Heterogeneous Firms and the Phillips Curve

Daniele Aglio and Eric Bartelsman[1]

[1]Vrije Universiteit Amsterdam; Tinbergen Institute
CompNet - MD Project

November 19^{th}, 2024

CompNet The Competitiveness Research Network

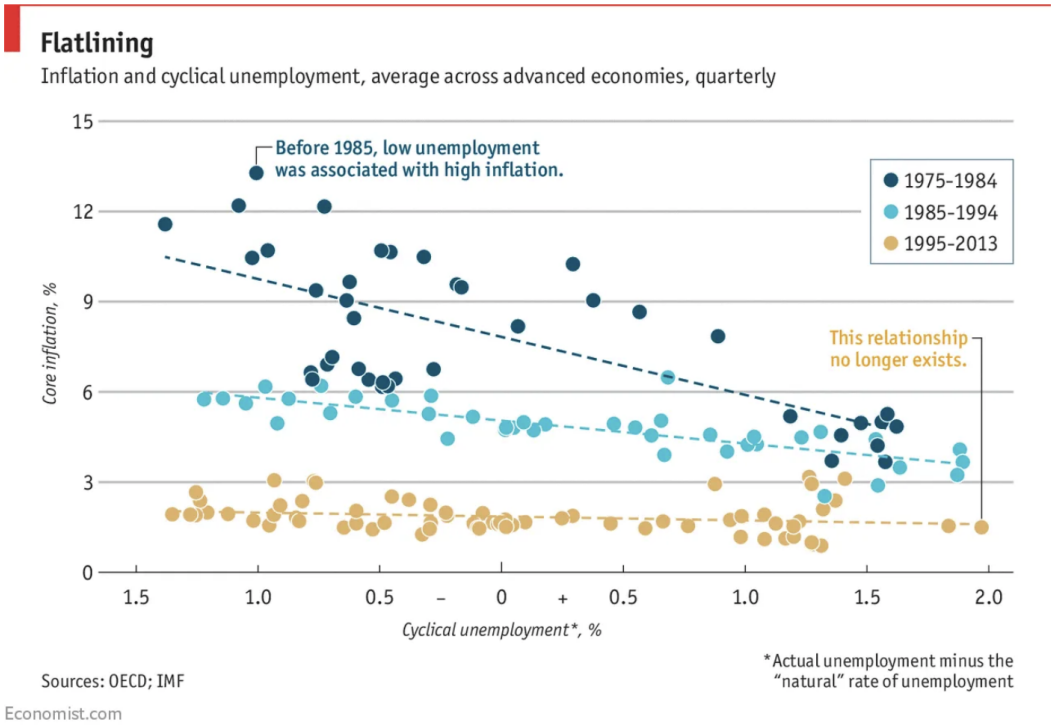
This project has received funding from the European Commission; Directorate-general for Structural Reform Support under grant agreement No 101101853.

Outline

- Introduction
- Related literature and our contribution
- New Keynesian model with heterogeneous technology
- Micro-aggregate evidence
- Data and empirical strategy
- Micro results
- Conclusion

Introduction

Debates on monetary policy often hinge on the slope of the New Keynesian Phillips curve, i.e., the relationship between economic slack and changes in prices or wages, conditional on expected inflation.



Related literature and our contribution

In the context of the New Keynesian model (e.g. [Galí, 1999]), the Phillips curve slope is determined by multiple factors:

- Price stickiness [Calvo, 1983]
- Wage stickiness [Roberts, 1997], [Siena & Zago, 2024]
- Inflation expectations and central bank credibility
  [Lucas & Rapping, 1969], [Bullard & Mitra, 2002],
  [Woodford & Walsh, 2005],
  [Demertzis et al., 2012],[Del Negro et al., 2020],
  [Carvalho et al., 2023]

Related literature and our contribution

- Non-linearities in supply [Boehm & Pandalai-Nayar, 2022]
- Supply shocks [Gagliardone et al., 2023]
- Competition [Gilchrist & Zakrajsek, 2019], [Fujiwara & Matsuyama, 2022]
- A rich literature on "time-varying" Phillips curve [Hooper et al., 2020]

Related literature and our contribution

- Our paper takes almost all of the above factors as given and explores the effect of heterogeneous technology and demand at the firm level.
- This study's contribution to the literature is to empirically evaluate the effect of firms' production technology heterogeneity on the slope of the Phillips curve.
- We show that firms with higher productivity levels feature lower and flatter marginal cost curves.
- The aggregate Phillips curve can be derived from firms' pricing behaviour. The more demand shocks are met by the most productive firms, the flatter the Phillips curve.

New Keynesian model with heterogeneous technology

- Firms differ in production technology:

$$Y_f = A_f(K^{\alpha}N^{1-\alpha})^{\gamma_f}$$

- Evidence that A_f and γ_f are positively correlated. Hence, we assume monotonic relationship: $(\gamma_f = \gamma(A_f), \frac{\partial \gamma}{\partial A} > 0)$.
- Monopolistic competition: firms compete à la Bertrand and there is strategic interaction in firms' pricing since sectors are not atomistic.
- Aggregate Phillips curve derived by weighted aggregation of firm-level pricing.
- Otherwise standard NK Framework.

New Keynesian model with heterogeneous technology

- As advocated by [Mrázová & Neary, 2017], we consider the "firm's eye view" of demand, where the residual demand curve facing a firm can be sufficiently characterized by its elasticity and convexity.
- From monopolistic competition and Calvo prices, firms' optimal price setting is:

$$\max_{P^o_{ft}} E_t \left\{ \sum_{k=0}^{\infty} \theta \left[\Lambda_{t,k} \left(\frac{P^o_{ft}}{P_{t+k}} D_{ft+k} - TC(D_{ft+k}) \right) \right] \right\}$$

New Keynesian model with heterogeneous technology

- From cost minimization, marginal costs are:

$$MC_{ft} = \left(\frac{W_t}{(1-\alpha)\gamma_f}\right)^{(1-\alpha)} \left(\frac{R_t}{\alpha\gamma_f}\right)^{\alpha} A_f^{-\gamma_f} Y_{ft}^{(\frac{1-\gamma_f}{\gamma_f})}$$

- Log-linearizing FOC of firms' optimal price setting around the steady state:

$$\hat{p}^o_{ft} = (1-\beta\theta)E_t \sum_{k=0}^{\infty} (\beta\theta)^k (\hat{\mu}_{ft+k} + \hat{mc}^n_{ft+k})$$

- Where markups depends on demand elasticity (σ in a CES function) and strategic pricing (the steady state is a Nash equilibrium):

$$\hat{\mu}_{fst+k} = \mu_{fst+k} - \mu_{fs} = -\Gamma_{fs}(\hat{p}^o_{ft} - p^{-f}_{st+k}) + u^{\mu}_{fst+k}$$

- Strategic interaction is studied by [Andrés & Burriel, 2018]; our argument holds even in atomistic competition.

