Fire sales, price-mediated contagion and systemic risk.

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Disclaimer

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Overview

Price-mediated contagion and endogenous risk

- Crisis of 2007-2008: Direct contagion (e.g. counterparty credit risk or funding relations) cannot explain the magnitude and breadth of contagion, across sectors, countries and asset classes that was observed.

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Goal: Develop models for macro stress testing that can quantify such second round effects in a realistic and robust way. ("Stresstesting 3.0")

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1. **Shock** to illiquid assets
2. **Deleveraging** of marketable assets by some institutions
3. **Feedback effects** via price-mediated contagion
   $\rightarrow$ potentially triggers more deleveraging (cascade).

Mathematically this is a discrete time non-linear dynamical system.

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Modelling fire sales

Model balancesheet

Illiquid assets
Residential mortgage exposures
Commercial real estate exposure
Retail exposures: Revolving credits, SME, Other
Indirect sovereign exposures in the trading book
Defaulted exposures
Residual exposures

Marketable assets
Corporate bonds
Sovereign debt
Direct sovereign exposures in derivatives
Institutional client exposures: interbank, CCPs,...

Table: Stylized representation of asset classes in bank balance sheets. (Data: European Banking Authority Stress Test)

- A stress scenario is defined by a vector $\epsilon \in [0,1]^K$ whose components ϵ_μ are the percentage shocks to asset class μ.
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- Gradual increase of the shock from 0% to 20%.
- Four scenarios:
  1. Spanish residential and commercial real estate losses
  2. Northern Europe residential losses
  3. Southern Europe commercial real estate losses
  4. Eastern Europe commercial real estate losses

Fire sales model

- Total value of illiquid holdings: $\Theta_t^i := \sum_{\mu=1}^{K} \Theta_t^{i\mu}$.
- Securities: $\Pi_t^i := \sum_{\mu=1}^{M} \Pi_t^{i\mu}$.
- Common Equity Tier 1 capital: C_t^i
- Initial loss: $L_0^i := \sum_{\mu=1}^{K} \Theta_0^{i\mu} \epsilon_\mu$

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When a bank exceeds the leverage constraint, $\lambda^i > \lambda_{\max}$, it engages in fire sales of magnitude $\Gamma^i \in [0, 1]$:

$$\frac{(1 - \Gamma_1^i)\Pi_0^i + \Theta_0^i - L_0^i}{C_0^i - L_0^i} = \lambda_{new}^i,$$

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which yields in the **fire sales model:**

$$\Gamma_1^i = \frac{C_0^i(\lambda_0^i - \lambda_b^i)}{\Pi_0^i} \mathbb{1}_{\lambda_i > \lambda_{\max}},$$

Price impact

The price of an asset undergoing a forced liquidation at t:

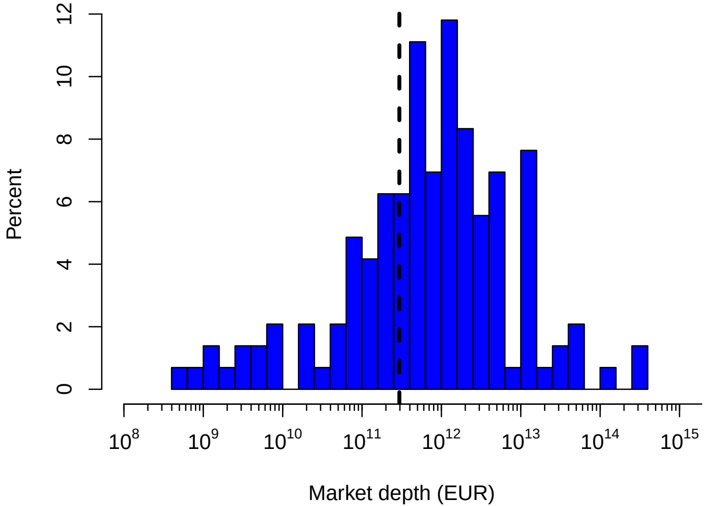
$$S_{t+1}^{\mu} = S_t^{\mu} \exp\left(-\delta_{\mu}^{-1} \sum_{j=1}^{M} \Pi_t^{j\mu} \Gamma_{t+1}^{j}\right),$$

