AMPLIFICATION OF CLIMATE POLICY RISKS FOR THE BANKING SYSTEM DUE TO PRODUCTION NETWORK CONTAGION

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MOTIVATION

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New policy plans to reduce CO2 emission

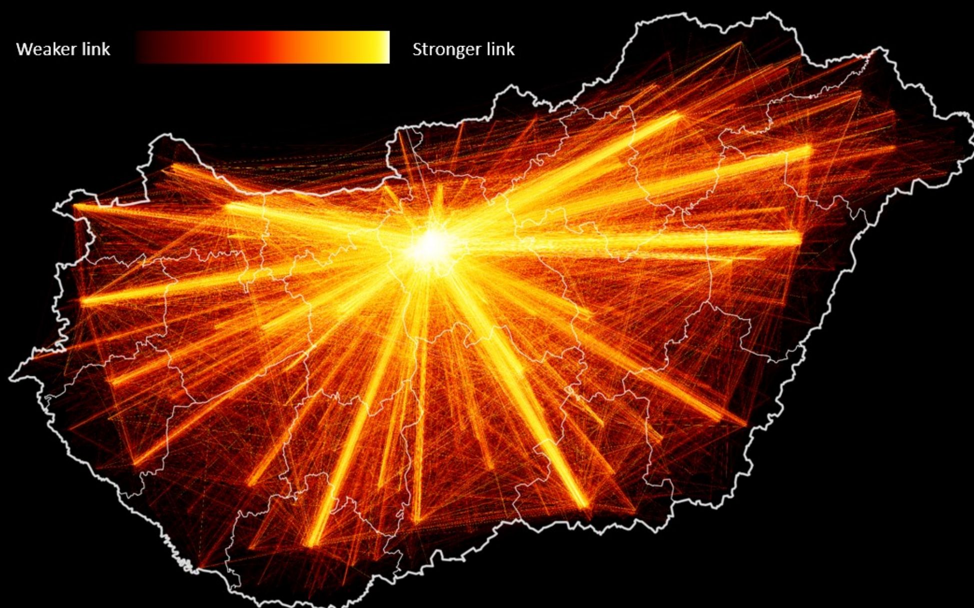
- Emission Trading System (ETS) 2:
  - ETS 1 covers **only 25-30% of all emissions**
  - **ETS 2** would cover **more industries:** Buildings, Energy generation, Road transportation, Manufacturing (unless already covered by the EU ETS), Construction
  - **No freel**y distributed allowances
  - 45 USD initial **price cap** (but many arguments for much higher prices)
- Carbon Border Adjustment Mechanism (CBAM)
  - Carbon price on certain goods imported into the EU
  - Targeting „Scope 3" **indirect emissions** in a company's **value chain**

Impact on the financial system

- Strict and sudden command-and-control approaches can cause:
  - → price shocks
  - → difficulties in transitioning to green technologies leading to firm defaults
  - → disruptions in the supply chains
  - → increased risks in the financial system
- There is no reliable methodology to handle these mechanisms in financial risk management:
  - insufficient data
  - only very partial knowledge of the parameters of the shock spreading
  - modelling challenges
- **→ Data-driven simulation model**

DATA

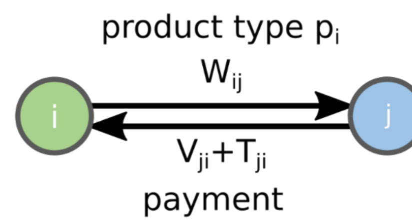
THE HUNGARIAN SUPPLIER NETWORK



Supplier connections among Hungarian firms (based on 2016 data)

- **Data source**: VAT tax reports (**2015-2022**)
- **Value threshold**:
    - 2015-2017: tax content above **EUR 2,500**/period
    - 2018-2020: tax content above **EUR 250**/invoice
    - 2021- : no threshold
- **Correction with ownership links**

- Record of (all) firms' stable supplier-buyer transactions, $\boldsymbol{W_{ij}}$, within the country
- Firm $\boldsymbol{i}$ (supplier) sells the amount $\boldsymbol{W_{ij}}$ of product type $\boldsymbol{p_{ij}}$ to firm $\boldsymbol{j}$ (buyer):

