Business Cycles with Pricing Cascades

Mishel Ghassibe — CREi, UPF & BSE

Anton Nakov — European Central Bank

BCEA Annual Conference

Sofia University, 24 June 2025

The views expressed here are the responsibility of the authors only, and do not necessarily coincide with those of the ECB or the Eurosystem.

Motivation

- Recent events have brought new evidence regarding the drivers and dynamics of inflation:

  i. Possibility of **large inflationary swings** in advanced economies ▸ Show

     Challenge: *NKPC with a realistic slope requires implausibly large shocks* (L'Huillier and Phelan, 2024)

  ii. Fluctuations in the **frequency of price adjustment** (Montag and Villar, 2023; Cavallo et al., 2024) ▸ Show

     Challenge: *a fixed menu cost model matches the frequency at the cost of an implausibly steep NKPC* (Blanco et al., 2024)

  iii. Importance of **sector-specific** drivers of inflation (Schneider, 2023; Rubbo, 2024) ▸ Show

     Challenge: *need to allow for large sector-specific shocks in a setting with menu costs*

- Develop a **dynamic quantitative** general equilibrium model that features: a number of **sectors interconnected by networks** with **state-dependent pricing** that is solved **fully non-linearly**

New cyclical mechanism: interaction of **networks** and pricing **cascades**

- **Interaction** of our model ingredients creates pricing **cascades**: large movements in aggregates trigger additional price adjustment decisions at the extensive margin

- **Demand shocks** **Networks slow down** adjustment along the extensive margin: **cascades dampening**
  - i Networks slow down the desired price changes, and firms are less willing to pay the cost of adjustment
  - ii Quantitatively, delivers a "global flattening" of the Phillips Curve, implying strong monetary non-neutrality even following very large shocks

- **Supply shocks** (Agg./sectoral) **Networks speed up** price adjustment: **cascades amplification**
  - i Networks amplify the desired price changes, and firms are more willing to pay the adjustment cost
  - ii Quantitatively, creates frequency increases and inflationary spirals following aggregate TFP/markup shocks, or TFP/markup shocks to sectors that are major suppliers to the rest of the economy

Model overview

- **Timing**: infinite-horizon setting in discrete time, indexed by $t = 0, 1, 2, \ldots$
- **Households**: continuum of identical households; consume output and supply labor
- **Firms**: continuum of monopolistically competitive firms, each belongs to one of N sectors, indexed $i \in \{1, 2, \ldots, N\}$; there is a measure one of firms in each sector
- **Factors**: firms use labor and intermediate inputs purchased from other firms
- **Government Policy**: central bank sets the level of money supply M_t

Households

- The representative household maximizes expected lifetime utility:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\log C_t - L_t\right]$$

subject to a standard budget constraint

- Households are also subject to a **cash-in-advance** constraint: $P_t^C C_t \leq M_t$

- Aggregate consumption: $C_t = \iota^C \prod_{i=1}^N C_i^{\overline{\omega}_i^C}, \quad \sum_{i=1}^N \overline{\omega}_i^C = 1, \quad \overline{\omega}_i^C \geq 0, \forall i$

- Sectoral consumption: $C_{i,t} = \left\{\int_0^1 \left[\zeta_{i,t}(j) C_{i,t}(j)\right]^{\frac{\epsilon-1}{\epsilon}} dj\right\}^{\frac{\epsilon}{\epsilon-1}}, \quad \epsilon > 1$

where $\zeta_{i,t}(j)$ is a **firm-level quality** process:

$$\log \zeta_{i,t}(j) = \log \zeta_{i,t-1}(j) + \sigma_i \varepsilon_{i,t}(j)$$

Firms: production

- Any firm j in sector i has access to the following production technology:

$$Y_{i,t}(j) = \iota_i \frac{1}{\zeta_{i,t}(j)} \times A_{i,t} \times L_{i,t}(j)^{\overline{\alpha}_i} \prod_{k=1}^{N} X_{i,k,t}(j)^{\overline{\omega}_{ik}},$$

where $A_{i,t}$ is a **sectoral productivity** process, $L_{i,t}(j)$ is firm-level labor input, $X_{i,k,t}(j)$ is firm-level intermediate input demand for sector k's goods and $\overline{\alpha}_i + \sum_{k=1}^{N} \overline{\omega}_{ik} = 1, \quad \overline{\alpha}_i \geq 0, \overline{\omega}_{ik} \geq 0, \ \forall i, k$

- Cost-minimization delivers the following real marginal cost:

$$MC_{i,t}(j) = \zeta_{i,t}(j) \times \frac{M_t}{A_{i,t}} \times \prod_{k=1}^{N} \frac{P_{k,t}^{\omega_{ik}}}{M_t}$$

Firms: pricing

- Price resetting involves paying a sector-specific **menu cost** $\kappa_{i,t}$ measured in labor hours

