Monetary policy shocks, structural transformation and production networks: a multi-country analysis

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ChaMP WS2 online workshop - December 9, 2025

This project

What is the role of production networks in the impact of monetary policy shocks?

- What is the impact on firm outcomes?
- How does the impact vary with their network position?
- How do monetary policy shocks propagate and generate aggregate outcomes (output, inflation)?

How does the network differ across countries?

- Contributors: Belgium, Estonia, Hungary, Italy, Portugal

Implications for policy

- Networks might amplify or attenuate propagation of monetary policy shocks
- Different network structures can imply different aggregate results

State of the project

The project is structured along 5 dimensions:

1. **Descriptive statistics**
   - number of firms and links across years
2. **Firm heterogeneity and networks**
   - correlations between network stats and firm size, firm size decomposition as in Bernard et al. (2022)
3. **Granularity**
   - Concentration: share of total B2B sales by firms and links
4. **Within-sector heterogeneity**
   - coefficients of variation across firm pairs within each sector pair
5. **Monetary policy**
   - with IRFs estimated on Belgium, how much of the total effect can be attributed to upstream firms?

Application to Belgian data

What we do

Methodology

- ECB monetary policy shocks (Jarocinski & Karadi, 2020).
- Impact on firm sales and prices.
- Local projections (Jorda, 2005; Barnichon & Brownlees, 2019).

Heterogeneity

- Across firms: network upstream/downstream position.
- Across sectors: variation in economic activity and exposure.
- (Next) Across countries: structural differences in specialization patterns and/or network structure?

Data sources: Unbalanced panel (2002-2022)

Monetary policy

- Unexpected ECB monetary policy shocks (Jarocinski & Karadi, 2020).

Firm outcomes

- VAT declarations (NBB): revenues for all firms, quarterly.
- Micro Producer Price Index (Statbel): firm-product-level prices, monthly.
- Sector GDP deflators (NBB): services deflators (NACE 2-digit), quarterly.
- Sectoral frequency of price adjustment, quarterly

Production network

- VAT listings (Dhyne, Duprez and Komatsu, 2023): sales firm-to-firm within Belgium, yearly.

Firm-level responses

Estimation: Impulse Response Functions

Smoothed local projections (Jorda, 2005; Barnichon & Brownlees, 2019)
The impact of a shock at time t at horizon $h = 1, \cdots, H$ on outcome Y for firm i is:

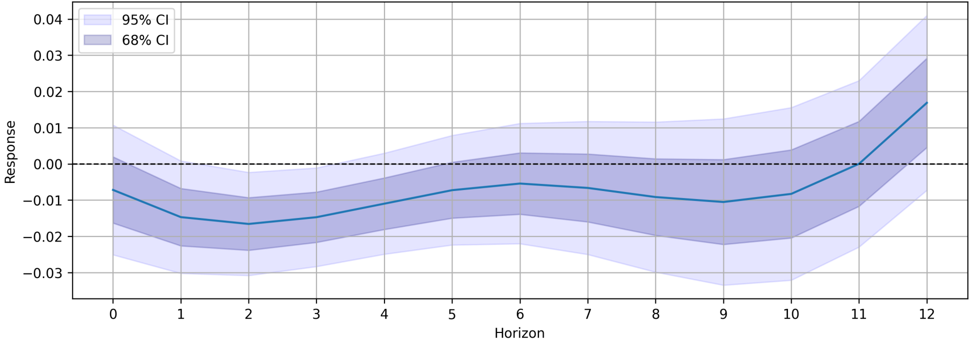
$$\begin{aligned}\Delta^h \log Y_{i,t+h} &= \log Y_{i,t+h} - \log Y_{i,t-1} \\ &= \beta_h \mathrm{MP}_t + \gamma_h X_{i,t} + \alpha_i + \epsilon_{i,t+h}\end{aligned}$$

where

- Outcome $Y_{i,t+h}$: real sales or prices of firm (or firm-product) i at horizon h.
- MP_t: monetary policy shock at time t.
- Controls $X_{i,t}$, including 4 lags of $\Delta \log Y_i$ and MP_t, sectoral frequency of price changes at t.
- Fixed effects α_i: firm or firm-product.
- Driscoll-Kraay SEs $\epsilon_{i,t+h}$: robust (heterosc. and auto-correlation).