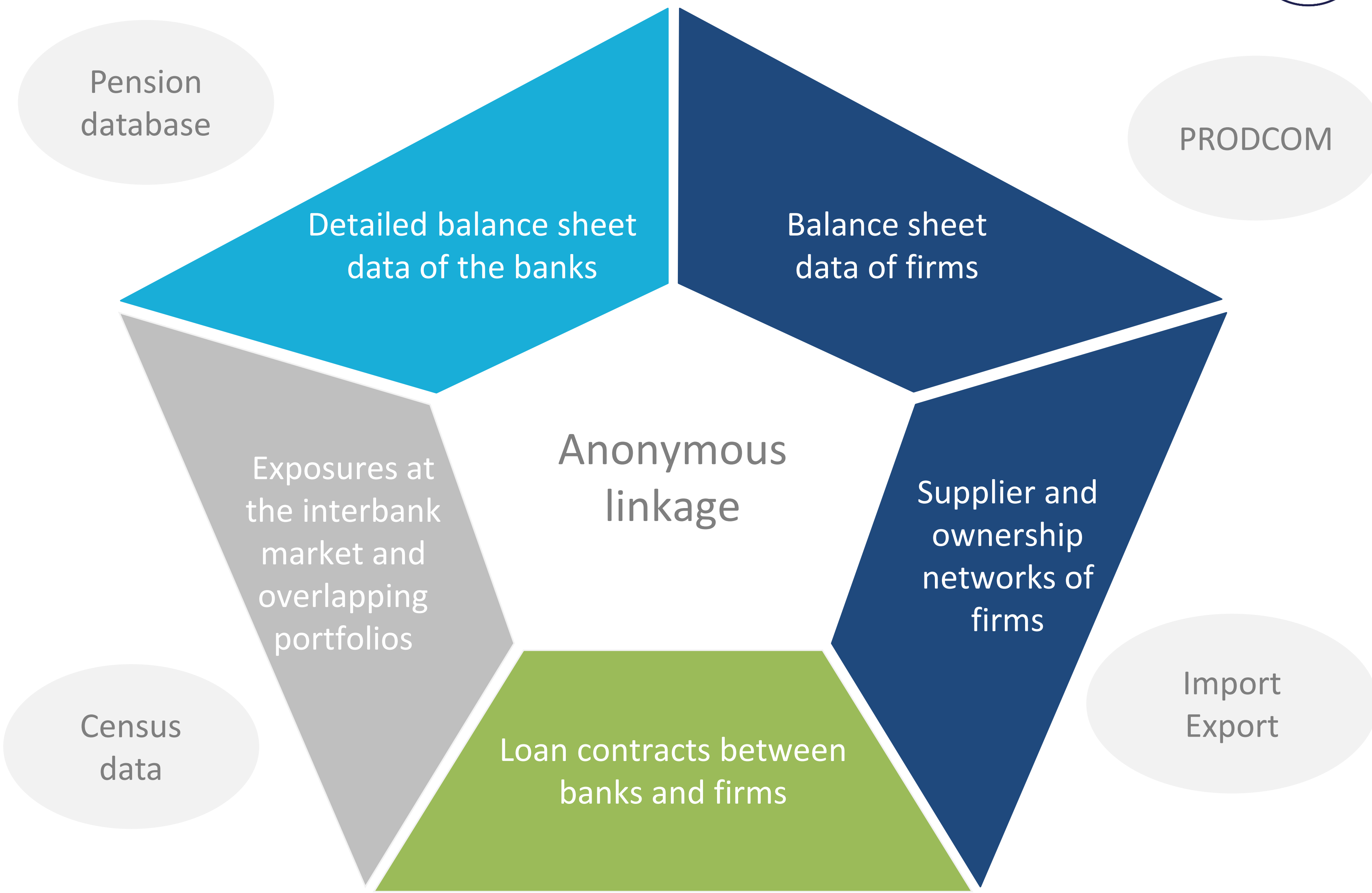


- Hungarian VAT data for 2022: 410,000 firms & 10,600,000 links
- No international trade, price and product data

Borsos A., Stancsics M.. Unfolding the hidden structure of the Hungarian multi-layer firm network. No. 139. MNB Occasional Papers, 2020.

Bacilieri, A., Borsos, A., Astudillo-Estevez, P., & Lafond, F. (2023). Firm-level production networks: what do we (really) know. Unpublished results, University of Oxford.

