



EUROPEAN CENTRAL BANK

EUROSYSTEM

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

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MNB-OMFIF Financial  
Stability Conference 2022

26 May 2022

**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.*

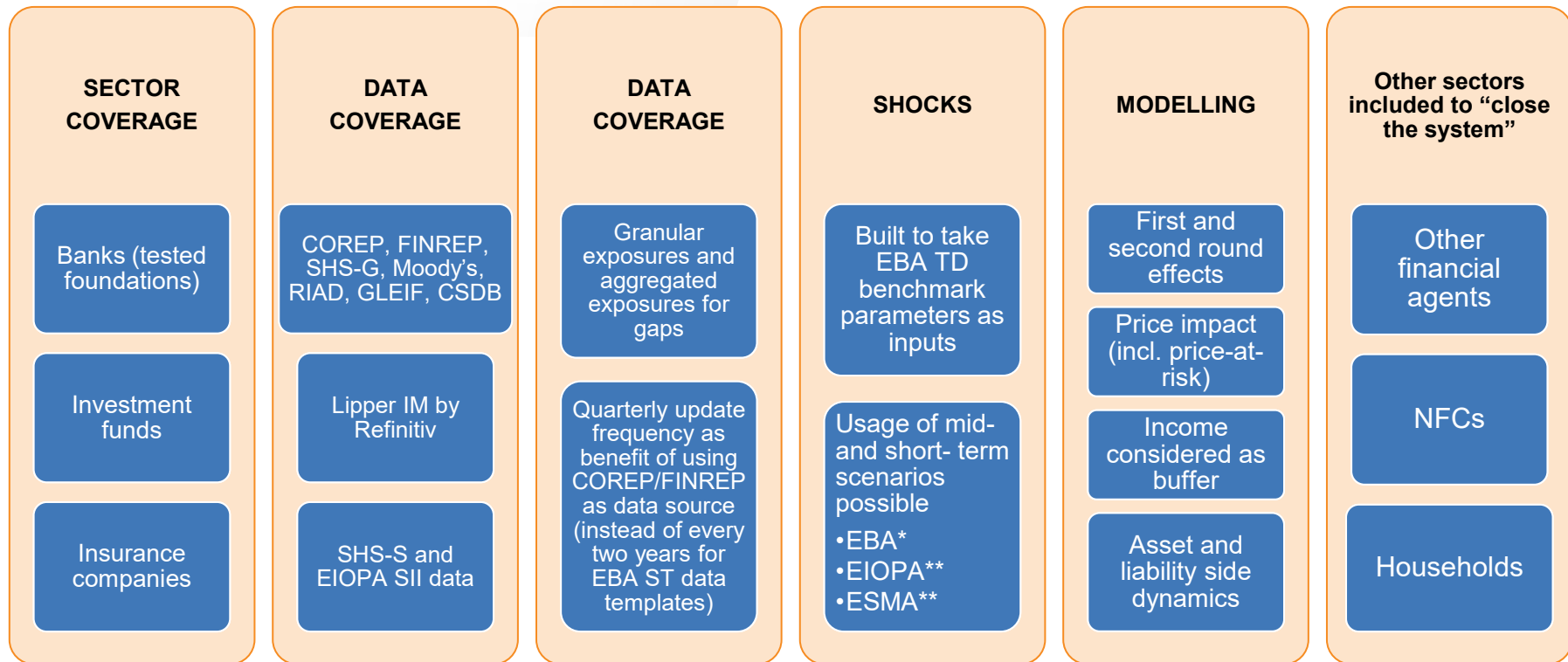
# Literature comparison

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 ( <b>representative agents</b> )	✓	✗	✓	✗	✓	✗
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	✓	✗	✓	✓	✓	✗
<b>Our framework</b>	Banks, funds, insurers	✓	✓	✓	✓	✓	✓

