \; p_{ft-1} \in [\underline{p}_{ft}, \bar{p}_{ft}] \end{cases}$$

- Unlike Calvo, endogenous adjustment frequency with selection.
- Recent literature: observational equivalence with Calvo (for small shocks):
  - Theoretical equivalence: Gertler Leahy (2008).
    - Selection effect gives higher slope.
  - Quantitative equivalence: Auclert et al. (2023).
    - Approximately flat hazard rate for canonical menu cost models (GL 07, NS 10).

Extension to Menu Costs (Cont'd)

- $\tilde{\theta}$:= virtual hazard (taking into account selection).
- When $\tilde{\theta}$ $(\leq \theta)$ is approximately flat:

$$\mathbb{E}\{p_{ft} - p_{ft-1} | p^o_{ft}, p_{ft-1}\} \approx \underbrace{(1-\theta)(p^o_{ft} - p_{ft-1})}_{\text{Calvo term}} + \underbrace{(\theta - \tilde{\theta})(p^o_{ft} - p_{ft-1})}_{\text{Selection term}}$$

$$\Longrightarrow p_{ft} \approx (1-\tilde{\theta})p^o_{ft} + \tilde{\theta} p_{ft-1} + v_{ft}$$

- Regressions identify $\tilde{\theta}$ and hence the slope adjusted for selection:

$$\tilde{\lambda} = \frac{(1-\tilde{\theta})(1-\beta\tilde{\theta})}{\tilde{\theta}}(1-\Omega)$$

- Results consistent with Calvo ($\tilde{\theta} \approx \theta^{PPI}$).
  - Also, kurtosis in data = 5.4, consistent with Calvo (Alvarez et al. 21).

Conclusions

- Stickiness and market structure play key role in explaining dynamic pass-through of fluctuations in marginal costs into prices.
- Slope of the marginal cost-based PC is steep and helps rationalize inflation dynamics.
- Weak connection between costs and output/unemployment.

Things to consider:

- Extending sample to inflation surge period post Spring 2021.
- Getting lagged inflation enter the Phillips curve (e.g. learning, anchoring).
- Theory and empirics on the output elasticity of marginal cost.

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Appendix

Summary statistics

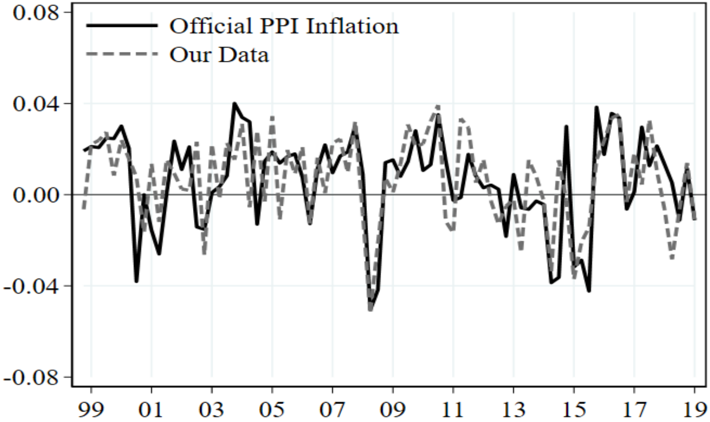
▷ Back

	Mean	5^{st} pctle	25^{th} pctle	Median	75^{th} pctle	95^{th} pctle
Firm Employees	75.62	9.00	17.42	30.50	59.00	276.50
Firm Sales	6663.15	228.13	666.11	1486.44	3870.36	21946.60
Number of industries within firm	1.10	1.00	1.00	1.00	1.00	2.00
Within firm revenue share of main industry	98.23	86.80	100.00	100.00	100.00	100.00
Firm's market share within industry	1.54	0.06	0.22	0.52	1.30	6.02
Firm's market share within sector	0.21	0.01	0.02	0.05	0.14	0.70
Firm's market share within manufacturing	0.02	0.00	0.00	0.01	0.01	0.08
Number of consecutive quarters in sample	42.03	10.00	24.00	38.00	58.00	82.00

Notes: The summary statistics reported in this table refer to the sample of domestic producers in PRODCOM. Firm's employees are measured in full-time equivalents. Firm's sales are measured in thousand of Euros, rounded to the nearest integer. Within firm revenues shares and firm's market shares are measured in percentages.

