Large Shocks, Networks and State-Dependent Pricing

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Back to Basics and Beyond: New Insights for Monetary Policy Normalisation

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Motivation

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- 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

Key results

- **Interaction** of **networks** and **state-dependent** pricing creates a novel source of **non-linearity** in inflation dynamics, and in business cycles more generally

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- **TFP shocks** (Agg./sectoral) Networks **amplify** the extensive margin adjustment: pricing **cascades**
  - i Networks amplify the effect of TFP shocks on the marginal cost, thus enhancing movements in the optimal reset price (more likely to be pushed out of Ss bands)
  - ii Quantitatively, creates inflationary spirals following aggregate TFP shocks, or TFP shocks to sectors that are major suppliers to the rest of the economy

MODEL

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: $P_t^C C_t \leq M_t$

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- 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

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- Cost-minimization delivers the following marginal cost:

$$MC_{i,t}(j) = \zeta_{i,t}(j) \times \frac{1}{A_{i,t}} \times W_t^{\overline{\alpha}_i} \prod_{k=1}^{N} P_{k,t}^{\overline{\omega}_{ik}}.$$

Firms: pricing

- 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

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- The value of a firm in sector i is given by the Bellman equation:

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

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

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- Following Golosov and Lucas (2007), we assume the following adjustment hazard

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

STATIC SETUP

Intuition in a simplified setup

- Consider the static limit of our model ($\beta = 0$) and focus on the initial time period only ($t = 0$)

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- For a firm j in sector i, the real profit gain from price adjustment satisfies:

$$\tilde{D}_i^*(j) - \tilde{D}_i(j) \quad \approx \quad \frac{1}{2}(\epsilon - 1)[\tilde{P}_i/\tilde{P}_i^*]^{\epsilon-1}\lambda_i \times [\tilde{p}_i(j)]^2$$

where $\tilde{P}_i^*$ is the real quality-adjusted optimal reset price in for firms in sector i, P_i is the real sectoral price index and λ_i is the sectoral sales share

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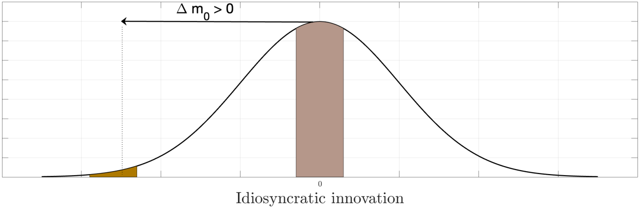
- The firm-level real **price gap** $\tilde{p}_i(j) \equiv \log \tilde{P}_{i,t}(j) - \log \tilde{P}_{i,t}^*$ satisfies:

$$\tilde{p}_i(j) = \underbrace{-\sigma_i \varepsilon_{i,0}(j) - m}_{\text{"Erosion"}} + \overbrace{a_i - \sum_{k=1}^{N} \overline{\omega}_{ik} \log \tilde{P}_k}^{\text{Sectoral optimal reset price}}$$

where m is money supply and a_i is exogenous productivity shock in sector i (all in logs)

Monetary shock: **anti-cascades** in pricing



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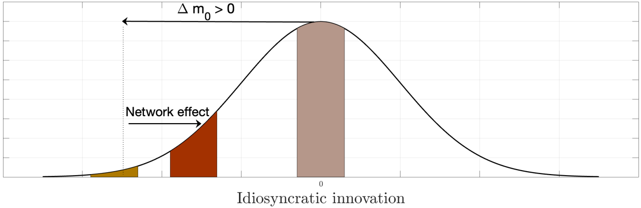

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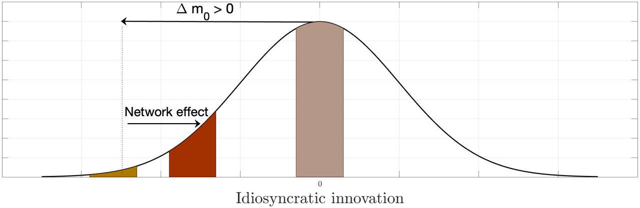
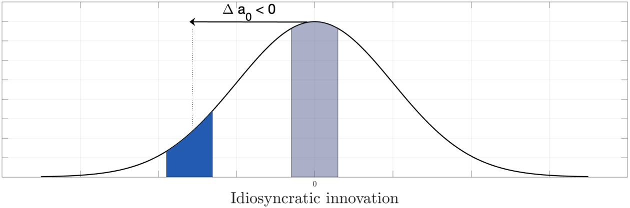