LINKED DATASETS



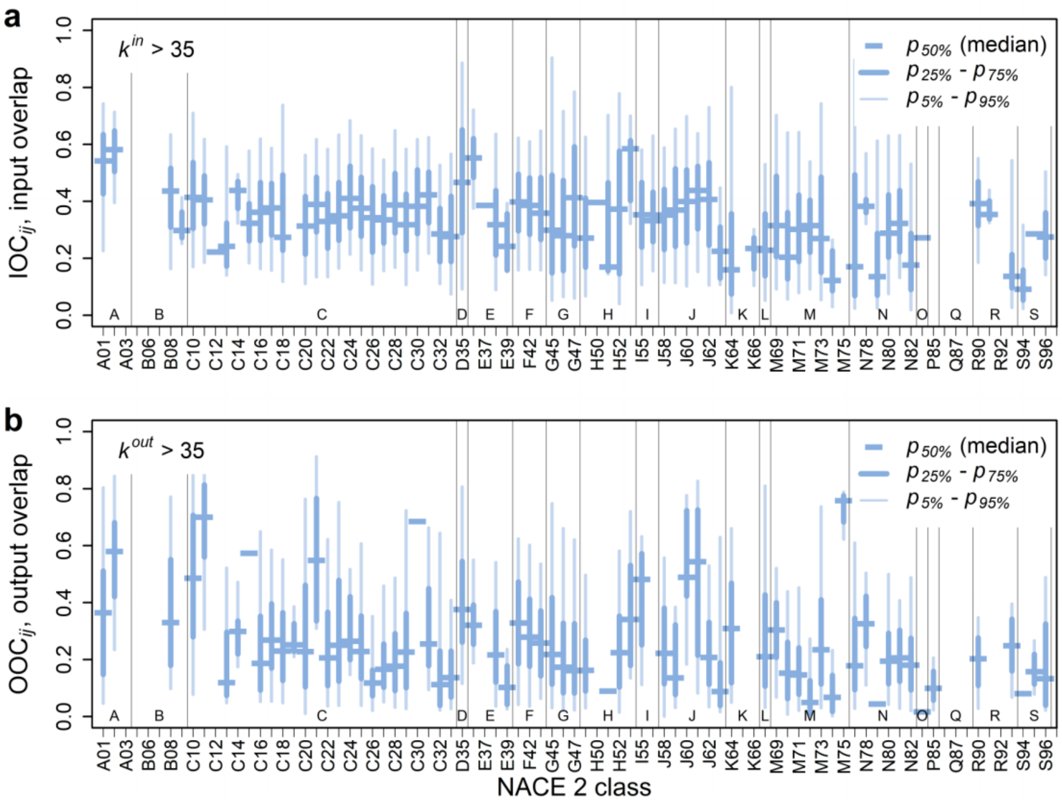
DO NETWORKS IN THE REAL ECONOMY MATTER? - THEORY

Arguments supporting the irrelevance of network effects in production

- Lucas Jr (1977):
  - Firm-level shocks do not have any influence on macroeconomic fluctuations.
  - They cancel each other out based on the law of large numbers.
- Hulten (1978):
  - Domar weights (sales as a share of GDP) of firms (or industries) are sufficient statistics to assess the aggregate total factor productivity (TFP) impact of micro-level TFP shocks.
  - Same weight for an electricity provider and for a retail company?