# Literature comparison (ctd.)

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

# Unique features

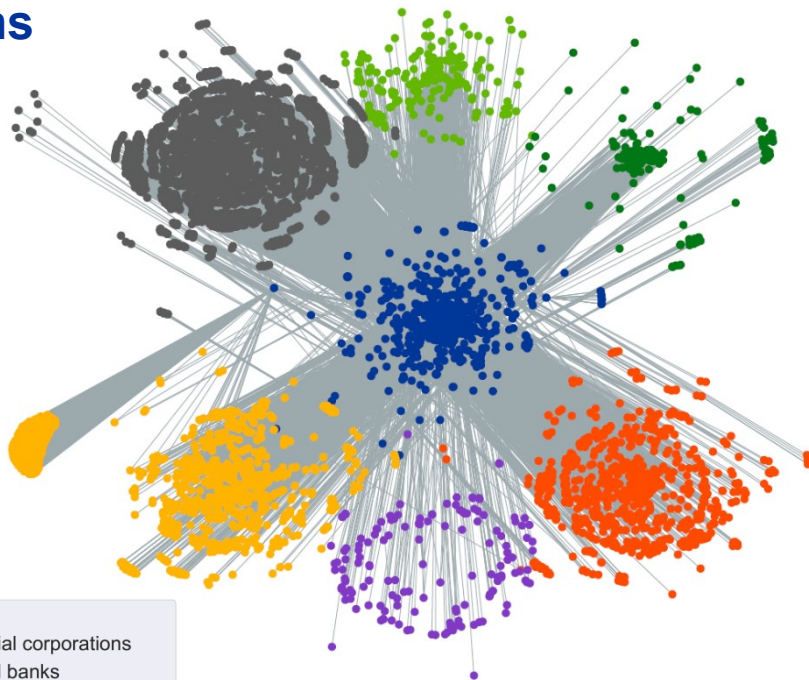


\* EBA: 3-year macrofinancial scenario

\*\* EIOPA/ESMA: instantaneous shock scenario

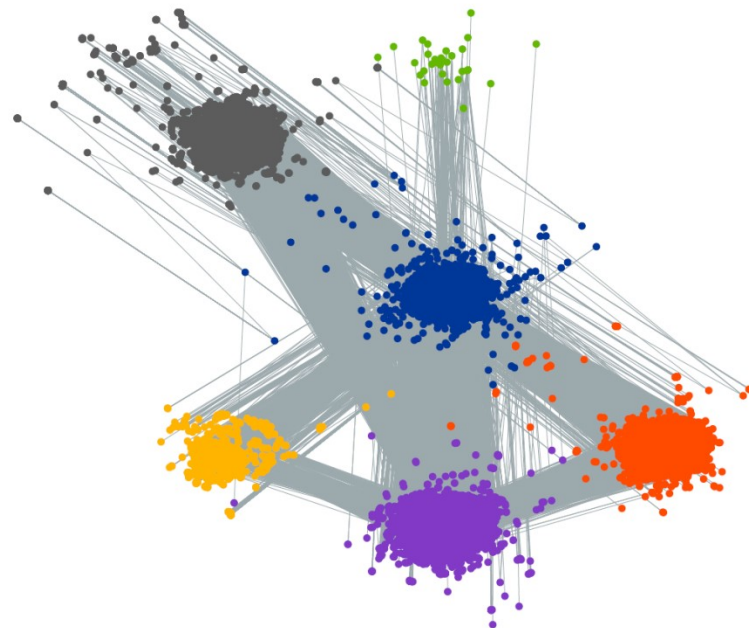
# Our exposure networks: 377 banks, 12655 funds