Proposition (Anti-cascades)

Consider an increase in money supply $m > 0$. If the pass-through of the money supply to sectoral prices is incomplete ($\log \tilde{P}_{k,0} < 0, \forall k$)*, networks (weakly)* ***lower the probability*** *of adjustment for any firm.*

Monetary shock: **cascades** in pricing



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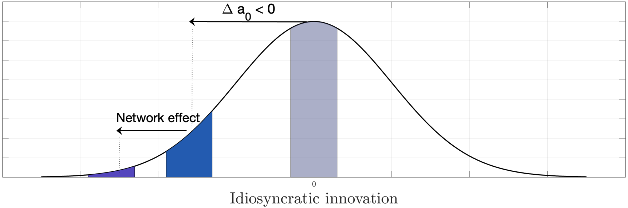

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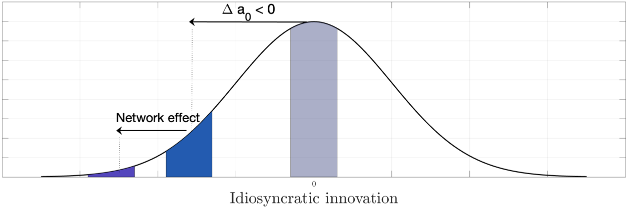
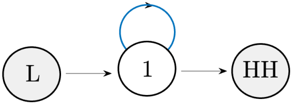
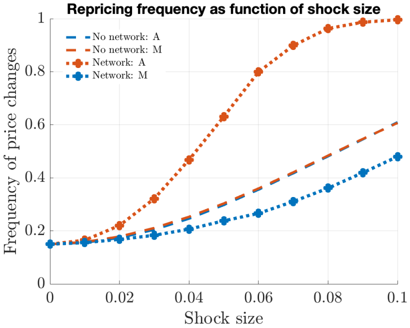


Proposition (Cascades)

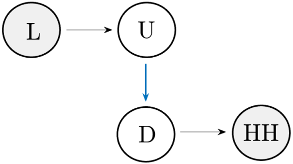
Consider a decrease in sectoral TFP, $a_i < 0$. If it leads to a rise in price indices of other sectors ($\log \tilde{P}_{k,0} > 0, \forall k$), *networks (weakly)* ***increase the probability*** *of adjustment for any firm in sector i.*