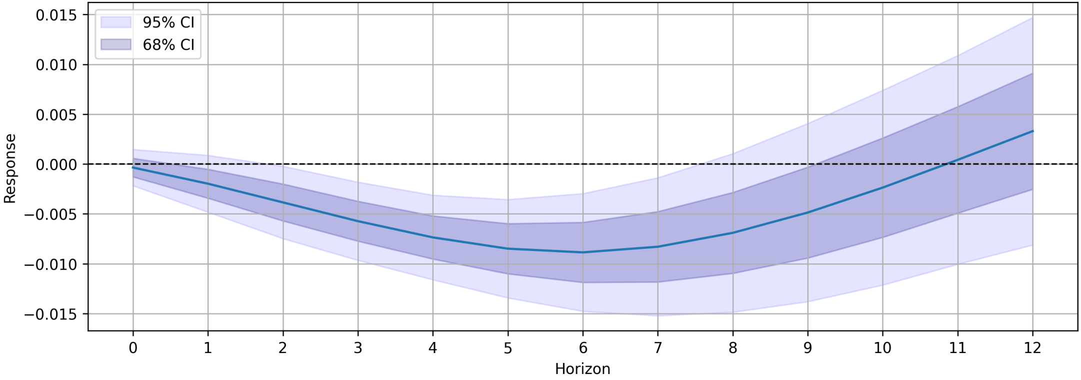
Real sales

- 1 std increase in mon pol shock (+/- 5bp tightening) decreases sales by around 1-2%.
- Largest effect at around 2 quarters.
- Most effect within 6 quarters but decays up to 3 years.



Prices

- 1 std increase in monetary policy shock decreases prices by 0.5-1%.
- Slower impact than sales (max at around 6 quarters).
- Most effect within 3 years.



Firm-level network position

Upstreamness: from final demand to upstream firms

Intuition

- Firm's average distance from final demand in the production network.
- Upstreamness $= 1$ for firms selling only to final demand.
- High upstreamness: firm mostly sells to other producers rather than final demand.

Definition (Antras & Chor, 2012; Fally, 2011)

$$U_i = 1 + \sum_j b_{ij} U_j \quad \Rightarrow \quad \mathbf{U} = (\mathbf{I} - \mathbf{B})^{-1}\mathbf{1}$$

- $B = [b_{ij}]$: revenue-share matrix (downstream to upstream).
- $b_{ij} = \frac{p_i x_{ij}}{p_i y_i}$: share of firm i's output sold to j.

Estimation: Interaction with network position

We estimate:

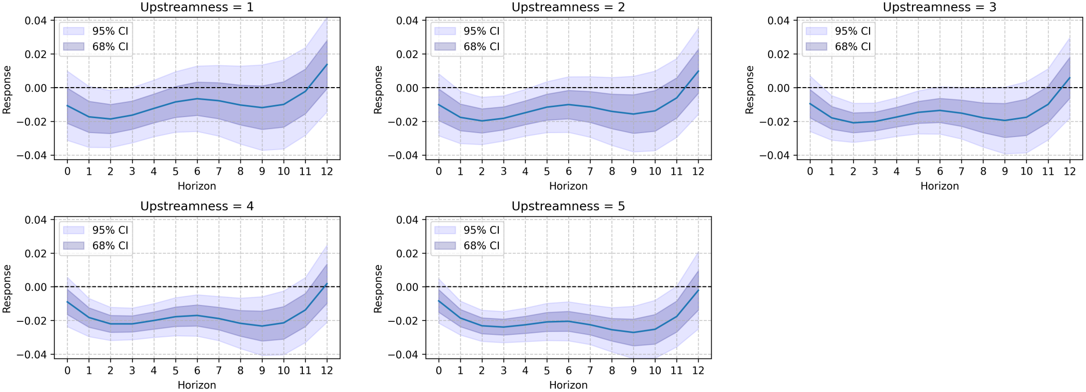
$$\Delta^h \log Y_{i,t+h} = \alpha_i + \beta_h \, \mathrm{MP}_t + \lambda_h \, \mathrm{Up}_{i,y(t)-1} + \delta_h(\mathrm{MP}_t \times \mathrm{Up}_{i,y(t)-1}) + \gamma_h X_{i,t} + \epsilon_{i,t+h}$$

where

- $\mathrm{Up}_{i,y(t)-1}$: at the annual level and fixed in year $y(t)$.
- Total effect: $\beta_h + \delta_h \times \mathrm{Up}_{i,y(t)-1}$.