PPI manufacturing inflation

▷ Back



Comparison of Instruments: Model A

▷ Back

Instruments:	$\{p_{it}^{\star EU}, p_{it}^{\star F}, mc_{ft}^{n\star}\}$	$\{p_{it}^{\star EU}, p_{it}^{\star F}, mc_{ft-8}^{n}\}$	$\{p_{it}^{\star EU}, p_{it}^{\star F}, mc_{ft}^{n\star}, mc_{ft-8}^{n}\}$
θ	0.709	0.713	0.717
	(0.019)	(0.013)	(0.012)
Ω	0.225	0.526	0.375
	(0.137)	(0.155)	(0.178)
λ	0.095	0.056	0.071
	(0.029)	(0.023)	(0.026)
Firm FE	y	y	y
Sect x time FE	y	y	y
Cragg-Donald F	144	696	440
Kleibergen-Paap F	1.86	14.78	13.46
Hansen J	2.857	5.720	5.850

Comparison of Instruments: Model B

▷ Back

Instruments:	$\{mc^{\star}_{ft}\}$	$\{mc^{n}_{ft-8}\}$	$\{mc^{\star}_{ft}, mc^{n}_{ft-8}\}$
θ	0.679	0.690	0.688
	(0.026)	(0.016)	(0.011)
Ω	0.459	0.645	0.643
	(0.179)	(0.073)	(0.058)
λ	0.084	0.050	0.052
	(0.044)	(0.016)	(0.011)
Firm FE	y	y	y
Ind x time FE	y	y	y
Cragg-Donald F	177	2735	948
Kleibergen-Paap F	1.81	68	31.1
Hansen J	1.935	0.129	0.314

Instruments Power

▷ Back

Dep Var	$(mc^n_{ft})^8$	$(p^{-f}_{it})^8$	$(mc^n_{ft})^8$	mc^n_{ft}
mc^n_{ft-8}	0.131	0.019	0.128	0.286
	(0.024)	(0.012)	(0.018)	(0.061)
$mc^\star_{ft}$	0.068	-0.019	0.046	0.046
	(0.025)	(0.025)	(0.031)	(0.029)
$p^{\star EU}_{it}$	0.120	0.590		
	(0.050)	(0.054)		
$p^{\star F}_{it}$	0.124	0.601		
	(0.042)	(0.048)		
p_{ft-1}	0.213	0.151	0.245	0.305
	(0.047)	(0.035)	(0.027)	(0.014)
Firm FE	y	y	y	y
Sect x time FE	y	y		
Ind x time FE			y	y

Returns to Scale

▷ Back

- With decreasing returns to scale:

$$\lambda := \frac{(1-\theta)(1-\beta\theta)}{\theta}(1-\Omega)\Theta$$

where

$$\Theta := \frac{1}{1+\gamma\nu(1-\Omega)} \leq 1$$

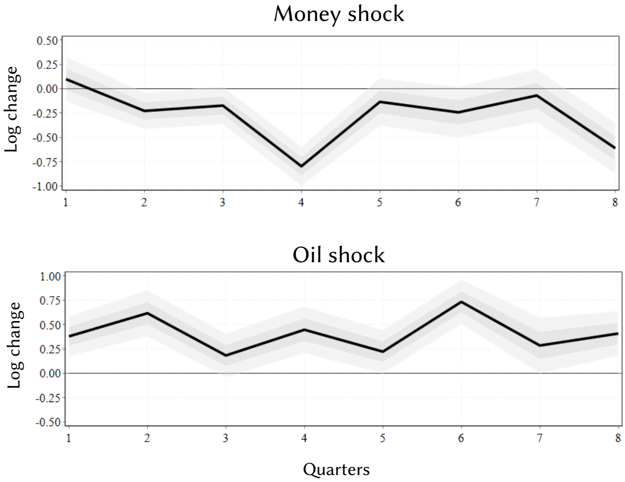
depends on the curvature of the production function (with CRS $\nu = 0$).