New Keynesian model with heterogeneous technology

- Substituting marginal costs and markups, the pricing equation for each firm becomes:

$$\hat{p}^{o}_{fst} = (1-\beta\theta)E_t \sum_{k=0}^{\infty}(\beta\theta)^k[(1-\Omega_{fs})(\hat{c}_{fst+k}+v_f\hat{y}_{fst+k})+\Omega_{fs}p_{st+k}+u^{\mu}_{fst+k}]$$

- $\Omega_{fs} = \frac{\Gamma_{fs}}{1+\Gamma_{fs}}$.
- $v_f = \frac{1-\gamma_f}{\gamma_f}$.

New Keynesian model with heterogeneous technology

- Aggregating firms' pricing equations (using market share at steady state as weights), we obtain the Phillips curve:

$$\pi_t = \beta E_t \pi_{t+1} + (1-\Omega)(1-\beta\theta)\hat{c}_t^r + (1-\beta\theta) v \hat{y}_t + u_t$$

- where

$$v\hat{y}_t = \int_0^1 \left(\frac{1}{N}\sum_{f=1}^{N} \bar{p}_f^{1-\sigma}(1-\Omega_{fs}) v_f \hat{y}_{fst}\right) ds$$

Micro-aggregate evidence

- Based on CompNet 9^{th} vintage database.
- Firm-level indicators that are aggregated to different levels, e.g., 2-digit industry.
- 21 European countries for the period 2004-2020 and most of the private non-farm business sector.
- We employ *joint distributions*, where "representative firms" are defined by their quintile location in the within-industry productivity (TFP) distribution.

Micro-aggregate evidence

- From the model marginal costs, firm wages are a function of input prices and output gap.
- We test the model on the input prices side for each productivity (tfp) quintile of the firms distribution.
- We test the following equation:

$$\delta w_{csqt} = \alpha x_{csqt} + \beta \delta w_{csqt-1} + \gamma \pi_{ct-1} + \delta_{csq} + \delta_t + \varepsilon_{csqt}$$

Micro-aggregate evidence

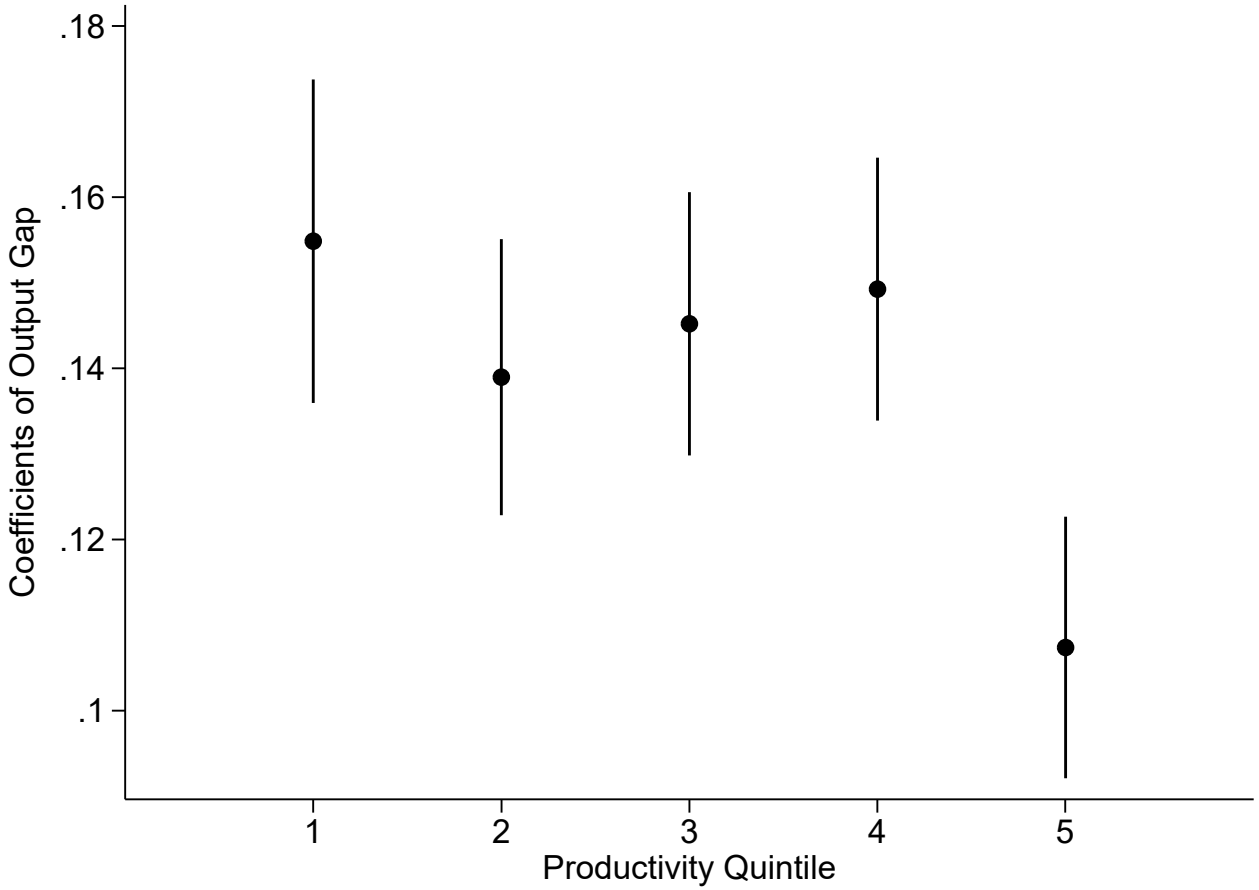
Table 1: Real wage growth on output gap

	(1)	(2)
	δw_{csqt}	δw_{csqt}
x_{csqt}	0.136***	0.123***
	(0.004)	(0.004)
δw_{csqt-1}	-0.311***	-0.313***
	(0.005)	(0.006)
π_{ct-1}		0.119***
		(0.025)
Constant	0.0548***	0.0481***
	(0.010)	(0.011)
Country-Industry-Quintile FE	Yes	Yes
Year FE	Yes	Yes
Observations	35,600	27,611
R-squared	0.167	0.163

Source: CompNet 9^{th} vintage and Eurostat.
Notes: panel regressions at the country-industry-productivity quintile level of real wage growth on output gap, lagged real wage growth, lagged country-level inflation (model 2), and year fixed effects. Standard errors clustered at industry-country level in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Micro-aggregated evidence