- Let $p_{i,t}(j) \equiv \log \tilde{P}_{i,t}(j) = \log \frac{P_{i,t}(j)}{\zeta_{i,t}(j) M_t}$ be the quality-adjusted *log* real price

- The value of a firm in sector i that has set a quality-adjusted real price p:

$$V_{i,t}(p) = \tilde{\mathcal{D}}_{i,t}(p) + \beta \mathbb{E}_t \left[\left\{ 1 - \eta_{i,t+1} \left(p - \sigma_i \varepsilon_{i,t+1} - m_{t+1} \right) \right\} \times V_{i,t+1}(\overbrace{p - \sigma_i \varepsilon_{i,t+1} - m_{t+1}}^{\text{"Eroded" real price}}) \right]$$

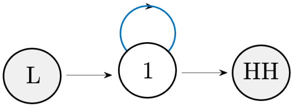
$$+ \beta \mathbb{E}_t \left[\underbrace{\eta_{i,t+1} \left(p - \sigma_i \varepsilon_{i,t+1} - m_{t+1} \right)}_{\text{Prob. of adjustment}} \times \left(\max_{p'} V_{i,t+1}\left(p'\right) - \kappa_{i,t} \right) \right]$$

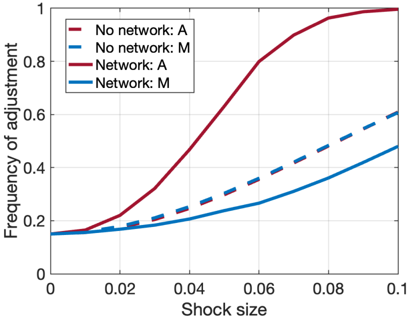
- Following Golosov and Lucas (2007), we assume the following **adjustment hazard** $\eta_{i,t}(.)$:

$$\eta_{i,t}(p) = \mathbf{1}(L_{i,t}(p) > 0) = \mathbf{1}\left(\max_{p'} V_{i,t}\left(p'\right) - V_{i,t}(p) > \overline{\kappa}_i \right)$$

Toy example 1: roundabout production

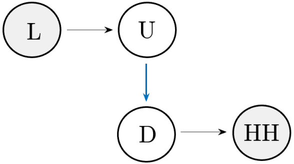
- Marginal cost: $MC(j) = \zeta(j) \times \frac{1}{A} \times M^{\overline{\alpha}} P^{1-\overline{\alpha}} = \zeta(j) \times \frac{M}{A} \times \left(\frac{P}{M}\right)^{1-\overline{\alpha}}$

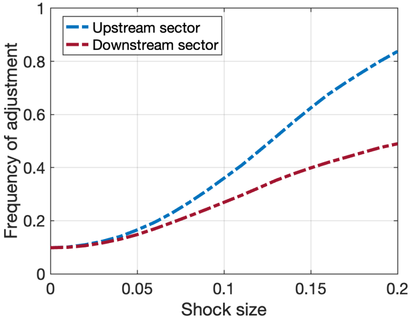




Toy example 2: two-sector vertical chain

- Marginal costs: $MC_U(j) = \zeta_U(j) \times \frac{1}{A_U} \times M, \quad MC_D(j) = \zeta_D(j) \times \frac{1}{A_D} \times P_U$

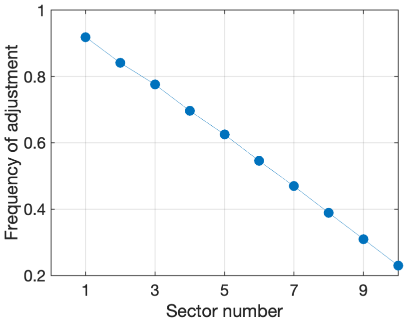




Toy example 3: *N*-sector vertical chain

- Marginal costs: $MC_i(j) = \zeta_i(j) \times \frac{1}{A_i} \times P_{i-1}$

$$L \rightarrow 1 \rightarrow 2 \rightarrow \cdots \rightarrow N \rightarrow HH$$



QUANTITATIVE RESULTS

Computation

- **Steady state**: solve the stationary Bellman equations and firms' price distribution on a grid of log quality-adjusted real prices for every sector

- Consider a **known** sequence of money supply $\{\Delta \log M_t\}_{t=0}^{\infty}$ and productivity $\{\log A_{k,t}\}_{t=0}^{\infty}$

- Assume that after a finite time period T the economy converges back to the stationary distribution

- From a guess for the sequences of aggregate and sectoral variables, follow **backward-forward iteration** until convergence:

  ① Starting from $t = T$, iterate **backwards** to $t = 0$ to solve for the micro value functions

  ② Starting from $t = 0$, iterate **forwards** to $t = T$ to solve for price distributions and aggregate numerically