## 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.

# 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))

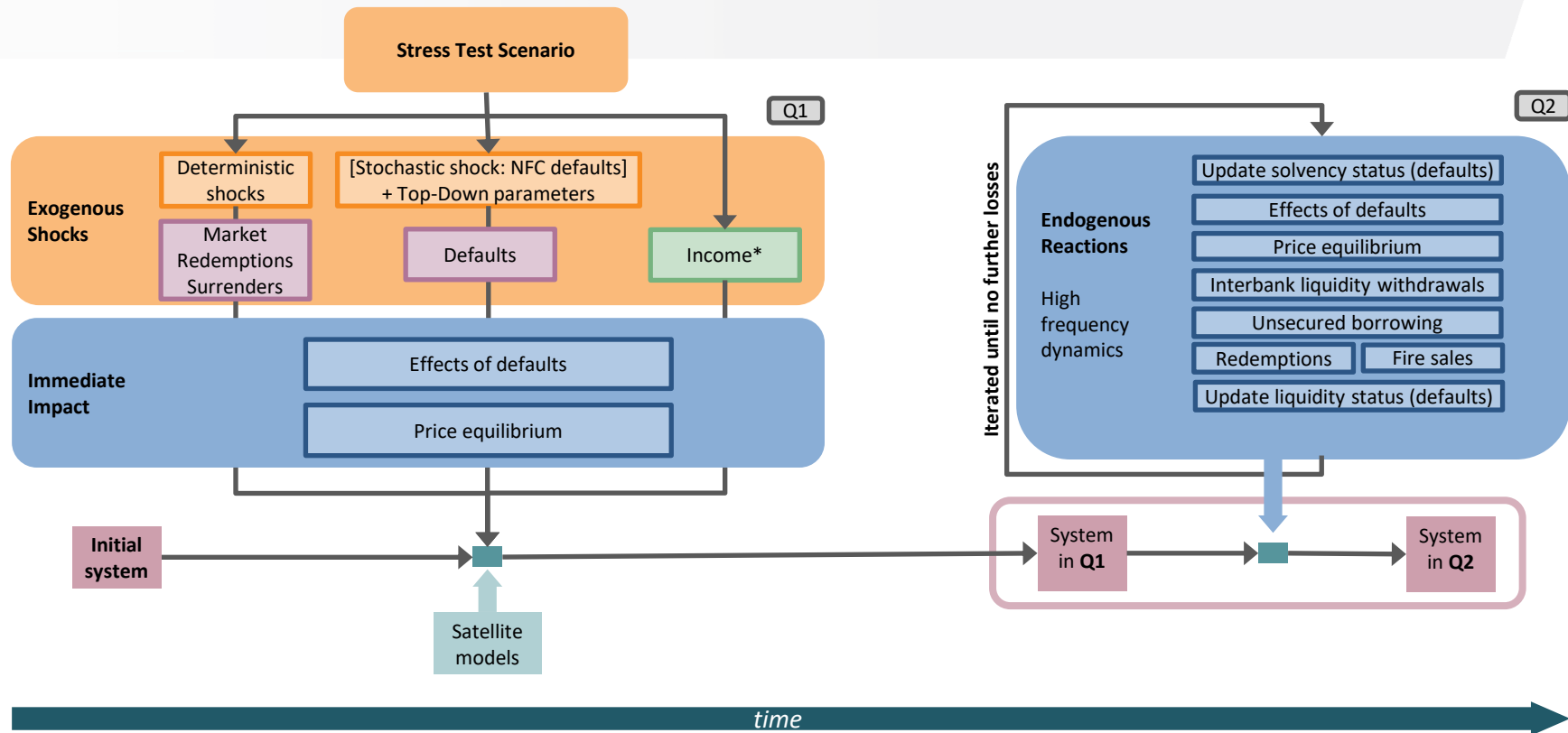
## **Market shock:**

Country-level stock market shocks

## **Redemption shock:**

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









# Modelling framework



\*Income channel is, e.g., approximated from EBA 2021 ST exercise and FINREP data



# Median losses

	Default losses		Market losses	
System	1.9		2.9	
	<i>Exogenous</i>	<i>Endogenous</i>	<i>Exogenous</i>	<i>Endogenous</i>
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\*\*