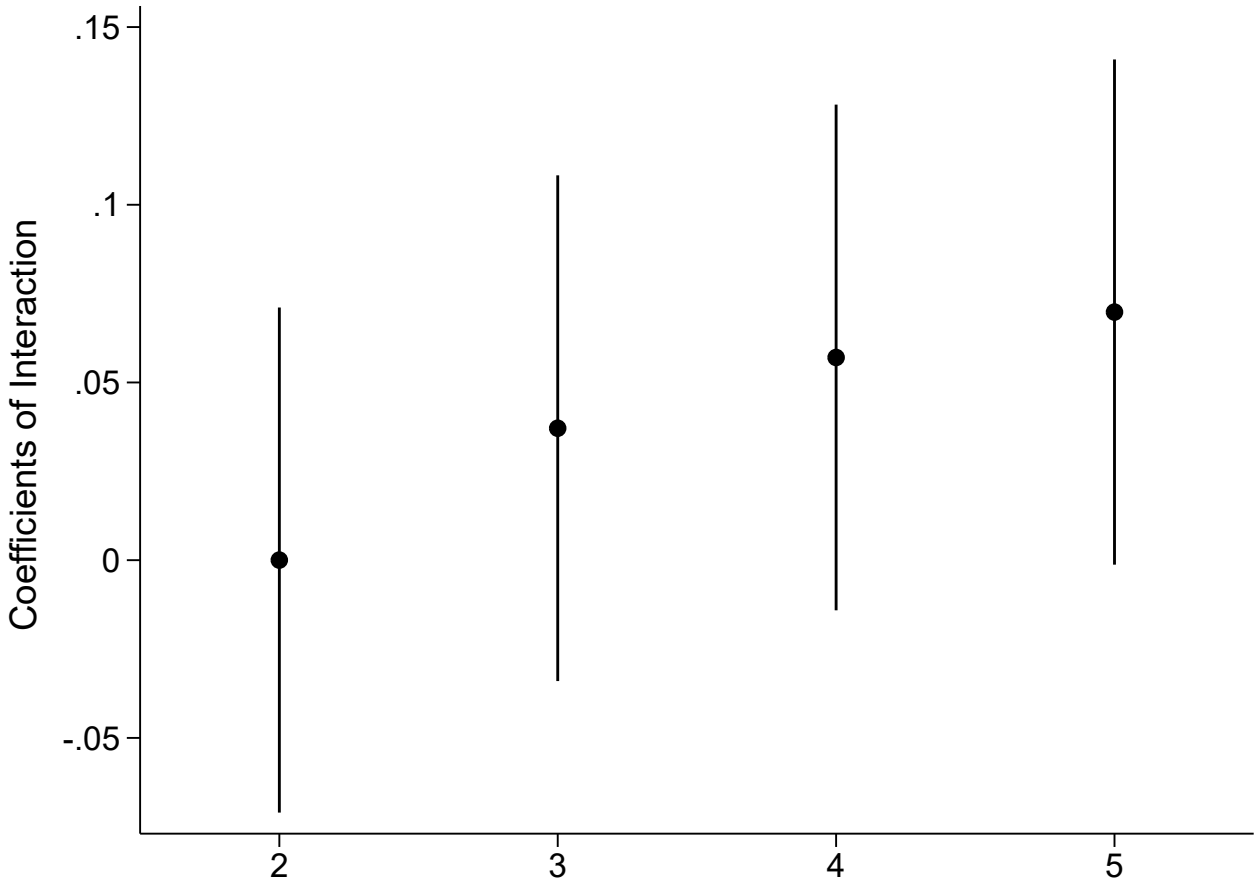
- The Phillips curve flattens for the most productive firms:



Micro-aggregate evidence

- The most productive firms respond more to aggregate output increase:

$$\delta Y_{csqt} = \alpha Y_{cst} * \delta_q + \delta_{csq} + \delta_t + \varepsilon_{csqt}$$



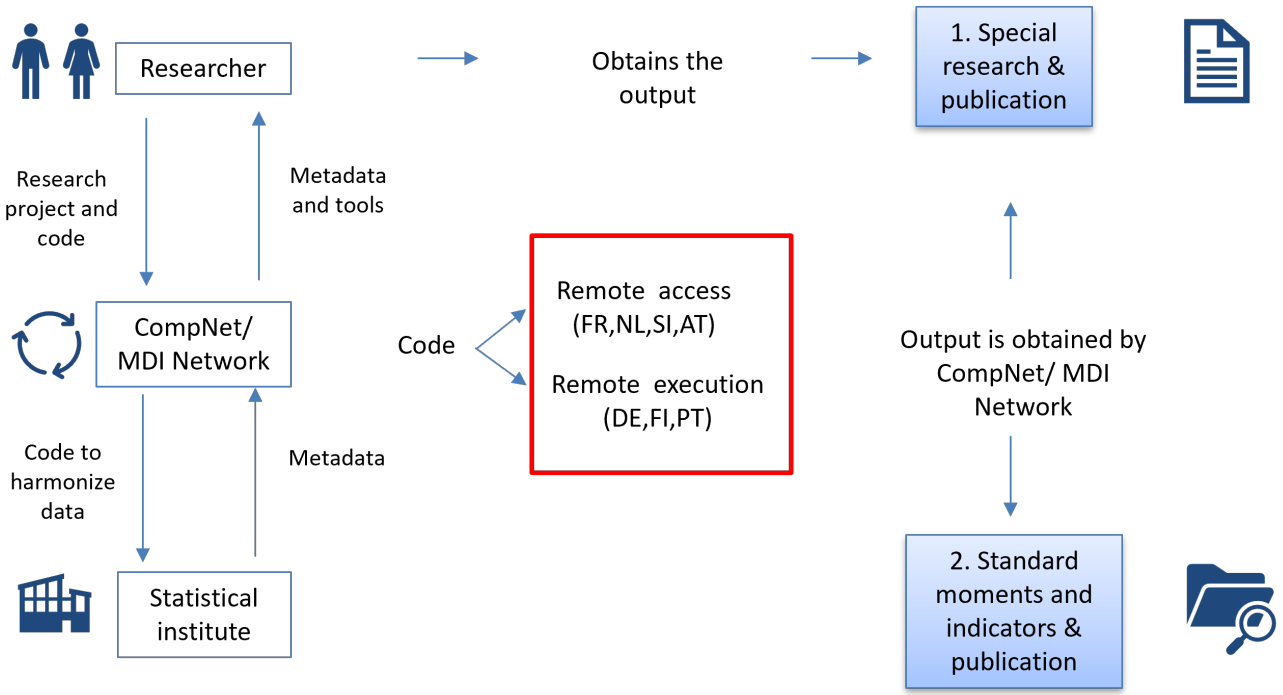
Data and empirical strategy

- Micro data infrastructure (MDI), created under the EU *Technical Support Instrument* project[1].
- Main datasets: PRODCOM, SBS, and BS.
- Main analysis is focused on France, from 2010 to 2020. Moreover, cross-country comparison with the Netherlands.
- Manufacturing sector.