Calibration (Euro Area, monthly frequency)

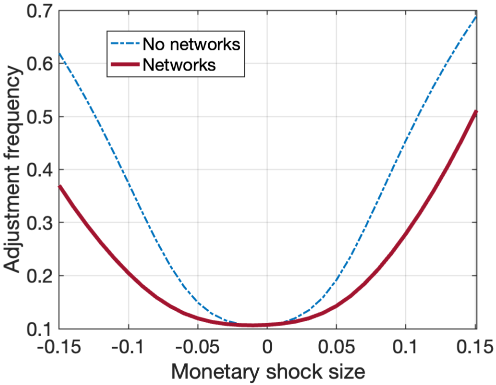
Aggregate parameters			
β	$0.96^{1/12}$	Discount factor (monthly)	Golosov and Lucas (2007)
ϵ	3	Goods elasticity of substitution	Midrigan (2011)
$\overline{\pi}$	0.02/12	Trend inflation (monthly)	ECB target
ρ	0.90	Persistence of the TFP shock	Half-life of seven months
Sectoral parameters			
N	39	Number of sectors	Data from Gautier et al. (2024)
$\{\overline{\omega}_i^C\}_{i=1}^N$		Sector consumption weights	World IO Tables
$\{\overline{\omega}_{ik}\}_{i,k=1}^N$		Sector input-output matrix	World IO Tables
$\{\overline{\alpha}_i\}_{i=1}^N$		Sector labor weights	World IO Tables
Firm-level pricing parameters			
$\{\overline{\kappa}_i\}_{i=1}^N$		Menu costs	Estimated to fit frequency, std dev.
$\{\sigma_i\}_{i=1}^N$		Std. dev. of firm-level shocks	of Δp from Gautier et al. (2024)

Monetary shocks

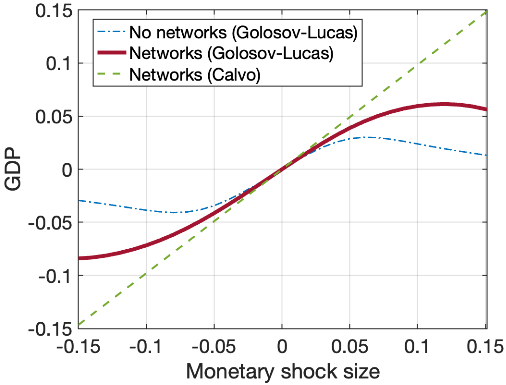
$$\log M_t = \overline{\pi} + \log M_{t-1} + \varepsilon_t^M$$