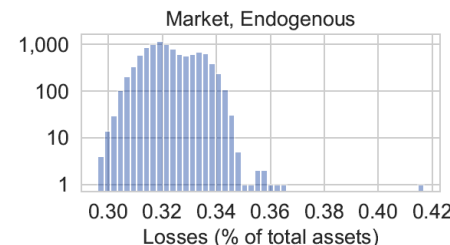
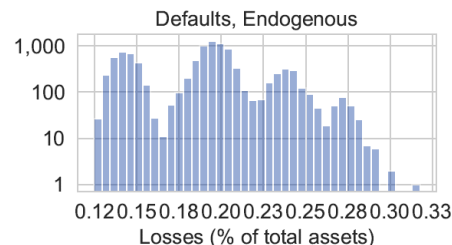
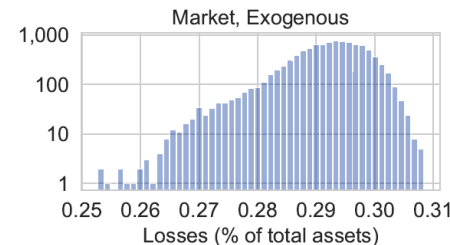
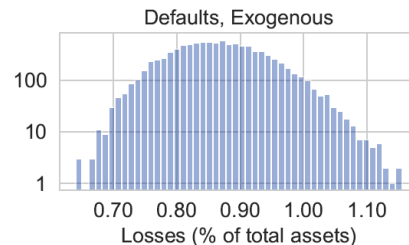
**Market losses:** stock market shocks and endogenous fire sale losses

- 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**

Bank losses



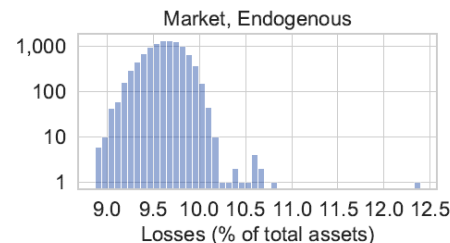
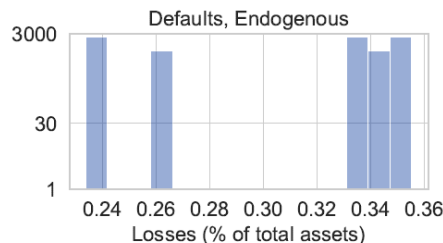
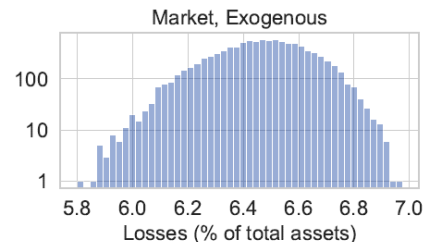
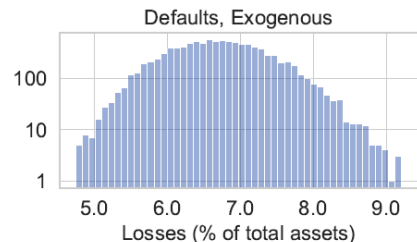
Histogram of losses from exogenous shocks and from endogenous reactions (contagion) for banks based on 10000 Monte Carlo simulations (in percentage of total banking sector assets).

'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.