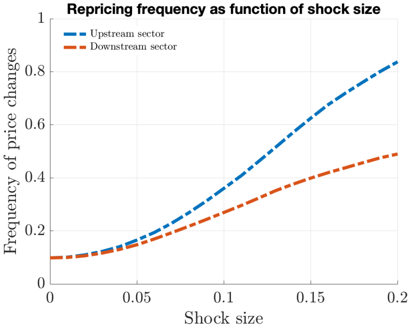
Toy example 1: roundabout production



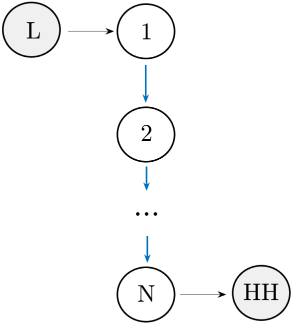


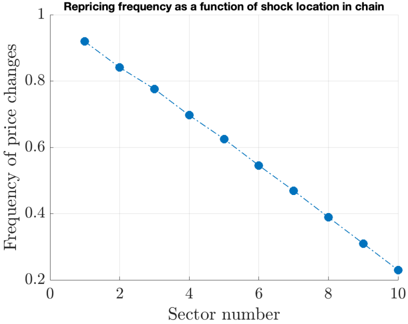
Toy example 2: two-sector chain





Toy example 3: *N*-sector chain





QUANTITATIVE RESULTS

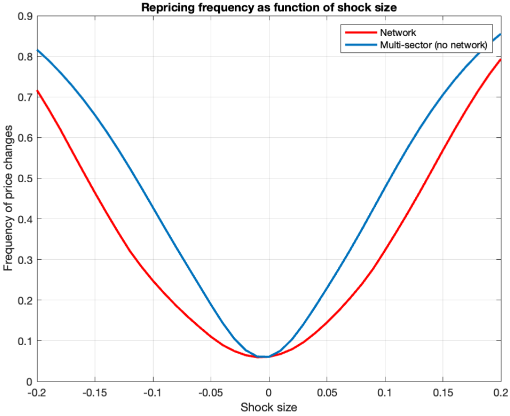
Calibration (Germany, monthly frequency)

Aggregate parameters			
β	$0.96^{1/12}$	Discount factor (monthly)	Golosov and Lucas (2007)
ϵ	9	Goods elasticity of substitution	Galí (2015)
$\overline{\pi}$	0.02/12	Trend inflation (monthly)	ECB target
ρ	0.90	Persistence of the TFP shock	Half-life of seven months
Sectoral parameters			
N	34	Number of sectors	Data from Gautier et al. (2024)
$\{\overline{\omega}_i^C\}_{i=1}^N$		Sector consumption weights	Input-output tables for Germany
$\{\overline{\omega}_{ik}\}_{i,k=1}^N$		Sector input-output matrix	Input-output tables for Germany
$\{\overline{\alpha}_i\}_{i=1}^N$		Sector labor weights	German national income accounts
Firm-level pricing parameters			
$\{\overline{\kappa}_i\}_{i=1}^N$		Menu cost	Estimated to fit frequency, std dev.
$\{\sigma_i\}_{i=1}^N$		Std. dev. of firm level shock	of Δp from Gautier et al. (2024)

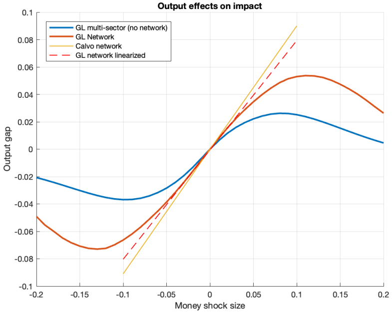
Monetary shocks

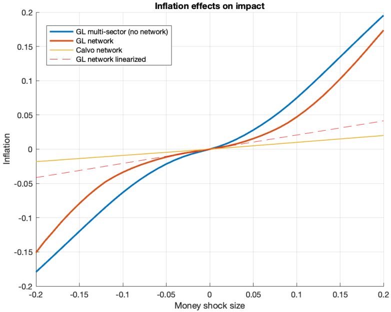
$$\log M_t = \overline{\pi} + \log M_{t-1} + \varepsilon_t^M$$

