EUROPEAN CENTRAL BANK

EUROSYSTEM

Shock Amplification in an Interconnected Financial System of Banks and Investment Funds

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Matthias Sydow
European Central Bank

Disclaimer

The views expressed in this presentation are those of the authors and do not necessarily represent the views of the European Central Bank and the Eurosystem.

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Motivation and overview

Overview

- **Workstream on system-wide stress testing (SWST):** Developing an operational framework using firm-level data to model sector-specific stress at the granular level and allow capturing the effects of interconnectedness within the financial system

- **Until now: Evaluation of (i) the Covid-19 severe scenario of the 2020 ECB Vulnerability Analysis and of (ii) NGFS climate risk scenarios**:
  - ‘Shock amplification in an interconnected financial system of banks and investment funds’ by Sydow et al. (2021), ECB Working Paper No. 2581
  - ‘Amplification of climate scenarios in an interconnected financial system of banks and investment funds’ (Box 8) in ‘Climate-related risk and financial stability’, ESRB Report (2021)

Granular, granular, granular…

The need for a fine-grained yet holistic perspective

Monitoring an **interconnected** financial system involves the availability of detailed and **granular data**.

Mario Draghi, ***Welcome remarks ESRB annual conference*** **27 September 2018**

International cooperation is needed to develop tools for **stress testing** but now at **system-wide** level.

Luis de Guindos, **Global financial regulation 21 May 2019**

The big picture was too blurry *[aggregate]*. […] **Better and more granular data are necessary**.

Sabine Lautenschläger, **20 years of ECB Statistics 07 October 2018**

A **system-wide** perspective is a key advantage […].

Yves Mersch, **Appointment hearing 4 September 2019**

System-wide stress tests have been established as an important tool for monitoring **financial stability**.

Luis de Guindos, **The evolution of stress-testing in Europe 4 September 2019**

A **holistic** assessment of the impacts on systemic stability […] is needed.

Benoît Cœuré, **Policy analysis with big data 3 May 2016**

It is time to rethink the design of stress tests.

Andrea Enria, **ESRB annual conference 26 September 2019**

Only a **holistic view of the system** will allow potential contagion channels to be identified and modelled. […] Developing the analytical toolkit to adequately monitor **interconnectedness** and **contagion** requires **granular datasets**, and the ability to map and link data across entities and markets.

Mario Draghi, **ESRB annual conference 26 September 2019**

SWST: a step-by-step approach

Conceptual framework (2019)
- All financial sectors
- High-level description

Initial operational framework (2020)
- Banks and funds
- Based on data
- Detailed mechanisms

- Full set-up for results production
- Understanding of results
- Documentation via ECB WP (VA Covid-19 scenario)

Augmented op. framework (2021)
- Add other sectors (insurers, HF)
- New data consistency
- New detailed mechanisms
- Understanding of results
- Documentation via new ECB WP (use e.g. climate risk scenario)

Final operational framework (2022)
- tbd…

Literature I.

Reference	Sectors	Multi-variate shock	Multi-country	Liquidity and solvency	Overlapping portfolios	Fire sales	Security-level price impact
Aikman et al. (2019)	Banks, funds, ICPF (**representative agents**)	☑	☒	☑	☒	☑	☒
Caccioli et al. (2020)	Banks, funds, insurers	☒	☒	☒	☑	☑	☒
Chretien et al. (2020)	Banks, funds, insurers	☒	☒	☒	☑	☒	☒
Farmer et al. (2020)	Banks, (hedge) funds	☒	☑	☑	☑	☑	☒
Roncoroni et al. (2021)	Banks, funds	☑	☒	☑	☑	☑	☒
Our framework	Banks, funds	☑	☑	☑	☑	☑	☑

Literature II.

Reference	Time horizon	Correlated defaults	Income channel	Default contagion	Funding shock	Derivatives/ margin calls	Portfolio opt.
Aikman et al. (2019)	1 month	☒	☒	☒	☑	☑	☑
Caccioli et al. (2020)	Instantaneous	☒	☒	☒	☒	☒	☒
Chretien et al. (2020)	Instantaneous	☒	☒	☑	☒	☒	☒
Farmer et al. (2020)	<1 month	☒	☒	☑	☑	☒	☒
Roncoroni et al. (2021)	35 years (uncertainty)	☒	☒	☑	☒	☒	☒
Our framework	Quarterly and high frequency	☑	☑	☑	☑	☒	☒

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Sectors and data

Sectors and data

Sectors currently covered by our framework (2020)

- Banks (COREP, FINREP, SHS-G, Moody’s, RIAD, GLEIF, CSDB)
- Investment funds (Lipper IM by Refinitiv)

Sectors to be included at the next development stage

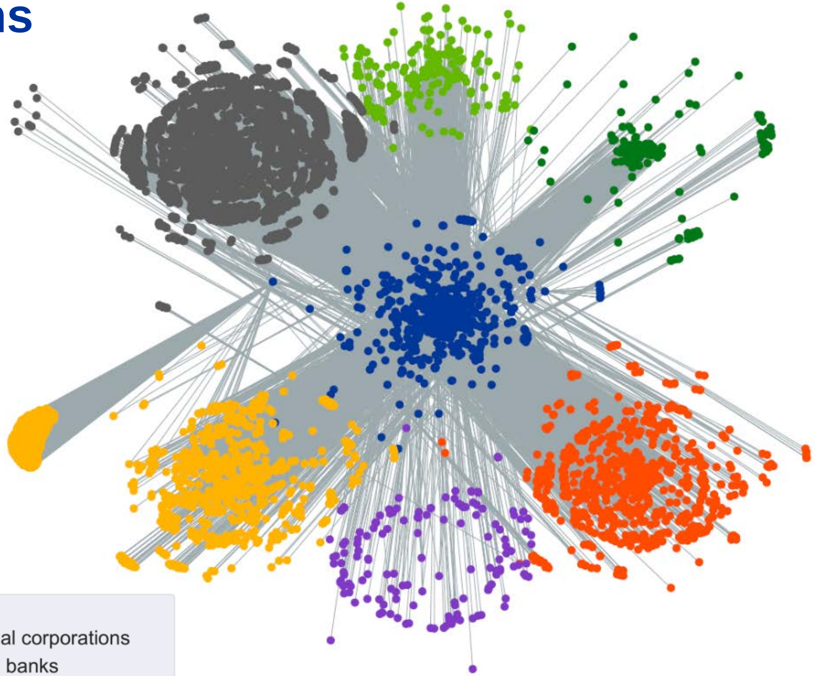
- Insurance companies (2021)
- Hedge funds, money market funds (at a later stage)

Other sectors are included in order to “close the system”

- Other financial agents
- NFCs
- Households

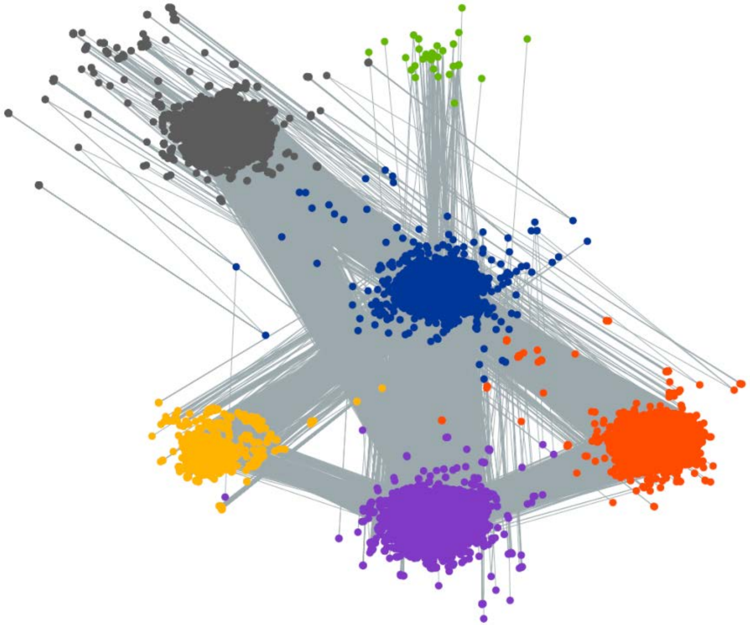
Our exposure networks: 377 banks, 12655 funds

Loans



An edge represents a loan from a bank to another entity in a given sector. Granular loan data are covering 21% of total bank assets.