Cascades dampening following monetary shocks

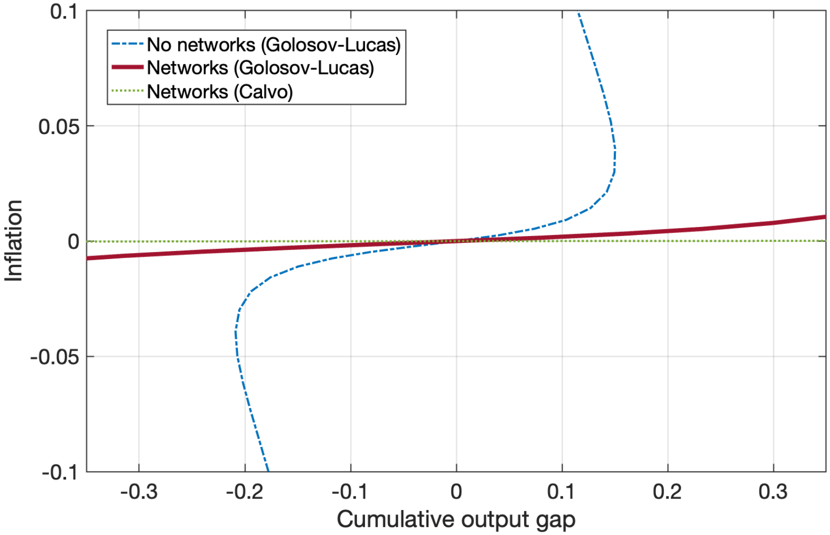
(a) Aggregate adjustment frequency



(b) GDP



Non-linear **Phillips Curves**

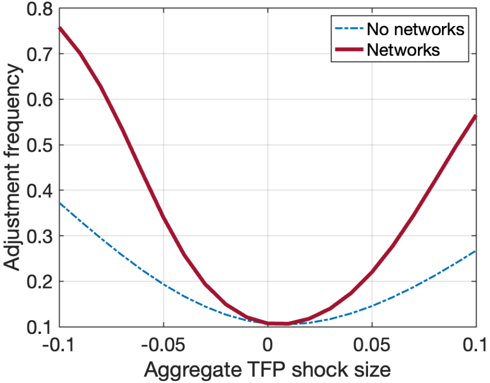


Aggregate TFP shocks

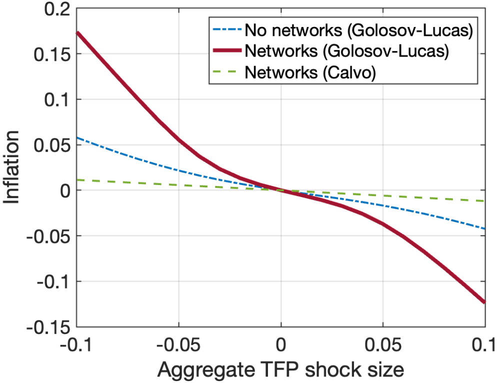
$$\log A_t = \rho \log A_{t-1} + \varepsilon_t^A$$

Cascades amplification following TFP shocks

(a) Aggregate adjustment frequency

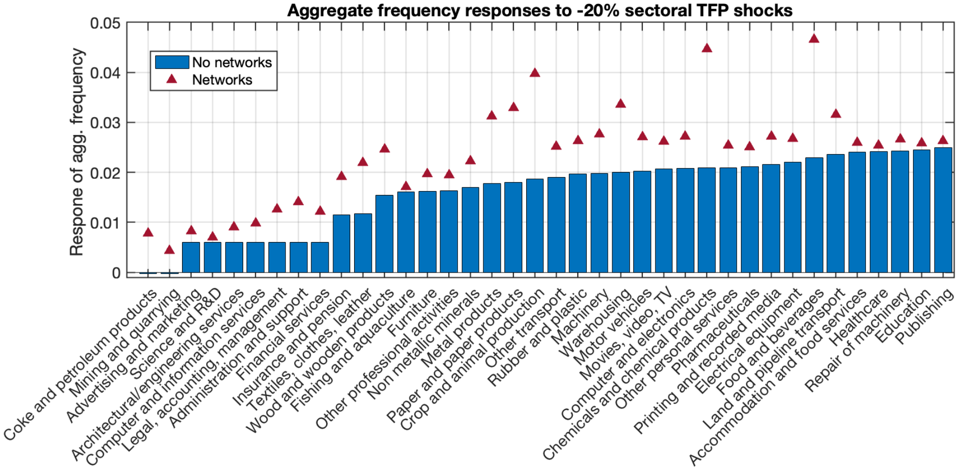


(b) CPI inflation



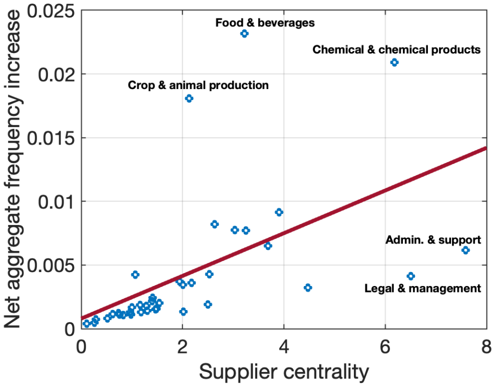
Sectoral TFP shocks

Aggregate frequency responses to sectoral TFP shocks (-20%)

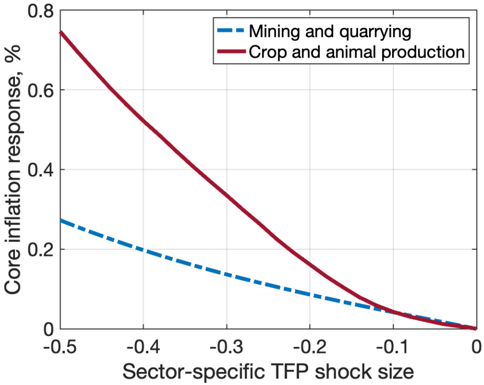


Aggregate frequency responses vs. sectoral **Supplier Centrality**

(a) (Net) aggregate adjustment frequency



(b) Core inflation response

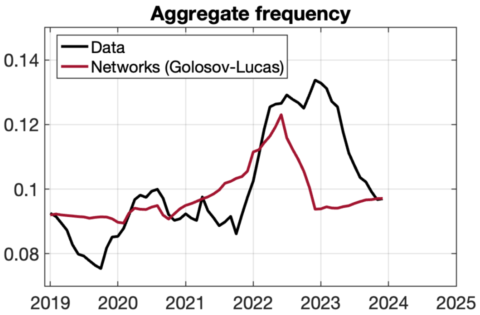


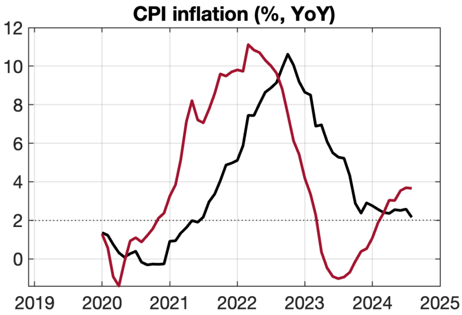
APPLICATION: (POST-) COVID EURO AREA INFLATION