New arguments claiming that network effects are important

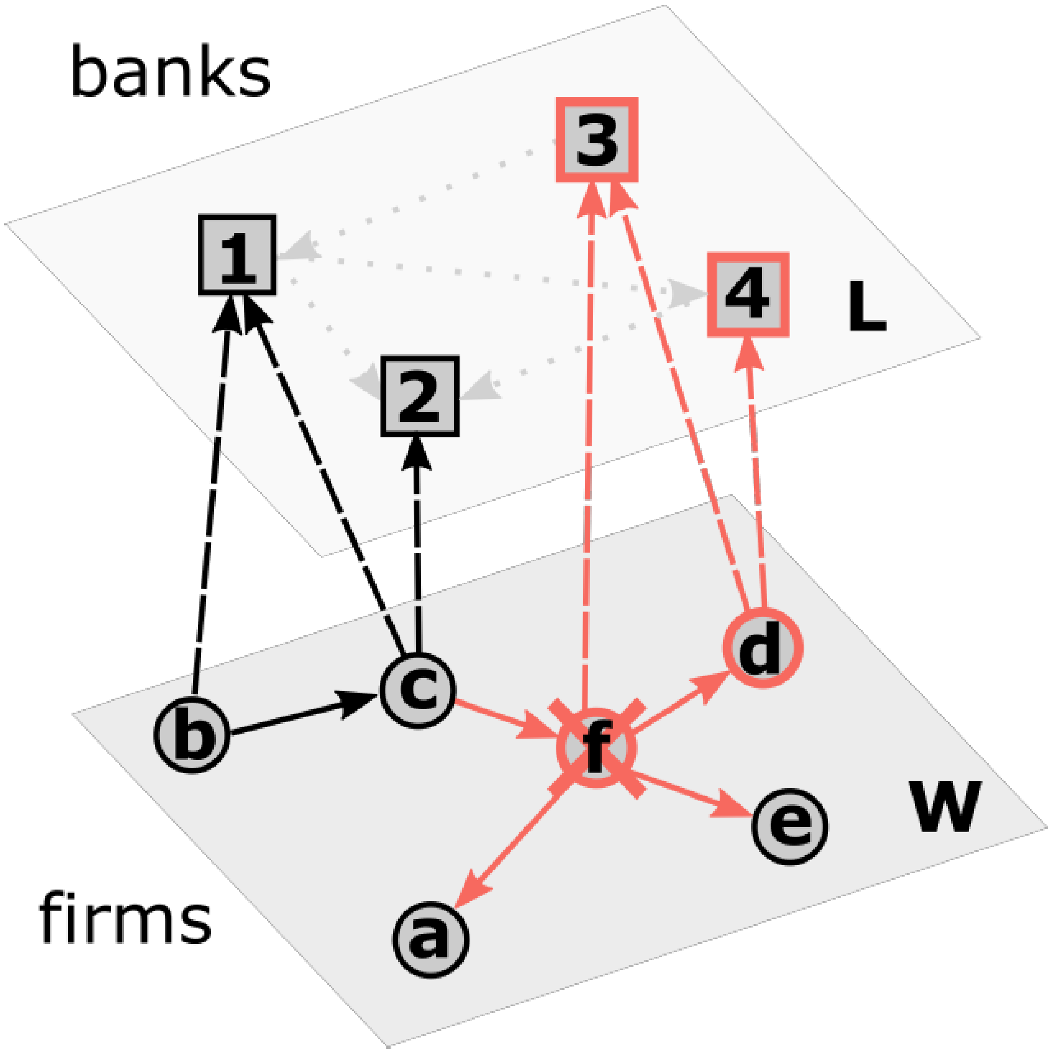
- Gabaix (2011) and Acemoglu et al. (2012):
  - The size of companies can be described by power-low distribution
  - High probability of extremely large observations → very slow convergence in diversification
- Baqaee and Farhi (2019):
  - Domar weights themselves can be influenced by TFP shocks→ second-order effects should also be considered
- Baqaee and Farhi (2020):
  - Even considering only first-order impacts, the network structure is important if there are frictions in the economy.



C. Diem, A. Borsos, T. Reisch, J. Kertész, S. Thurner, Estimating the loss of economic predictability from aggregating firm-level production networks, PNAS Nexus, 2024 page064, https://doi.org/10.1093/pnasnexus/pgae064

- From the point of view of shock propagation, industry classification is a rather unreliable grouping of firms
  - Firms in each industry can have very different in(out)put structures.
  - **Relative Overlap Coefficient** for two in(out)put vectors:
  - $roc_{x,y} = \sum_i \min(\bar{x}, \bar{y})$
  - The fraction of in(out)puts firm i and firm j buy (sell) from (to) the same industries
- The typical average pairwise in(out)put overlap between firms in most sectors is very low (0.33 and 0.26 on avg.)

METHODOLOGY



- Firm **f** profit reduction:
  - (1 – shock)*(rev. – costs)
- Firm **f** defaults if
  - equity ≤ profit reduction
  - (short term liquidity ≤ profit reduction)
- Firms **a, c, d, e** are also affected by the failure of **f**
  - Firm **d** defaults too
- Banks suffer losses
  - Bank **3**'s losses are amplified direct loss from **f** and indirect loss from **d**
  - Bank **4** was not connected to the initially affected firm, but it still suffers indirect losses

SIMULATION STEPS

1. We construct a **firm-level initial price shock** from empirical emission data (ETS) and supply chain links to the oil, gas, and coal producer/distributor industries.