Networks **slow down** frequency response to monetary shocks

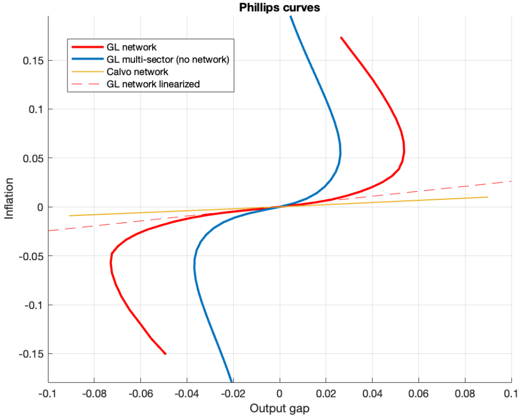


Output amplification and inflation attenuation due to networks





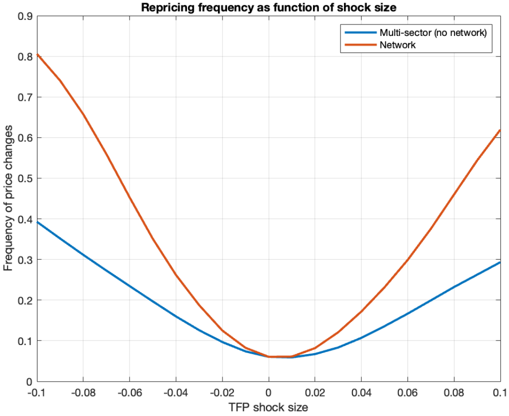
Non-linear Phillips Curve



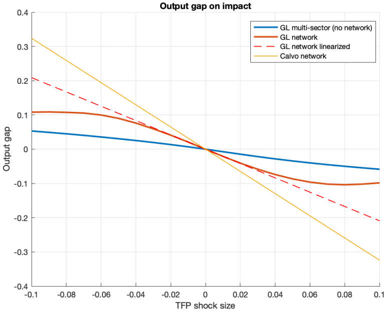
Aggregate TFP shocks

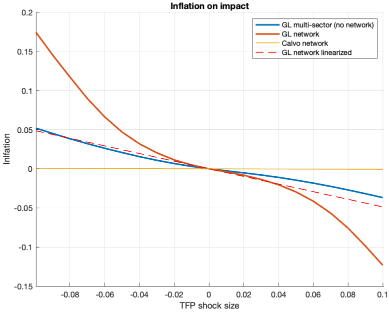
$$\log A_t = \rho \log A_{t-1} + \varepsilon_t^A$$

Networks **speed up** frequency response to TFP shocks



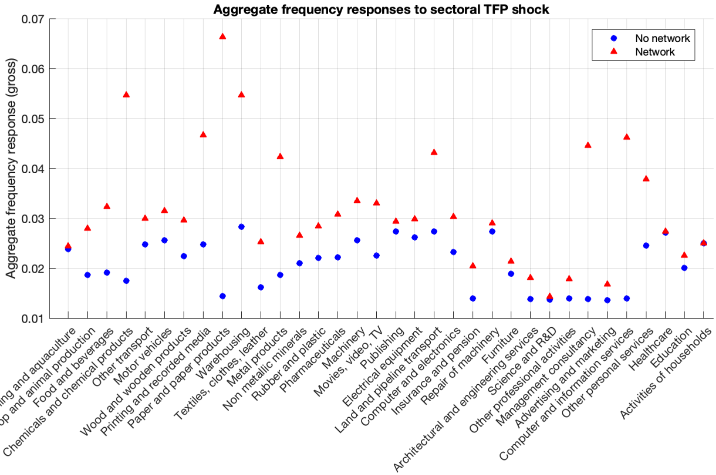
Amplification of output gap and inflation due to networks



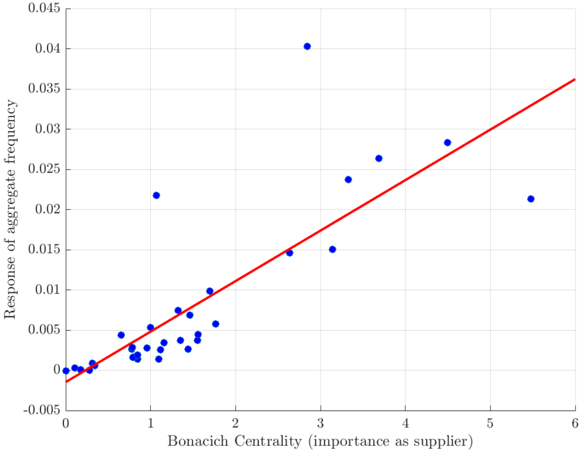


Sectoral TFP shocks

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



Aggregate frequency responses vs. Sectoral Centrality (Katz-Bonacich)



Conclusions

- Present a **dynamic quantitative** general equilobrium model that features: a number of sectors interconnected by networks with state-dependent pricing that is solved fully non-linearly
- Networks **dampen** the extensive margin pricing response to **monetary shocks**: **anti-cascades**
- Networks **amplify** the extensive margin response to **TFP shocks**: **cascades**
- Estimate the model to match sectoral pricing moments and input-output structure for Germany
- Current work
  - Calvo Plus or smooth state-dependent hazard model
  - Application to the (post-)Covid inflationary episode

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