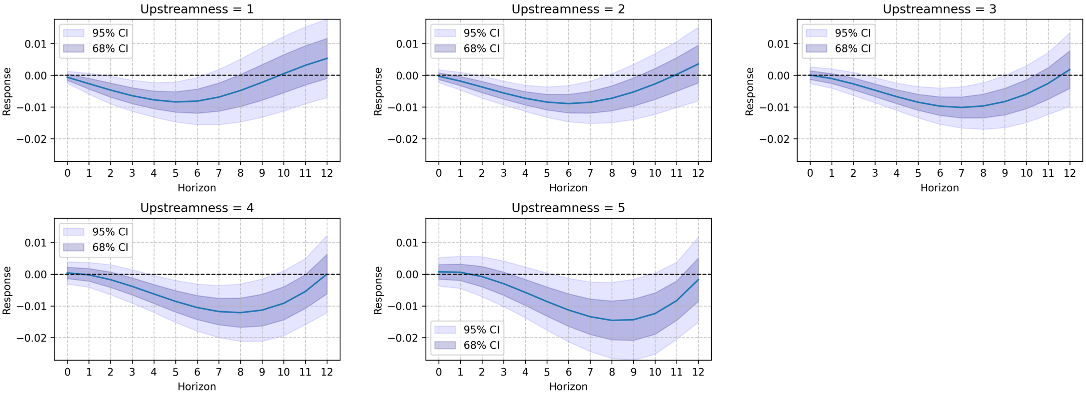
Real sales - upstreamness

- The effect on upstream firms is larger, maxes out later, and is more persistent (up to 3 years).



Prices - upstreamness

- Downstream firms react first, upstream with some delay.



Direct and indirect effects

The transmission of shocks through the network

Question: How do monetary policy shocks propagate across firms linked by input-output relationships?

- Firms are embedded in **production networks**, where outputs of some firms are inputs for others.
- Shocks do not remain localized: they **transmit across the network** via input demand and input costs.
- The structure of the network determines which firms are more exposed to shocks.

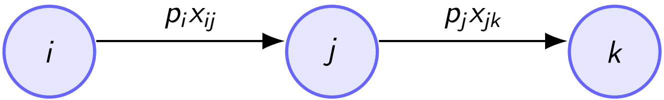
Key mechanisms:

- **Backward propagation** via revenue-based linkages
- **Forward propagation** via cost-based linkages

Revenue-Based propagation

Key idea: Shocks to downstream firms propagate upstream through input demand.

- A **monetary contraction** decreases final demand $\Rightarrow$ contracts sales of final-good firms.
- These firms decrease demand for intermediate goods.
- Upstream suppliers are also affected via **backward propagation**.



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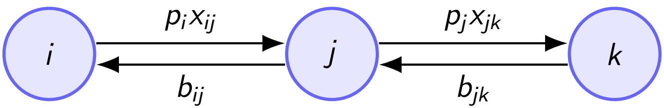
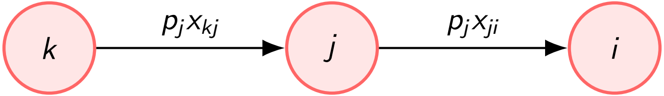


- $b_{ij} = \frac{p_i x_{ij}}{p_i y_i}$: share of firm i's output sold to j.
- Exposure to j: b_{ij}
- Exposure to k: $b_{ij} b_{jk}$
- All-paths (direct + indirect) exposure: $(\mathbf{I} - \mathbf{B})^{-1}\mathbf{1}$

Cost-Based propagation

Key idea: Shocks to upstream firms propagate downstream via input costs.