Securities holdings



An edge shows that a bank/fund holds assets issued by another entity in a given sector. Granular securities data are covering 7% of total bank assets.

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Scenario and exogenous shocks

Scenario and exogenous shocks

Scenario:

Covid-19 adverse severe scenario used in the 2020 ECB VA exercise with a GDP decline of 12.6% y-o-y in 2020

Default shocks:

Merton model geometric Brownian motion parameters regressed on scenario variables using Bayesian Model Averaging (BMA) + ECB top-down models by country/sector for aggregate exposures (Gross and Población (2017))

Market shock:

Country-level stock market shocks

Redemption shock:

Fund-level exogenous redemptions using BMA approach (Gourdel et al. (2019))

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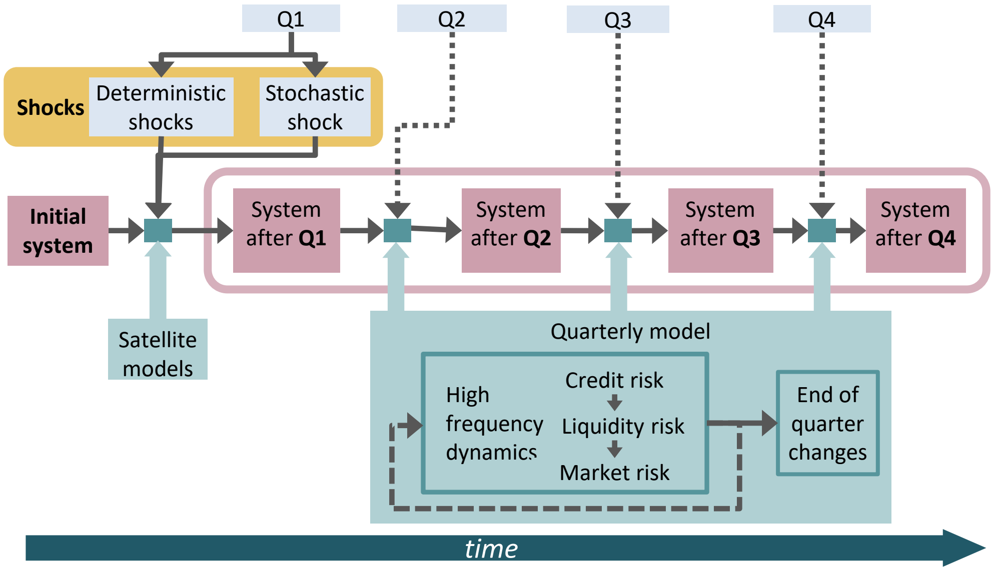
Model dynamics

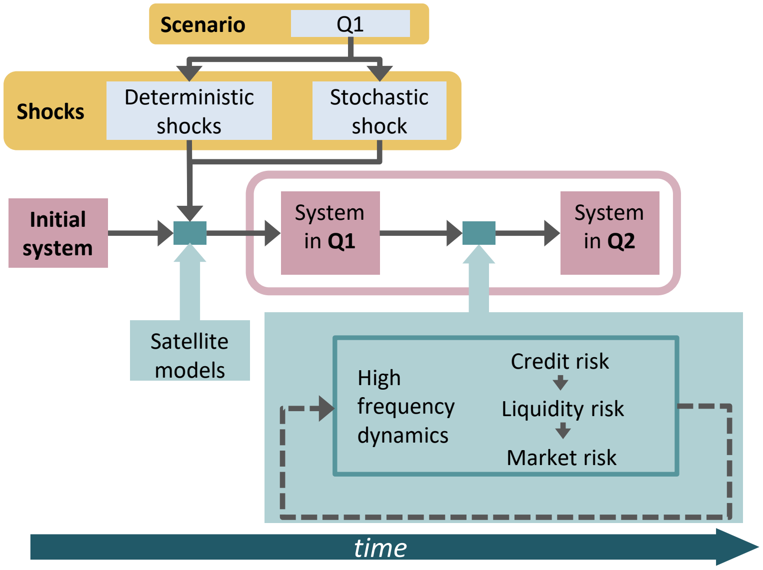
Stress testing framework for banks and funds

Plan



Sectors: Banks, funds and insurers (hedge funds)

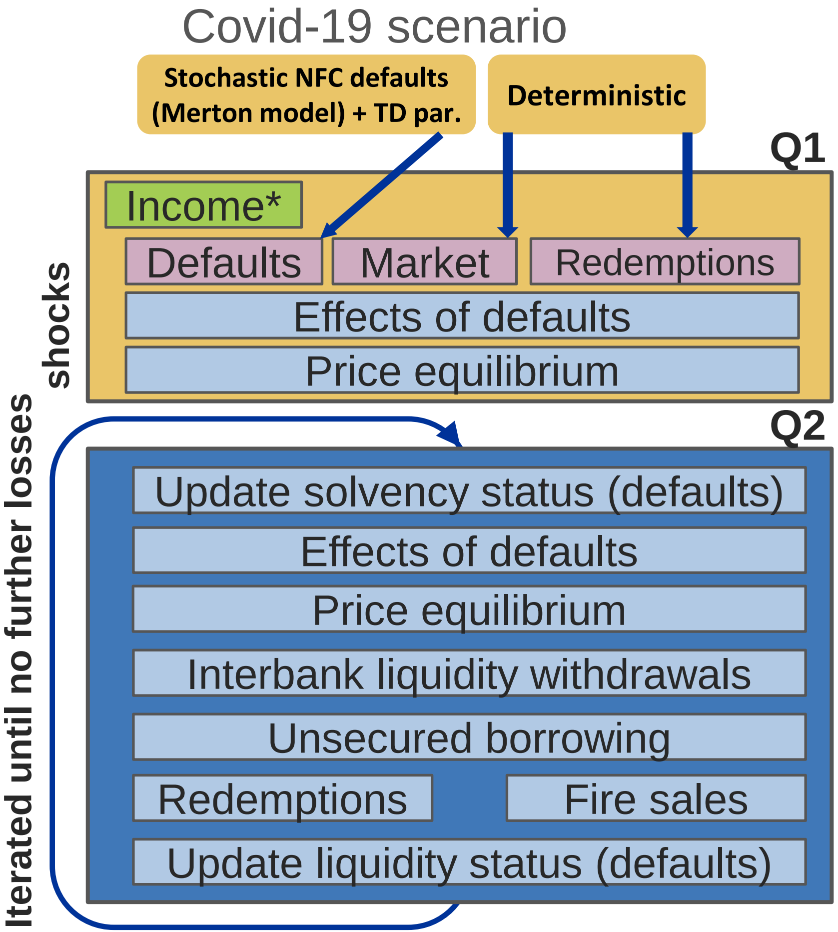
Status quo



Sectors: Banks and funds

Modelling summary

- **Effects of defaults:** loan losses and price decline of corresponding issued securities
- **Price equilibrium:** price changes in tradable assets reflected in fund prices + then all holdings
- **Interbank withdrawals:** short-term funding withdrawn from/by defaulted/distressed banks
- **Unsecured borrowing:** well-capitalized banks able to provide liquidity
- **Redemptions, fire sales:** pro rata depending on liquidity shortfalls leading to price declines



