Beyond firm size: network position and shock transmission in firm-to-firm production networks across five economies

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Motivation

Production networks are central to modern macroeconomics

- How shocks propagate, how micro shocks become aggregate fluctuations, how policy transmits — all depend on firm-to-firm linkages.

Yet quantitative work leans on two workhorses

- **Firm size** (Domar weights): a scalar summary of a firm's importance.
- **Sector-level input–output tables**: representative firms linked by average relationships.

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Question: when studying propagation and aggregation, how much do we lose by working with size and sectors alone? What is the *economically relevant* heterogeneity that lives *within* sectors and *beyond* scale?

This project

Systematic characterization of firm-to-firm production networks

- Administrative VAT + tax-filing data for **five European economies**.
- Harmonized, comparable network moments across countries.

Two goals

- **Measurement:** document structural, distributional and aggregation properties of firm-level networks.
- **Relevance:** show these distinctions matter economically — leading application: transmission of monetary policy.

Preview: five facts

1. Position vs. scale. Size and centrality summarize a firm's first-order aggregate *impact*; **vertical position** (up/downstreamness) is orthogonal to size and governs *propagation*.

2. Size is a network object. $\sim$half of within-industry size dispersion reflects a firm's **number of customers**, not a primitive like productivity.

3. Granularity beyond size. Network sales, transaction values and number of customers are **heavy-tailed**, spanning several orders of magnitude within narrow industries.

4. Firm networks $\neq$ IO tables. Firm-to-firm networks are **orders of magnitude sparser**, "roundabout" production vanishes, and input shares vary widely within narrow sector pairs.

5. It matters for policy. Firm responses to monetary policy vary systematically with **vertical position**; cross-country differences generate heterogeneous aggregate responses to a common shock.

Data

Data sources

Firm-to-firm production network

- Administrative VAT filings, from annual client listings to invoice-level electronic invoicing: domestic business-to-business transactions at the firm level, yearly.
- Hundreds of thousands to millions of firms; up to tens of millions of relationships per country.

Firm characteristics

- Annual accounts and business registries: sales, inputs, NACE sector.

Five economies, harmonized

- Belgium, Estonia, Hungary, Italy, Portugal — different sizes, industrial structures, institutions.

Firms' positions in production networks

Fact 1

Two network measures

Katz–Bonacich centrality — aggregate influence (Acemoglu et al., 2012; Magerman et al., 2017)

- A firm's (first-order) **aggregate influence**: how much a shock to it moves the economy-wide aggregate, propagating through its **direct and indirect sales** across the network.

Upstreamness / downstreamness — vertical position (Antras & Chor, 2012; Fally, 2011)

- **Upstreamness:** average distance from **final demand** along supply chains — how many production stages before a firm's output reaches consumers.
- **Downstreamness:** the symmetric distance from **primary inputs**.

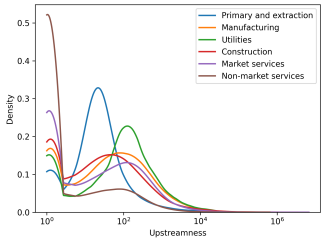
Centrality tracks size, vertical position is the distinct dimension

- **Centrality and firm size coincide** — by construction: the influence vector is the Domar weight ($\mathbf{v} \propto$ size, Hulten logic), so centrality adds no dimension beyond scale.
- **Upstreamness and downstreamness** — a firm's *vertical position* along supply chains — are instead **orthogonal to size** and **uncorrelated with each other** at the firm level (unlike the positive *sector*-level correlation in *Antras & Chor, 2018* — an aggregation artifact).

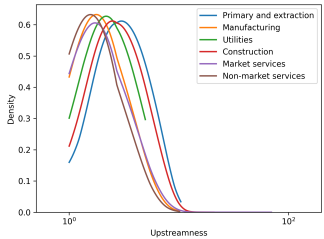
	Belgium	Estonia	Hungary	Italy	Portugal
Corr($\ln U_i$, $\ln S_i$)	0.01	−0.10	−0.04	0.06	−0.03
Corr($\ln U_i$, $\ln D_i$)	−0.03	0.17	0.17	−0.01	−0.01

Fact 1: what firm size does *not* capture is **vertical position** — and it is not recoverable from sector-level IO tables.