2. The **increased costs** can be partially passed through to the buyers (based on bargaining power estimation from market shares) leading to a **reduction of income and profit** of firms.

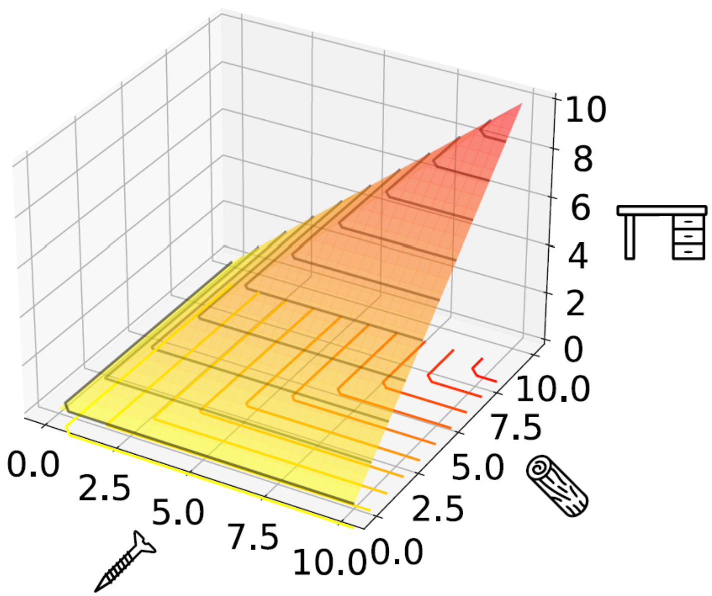
3. The equity (and liquidity) buffers of firms might be insufficient to survive the shock leading to **1) the halting of production** and **2) defaulting on loans.**

4. Due to **1)** the shock propagates along the **supply links** of firms **upstream** and **downstream** until production levels are stable.

5. Due to **2) banks suffer losses** after writing off the loans of the **initially shocked** (and defaulted) firms, and the firms that default due to supply chain **network contagion.**

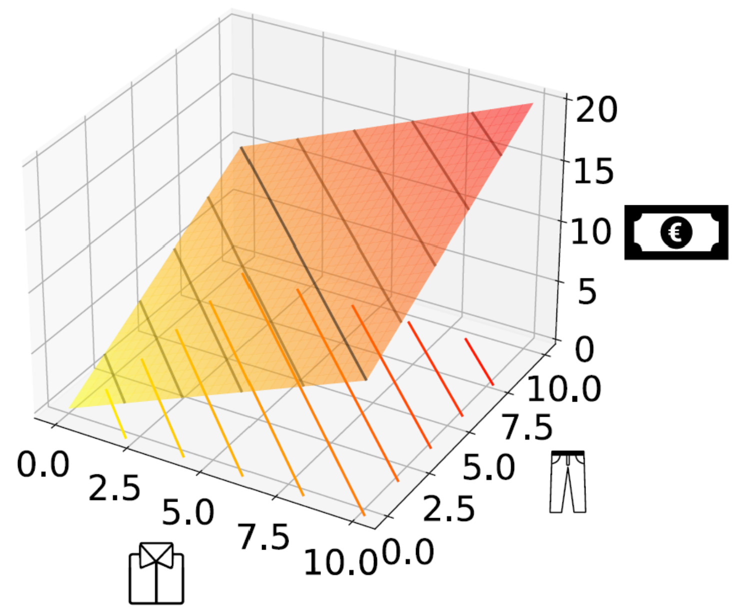
Leontief PF
(physical production)

(a) α_1 + α_2 $\longrightarrow$ $\min(\alpha_1,\alpha_2)$



Linear PF
(trade and services)

(b) α_1 + α_2 $\longrightarrow$ $(\alpha_1 + \alpha_2)$



Production functions of firms can even be the combination of the two

(E.g. essential inputs: Leontief, but non-essential inputs: linear)

ITERATE UPDATE EQUATIONS UNTIL CONVERGENCE TIME T:

Replaceability factor:

$$\sigma_j(t) = \min\left[\frac{s_j^{\text{out}}(0)}{\sum_{l=1}^{n} s_l^{\text{out}}(0) h_l^d(t)\delta_{p_l,p_j}}, 1\right]$$