- A **monetary contraction** raises input costs via interest rates or credit constraints
- Upstream firms pass cost increases to downstream customers
- Downstream firms are affected due to **forward propagation**



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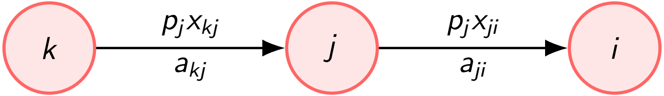


- $a_{ji} = \frac{p_j x_{ji}}{p_i y_i}$: share of firm j's output in the production of i.
- Exposure to j: a_{ji}
- Exposure to k: $a_{kj} a_{ji}$
- All-paths (direct + indirect) exposure: $\mathbf{1}'(\mathbf{I} - \mathbf{A})^{-1}$

Capturing indirect effects through the production network

We estimate:

$$\Delta^k \log Y_{i,t+h} = \beta_h \, \mathrm{MP}_t + \rho_h^1 \sum_j b_{ij} \mathrm{MP}_t + \rho_h^2 \sum_k \sum_j b_{ij} b_{jk} \mathrm{MP}_t + \ldots + \theta_h^1 \sum_j a_{ji} \mathrm{MP}_t + \theta_h^2 \sum_k \sum_j a_{kj} a_{ji} \mathrm{MP}_t + \ldots + \alpha_i + \gamma_h X_{i,t} + \epsilon_{i,t+h}$$

or, in matrix notation:

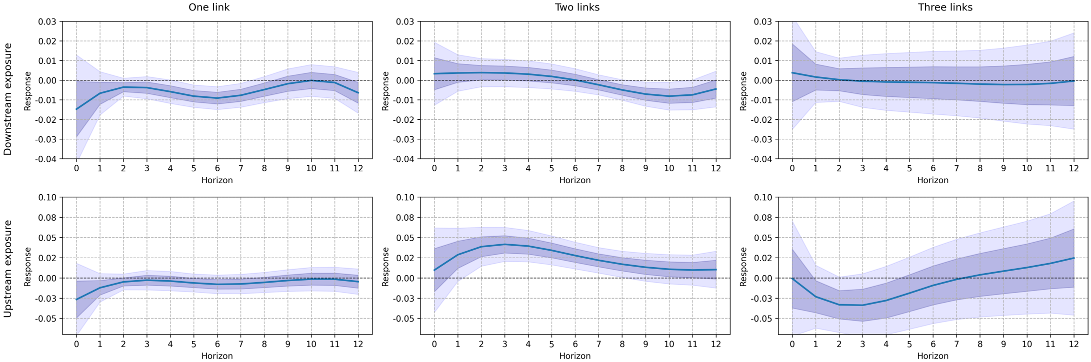
$$\boldsymbol{\Delta}^{\mathbf{k}} \log \mathbf{Y}_{\mathbf{t+h}} = \beta_h \, \mathbf{MP_t} + \rho_h^1 \, \mathbf{B} \, \mathbf{MP_t} + \rho_h^2 \, \mathbf{B}^2 \, \mathbf{MP_t} + \ldots + \theta_h^1 \, \mathbf{MP_t} \, \mathbf{A} + \theta_h^2 \, \mathbf{MP_t} \, \mathbf{A}^2 + \ldots + \boldsymbol{\alpha} + \boldsymbol{\gamma}_h' \mathbf{X_t} + \boldsymbol{\epsilon}_{t+h}$$

Total effect by firm-horizon is:

$$TE_{i,h} = \beta_h + \sum_k^K \rho_h^k \mathbf{B}^{\mathbf{k}} + \sum_k^K \theta_h^k \mathbf{A}^{\mathbf{k}}$$

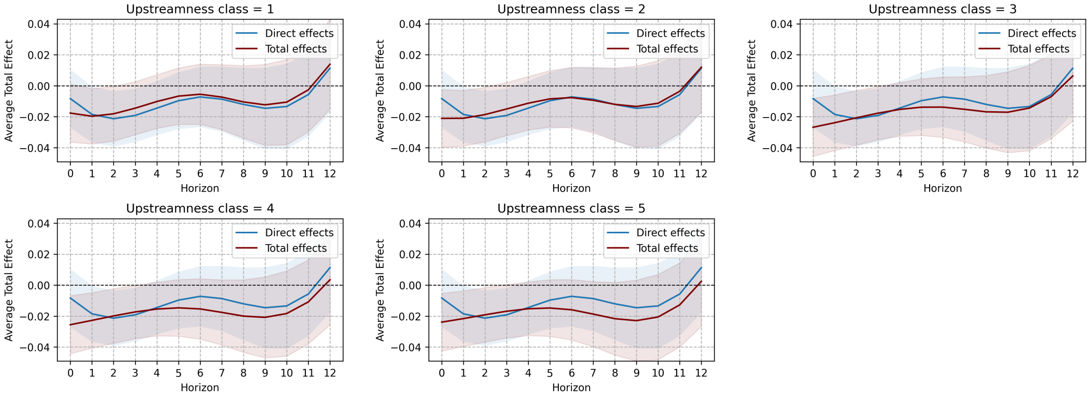
Sales: indirect effects at various distances