where the market depth

$$\delta_{\mu} \sim \frac{ADV_{\mu}}{\sigma_{\mu}},$$

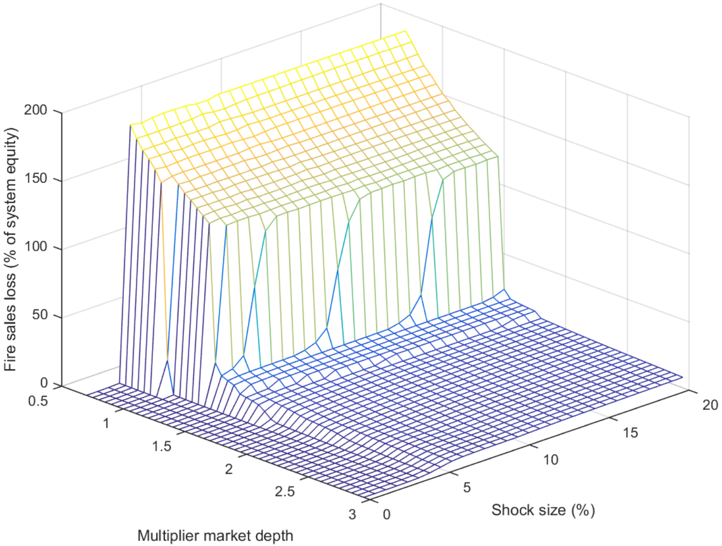
- ADV: average daily volume
- σ_{μ} daily volatility

Estimated market depth



Is it relevant?

Fire sales losses and market depth



Indirect exposures and stress test outcomes

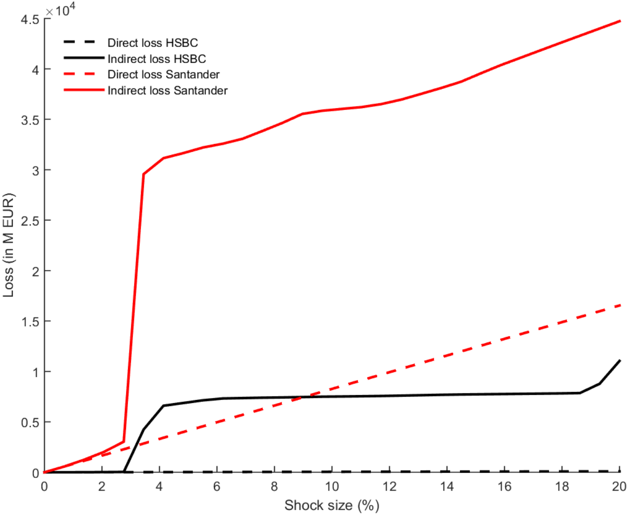


Figure: Source: EBA (public) & authors calculations.

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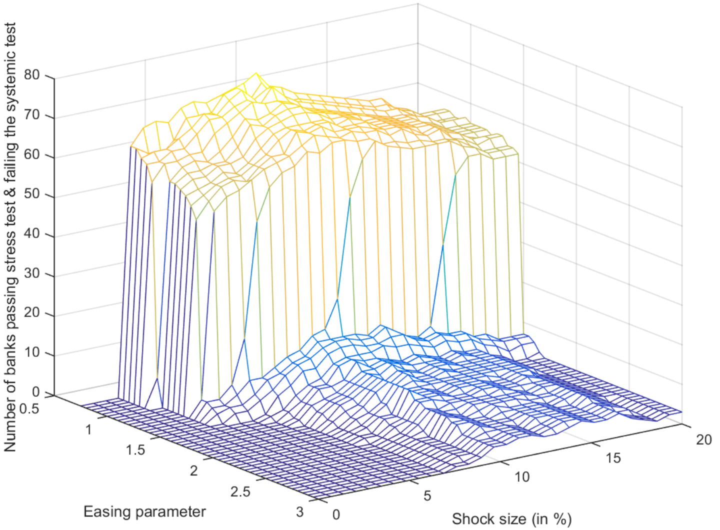