Fraction of essential inputs:

$$\tilde{\Pi}_{ik}(t) = 1 - \sum_{j=1}^{n} \sigma_j(t)\Lambda_{ji}^{d}\left(1 - h_j^{\text{d}}(t)\right)\delta_{p_j,k}$$

Fraction of non-essential inputs:

$$\tilde{\Pi}_{ik'}(t) = 1 - \sum_{k\in\mathscr{I}_i^{\text{ne}}}\sum_{j=1}^{n} \sigma_j(t)\Lambda_{ji}^{d}\left(1 - h_j^{\text{d}}(t)\right)\delta_{p_j,k}$$

Downstream production level:

$$h_i^{\text{d}}(t+1) = \min\left[\min_{k\in\mathscr{I}_i^{\text{es}}}\left(\tilde{\Pi}_{ik}(t)\right), \tilde{\Pi}_{ik'}(t), \psi_i\right]$$

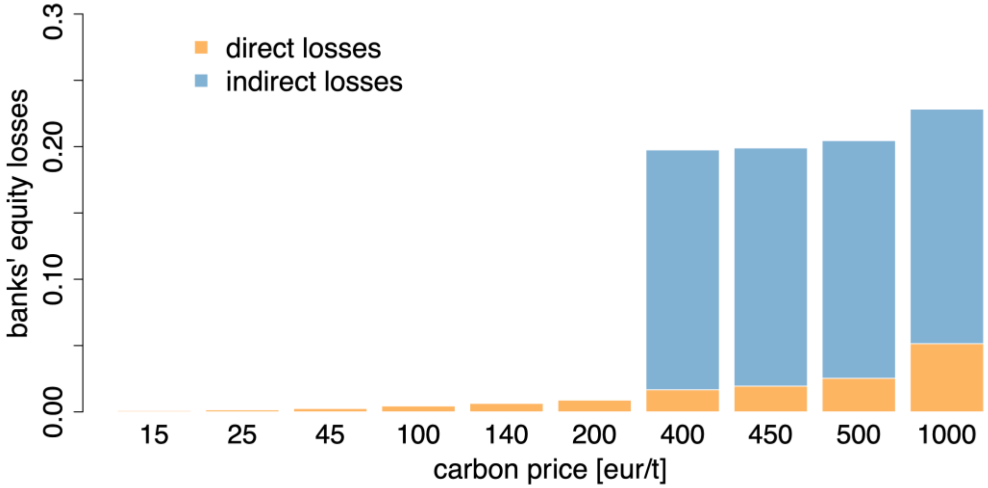
Upstream production level:

$$h_i^{u}(t+1) = \min\left[\sum_{j=1}^{n} \Lambda_{ji}^{\text{u}} h_j^{\text{u}}(t), \psi_i\right]$$

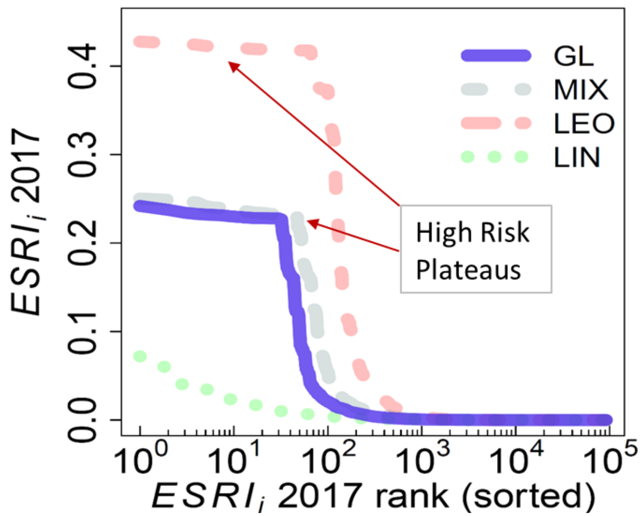
Diem, C., Borsos, A., Reisch, T., Kertész, J., & Thurner, S. (2022). Quantifying firm-level economic systemic risk from nation-wide supply networks. *Scientific reports*, *12*(1), 7719.