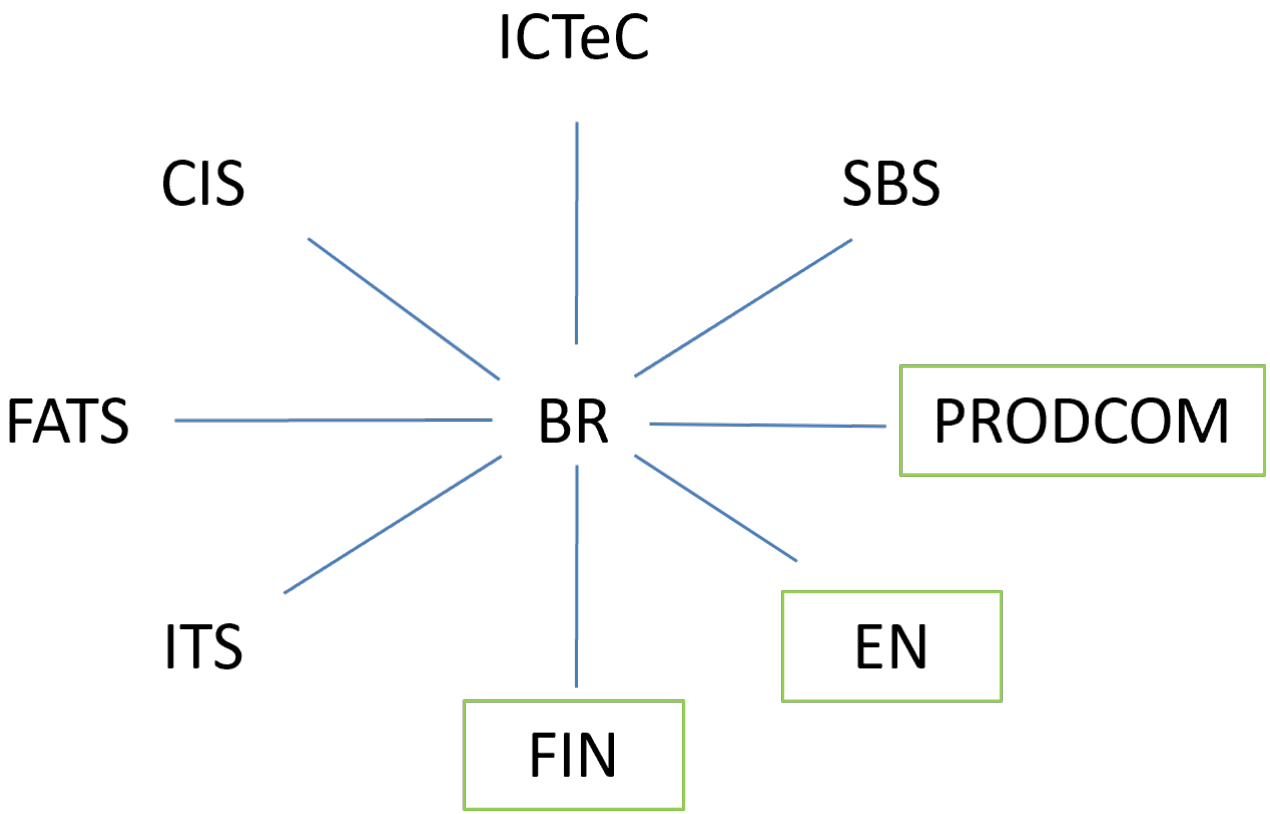
[1] The MDI received funding from the H2020 project grant *Microprod*, 2019-222, and the EU TSI project, European Commission, Directorate-general for Structural Reform Support under grant agreement No. 101101853 and No. 101140673 (Austria).

Data and empirical strategy

- Homogeneous firm-level data, annual frequency.



Data and empirical strategy



Data and empirical strategy

- PRODCOM data are used to create prices at the firm level:

$$\frac{P_{ft}}{P_{ft-1}} = \prod_{g \in f_g} \left(\frac{P_{gft}}{P_{gft-1}} \right)^{s_{gft}}$$

- SBS to collect information about firms' revenues, labour, intermediate material expenses, and wages. BS for capital and interest paid. These data are used to implement our clustering analysis on firm production and costs pass-through.

Data and empirical strategy

- Exogenous measures of demand shock: two typologies of downstream demand indicators.
- At industry level, from the OECD Inter-Country Input-Output Tables:

$$DS_{st}^{Shea} = \sum_{j \in J_{st-1}} s_{jst-1} \Delta lnM_{jt}$$

- From country-product level to firm specific downstream, using UN Comtrade:

$$DS_{ft}^{wid} = \sum_{p \in \mathcal{P}_{pt-1}} s_{fpt-1} \Delta lnWID_{pt}$$

Data and empirical strategy

- Objective: estimate the supply curves of heterogeneous firms along the production technology distribution. The coefficient v_f in firms' pricing equation, which governs the slopes of the supply curves.
- Such a parameter can be derived by estimating the coefficients of the output component and the competitors' price, Ω_{fs}.
- However, the strategic component Ω_{fs} could, in principle, be affected by firm-specific demand elasticity.
- Therefore, we cluster firms along the production technology distribution and according to similar demand characteristics.

Data and empirical strategy

- Firms are clustered in 5 technology groups and 3 demand groups.
- Initial clustering along labour productivity and price - marginal costs ratio.
- Clustering along production technology:

$$y_{ft} = \alpha + \beta_1 k_{ft} + \beta_2 l_{ft} + \beta_3 m_{ft} + \delta_t + \epsilon_{ft}$$

- Clustering along demand characteristics ([Mrázová & Neary, 2017]):

$$\delta p_{ft} = \beta_0 + \beta_1(\eta_d, \rho_d)\delta mc_{ft} + \delta_t + \epsilon_{ft}$$

- Iterations until RSS minimized for both regressions in each cluster.

Data and empirical strategy

- The algorithm has been updated to estimate production function with the interaction of the residual demand elasticity firms face.
- To do that, GMM criterium is minimized where production function and cost pass-through equation are stacked.

$$Q(\beta) = (Y - X\beta)^\top W(W^\top \Omega W)^{-1} W^\top (Y - X\beta)$$

- Production function instruments (lagged variable inputs, capital, lagged capital, as well as time and constant) are used also in the GMM moment of the cost pass-through.
- Each cluster's production function is estimated conditional on its demand elasticity cluster.
- Production technology (dynamic panel data with productivity shocks):

$$\delta y_{ft} = \alpha + \beta_1 \delta k_{ft} + \beta_2 \delta l_{ft} + \beta_3 \delta m_{ft} + \delta_t + \xi_{ft} + \epsilon_{ft}$$

- Demand ([Mrázová & Neary, 2017]):

$$\delta p_{ft} = \beta_0 + \beta_1(\eta_d, \rho_d)\delta mc_{ft} + \delta_t + \epsilon_{ft}$$

Data and empirical strategy

- Firm-years observations by technology and demand groups:

	Demand 1	Demand 2	Demand 3
Technology 1	5522	1699	18180
Technology 2	32544	4370	52709
Technology 3	10362	6365	38714
Technology 4	1045	5039	17595
Technology 5	339	2524	6356
Cost pass-through	0.177	0.826	0.914

Note: *Cost pass-through* indicates the estimated coefficient for the demand side clustering.

