Business Cycles with Pricing Cascades

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These comments are personal views of the discussant and do not represent the views of the Eurosystem or the Banco de España.

State-dependent pricing in an input-output network

- We know that **strategic complementarities in price adjustment** can be very important in theory (e.g. Cooper/John 1988)
  - How does my firm's stickiness or adjustment depend on the stickiness or adjustment of other firms?
  - May be crucial for amplifying effects of small frictions on macro outcomes, e.g. monetary non-neutrality
- Finally, here is a **quantitative framework** to evaluate how important strategic complementarities are for macroeconomic dynamics and monetary policy.
- **Four key ingredients** are required:
  - **State-dependent pricing** (endogenizing extensive and intensive margins of price adjustment)
  - Heterogeneous **input-output network** structure
  - Demand and supply shocks
  - Fully nonlinear solution
- Combining two **technically challenging, data-driven** areas of macroeconomic literature
  - State-dependent pricing literature (Golosov/Lucas 2007 and followers)
  - Macroeconomic networks literature (Acemoglu et al. 2012, Rubbo 2023)

Main results

- **Input-output relationships matter** – differently for different shocks
  - Price adjustment to **monetary shocks** is slowed down if input prices adjust sluggishly
  - Price adjustment to **sectoral productivity shocks** is accelerated if input prices also adjust
- Effects of shocks are **highly nonlinear** and vary with **position in network**
- Analytical results on **measures of network centrality** predict how sectoral adjustment frequency reacts to monetary shocks and productivity shocks
- Simulation of **post-Covid inflation** explains large movements in the aggregate adjustment frequency and aggregate inflation rate
  - Shocks to energy and food prices had large aggregate effects
  - Both state-dependence and network structure are needed to explain variation in frequency and inflation

Making a complex environment tractable

- Log-linear household utility: $U(C_t, L_t) = \log C_t - L_t$.
- Cash-in-advance constraint and exogenous money supply M_t
  - Implies that the **nominal wage is exogenous**, and equals nominal consumption: $P_t^C C_t = W_T = M_t$.
- Economy has $N = 38$ **goods producing sectors** i
  - Continuum of monopolistically-competitive firms in each sector
  - Each firm produces one good (one variety)
  - Nominal price adjustment is subject to **menu costs**
- Consumption C_t and materials inputs $X_{kt}(j)$ are Cobb-Douglas aggregates across sectors i
- Consumption C_{it} and material inputs $X_{kit}(j)$ from sector i are CES aggregates across varieties v
  - Implies that **expenditure shares are constant over time**, and **equalized across firms** in a sector.
- Only the **"labor union"** (sector 39) purchases labor
  - Sector 39 is upstream: it uses no materials inputs
  - Price of labor is state-dependent, like other prices

Analytical results: Propagation of monetary shocks

- Let $\bar{\Psi} \equiv (I - \bar{\Omega})^{-1}$ be the Leontief inverse matrix, and let superscript (i) indicate row i of a matrix;
- Let $\mu \equiv [\log \mathcal{M}_1, \ldots \log \mathcal{M}_N]^T$ be the vector of log sectoral markups, and let $\bar{\mu}$ be its mean. Then:

- **Prop. 1.** Given technical assumptions, the **effect of a money supply shock** m on the **sector-i** adjustment frequency is:

$$\frac{1}{\chi_i}\Delta\rho_i(m) \approx \left[m + \bar{\mu}\mathbf{C}_i + N\text{Cov}\left((\bar{\Psi} - I)^{(i)}, \mu\right)\right]^2$$

  where $\mathbf{C}_i \equiv \sum_{j=1}^{N} \bar{\Psi}_{ij} - 1$ is the **customer centrality** of sector i.

- We see that 3 terms have a quadratic effect on the adjustment frequency:
  - The money shock m;
  - The **customer centrality** $\mathbf{C}_i$ of sector i (times the average log markup);
  - The covariance between sector i's exposure to other sectors j as a customer, and the markups of those sectors.

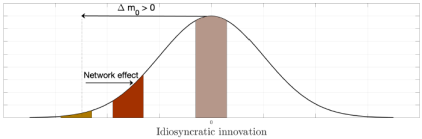
Intuition: Responses to money and TFP

- **Increased money supply** shifts firm's **inaction region left**
- Increases fraction of firms **raising** prices
- If some input suppliers don't react yet, the firm's preferred **shift is reduced**

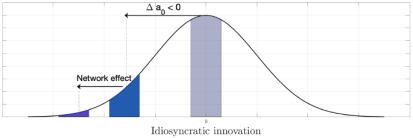
- **Reduced sectoral productivity** shifts firm's **inaction region left**
- Increases fraction of firms **raising** prices
- If some input suppliers raise their prices, the firm's preferred **shift is increased**

Figure 1: **Networks and inaction regions**

(a) Cascades dampening under monetary shocks



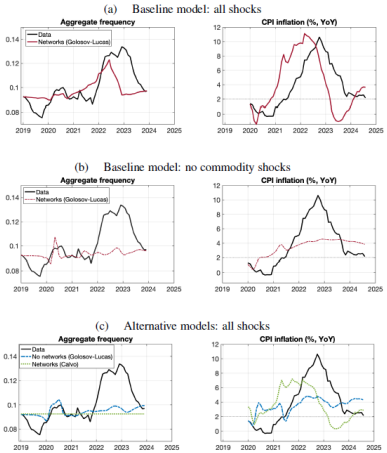
(b) Cascades amplification under TFP shocks