RESULTS

STRONG NON-LINEARITY IN THE LOSSES DEPENDING ON THE SIZE OF THE COST SHOCK



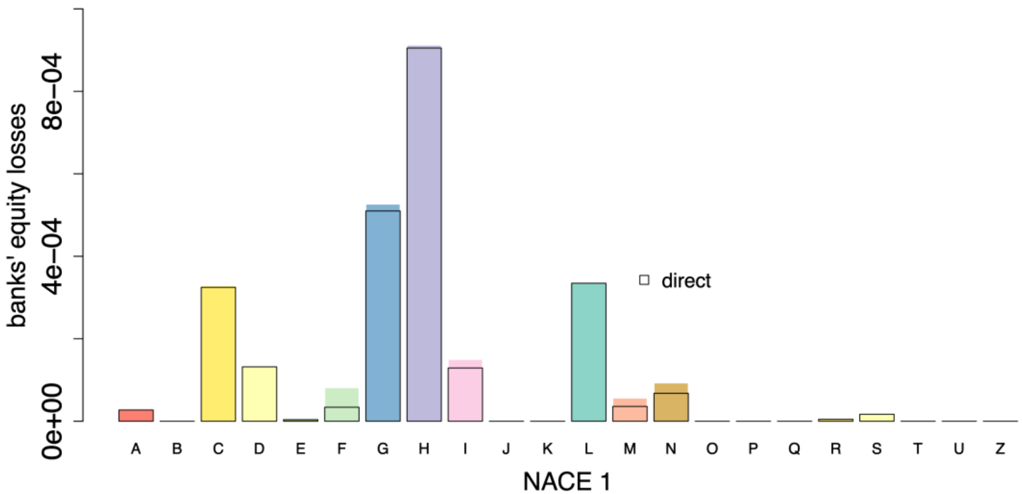
(In)direct losses of the banking system in the case of different carbon price shock scenarios



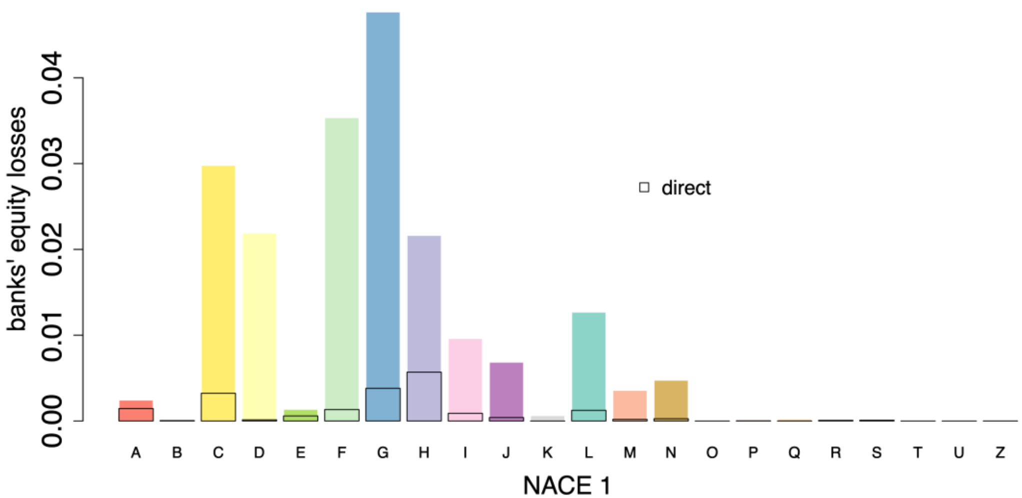
Plateau firm network (downstream)

- There is a **crossover after hitting plateau firms** (based on firms' Economic Systemic Risk Index)
- Plateau firms form a **strongly connected component of highly critical supply relations**
- The 45$ level has only moderate impact however,
  - **the crossover point is highly sensitive** to the **topology of the network** and the **modelling assumptions**.
  - (e.g. we assume infinite time horizon for the shock propagation, and no adjustments or interventions)