*Income channel is approximated from ECB VA exercise results and FINREP data

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Results

Median losses

	Default losses		**Market losses**	
System	*1.9*		*2.9*	
	Exogenous	*Endogenous*	*Exogenous*	*Endogenous*
Banks	*0.7*	* *0.2*	*0.3*	*0.3*
Funds	** *0.9*	*0.05*	*0.9*	*1.4*

Note: Median losses expressed as a percentage of total system assets.

Default losses: loan losses and price decline of corresponding issued securities

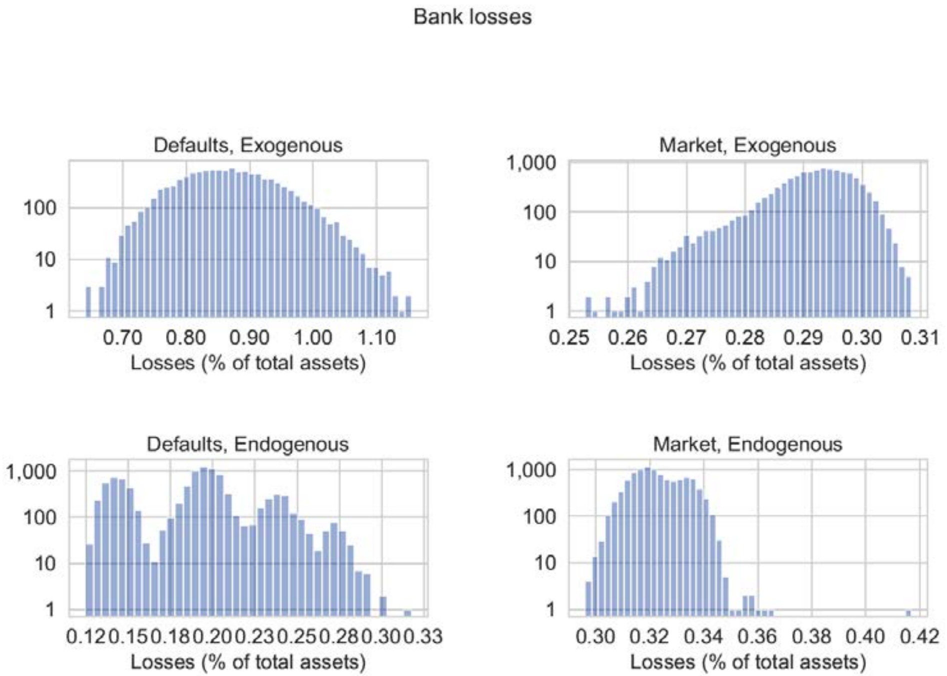
- No policy response (relief measures or moratoria): more endogenous bank defaults*
- Funds directly exposed to real economy**

Market losses: stock market shocks and endogenous fire sale losses

- Banks' portfolio changes mainly due to funds' fire sales
- Endogeneity matters (scenario design)

Drivers of bank losses

- Banks' exogenous default losses are **the main driver of losses** (credit risk channel)
- All other channels combined lead to a similar amount of losses
- Endogenous market losses are persistent due to fire sales, which are **caused by investment funds**
- Losses from endogenous defaults exhibit a multi-modal property due to stochastic **bank defaults**

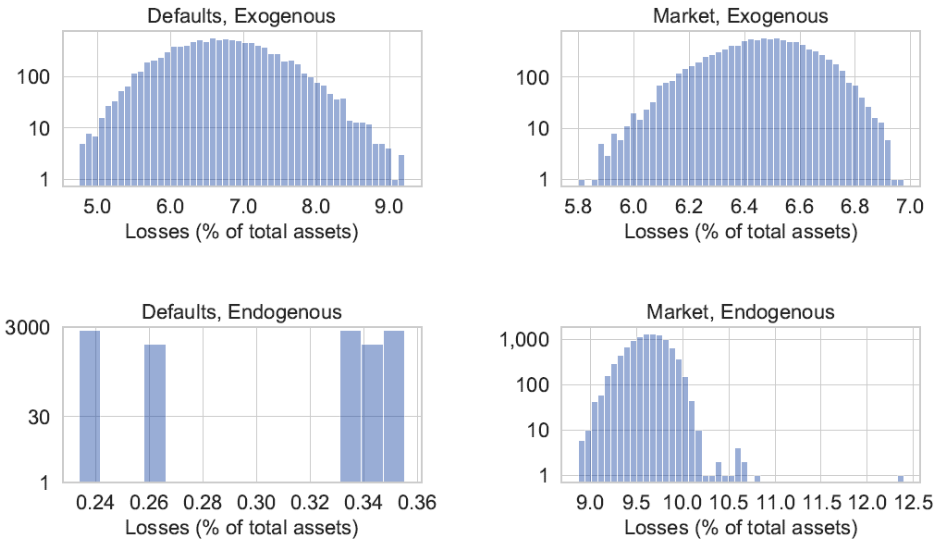


Histogram of losses from exogenous shocks and from endogenous reactions (contagion) for banks based on 10000 Monte Carlo simulations (in percentage of total banking sector assets).
'Defaults, Exogenous' refer to NFC defaults. 'Market, Exogenous' refers to exogenous market losses both from the market scenario and from the price drop of exogenously defaulting NFCs issuing securities. 'Endogenous' losses are model-driven.

Drivers of fund losses

- Funds losses due to exogenous shocks are larger compared to the ones observed for the banking sector
- Only a few leveraged funds (via bank loans) default in our simulations but persistently
- Given their portfolio structure, funds are not exposed to defaulting banks in our sample but **losses from fire sales** are significant