Model vs. Data

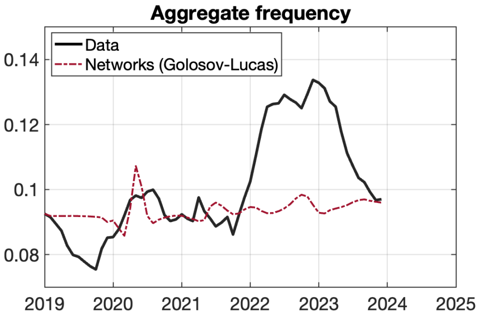
- To assess the model quantitatively, we feed in observed demand and supply processes as exogenous shocks
- **Aggregate demand shock**: Euro Area nominal GDP as a proxy for the $\{M_t\}_{t\geq 0}$ process
- **Energy price shock**: calibrate the productivity process of the "Mining and Quarrying" sector to match the IMF Global Price of Energy Index movements
- **Food price shock**: calibrate the productivity process of the "Crop and Animal Production" sector to match the IMF Global Price of Food Index movements
- **Labor market shock**: calibrate the productivity process of the labor union sector to match the hourly earnings dynamics in the Euro Area

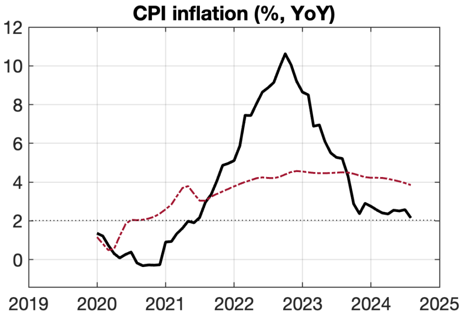
Model vs. Data: baseline setup, all shocks



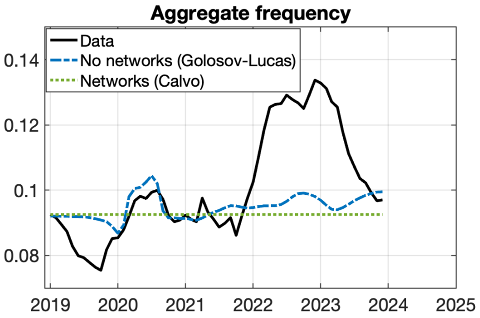


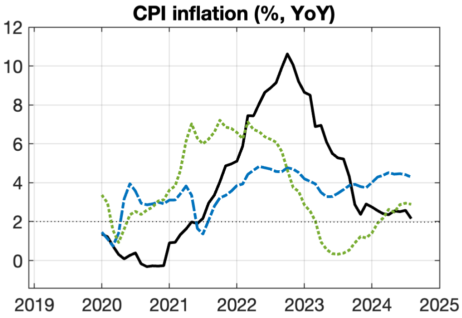
Model vs. Data: baseline setup, no commodity shocks





Model vs. Data: alternative setups, all shocks





Conclusions

- Present a **dynamic quantitative** general equilibrium model that features: a number of **sectors interconnected by networks** with **state-dependent pricing** that is solved **fully non-linearly**
- Networks **slow down** the extensive margin pricing response to **demand shocks**: **cascades dampening**
- Networks **speed up** the extensive margin response to **supply shocks**: **cascades amplification**
- **Interaction** of networks and pricing cascades crucial for **quantitatively** matching the observed surges in inflation and repricing frequency in the Euro Area

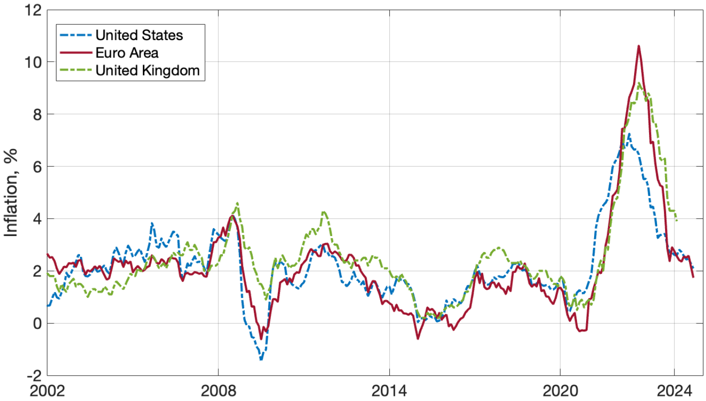
References

Gautier, Erwan, Cristina Conflitti, Riemer P. Faber, Brian Fabo, Ludmila Fadejeva, Valentin Jouvanceau, Jan-Oliver Menz, Teresa Messner, Pavlos Petroulas, Pau Roldan-Blanco, Fabio Rumler, Sergio Santoro, Elisabeth Wieland, and Hélène Zimmer (2024) "New Facts on Consumer Price Rigidity in the Euro Area," *American Economic Journal: Macroeconomics*, Vol. 16, p. 386–431.