DISAGGREGATED RESULTS



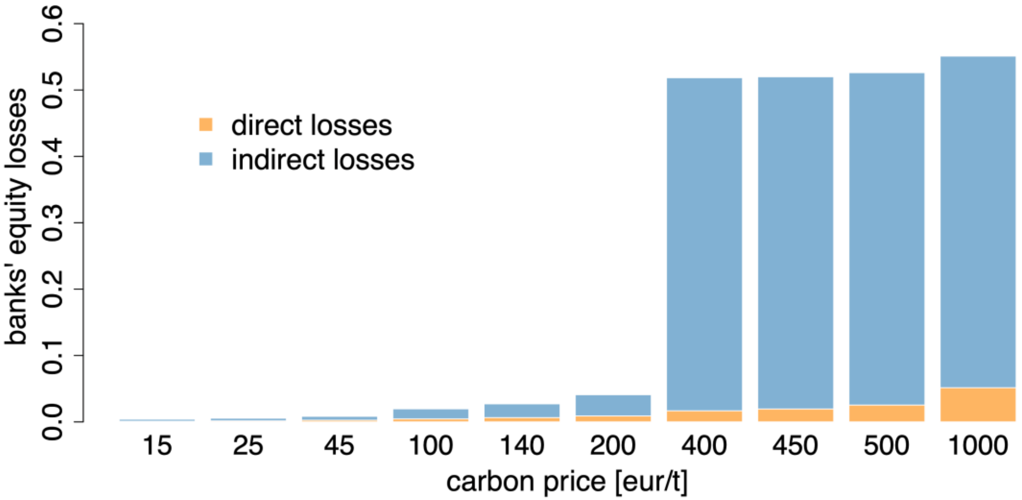
(In)direct losses of the banking system in the case of a **45$** carbon price shock by industries



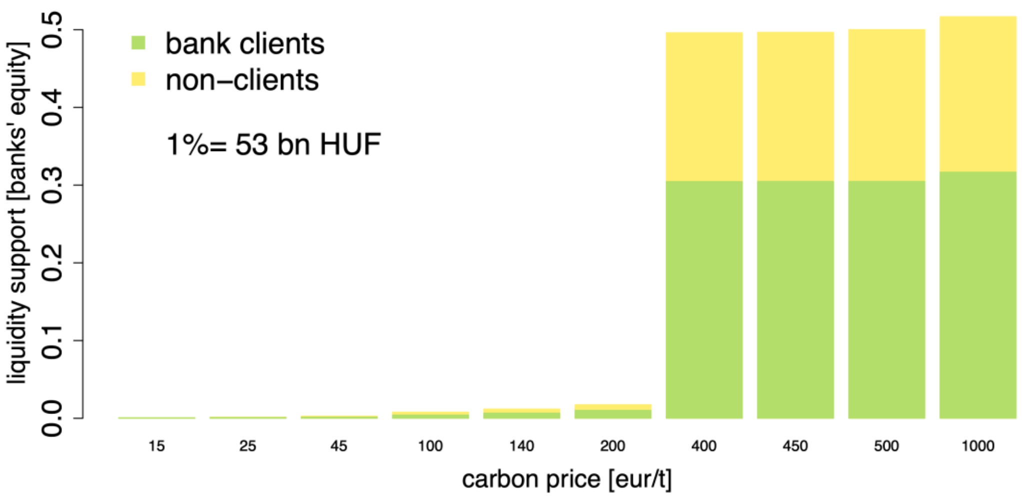
(In)direct losses of the banking system in the case of a **450$** carbon price shock by industries

- Most important sectors are intuitive:
  - Transportation (H), Trade (G), Manufacturing (C), Construction (L), Real estate (F), Electricity, gas (D)
- Losses to the financial system caused by defaults in different sectors…
  - …can be very different depending on the size of the cost shock (mostly due to indirect effects).
  - …are not proportional to the production reduction of these sectors
  - (They depend on the distribution of loans and financial buffers across the firms.)

TARGETED POLICIES CAN REDUCE THE COSTS OF THE SHOCK



(In)direct losses of the banking system in the case of different carbon price shock scenarios and liquidity defaults



Liquidity gaps of (non) bank client firms in the case of different carbon price shock scenarios

- If we also consider liquidity defaults of firms,
  - Losses would be even higher
  - (But we assume that firms cannot obtain additional funding.)
- Liquidity support:
  - If we **allocate liquidity** to the firms with bank loans, an **optimally allocated** support policy would cost around **half of the losses** in the banking system.

LIMITATIONS & FUTURE RESEARCH

LIMITATIONS

- **Data availability** could be improved regarding
  - price,
  - product and
  - international trade information
- **Model caveats:**
  - no time dimension,
  - no inventories,
  - no elasticity estimates
- **Conservative** assumptions
  - Default criteria
  - Foreclosure protocols (forbearance, differentiated LGD)

FUTURE RESEARCH

1. **Model development based on the current caveats**
2. **Connect the model with a banking system contagion framework**
3. **Embed the system in a macroeconomic environment**