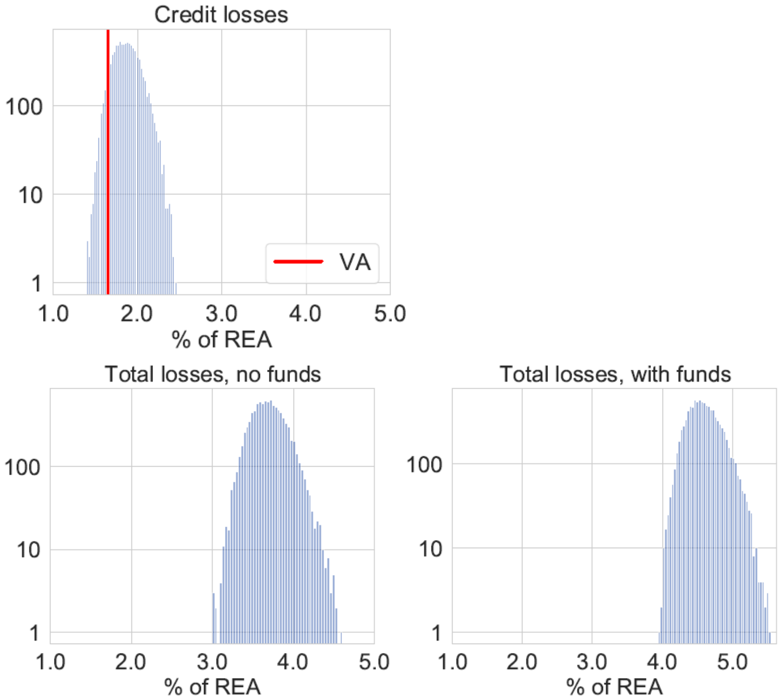
Fund losses



Histogram of losses from exogenous shocks and from endogenous reactions (contagion) for funds based on 10000 Monte Carlo simulations (in percentage of total investment fund sector assets).
'Defaults, Exogenous' refer to NFC defaults. 'Market, Exogenous' refers to exogenous market losses both from the market scenario and from the price drop of exogenously defaulting NFCs issuing securities. 'Endogenous' losses are model-driven.

Funds' impact on banks' capital ratios

- Somewhat higher **loan loss impact** than in ECB VA from:
  - COREP PDs
  - Correlated default events
- **Endogenous reactions**:
  - Significant additional losses (bottom row)
- One percentage point **higher capital depletion** in the presence of funds
  - Impact on funds primarily driven by fire sale effects



Distribution of average bank capital depletion along the 10000 Monte Carlo simulations. VA results on credit losses refer only to the first two quarters of 2020.

Conclusions

- Stress testing tool for the analysis of the short-term dynamic reaction of a granular network of banks and investment funds conditional on a macro-financial shock scenario

- We show that inter-sectoral contagion significantly increases losses in the system

- Joint asset fire sales of banks and funds have the largest systemic effect in our model

- Application of the model for macroprudential policy, climate risk and potentially monetary policy

- Model extension with regard to other financial sectors such as insurance corporations, hedge funds, money market funds

Thank you for your attention!

Appendix: System-wide stress testing

For more details, see ECB WORKING PAPER SERIES - No. 2581:

‘Shock amplification in an interconnected financial system of banks and investment funds’

by Sydow et al. (2021)

https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2581~63c8ffb7dc.en.pdf?8a567fb4ed1bba41721c678c32e6ab09

For a climate risk application, see Box 8 **‘Amplification of climate scenarios in an interconnected financial system of banks and investment funds’** in ESRB Report (July, 2021):

‘Climate-related risk and financial stability’

https://www.esrb.europa.eu/pub/pdf/reports/esrb.climateriskfinancialstability202107~79c10eba1a.en.pdf?71a273dc36a85ef05c8bed530466f900

A

Data

Banks

Scope

- Significant and less significant banks domiciled in the EA

Data sources

- COREP
  - Large Exposures dataset: bilateral exposures; breakdown along two dimensions: (i) original exposure and net or unsecured exposure (LGD proxy) and (ii) long-term and short term (with 30 days as threshold)
  - Large Liabilities dataset: Top 10 bilateral liabilities with a value > 1% TA
- FINREP
  - Aggregate exposure on country-sector basis towards CI, FC, NFC, GOV, HH
  - Provisions, balance sheet and income statements
  - Disclosure of financial assets and liabilities, off-balance sheet activities, non-financial instruments
- Securities Holding Statistics by banking group (SHS-G)

Investment funds

Scope

- Funds domiciled in the EA
  - Open-ended investment funds. Prone to redemption risk, thus, play an active role in our model
  - Closed-end funds. Standard price impact, thus, only intervene in form of securities whose price is changing

Data sources

- Granular securities holdings from Lipper IM by Refinitiv:
  - Market value of exposure amount security-by-security (ISIN)
  - Cash information

Entities and securities

Scope

- Entities reported as counterparty by any bank or investment fund
- ISIN-level securities
- PDs for passive NFCs and FCs in the SWST

Data sources

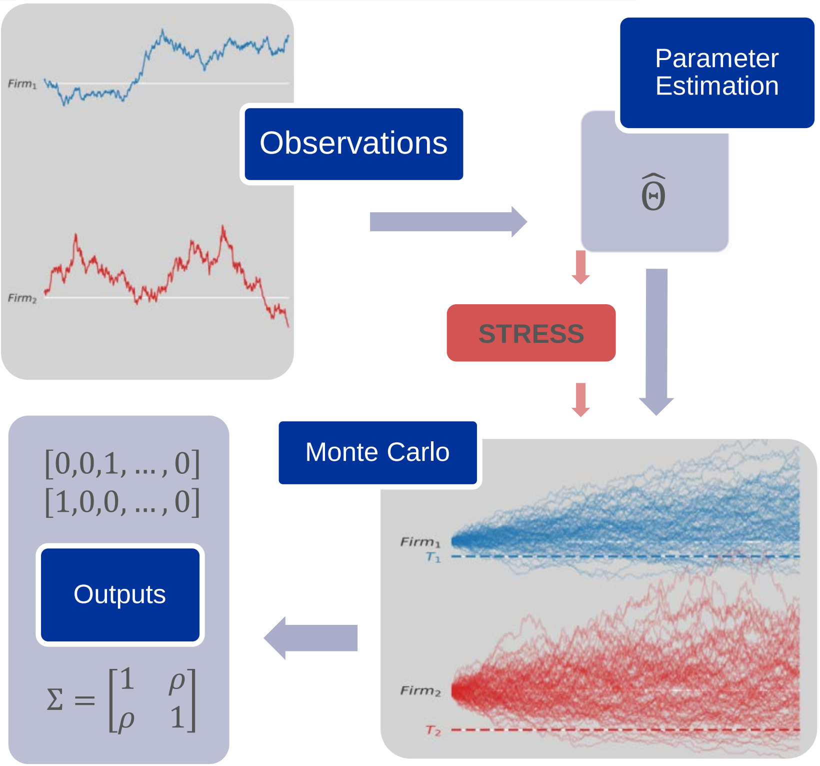
- RIAD and GLEIF:
  - Identification via LEI and RIAD code and check of country-sector information
  - Groups consolidation
- CSDB:
  - Identification of securities via ISIN code and check information about type and issuer
- Moody’s:
  - Market asset value (AVL) and PDs to generate correlated random defaults in the counterparty subsample of NFCs and FCs
  - Use of country-sector averaging to account for missing values

B

Scenario

Modelling correlated defaults

- Capture firm-by-firm default correlations.
- Estimate parameters of the asset market value generating processes.
- Simulate series in a Monte Carlo environment to generate real-economy defaults realisations.
- Allow for dependencies to macro-financial variables.