Golosov, Mikhail and Robert E. Lucas (2007) "Menu Costs and Phillips Curves," *Journal of Political Economy*, Vol. 115, pp. 171–199.

APPENDIX

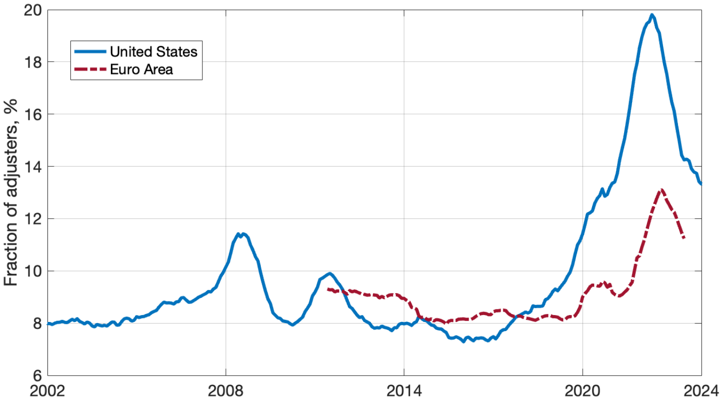
Evidence I: inflation spikes in advanced economies (headline)



Source: FRED.

Back

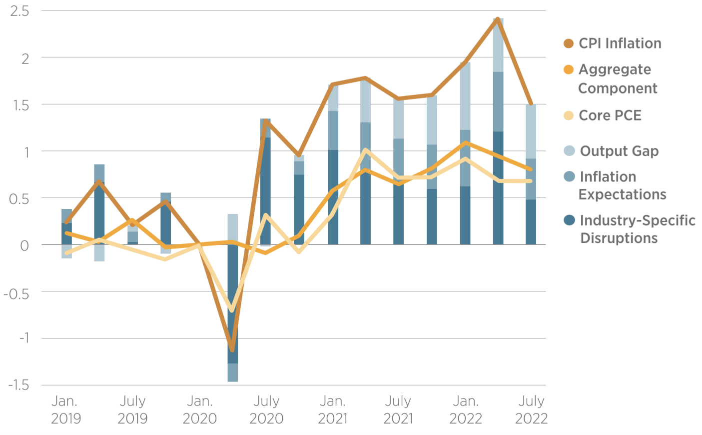
Evidence II: changes in frequency of price adjustment



Source: Montag and Villar (2024), Dedola et al. (2024).

Back

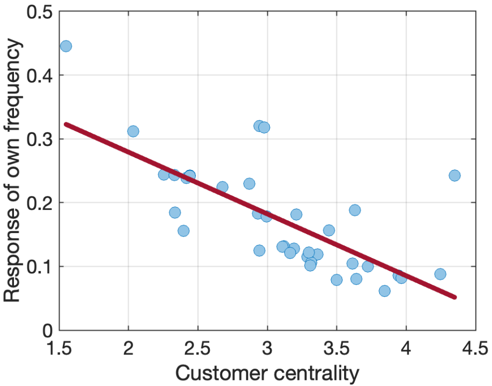
Evidence III: sectoral origins of inflation

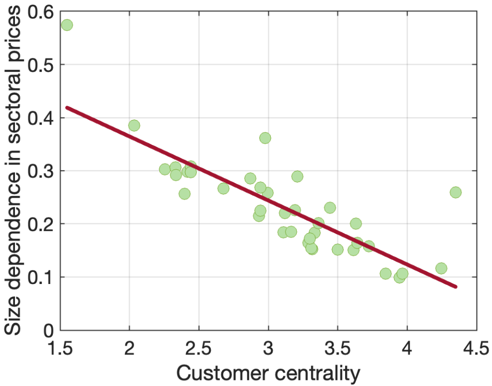


Source: Rubbo (2024).