# 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

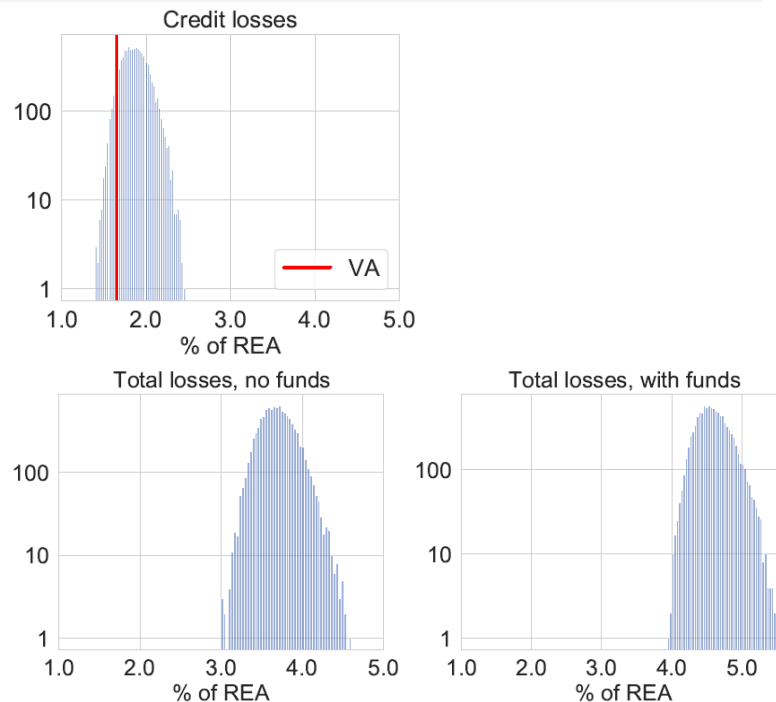


Histogram of losses from exogenous shocks and from endogenous reactions (contagion) for funds based on 10000 Monte Carlo simulations (in percentage of total investment fund sector assets).

'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 monetary policy analysis
- **Model extension** with regard to other financial sectors such as insurance corporations [done], 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



# 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

# 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

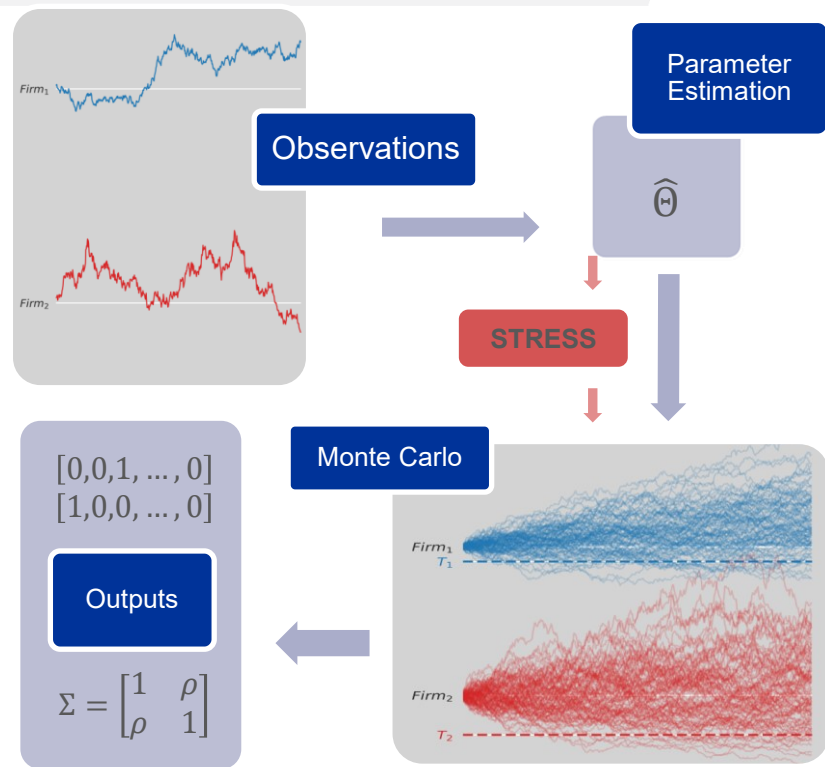
- Granular securities holdings from Lipper IM by Refinitiv:
  - Market value of exposure amount security-by-security (ISIN)
  - Cash information