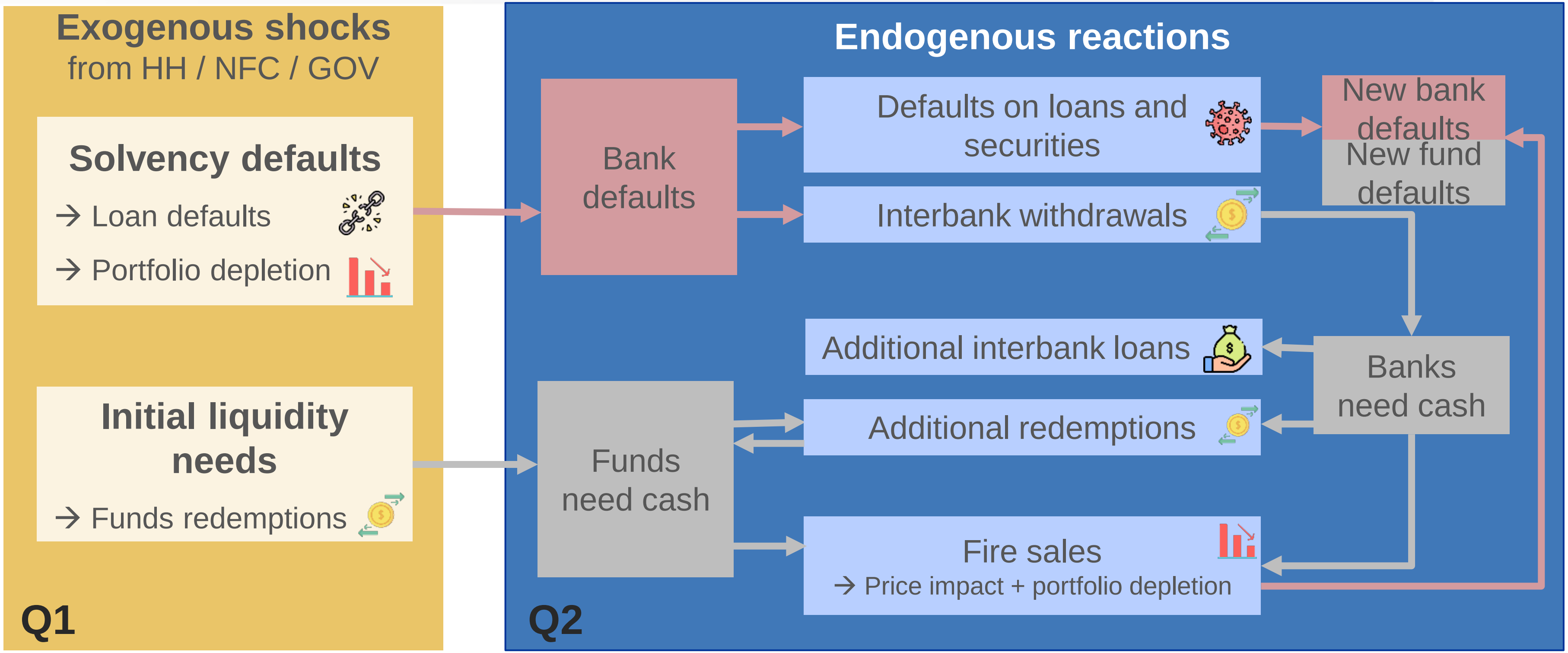
Scenario translation

Formally, ARDL models of the following form are used for both PDs and redemptions:

$$Y_t = \alpha + \rho_1 Y_{t-1} + \cdots + \rho_p Y_{t-p} + \sum_{X^k \in M} \left(\sum_{q=0}^{p_k} \beta_{k,q} X_{t-q}^k \right) + \varepsilon_t$$

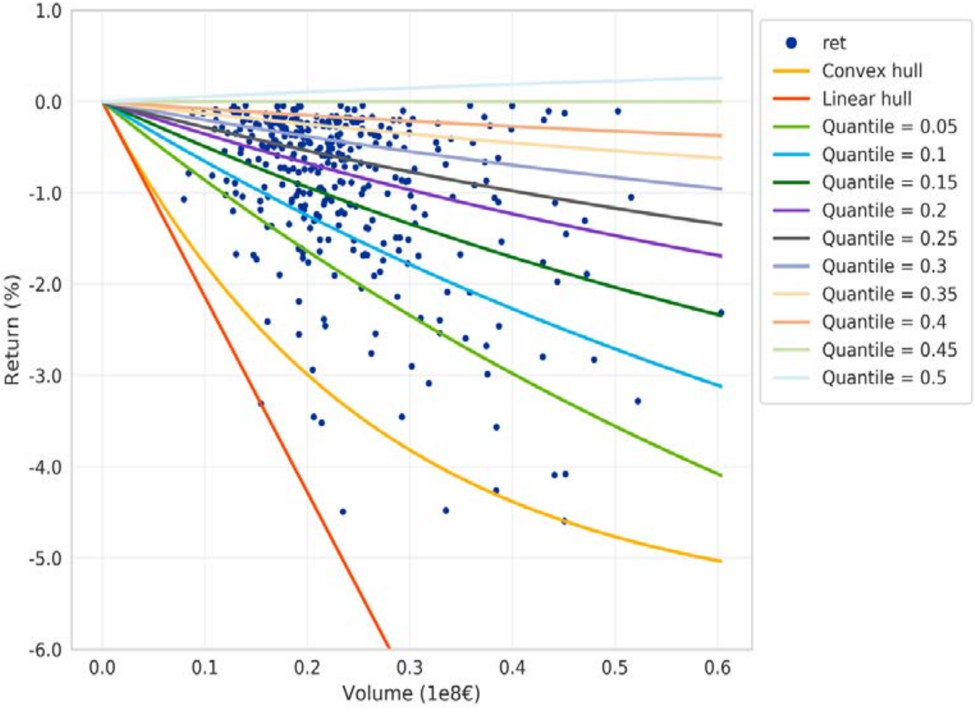
With $X^1, \ldots, X^K$ being predictor variables (macro-economic series from the scenario), *M* a subset of $\{X^1, \ldots, X^K\}$ and all variables in a given equation being country-specific.

Mechanisms at play *(simplified scheme)*



Fire sale assumptions

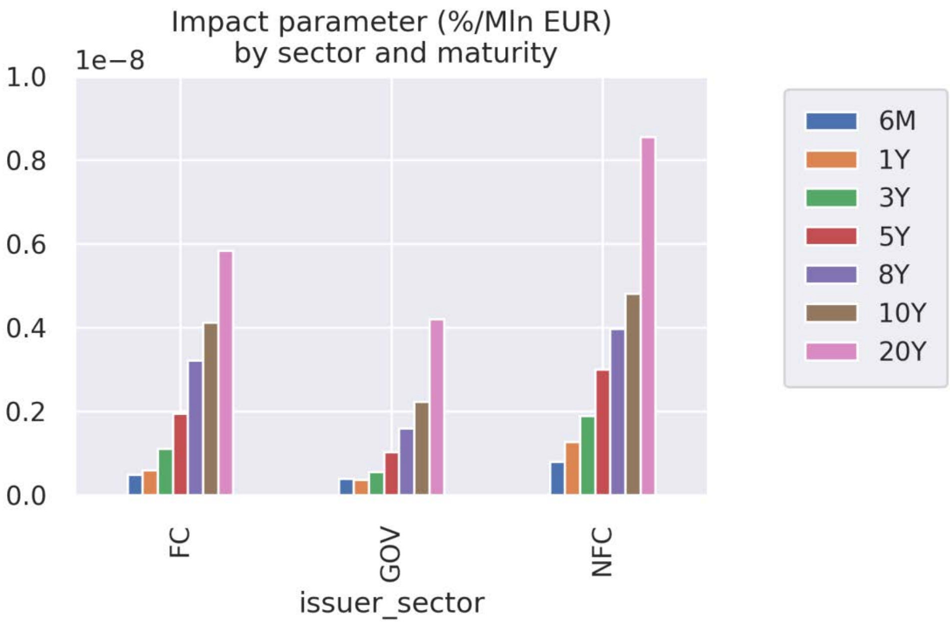
- **Driven by liquidity shortfalls:** banks/funds cover their liquidity shortfalls by selling their tradable assets
- **Pro rata approach:** amounts sold are proportional for all securities held
- **Price equilibrium:** price impacts re-calculated until no further change in market values of holdings
- **Price impact functions:** estimation at ISIN/issuer level (hull or quantile approach)



Price impact calibration - results

The calibrated securities contain bonds and equity.