- Significant effects downstream, become insignificant after 2 links



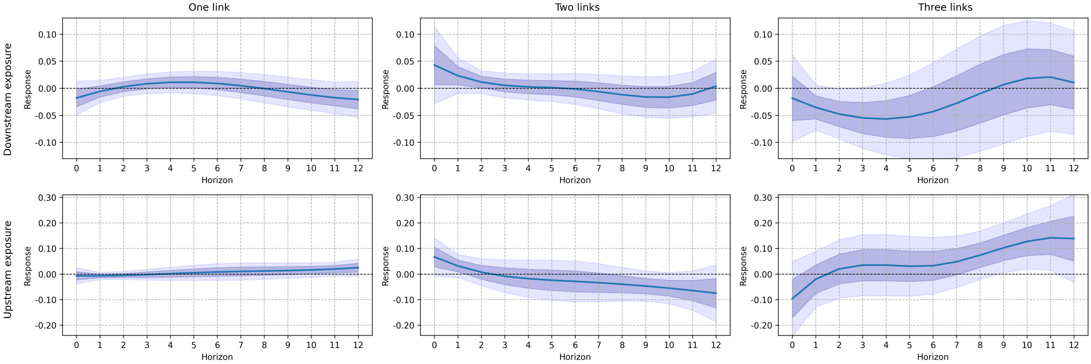
Sales: total vs direct average effects

- Total effects larger for upstream firms, indirect effects dominating after 4 quarters



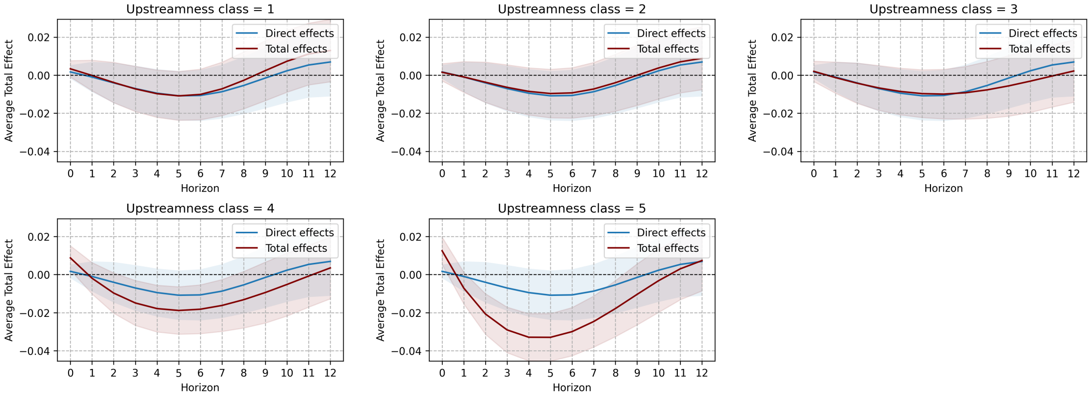
Prices: indirect effects at various distances

- No significant indirect effects on prices



Prices: total vs direct average effects

- Total effects are larger for upstream firms: demand effect



Conclusion

Monetary tightening is consistent with intuition

- Reducing output and prices across the board.
- Price effect takes longer to max out.
- Larger effects in Utilities and Services.

Network position matters for policy response

- More upstream firms react stronger and more persistent in sales.
- Downstream firms react first, upstream with some delay.

Indirect effects play a big role in the transmission of monetary policy

- Backward propagation through sales causes larger effects for upstream firms
- The effects on prices are demand-driven: no forward propagation of costs

Appendix

Monetary Policy Shock: Jarocinski & Karadi (2020)

Extracting monetary policy surprises

- CB announcements include both information on monetary policy and economic outlook.
- Disentangle both using a structural VAR model.
- Exploit high-frequency co-movement of interest rates and stock prices around policy announcements.
- Surprise policy tightening raises interest rates and reduces stock prices.