Monitoring

Fire sales losses

Linearising the price impact function yields

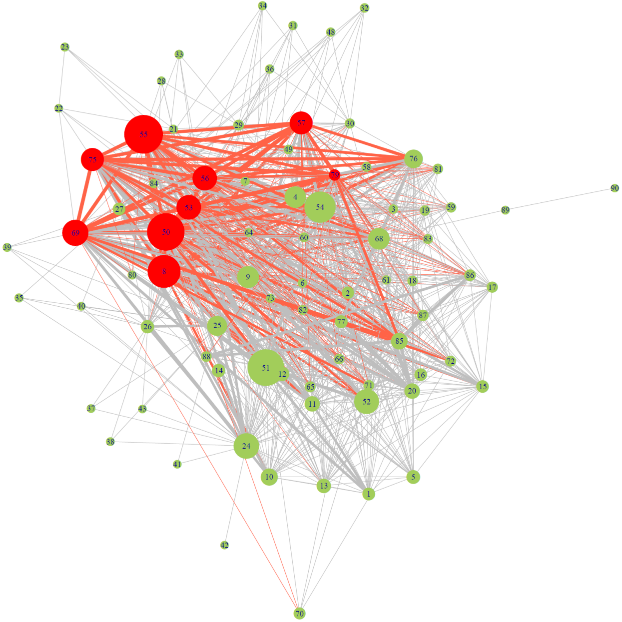
$$L_t^i \approx (1-(1-\alpha)\Gamma_{t+1}^i)\sum_{\mu=1}^{M}\sum_{j=1}^{N}\delta_\mu^{-1}\Pi_t^{i\mu}\Pi_t^{j\mu}\Gamma_{t+1}^j$$

$$= (1-(1-\alpha)\Gamma_{t+1}^i)\sum_{j=1}^{N}\omega_{ij}\Gamma_{t+1}^j,$$

where $\omega_{ij} := \sum_{\mu=1}^{M}\Pi_0^{i\mu}\Pi_0^{j\mu}\delta_\mu^{-1}$ is the liquidity weighted overlap of portfolios i and j. This gives rise to a weighted and undirected "liquidity weighted overlap network" given by the symmetric (positive semidefinite) matrix:

$$\Omega := \Pi D^{-1}\Pi^\top.$$

European banking system: liquidity weighted overlap



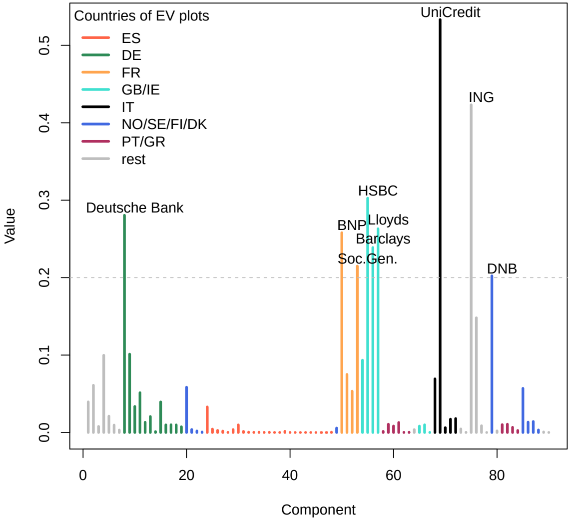


Figure: European banking system: Liquidity weighted overlaps. Source: EBA (public)

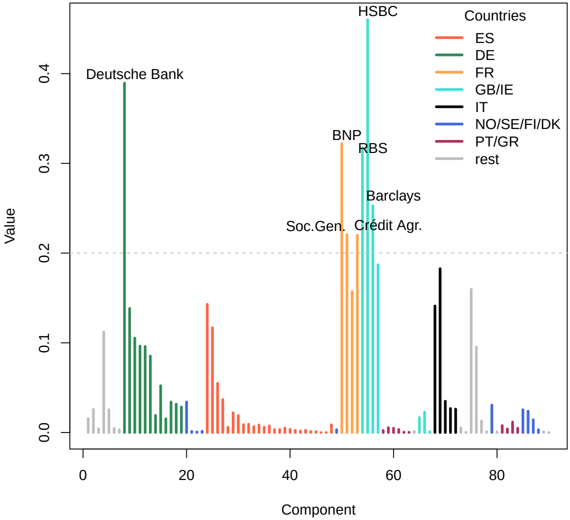


Figure: European banking system: Nominal overlaps. Source: EBA (public)