A clear relation exists between a bonds' residual maturity and the price impact.

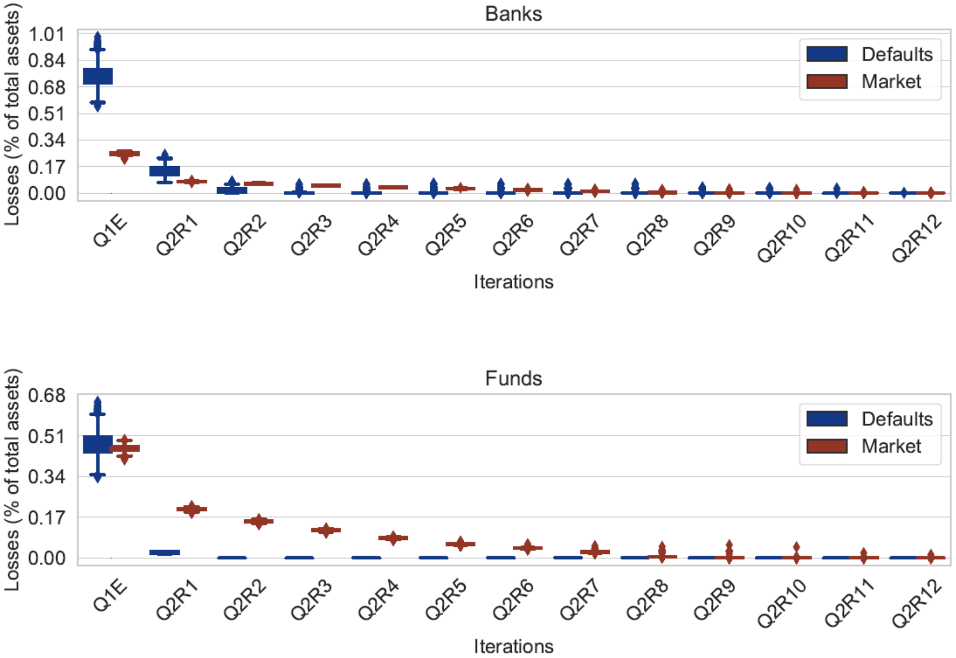


C

Results

Loss distributions for banks and funds

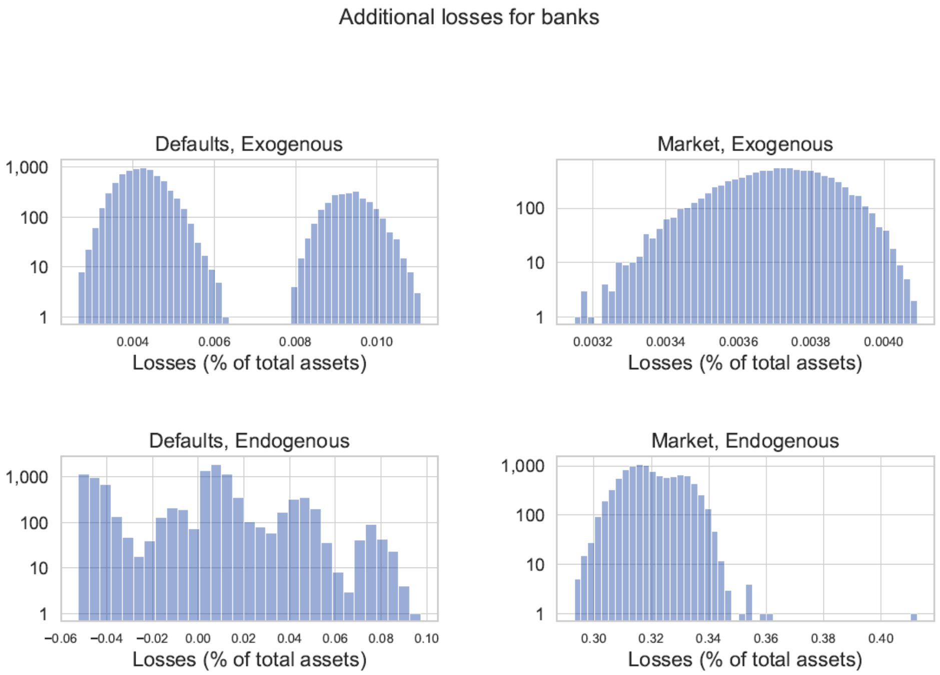
- After the first shock, the dispersion of subsequent losses is extremely low across the simulations: **similar sets of defaulting entities**
- Contagion mechanisms imply losses for banks both due to defaults and fire sales
- Market shocks hit funds more severely
- Funds only suffer losses due to market fire sales and are not exposed to endogenously defaulting banks



Distribution of losses for banks and funds based on 10000 Monte Carlo simulations (in percentage of total assets in the system).
'Q1E' initial exogenous shocks in the first quarter.
'Q2R1' to 'Q2R12' represent the iterations until convergence

Funds' impact on banks' losses

- The existence of funds in our model increases exogenous bank losses much less than endogenous losses (reason for exogenous losses: NFC defaults already have a price impact)
- Endogenous losses are high, confirming that funds have a very large impact on the market and on banks
- Funds may have a **mitigating role** for some banks (negative additional losses; higher market liquidity)