Method

- Use high-frequency financial data in a 30-minute window around:
  - ECB Governing Council's policy rate decision.
  - ECB President's press conference (forward guidance and communication).
- 280 ECB policy announcements between 1999 and 2016 (extended)
- Estimate surprises in the EONIA interest rate swaps with maturities between 1 month and 2 years and EURO STOXX 50

Smooth Local Projections (Barnichon & Brownlees, 2019)

Standard local projections (LPs)

- Estimate IRF separately at each horizon h, leading to noisy IRFs.

Smooth Local Projections (SLP)

- Impose a smoothness prior across horizons to reduce variance.
- Reduces estimation noise while retaining the flexibility of local projections.

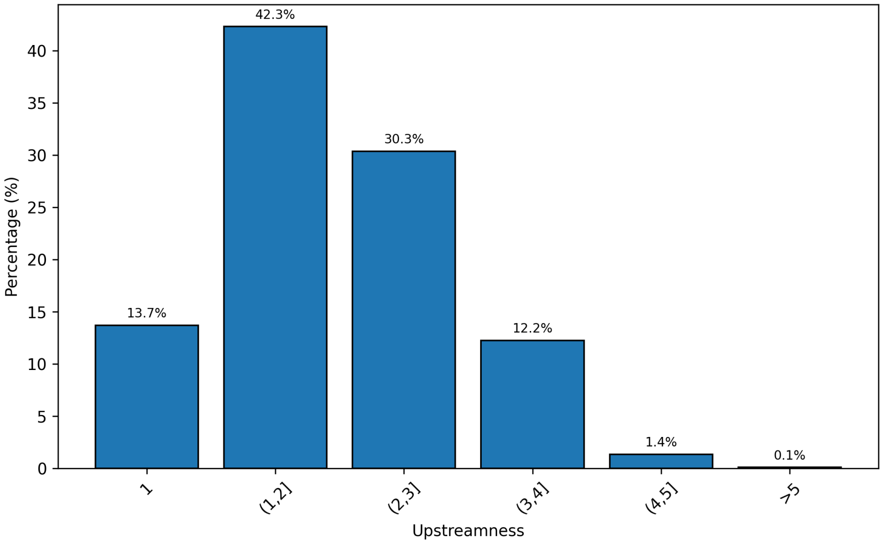
Approach

- Estimate the LP regression: $y_{t+h} = \alpha_h + \beta_h z_t + \varepsilon_{t+h}$
- But treat the impulse response $\{\beta_h\}$ as the evaluation of a smooth function:

$$\beta_h = \sum_{k=1}^{K} \theta_k B_k(h)$$

  where $B_k(h)$ are basis functions (e.g., B-splines)
- Estimate $\theta = (\theta_1, \ldots, \theta_K)$ via penalized least squares

Distribution of upstreamness (pooled across years)



Sales - number of customers/suppliers

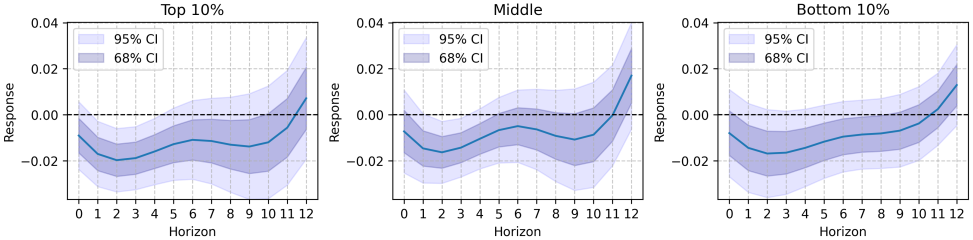
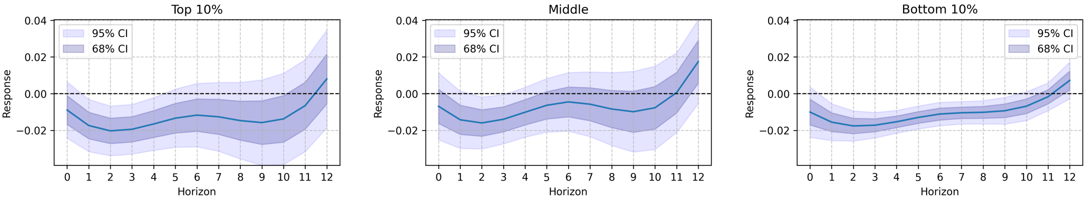


Figure: IRFs for top and bottom 10% of **outdegree** distribution.