Data and empirical strategy

- Descriptive statistics by technology group:

Technology	firms	TFP	oe_{k+l}	$oe_{k+l,ACF}$	lprod	size	$markup_m$	marg. costs
1	4593	1.470	0.187	0.881	4.44	8370.33	1.19	2.38
2	14397	1.389	0.195	0.895	5.10	12857.79	1.25	1.05
3	8442	1.684	0.229	0.917	5.44	19788.32	1.37	0.73
4	3428	1.744	0.240	0.937	6.01	22721.60	1.43	0.55
5	1371	2.324	0.412	0.961	6.92	24991.31	1.81	0.27

Note: *Firms* refers to the number of firms, *TFP* is total factor productivity which, together with the sum of output elasticities of capital and labour (oe_{k+l}), is computed through the production function estimation by group in the cluster analysis; $oe_{k+l,ACF}$ is the sum of output elasticities from a value-added production function estimation with ACF methodology; *lprod* means labour productivity in logs; *size* is sales in thousands of euros; $markup_m$ is markup over intermediate inputs estimated as in Loecker and Warzynski 2012; *marg. costs* are marginal costs proxied by unit variable costs as computed in the main analysis.

Data and empirical strategy

- Descriptive statistics by technology group:

	Δs	$se(\Delta_y)$
Production 1	-1.40%	3958.62
Production 2	-1.55%	4468.83
Production 3	-1.50%	7598.99
Production 4	+3.80%	8174.57
Production 5	+0.65%	12515.39

Note: Δs is the change in market shares between 2013 and 2019, while $se(\Delta_y)$ is the volatility of output change, respectively.

Data and empirical strategy

- Based on such clustering, it is now possible to test whether firms' supply curves are heterogeneous across the production technology distribution, controlling for demand characteristics as well.
- From the New Keynesian framework, and considering we are employing annual data, we estimate the following firms' pricing equation:

$$\delta p_{ft} = \beta_1 \delta y_{ft} + \beta_{1c} \delta y_{ft}{}^{*} D_c + \beta_2 \delta p^{-f}_{st-1} + \beta_3 \delta p_{ft-1} + \delta_{st} + \delta_f + \epsilon_{ft}$$

- 2SLS regressions to instrument firm real output increase δy_{ft} by the downstream demand indicators

Micro results

- Pricing equation by technology cluster:

	δp_{it}	Slope	δp_{it}	Slope
δy_{it}	0.335***		0.338***	
	(0.014)		(0.015)	
$\delta y_{it} \times \text{tech}_2$	-0.090***	***	-0.090***	***
	(0.010)		(0.010)	
$\delta y_{it} \times \text{tech}_3$	-0.147***	***	-0.144***	***
	(0.010)		(0.010)	
$\delta y_{it} \times \text{tech}_4$	-0.200***	***	-0.201***	***
	(0.012)		(0.012)	
$\delta y_{it} \times \text{tech}_5$	-0.507***	***	-0.505***	***
	(0.012)		(0.013)	
δp_{st-1}^{-i}	0.056***		0.079***	
	(0.007)		(0.022)	
δp_{it-1}	-0.253***		-0.255***	
	(0.005)		(0.004)	
δp_{st-1}^{-i}-Technology group fixed effects	No		Yes	
2 digit Industry-Year fixed effects	Yes		Yes	
Firm fixed effects	Yes		Yes	
Obs	200227		200227	
R^2	0.22		0.23	

Note: 2sls regression at the firm level, weighted by the share of nominal revenue. Standard error clustered by 2-digit sector in parenthesis. *** p < 0.01, ** p < 0.05, * p < 0.1, $^{+}$ < 0.15. *Slope* column indicates whether there is a significant flattening of the pricing equation along the productivity distribution.

Micro results

- Pricing equation by technology and demand cluster:

	δp_{it}			Slope		
	demand_1	demand_2	demand_3			
$\delta y_{it} \times \text{tech}_1$	0.200***	0.129**	0.152***			
	(0.032)	(0.061)	(0.032)			
$\delta y_{it} \times \text{tech}_2$	0.044	-0.028	0.059*		***	***
	(0.032)	(0.039)	(0.031)			
$\delta y_{it} \times \text{tech}_3$	0.064*	-0.044	-0.006		***	***
	(0.035)	(0.036)	(0.031)			
$\delta y_{it} \times \text{tech}_4$	-0.092^{+}	-0.154***	-0.046^{+}	***	***	***
	(0.057)	(0.045)	(0.032)			
$\delta y_{it} \times \text{tech}_5$	-0.087	-0.277***	-0.350***		***	***
	(0.090)	(0.034)	(0.031)			
δp^{-i}_{st-1}	0.055***					
	(0.007)					
δp_{it-1}	-0.227***					
	(0.004)					
2 digit Industry-Year fixed effects		Yes				
Firm fixed effects		Yes				
Obs		200227				
R^2		0.22				

Note: 2sls regression at the firm level, weighted by the share of nominal revenue. Standard error clustered by 2-digit sector in parenthesis. *** p<0.01, ** p < 0.05, * p < 0.1, $^{+}$ < 0.15. Reference group is $prod_1 \times demand_1$. *Slope* column indicates whether there is a significant flattening of the pricing equation along the productivity distribution for each demand cluster.