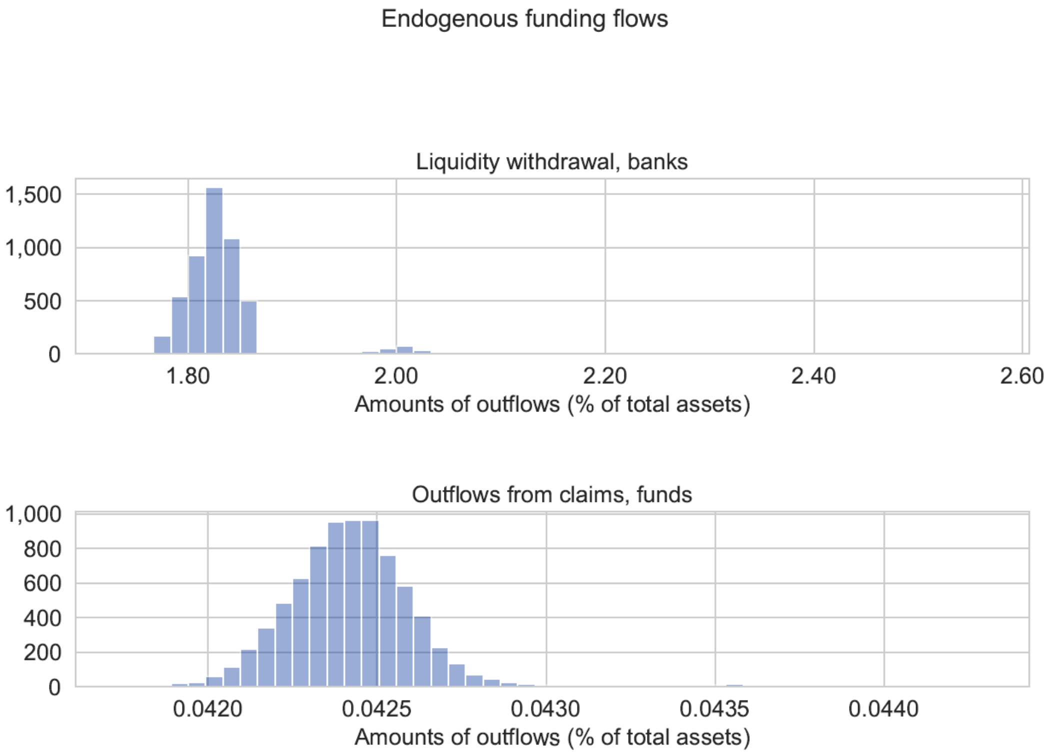


Histogram of losses from exogenous shocks and from endogenous reactions (contagion) for banks based on 10000 Monte Carlo simulations (in percentage of total banking sector assets).
'Defaults, Exogenous' refers to NFC defaults 'Market, Exogenous' refers to exogenous market losses both from the market scenario and from the price drop of exogenously defaulting NFCs issuing securities. 'Endogenous' losses are model-driven.

Aggregate endogenous outflows from banks and funds

- High amount of liquidity withdrawals driven by the information contagion assumption

- Funds do not face severe endogenous liquidity problems in the model

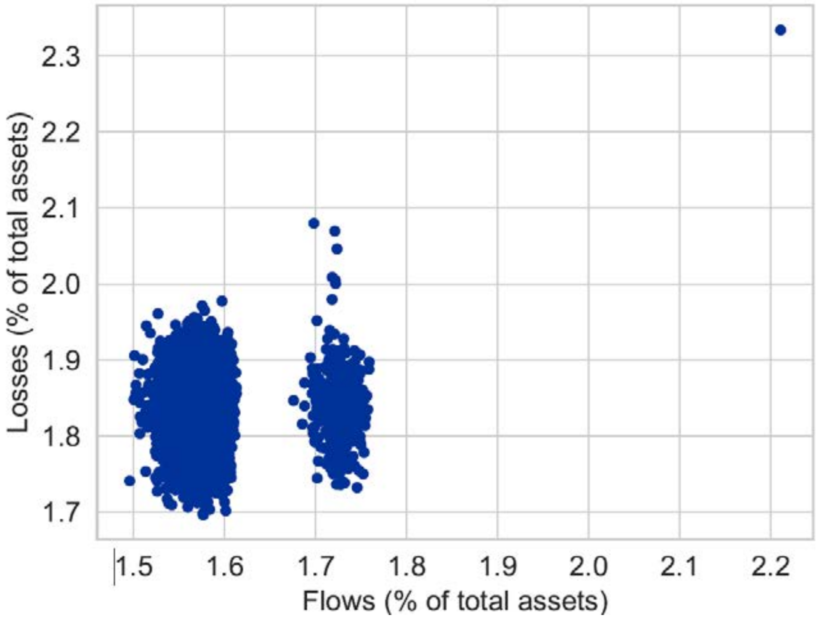


Histogram of financial flows following endogenous reactions based on 10000 Monte Carlo simulations (in percentage of total assets of the respective sector).

System-level flows and losses

- Clusters for liquidity flows reflect the larger importance of stochastic bank defaults with common sets of large defaulting banks

- Higher amounts of outflows do not necessarily mean higher losses: solvency also matters



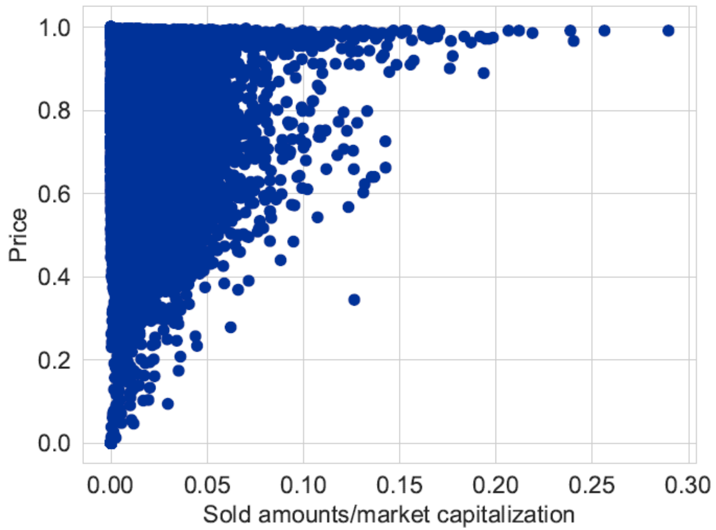
System-level flows and losses based on 10000 Monte Carlo simulations (in percentage of total assets).
’Flows’ represent the total redeemed and withdrawn amount of liquidity in the endogenous loops. ’Losses’ cover final losses from endogenous defaults and fire sales at the system level. Each dot represents the outcome of an individual Monte Carlo simulation.

Price impacts parameters

- Price impact parameters for more than 25K individual securities, aggregated to issuer level
- we use information at a security level

Filling missing information: When possible, we use the aggregated average

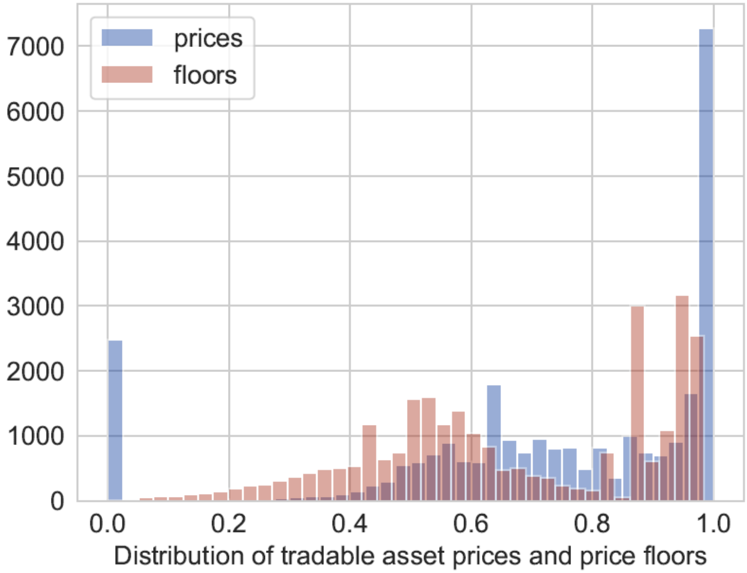
- o at an issuer level
- o at a country-sector-security-type level
- o at a continent-sector-security type level



Sold volumes over market capitalization (decimal) and equilibrium prices (decimal; a value of 1 means no price change) after convergence of the algorithm.
Market capitalization is the total amount of holdings in the system for a given security, before the shock.