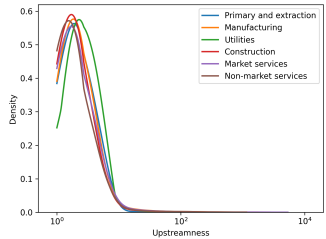
Vertical position is not a sector phenomenon



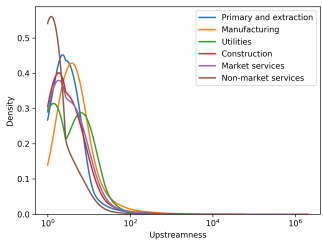
Belgium



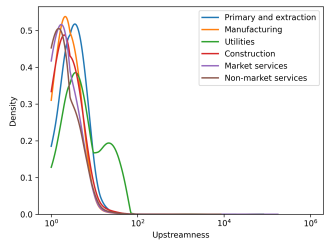
Estonia



Hungary



Italy



Portugal

What drives firm size?

Fact 2

An exact decomposition of firm size

Splitting total sales into domestic network sales and final demand, $S_i = \sum_{j \in \mathcal{C}_i} m_{ij} + F_i$, firm size decomposes exactly (*Bernard et al., 2022*):

$$\ln S_i = \ln G + \ln \psi_i + \ln n_i^c + \ln \bar{\theta}_i + \ln \Omega_i^c + \ln \beta_i$$

- $\ln \psi_i$ — **upstream**: seller fundamentals (sales to its average customer).
- $\ln n_i^c$ — **number of customers** (extensive margin).
- $\ln \bar{\theta}_i$ — average size of those customers (intensive margin).
- $\ln \Omega_i^c$ — match quality.
- $\ln \beta_i = \ln\left(S_i / S_i^{net}\right)$ — **final demand**: sales outside the domestic network.

The extensive margin of customers dominates

	Upstream	Downstream			Final dem.
Country	$\ln \psi_i$	$\ln n_i^c$	$\ln \bar{\theta}_i$	$\ln \Omega_i^c$	$\ln \beta_i$
Belgium	0.18	**0.46**	0.05	0.20	0.12
Estonia	0.21	**0.45**	0.03	0.21	0.10
Hungary	0.22	**0.42**	0.04	0.22	0.11
Italy	0.16	**0.51**	0.05	0.26	0.01
Portugal	0.19	**0.49**	0.02	0.23	0.07

- The **number of customers** accounts for $\sim$**half** of within-industry size variance.
- Seller-side fundamentals: secondary; final demand: modest.
- Strikingly stable across countries.

Fact 2: firm size is itself a **network object** — driven by how many customers a firm reaches, not a scalar primitive.

Multi-dimensional granularity

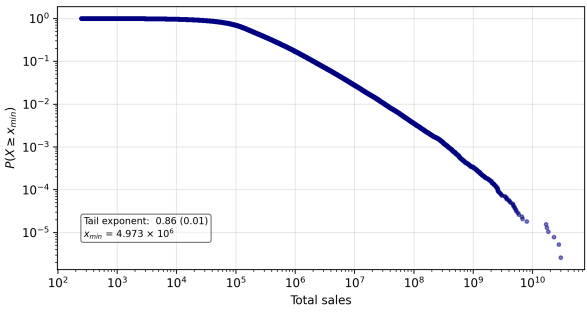
Fact 3

Activity is highly concentrated

	Network sales		Bilateral relationships	
Country	Top 10%	Top 1%	Top 10%	Top 1%
Belgium	0.89	0.64	0.92	0.72
Estonia	0.81	0.45	0.81	0.50
Hungary	0.86	0.59	0.86	0.61
Italy	0.87	0.61	0.93	0.72
Portugal	0.87	0.63	0.96	0.79

- Concentration along *two* margins: across firms *and* across relationships.
- Top 1% of firms account for $\sim$45–64% of all inter-firm sales.
- Top 1% of bilateral relationships account for $\sim$50–80% of total network sales.
- Representative firms / relationships are a poor approximation of the real network.

Heavy tails along several dimensions



CCDF of firm sales, Belgium (2019, log-log).

- Sales, network sales, transaction values, and number of customers are all **heavy-tailed**.
- Spanning several orders of magnitude.

Granularity is **multi-dimensional**:

- a few firms dominate $\rightarrow$ a shock to them is a shock to the aggregate
- it does not reduce to a single "firm size" distribution.

Dispersion persists within narrow industries

- Demeaning by NACE 4-digit industry leaves distributions almost unchanged.
- Within-industry dispersion in connections, sales and exposure remains large.
- Remarkably similar across the five countries.

Fact 3: heterogeneity is a firm-level phenomenon — it cannot be attributed to sectoral composition.