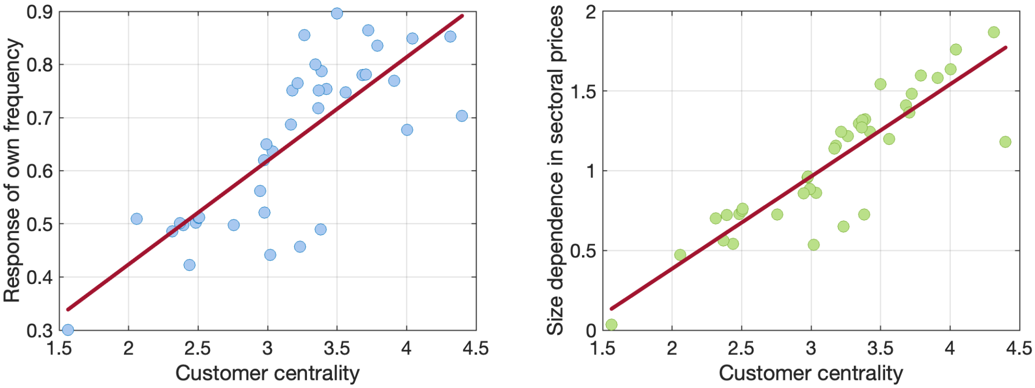
Back

Sectoral frequencies and prices following monetary shocks





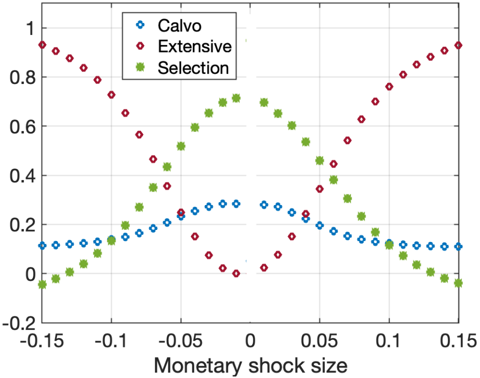
Sectoral frequencies and prices following TFP shocks

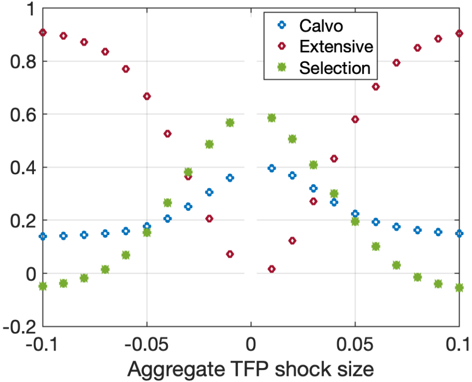


Inflation decomposition and network effects

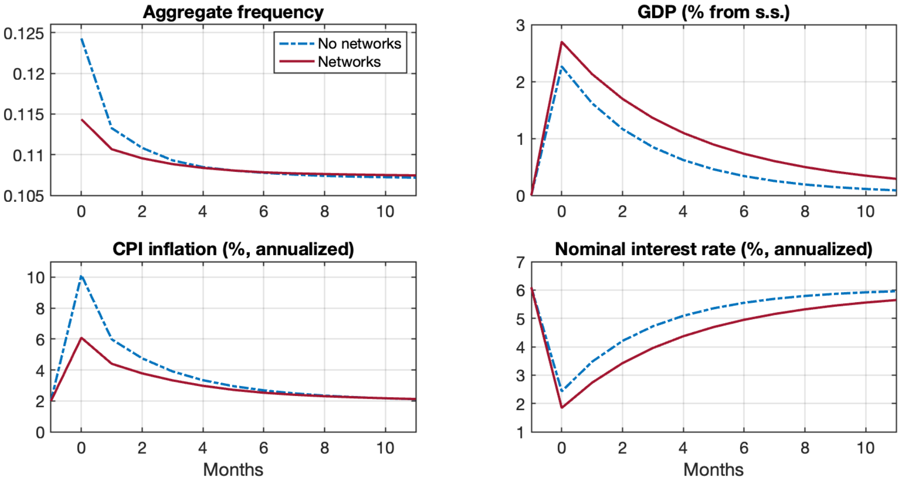
- Make use of the following inflation decomposition:

$$\Delta\pi \quad = \quad \Delta\pi^{\text{Calvo}} \quad + \quad \Delta\pi^{\text{Extensive}} \quad + \quad \Delta\pi^{\text{Selection}}$$