(Shows distribution of possible quality shocks)

Quantitative results: Post-Covid inflation

Figure 12: **Explaining the observed surge in frequency and inflation (Euro Area)**



- Matches aggregate data well, though data seem more sluggish than model
- Propagation of commodity shocks is crucial for the aggregate dynamics
- Both SDP and networks are needed to get large movements in frequency and inflation

Minor suggestion (0): Simplify Assumptions 6-7

- The analytical results rely on two technical assumptions about shapes of distributions
  - Assumptions 6-7 are notation heavy, and **never explained**
- Please **state both assumptions in words**, in addition to the math notation
  - Initial distribution (Assumption 6): All firms adjusted last period?
  - Menu cost process (Assumption 7): Seems to define a deterministic, but endogenous, path for the sector-specific menu cost. Couldn't some more natural assumption give similar results?
- There are probably a variety of assumptions that deliver similar results. Try to find a simple base case that is easy to interpret economically.

Suggestions (1): Intermediates vs networks

- The paper shows that the **input-output structure** is quantitatively important.
  - **Intermediate inputs** amplify output effects of monetary and productivity shocks (Figs 3 and 7)
  - Especially for large shocks

- But "eliminating networks" ($\bar{\omega}_{ik} \to 0$) mixes two mechanisms:
  - **Intermediate inputs** in production amplify strategic complementarities
  - Then **asymmetries and heterogeneity** (centrality and Herfindahl measures) in the input-output network can reinforce the effects

- A **"roundabout production" scenario with wage stickiness** could distinguish these effects.
  - Consider a model with 38 goods sectors, plus the labor union sector
  - Suppose the labor union sector uses labor as its only input
  - Impose Basu (1995) "roundabout production" on the goods sectors (all $\bar{\omega}_{ik}$ equal)
  - IRFs should lie between "no networks" and "networks" cases in Figs 3 and 7
  - Thus we distinguish effects of intermediate inputs, per se, from effects of the network structure

- Your heterogeneous network is more realistic. But roundabout production would be much easier for other researchers to apply. How much do the effects shrink in that case?

Suggestions (2): Smooth hazard functions

- Paper shows that **state-dependent pricing** is quantitatively important, and seems to fit well
  - But the model imposes **fixed menu costs** (Golosov/Lucas 2007), which are unrealistic
  - Fails to match micro distribution of price changes; exaggerates state dependence of adjustment
- Appendix D.2 considers **"Calvo-plus"** stochastic menu cost model
  - But this still matches microdata poorly
  - A pity, since your goal is quantitative realism!!
- Instead, microdata show that the **adjustment probability increases smoothly** with the price gap (Campbell/Eden 2014, among others)
  - Multiple possible microfoundations for smooth adjustment probability
  - Regardless, they act like stochastic MC models with a smooth hazard function
- Why not make a **smooth hazard function** your base case?
  - Alvarez/Lippi/Oskolkov (2022) show how to identify the stochastic MC distribution from the observed price change distribution
  - Could move Golosov/Lucas fixed MC case to the appendix
- The smooth hazard model is not really harder to implement or understand. But would be a more credible building block for your quantitative results.

Suggestions (3): More sectoral evidence

- Calibrated model has rich dynamics at aggregate and sectoral level
  - But few of the model's predictions have been tested against the data

- Simulation **fits aggregate post-Covid data well**, using four exogenous shocks:
  - Euro-area nominal GDP $\rightarrow$ money supply shock
  - Euro-area nominal hourly earnings $\rightarrow$ productivity of labor union
  - IMF energy price index $\rightarrow$ productivity of "Mines and quarries" sector
  - IMF food price index $\rightarrow$ productivity of "Crops and animals" sector

- Testing the model **against sectoral data** would be far more convincing. For example,
  - Regress (or scatter) frequency in the data against frequency in the model
  - Regress (or scatter) inflation in the data against inflation in the model
  - Do your network centrality statistics explain sectoral outcomes?

- Looking at how the **size of adjustments** varies over time at the sectoral level would also be a useful test of the model

Conclusions

- **Great paper, rich results**
  - Both analytical and quantitative contributions
  - Lots of variations to demonstrate robustness
  - Long-standing issues and ideas, but quantification is only possible now
- Important **technical advance**, without losing sight of the **data**
  - Combining two challenging modelling frameworks
  - Built to match multiple features of microdata, sectoral data, and macrodata
- Yes, quantitative, microfounded model of **nominal rigidity** helps explain macrodynamics and helps understand monetary policy
- Yes, **strategic complementarities in nominal adjustment** are quantitatively important for the macroeconomic impact of shocks
  - Other firms' delay in reacting to monetary policy shocks slows down my own reaction to monetary policy shocks
  - Other firms' accelerated price adjustment after sector-specific productivity shocks accelerates my own reaction to those productivity shocks

THANKS FOR YOUR ATTENTION!