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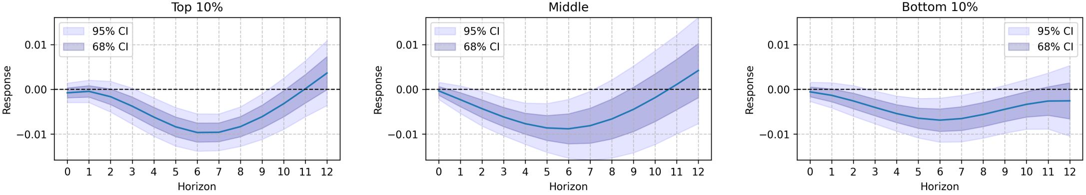

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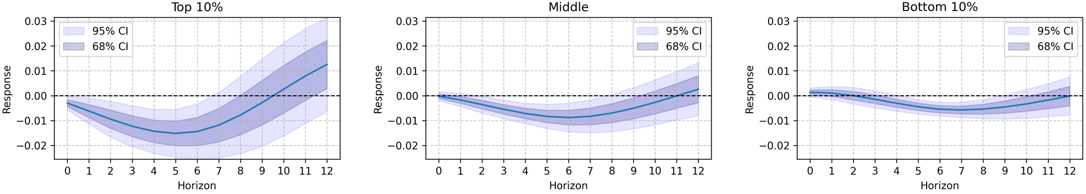

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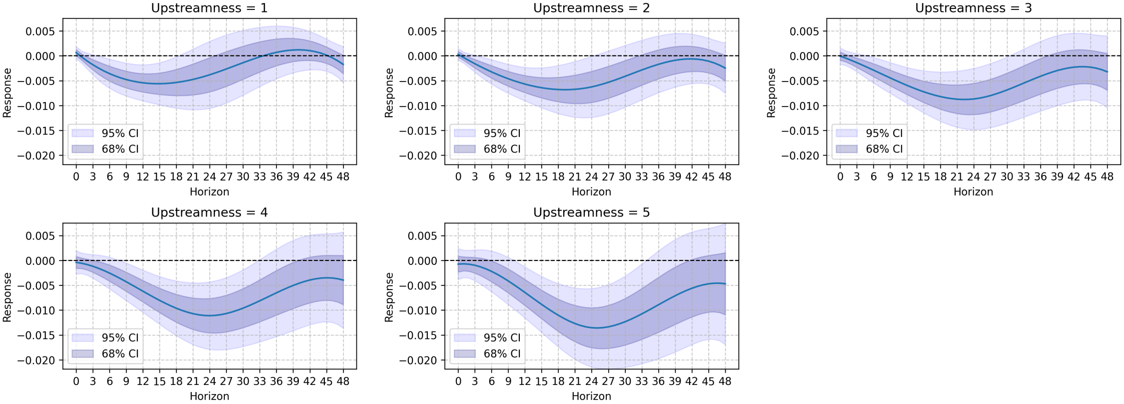
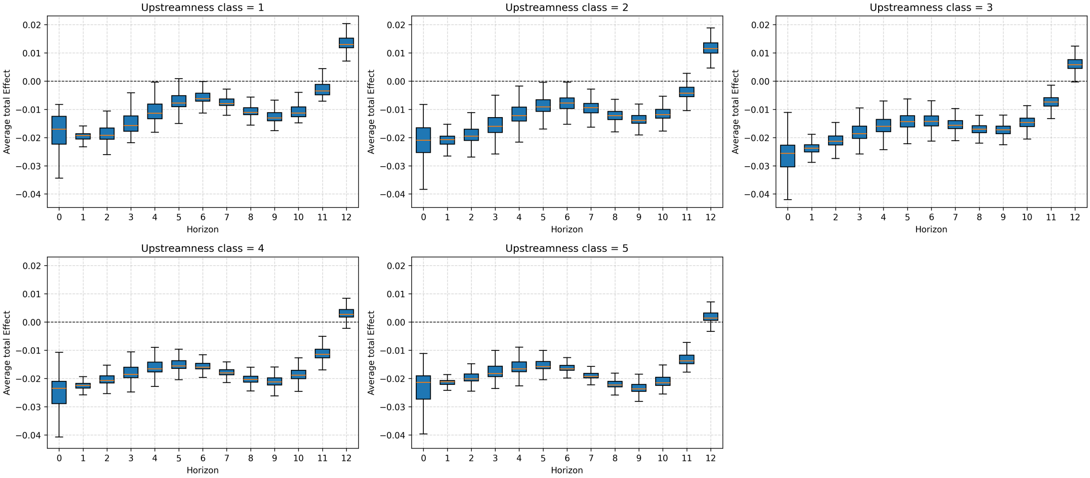
Monthly prices - upstreamness