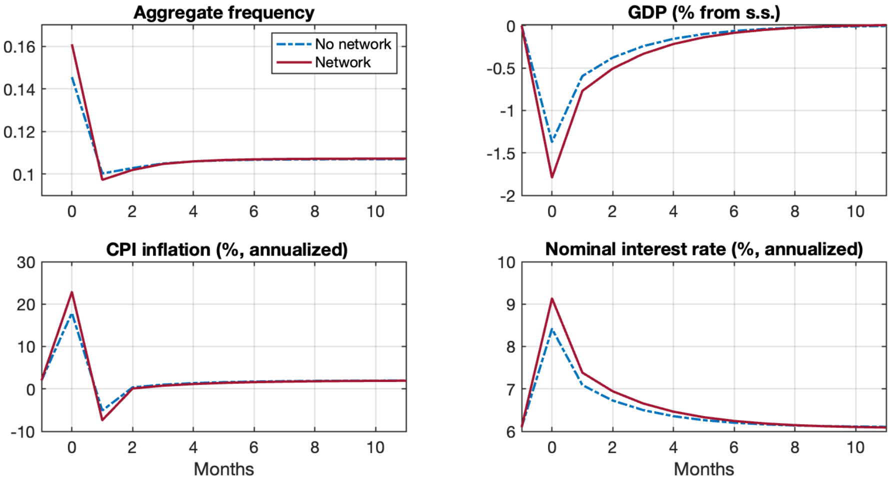




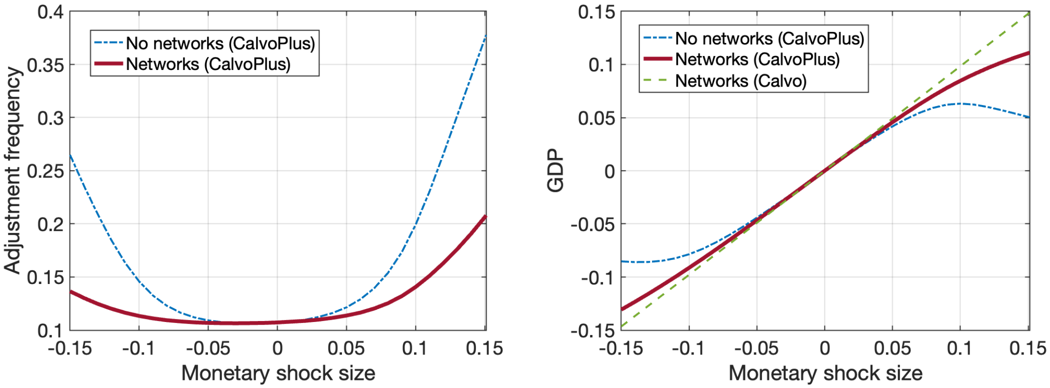
Cascades dampening following monetary shocks: Taylor rule



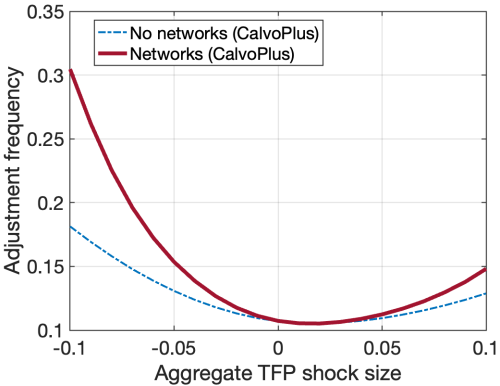
Cascades amplification following TFP shocks: Taylor rule

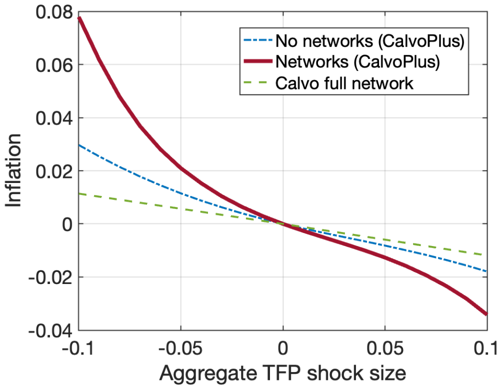


Cascades dampening following monetary shocks: CalvoPlus

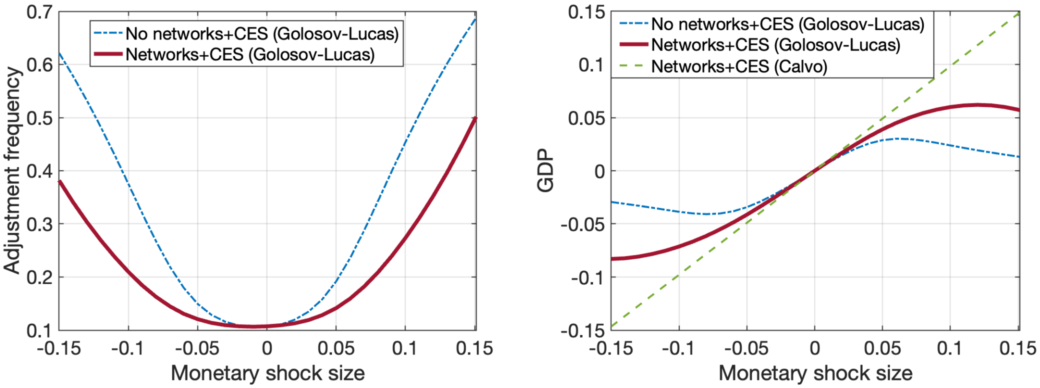


Cascades amplification following TFP shocks: CalvoPlus





Cascades dampening following monetary shocks: CES aggregation



Cascades amplification following TFP shocks: CES aggregation