Equilibrium prices

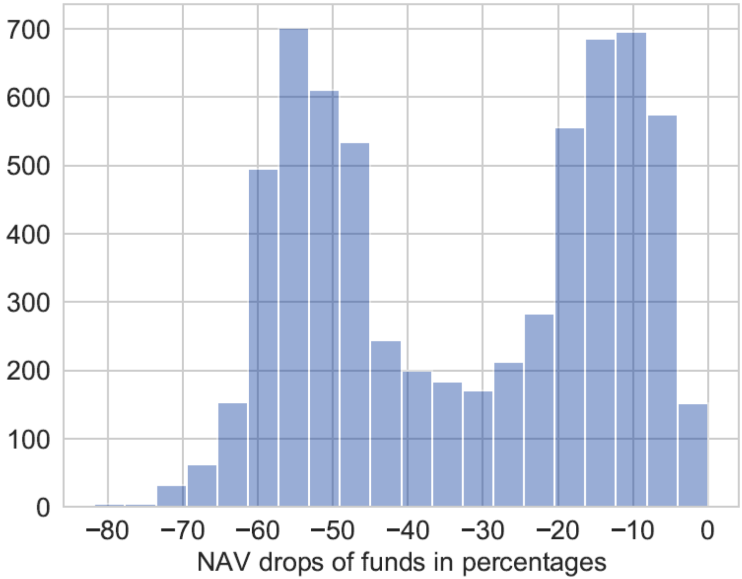
- Equilibrium prices generally do not reach their calibrated price floors
- Only securities issued by defaulted NFCs reach zero prices
- Large fraction of securities are not sold at all



Distribution of tradable asset prices in equilibrium and distribution of estimated price floors after convergence of the algorithm (decimal; a value of 1 means no price change, a value of 0 the default of the issuer)

Drop in funds NAV

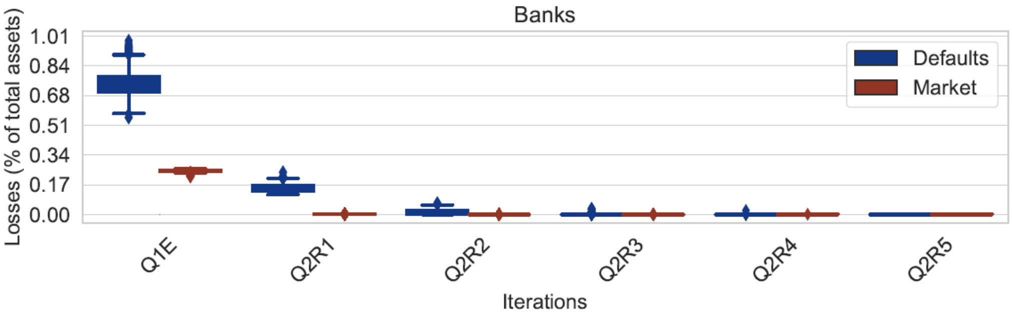
- Different behaviour of funds depending on their type
- Equity funds suffer more severe depreciations in their net asset values (NAV) consistent with our expectations



Distribution of declines in net asset values (NAV) for investment funds after convergence of the algorithm (percent).

Bank loss distribution
No funds case

- Relevance of fund interaction only from a market portfolio perspective
- Without fund fire sales, market losses are strongly reduced and induce a much faster convergence
- The reduction in steps, in turn, induces also fewer defaults and associated losses

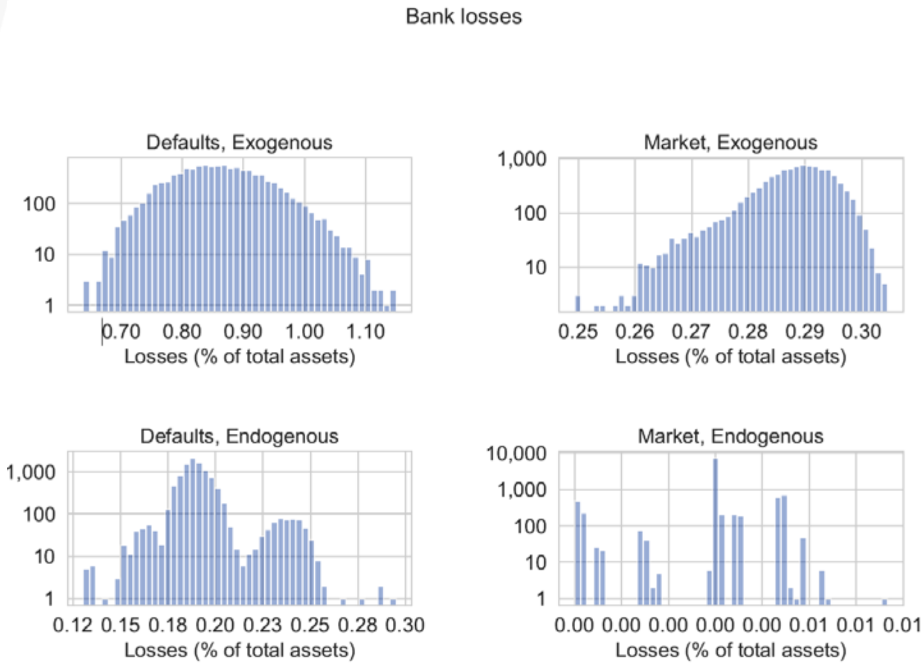


Distribution of market and default losses for 10000 Monte Carlo simulations, without funds (in percentage of total assets in the system of banks). ’Q1E’ shows the reaction following the initial exogenous shocks in the first quarter. ’Q2R1’ to ’Q2R5’ represent the iterations in the second quarter until convergence of the algorithm. In ’Q1E, ’Defaults’ refer to NFC defaults and ’Market’ to exogenous market losses both from the market scenario and from the price drop of exogenously defaulting NFCs. From ’Q2R1’ onward bank and fund defaults as well as market losses are model-driven.

Bank losses
No funds case

- Consistent with expectations, market endogenous losses are largely reduced

- Similarly and as predicted, fewer interactions cause a lower rate of bank defaults and implied losses

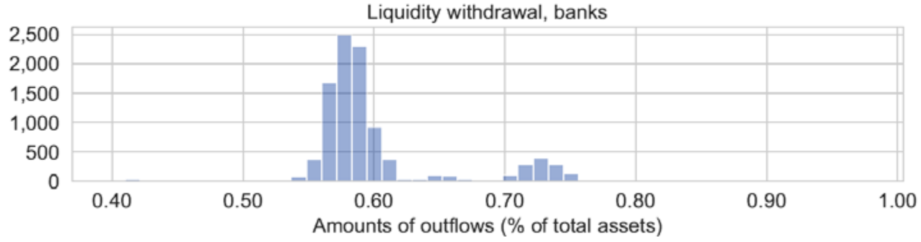


Histogram of losses from exogenous shocks and from endogenous reactions (contagion) for banks based on 10000 Monte Carlo simulations (in percentage of total banking sector assets). ’Defaults, Exogenous’ refer to NFC defaults. ’Market, Exogenous’ refers to exogenous market losses both from the market scenario and from the price drop of exogenously defaulting NFCs issuing securities. ’Endogenous’ losses are model-driven.

Bank’s liquidity withdrawals
No funds case

- As a further consequence of the aforementioned decreased losses, also liquidity withdrawals are reduced by about 1% of the total assets
- The distribution shape remains multi-modal
- The results from this experiment strongly support the need for including investment funds in banking sector stress testing exercises

Endogenous funding flows



Funding flows for banks (without funds), following endogenous reactions, in form of liquidity withdrawal based on 10000 Monte Carlo simulations (in percentage of total assets of the respective sector)