# B

## Methodolgy

# 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

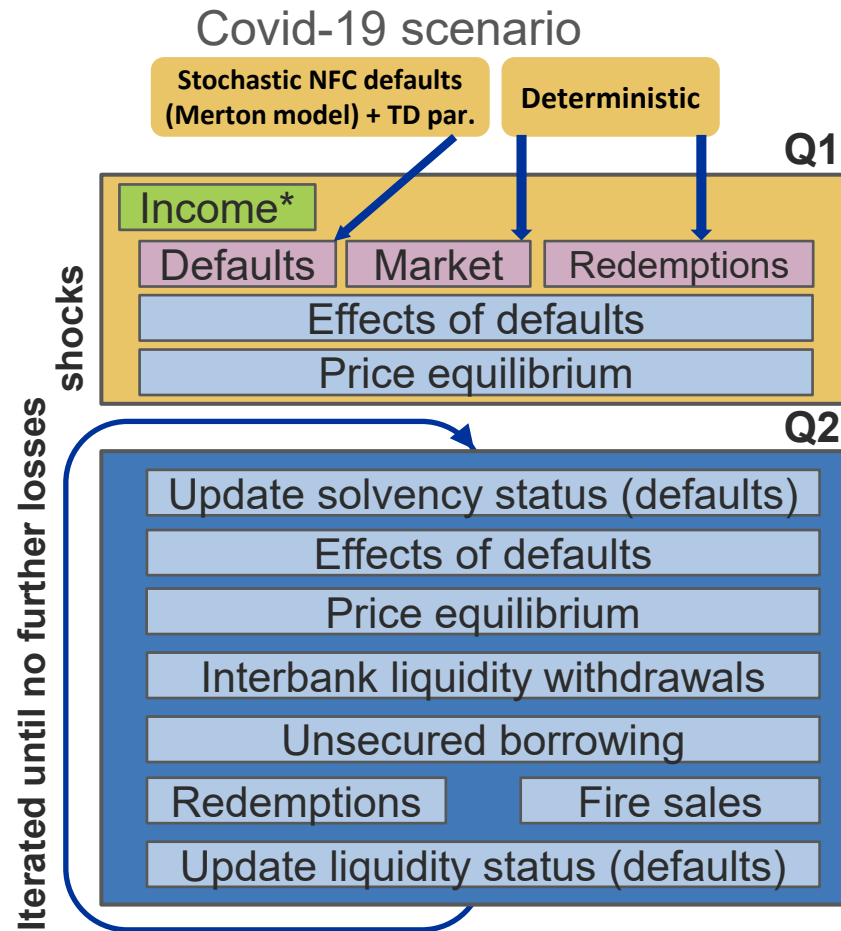
Formally, ARDL models of the following form are used for both PDs and redemptions:

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

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

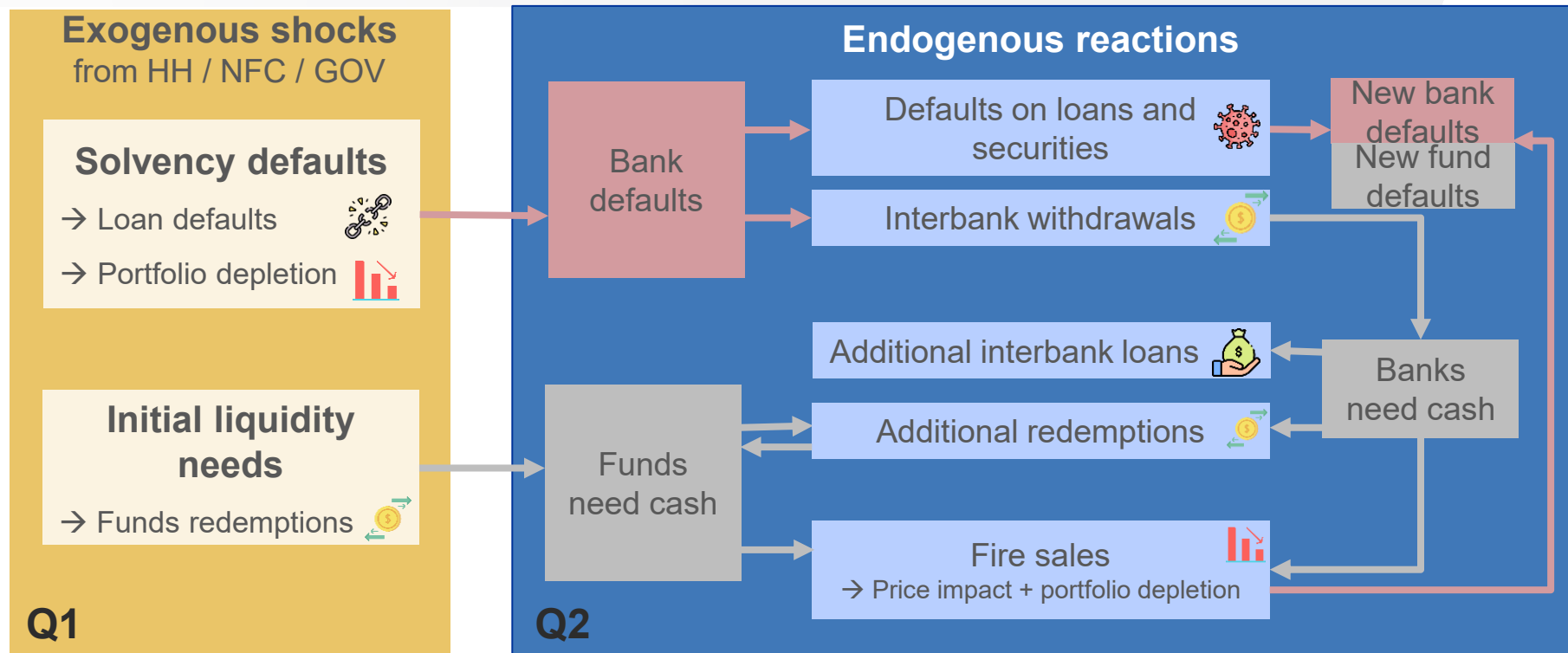
# Modelling summary

- **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

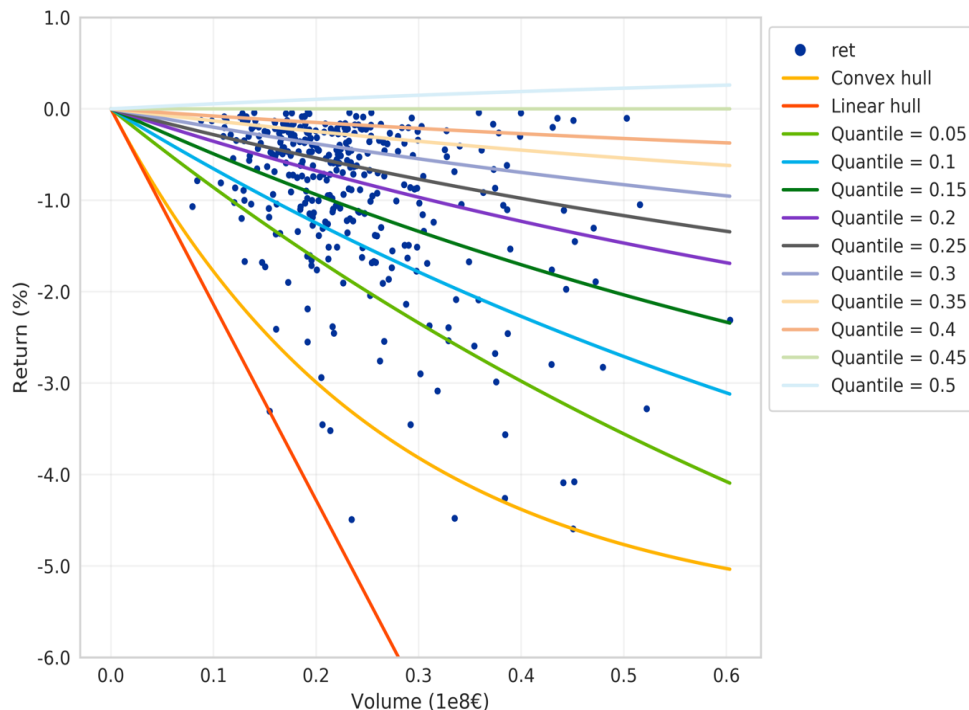
# Mechanisms at play *(simplified scheme)*





# 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 recalculated until no further change in market values of holdings
- **Price impact functions:** estimation at ISIN/issuer level (hull or quantile approach)