Micro results

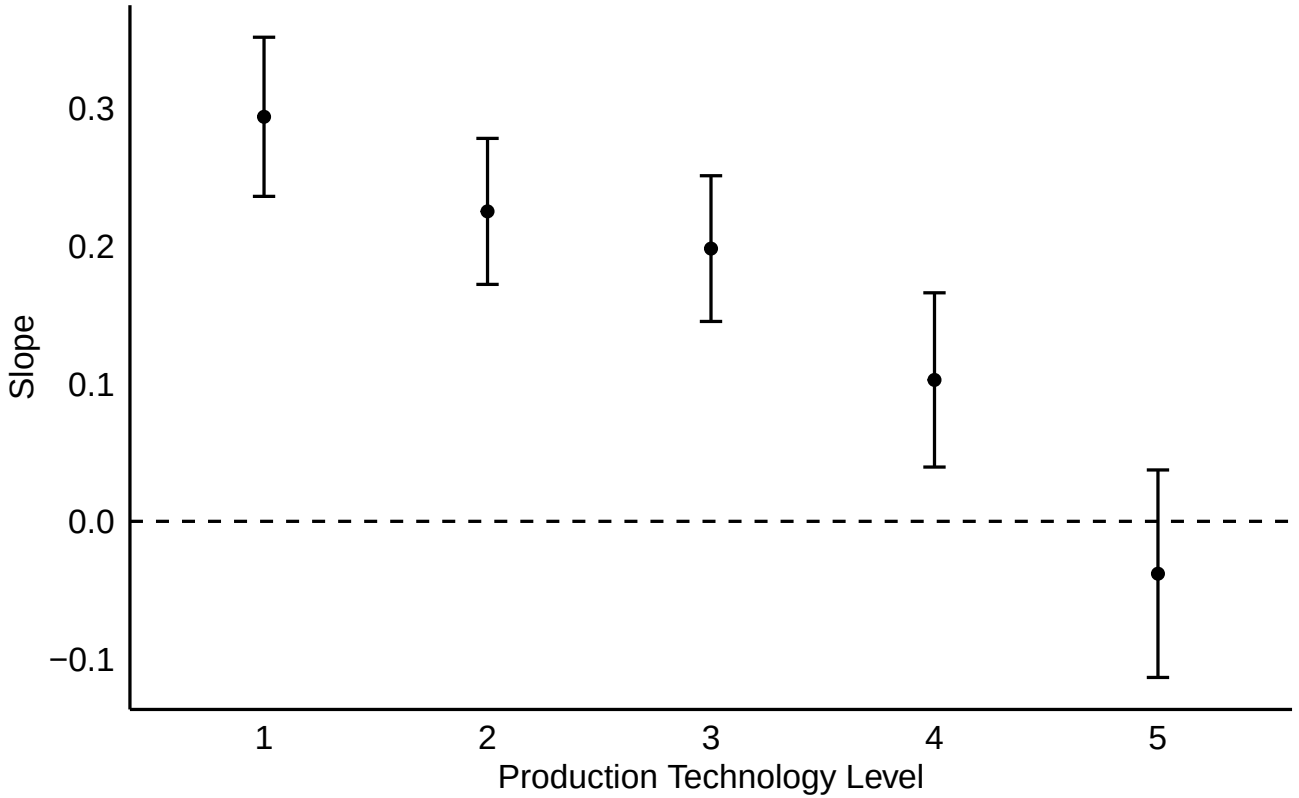
- Pricing equation by aggregate technology and demand cluster:

	δp_{it}			Slope		
	demand_1	demand_2	demand_3			
$\delta y_{it} \times \text{agg\_tech}_1$	0.130***	-0.091***	0.006			
	(0.026)	(0.018)	(0.009)			
$\delta y_{it} \times \text{agg\_tech}_2$	-0.070*	-0.180***	-0.230***	***	***	***
	(0.015)	(0.017)	(0.031)			
δp_{st-1}^{-i}	0.060***					
	(0.007)					
δp_{it-1}	-0.173***					
	(0.008)					
2 digit Industry-Year fixed effects		Yes				
Firm fixed effects		Yes				
Obs		200227				
R^2		0.22				

Note: 2sls regression at the firm level, weighted by the share of nominal revenue. Standard error clustered by 2-digit sector in parenthesis. *** p<0.01, ** p < 0.05, * p < 0.1, $^{+}$ < 0.15. Reference group is $prod_1 \times demand_1$. *Slope* column indicates whether there is a significant flattening of the pricing equation along the productivity distribution for each demand cluster.

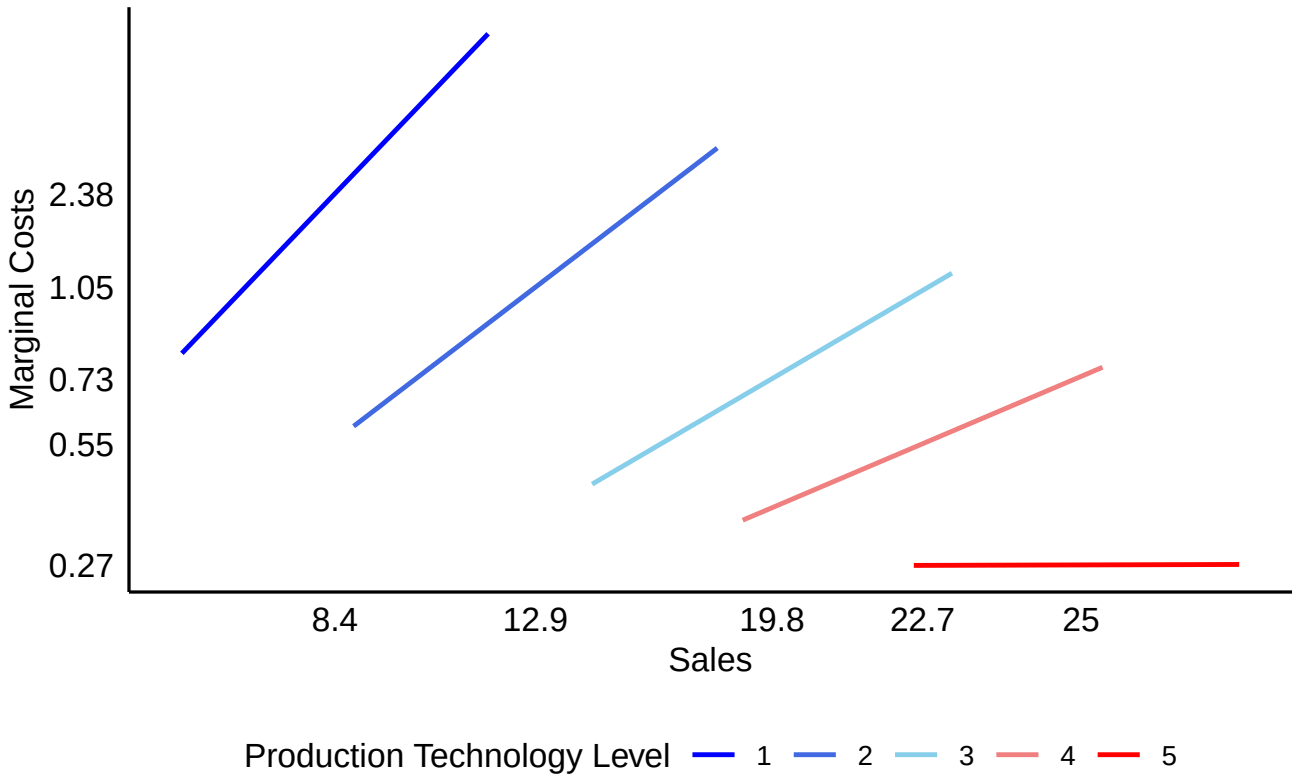
Micro results

- Slope of pricing equations by technology group:



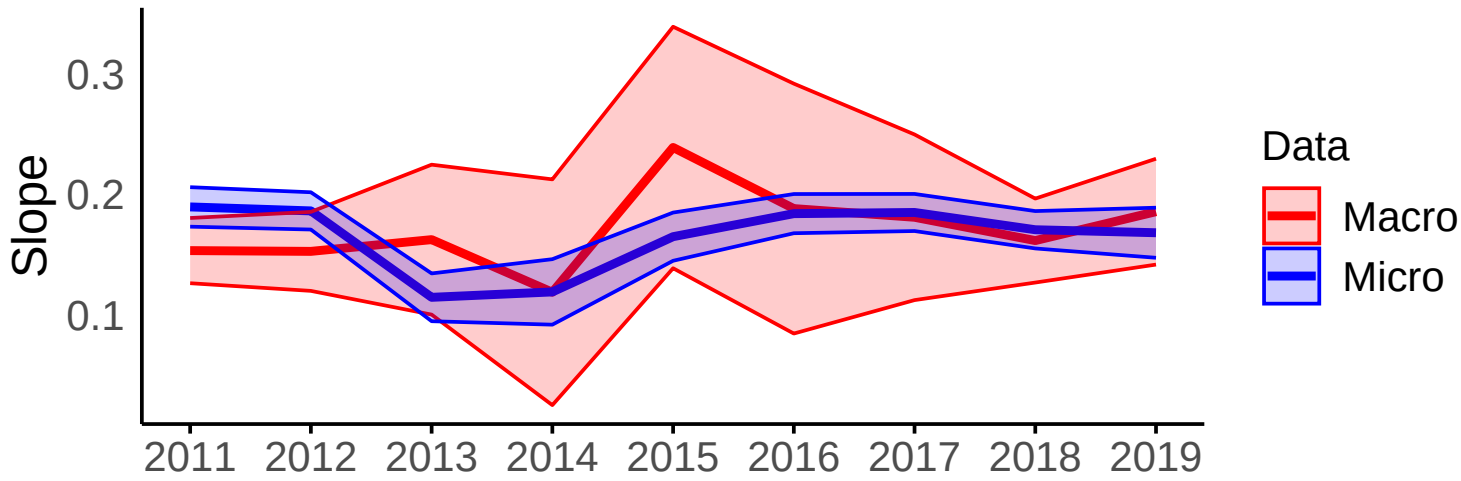
Micro results

- Heterogeneous Phillips curves:



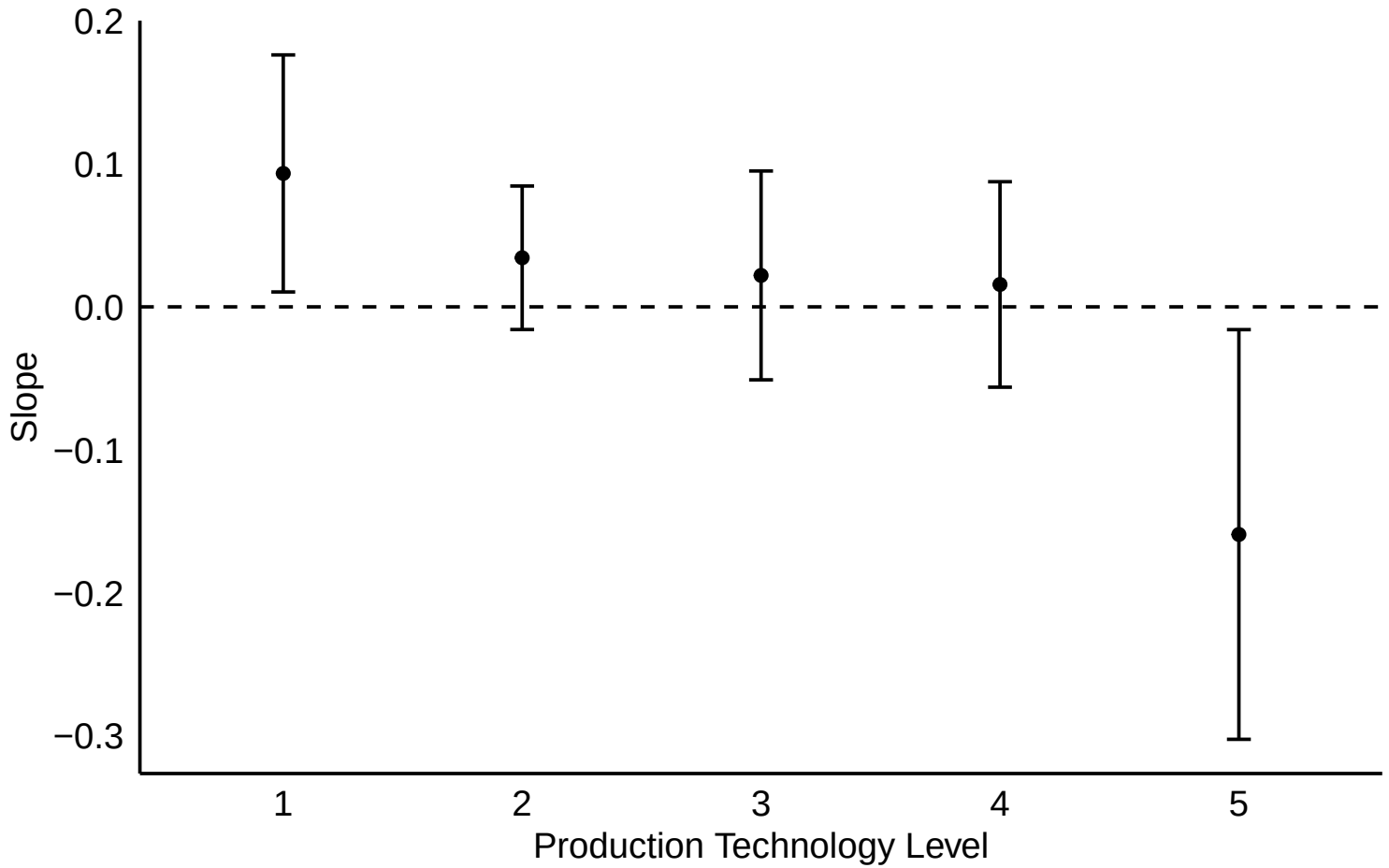
Micro results

- The Phillips curve, from micro to macro:



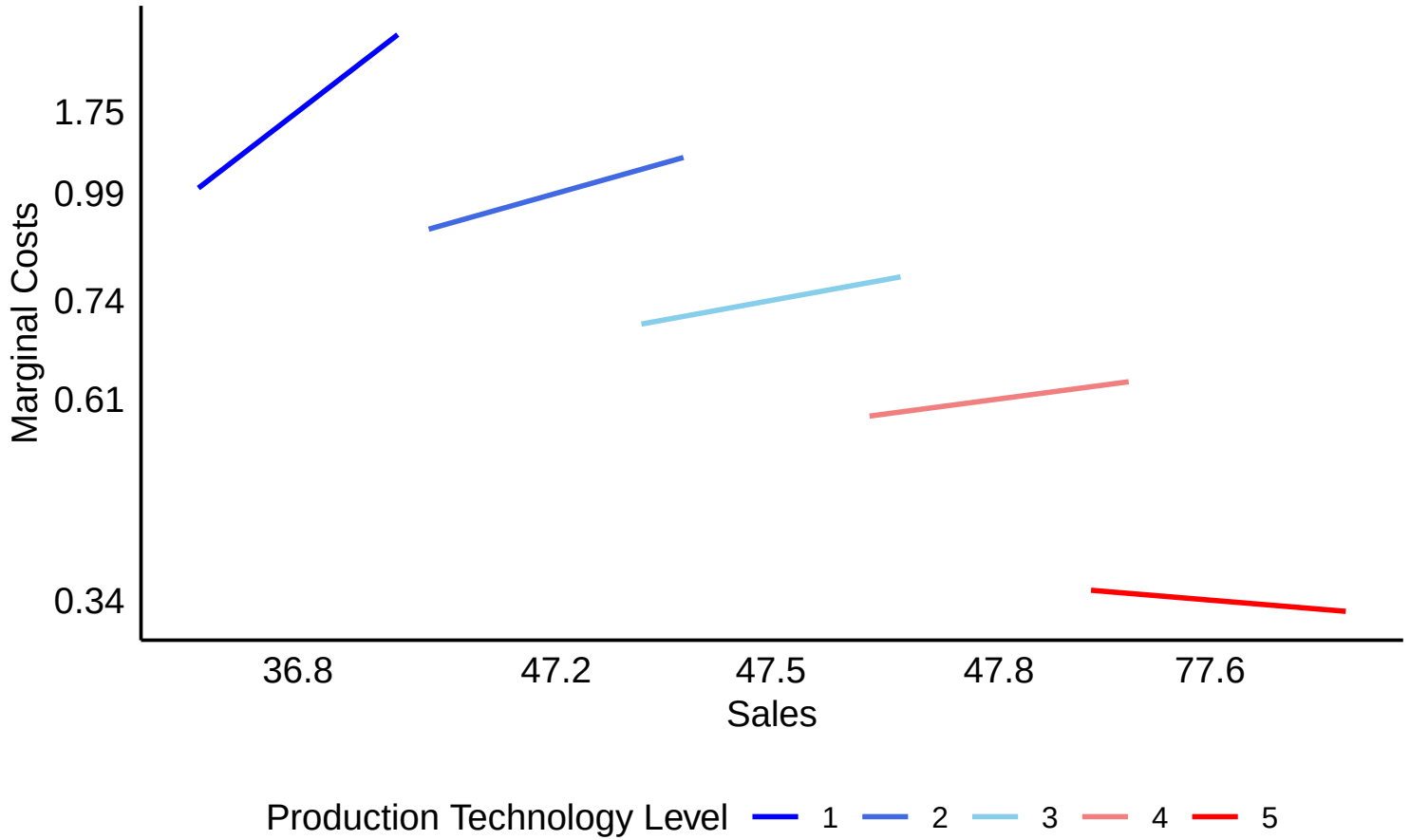
Micro results

- Cross-country comparison with the Netherlands:



Micro results

- Cross-country comparison with the Netherlands:



Conclusion

- Production technology matters for firm pricing decisions.
- The most productive firms have flatter supply curves, even after controlling for differences in firm residual demand and net of strategic competition.
- The Phillips curve slope, then, turns out to be well represented by a weighted average of the slopes of these firm supply curves.
- The empirical findings rely on French and Dutch manufacturing firm-level data, and are supported by cross-country evidence on micro-based data regarding several European countries for the entire business economy (including services).

Conclusion

- We employ aggregate demand measures to instrument firm demand shocks. Finding a closer measure of a firm-specific demand shock would be very effective and better track demand-driven increases in firm sales.
- We mostly focused on manufacturing. It is, hence, a natural further step in this field to include a larger part of the economy, in particular, services.

Thank you for your kind attention!

References I

Andrés, J., & Burriel, P. (2018)
Inflation and optimal monetary policy in a model with firm heterogeneity and Bertrand competition
European Economic Review 103, 18 – 38.

Boehm, C. E., & Pandalai-Nayar, N. (2022)
Convex supply curves
American Economic Review 112(12), 3941 – 3969.

Bullard, J., & Mitra, K. (2002)
Learning about monetary policy rules
Journal of monetary economics 49(6), 1105 – 1129.

Calvo, G. A. (1983)
Staggered prices in a utility-maximizing framework
Journal of Monetary Economics 12(3), 383 – 398.

Carvalho, C., Eusepi, S., Moench, E., & Preston, B. (2023)
Anchored inflation expectations
American Economic Journal: Macroeconomics 15(1), 1 – 47.

References II

Demertzis, M., Marcellino, M., & Viegi, N. (2012)
A credibility proxy: Tracking US monetary developments
The BE Journal of Macroeconomics 12(1).

Fujiwara, I., & Matsuyama, K. (2022)
Competition and the Phillips curve
Centre for Economic Policy Research

Gagliardone, L., Gertler, M., Lenzu, S., & Tielens, J. (2023)
Anatomy of the Phillips Curve: Micro Evidence and Macro Implications
National Bureau of Economic Research No. w31382.

Galí, J. (1999)
Technology, employment, and the business cycle: do technology shocks explain aggregate fluctuations?
American economic review 89(1), 249 – 271.

Gilchrist, S., & Zakrajsek, E. (2019)
Trade exposure and the evolution of inflation dynamics.
FEDS Working Paper No. 2019 – 007.

References III

Del Negro, M., Lenza, M., Primiceri, G. E., & Tambalotti, A. (2020)
What's up with the Phillips Curve?
National Bureau of Economic Research No. w27003.

Hooper, P., Mishkin, F. S., & Sufi, A. (2020)
Prospects for inflation in a high pressure economy: Is the Phillips curve dead or is it just hibernating?
Research in Economics 74(1), 26 – 62.

Lucas, R. E., & Rapping, L. A. (1969)
Price expectations and the Phillips curve
The American Economic Review 59(3), 342 – 350.

Mrázová,M., & Neary, J. P. (2017)
Not so demanding: Demand structure and firm behavior
The American Economic Review 107(12), 3835 – 3874.

Roberts, J. M. (1997)
The wage curve and the Phillips curve.
Available at SSRN 94270.

References IV

Shea, J. (1993)
The Input-Output Approach to Instrument Selection." Journal of Business.
Journal of Business & Economic Statistics 11(2) 145 – 155.

Siena, D., & Zago, R. (2024)
Job Polarisation, Labour Market Fluidity and the Flattening of the Phillips Curve
The Economic Journal, ueae006.

Woodford, M., & Walsh, C. E. (2005)
Interest and prices: Foundations of a theory of monetary policy
Macroeconomic Dynamics 9(3), 462 – 468.