- Similar results also with monthly prices

Total average indirect effects sales - Boxplots



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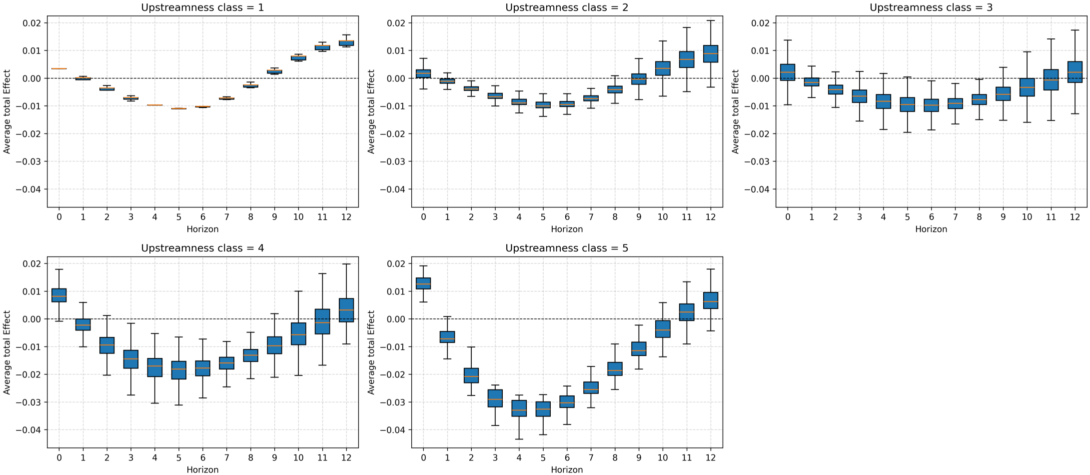
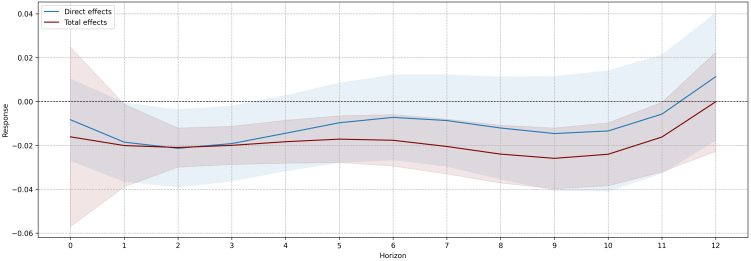
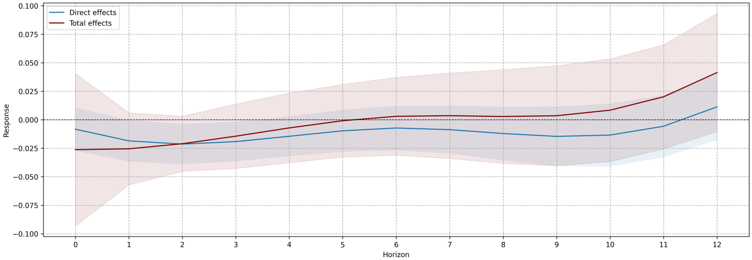


Sales: upstream vs downstream firms

$\mathbf{A^k} = 0 \rightarrow$



$\mathbf{B^k} = 0 \rightarrow$



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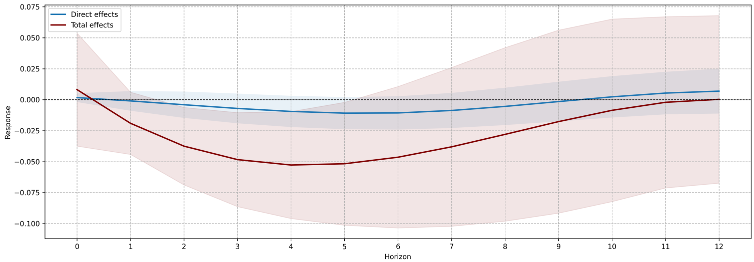

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