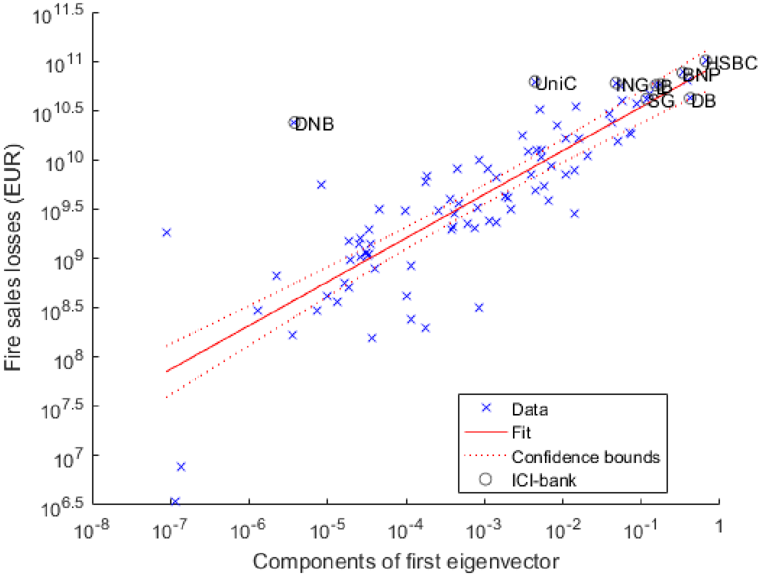


Figure: Source: EBA (public) & authors calculations

Constructing a Systemic Vulnerability Indicator

Figure: Threshold model: Fire sales losses as function of the initial shock and the market depth. Source: Statistics Norway.

A Systemic Vulnerability Indicator

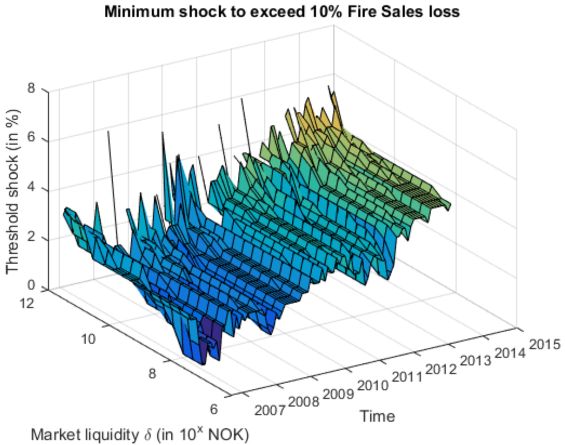


Figure: Minimum shock required to trigger large fire sales cascades, as a function of time and market depth. Source: Statistics Norway.

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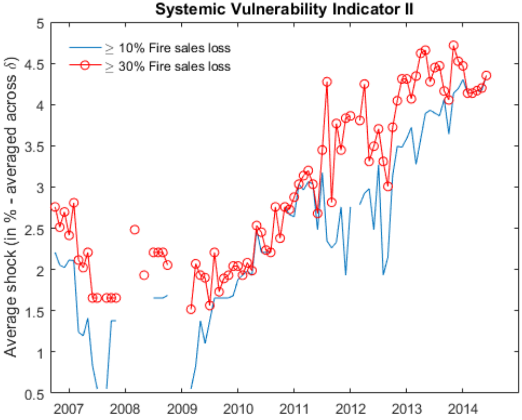


Figure: Minimum shock required to trigger large fire sales cascade, average over market depths. Source: Statistics Norway.