Networks vs. input–output tables

Fact 4

Aggregation changes the object: density collapses

	Density ρ			Within share	
Country	NACE-2	NACE-4	Firms	NACE-2	Firms
Belgium	0.95	0.54	4.4×10^{-5}	0.17	0
Estonia	0.80	0.24	7.8×10^{-5}	0.10	0
Hungary	0.78	0.29	2.1×10^{-5}	0.16	0
Italy	0.91	0.58	2.1×10^{-5}	0.22	0
Portugal	0.93	0.62	1.8×10^{-4}	0.08	0

- Sector IO networks are **dense**, firm networks are **extremely sparse**: >99.99% of potential links absent.
- "Roundabout" production (diagonal within-share) **vanishes** at the firm level.

Sector coefficients hide enormous firm-level dispersion

Country	Avg. input share (NACE-4)	CV (NACE-2)	CV (NACE-4)
Belgium	0.02	3.36	1.98
Estonia	0.05	2.09	1.35
Hungary	0.03	2.22	1.45
Italy	0.01	3.84	2.17
Portugal	0.01	4.28	2.36

- The CV measures how spread out firms are relative to their average: a "representative" coefficient describes almost no firm.
- Output side: the same picture.

Fact 4: sector IO coefficients are, at best, a coarse summary of firm-to-firm linkages.

Economic relevance: monetary policy

Fact 5

Transmission of monetary policy: setup

Three steps

- **Belgium:** estimate firm-level responses that vary with vertical position (*Dhyne, Magerman & Palazzolo, 2026*).
- **Estonia:** re-estimate independently — out-of-sample check.
- **Calibration:** combine the estimated responses with each country's upstreamness distribution.

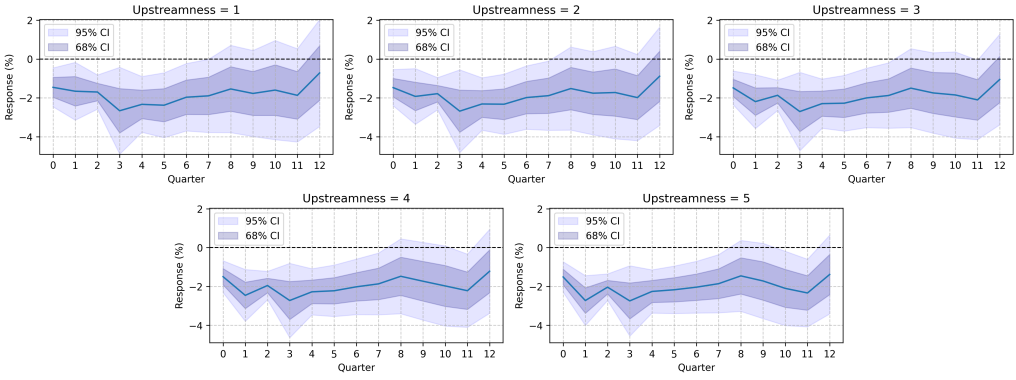
Local projection, shock × vertical position (Jorda, 2005; ECB shocks: Jarocinski & Karadi, 2020):

$$\Delta^h \log Y_{i,t+h} = \underbrace{\alpha_i + \kappa_{q(t)}}_{\text{FE}} + \underbrace{\beta_h \, \text{MP}_t}_{\substack{\text{effect} \\ \text{of MP shock}}} + \underbrace{\delta_h \big(\text{MP}_t \times \bar{U}_{i,t-1}\big)}_{\substack{\text{differential effect} \\ \text{(interaction)}}} + \lambda_h \, \bar{U}_{i,t-1} + \gamma_h X_{i,t} + \epsilon_{i,t+h}$$

- $\bar{U}_{i,t-1}$: 3-year moving-average upstreamness (predetermined). Total effect: $\beta_h + \delta_h \, \bar{U}_{i,t-1}$.

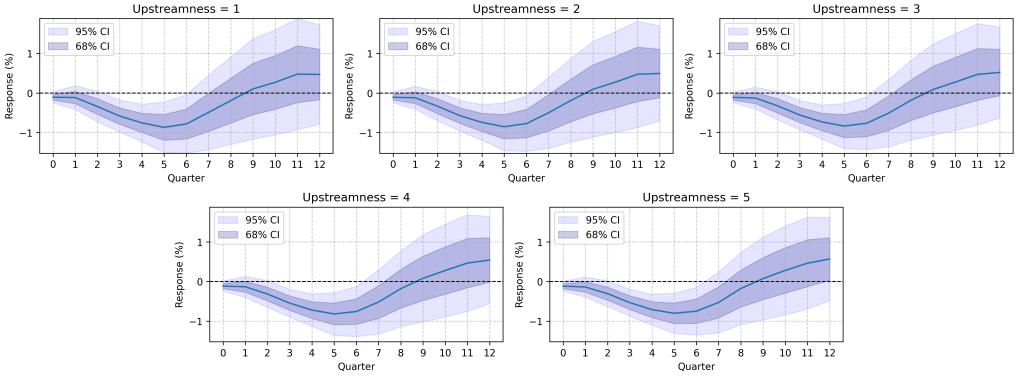
Belgium: real sales by upstreamness

- A 1 s.d. contractionary shock cuts real sales $\sim$1.5% on impact, troughing at $\sim$2.5% (quarter 3) and $\sim$2% below baseline for about two years.
- The gradient is in the *recovery*: downstream ($U=1$) returns to zero by the 3-year horizon; upstream ($U=5$) stays depressed longer.