- Follow Lenzu et al. (2023) to estimate the returns to scale via production function estimation.

- Direct estimate of $\hat{\Theta} = 0.94$ implies $\hat{\lambda} = 0.056$.

Aggregate Shocks (Money and Oil) as Instruments

▷ Back



- Money: High-frequency surprises in policy rate swaps around ECB announcements.
- Oil: High-frequency surprises in WTI oil futures around OPEC announcements.

Jorda projections:

$$mc^n_{ft+h} - mc^n_{ft-1} = \alpha_f + \zeta_h S_{t-1} + \varepsilon^S_{ft+h}$$

Construction of the Instruments

▷ Back

- Estimate firm-specific sensitivities to aggregate shocks (loadings):

$$mc^n_{ft} = \alpha_f + \zeta^m_f MS_{t-1} + \varepsilon^m_{ft}$$
$$mc^n_{ft} = \alpha_f + \zeta^o_f OS_{t-1} + \varepsilon^o_{ft}$$

- Instruments combining firm-specific loadings with aggregate variation of the shocks:

$$\hat{MS}_{ft} := \hat{\zeta}^m_f \cdot MS_{t-1}; \quad \hat{OS}_{ft} := \hat{\zeta}^o_f \cdot OS_{t-1}.$$

- Use current and four lags of instruments to capture timing of shocks.

Estimates with Aggregate Instruments

▷ Back

	Money shocks		Oil shocks	
	(1)	(2)	(3)	(4)
θ	0.688	0.705	0.703	0.708
	(0.014)	(0.005)	(0.007)	(0.006)
Ω	0.719	0.534	0.748	0.528
	(0.041)	(0.029)	(0.041)	(0.036)
ρ^{mc}		0.782		0.801
		(0.005)		(0.018)
λ	0.041	0.059	0.032	0.058
	(0.010)	(0.003)	(0.007)	(0.006)
Hansen J-test χ^2	6.138	6.864	9.454	6.659

Alternative Identification of Elasticity

▷ Back

$$\widehat{mc}_{ft} = \sigma^y (y_{ft} - y^{\star}_{ft}) - \sigma^w \varepsilon^d_{ft}$$

- Estimate long-run relationship with real output gap:

$$\Delta mc_{ft} = \sigma^y \Delta y_{ft-1} + \alpha_f + \alpha_{s \times t} + \varepsilon^y_{ft}$$

$$\varepsilon^y_{ft} := -\sigma^y y^{\star}_{ft} - \sigma^w \varepsilon^d_{ft}.$$

- Construct "Bartik-"style instrument for real output growth rate with money shocks.

Alternative Estimates of Elasticity

▷ Back

Dep Var	Δmc^r_{ft}	Δmc^r_{ft}	Δmc^r_{ft}
Δy^r_{ft-1}	0.097	0.092	0.089
	(0.040)	(0.035)	(0.037)
Firm FE	y	y	y
Sect x time FE	y		
Time FE		y	
Cragg-Donald F	574	667	644
Kleibergen-Paap F	27	32	33
$\kappa = \lambda \cdot \sigma^y$	0.0068	0.0065	0.0063

Estimates of σ^y and κ assuming $\rho^y = 1$

▷ Back

	(1)	(2)	(3)
σ^y	0.178	0.135	0.167
	(0.138)	(0.182)	(0.236)
Firm FE	y	y	y
Sect x time FE	y		
Time FE		y	
Cragg-Donald F	632	763	838
Kleibergen-Paap F	32	20	16
$\kappa = \lambda \cdot \sigma^y$	0.0127	0.0095	0.0118