Comparison to “leverage targeting” models

Response functions

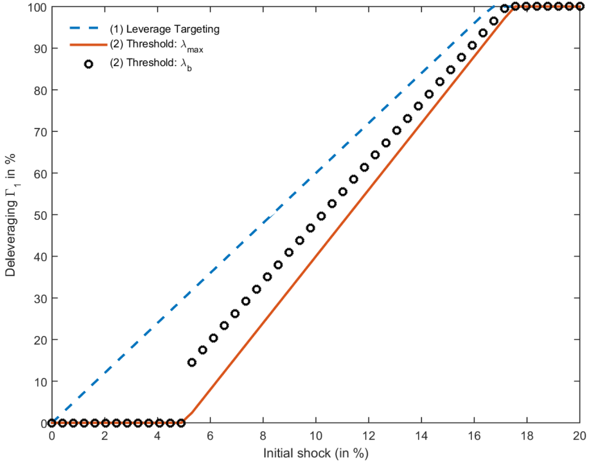
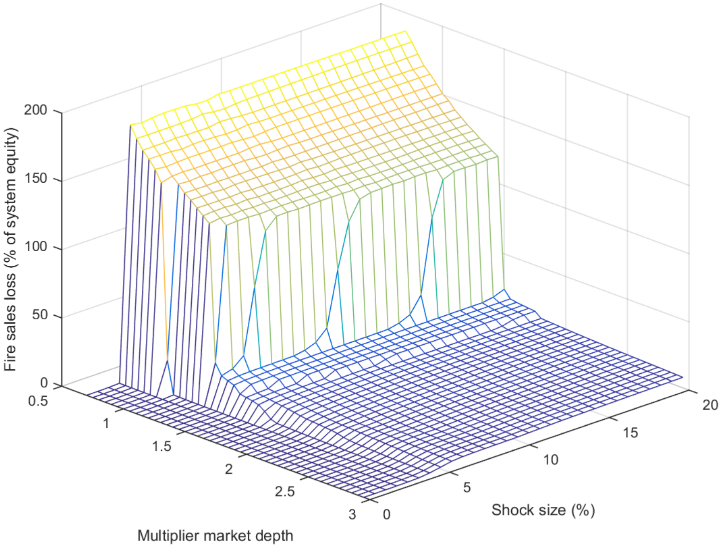


Figure: Leverage targeting response function (dashed) and two variants of the fire sales (full and circles) response functions.

Fire sales losses and market depth



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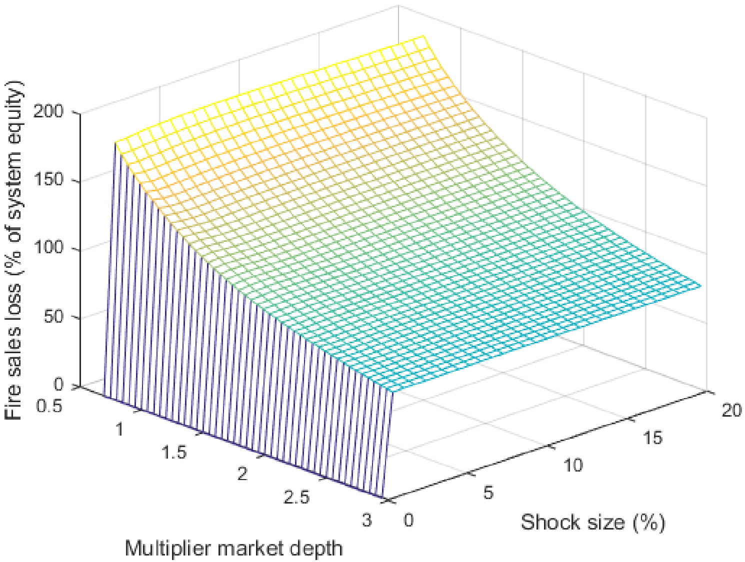


Distribution of fire sales losses

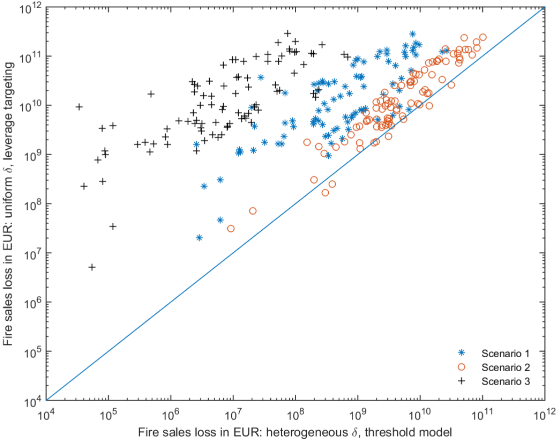


Figure: Fire sales loss for different scenarios and different model combinations.