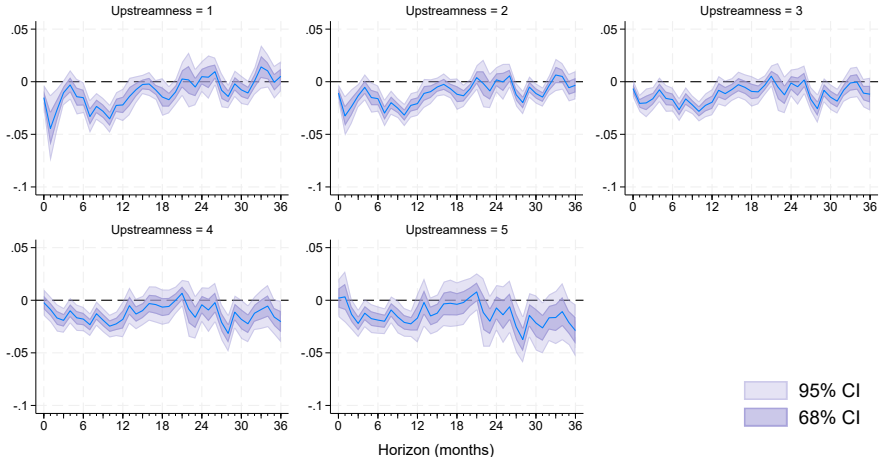
Belgium: prices by upstreamness

- Prices adjust less and slower than sales: a gradual decline to ∼0.8–0.9% (quarters 5–6), back to baseline by quarter 8–9.
- The price trough lags the sales trough by 2–3 quarters — slow, demand-driven adjustment.

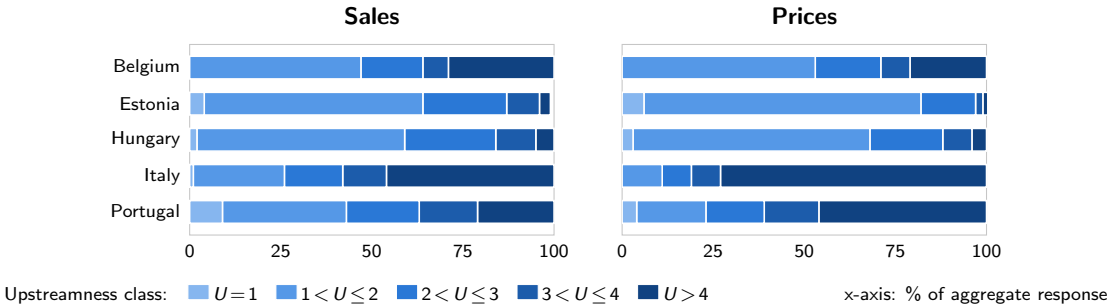


Estonia: out-of-sample (monthly real sales)

- Re-estimated independently on Estonian monthly VAT data (36 months): the position gradient reappears out of sample.
- Downstream ($U=1$) drops sharply on impact ($\sim$5–7%), reverting by $\sim$20 months; upstream ($U=5$) is muted early, then *deepens* to $\sim$4–5% late (months $\sim$28–36).



Cross-country: position shapes the aggregate response



- Each bar splits a country's aggregate response by upstreamness class (Belgian IRFs $\times$ local upstreamness distribution); bars sum to 100%.
- Italy's response mass sits *upstream*, Estonia/Hungary *downstream* $\Rightarrow$ **heterogeneous aggregate responses** to a common shock.

Fact 5: firm-level vertical position is economically first-order — and invisible in sector-level aggregates.

Conclusion

One point, five facts

1. Size and centrality capture aggregate *impact*; **vertical position** captures *propagation* and is orthogonal to both.
2. Firm size is a **network object**: driven by the number of customers.
3. Granularity is **multi-dimensional** and lives within industries.
4. Firm networks are **sparse and heterogeneous** — fundamentally different from IO tables.
5. Position drives **monetary-policy transmission** and cross-country aggregate responses.

Firm size and sector IO tables miss economically meaningful variation in **network position**.

Future work: estimate monetary-policy responses *country by country*, so the aggregation uses each economy's *own* impulse responses.