Sensitivity to initial stress scenario

Scenario combination	Sample correlation coefficient
1 & 2	0.0840
1 & 3	0.2130
1 & 4	-0.1449
2 & 3	-0.0509
2 & 4	0.0394
3 & 4	-0.0149

Table: Sample correlations between the initial loss vectors from the stress scenarios. The four stress scenarios are very different in terms of which banks are hit by the corresponding shock.

Sensitivity to initial stress scenario

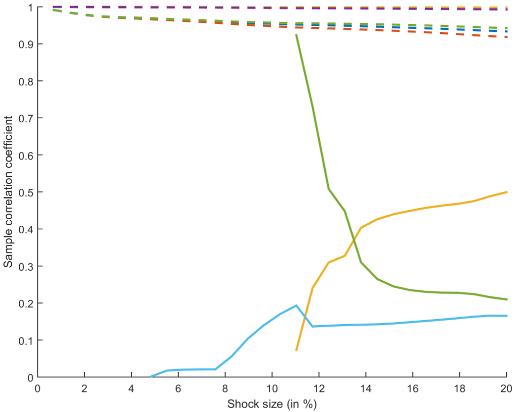


Figure: The pairwise sample correlation between the fire sales loss vectors of different scenarios as a function of the initial shock. Threshold model full lines - leverage targeting dashed lines.

Sensitivity to initial stress scenario

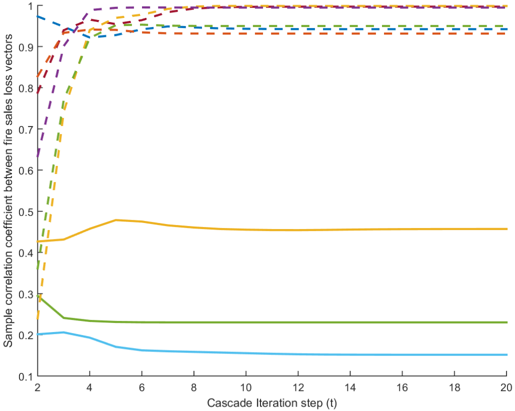
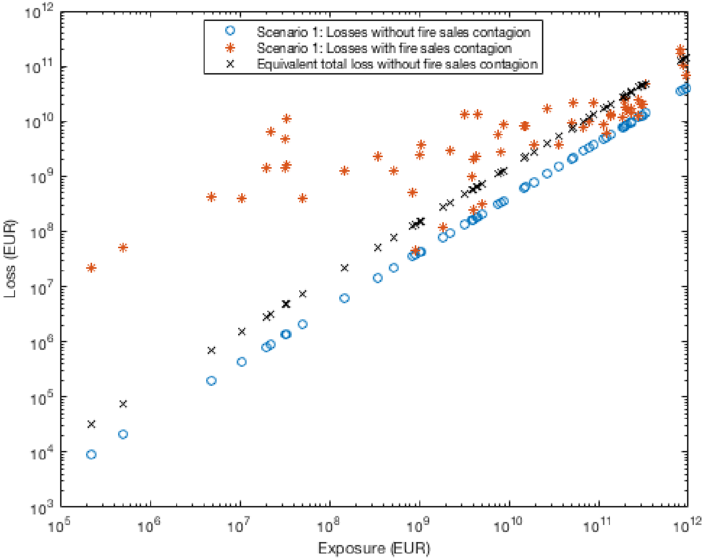


Figure: The evolution of the pairwise sample correlation during the fire sales cascade for a given scenario. Threshold full - leverage targeting dashed.

Conclusion

Account for fire sales losses “without fire sales model?”



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- Liquidity-weighted overlaps lead to a bank-level indicator that may be used for monitoring and for quantifying the contribution of a financial institution to price-mediated contagion;
- The phenomenon of fire sales calls for the collection of portfolio holdings data on a broad scale (banks *and* shadow banks)

Conclusions

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- Contagion through fire sales cannot be accounted for simply by applying a larger macro-shock to bank portfolios;
- Results in our model differ significantly from results obtained in “leverage targeting” models.

Thank you!

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