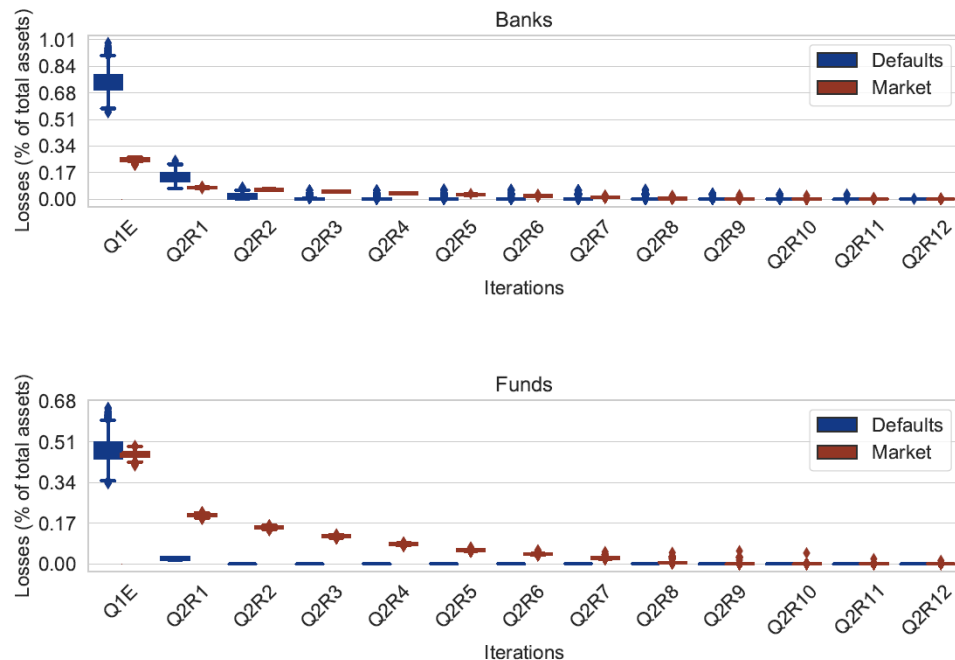


# C

## 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).

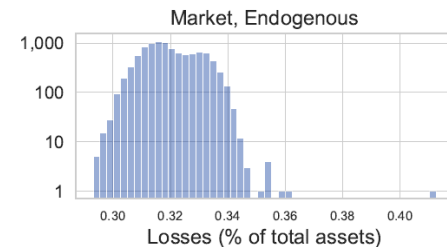
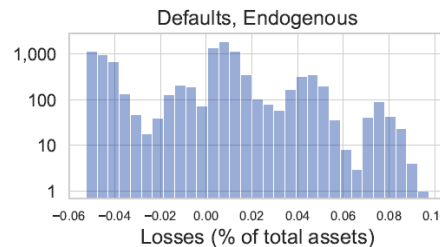
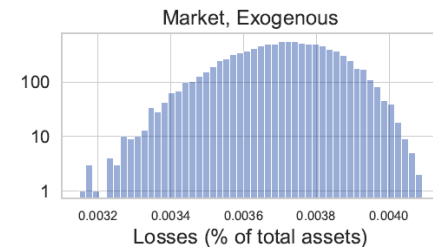
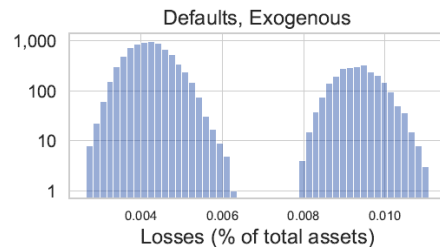
'Q1E' initial exogenous shocks in the first quarter.

'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)

Additional losses for banks



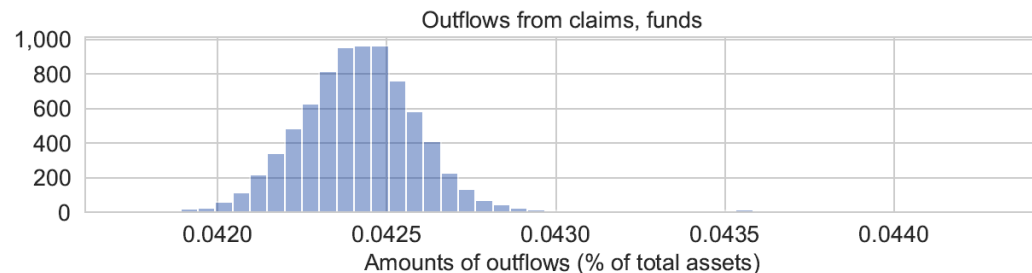
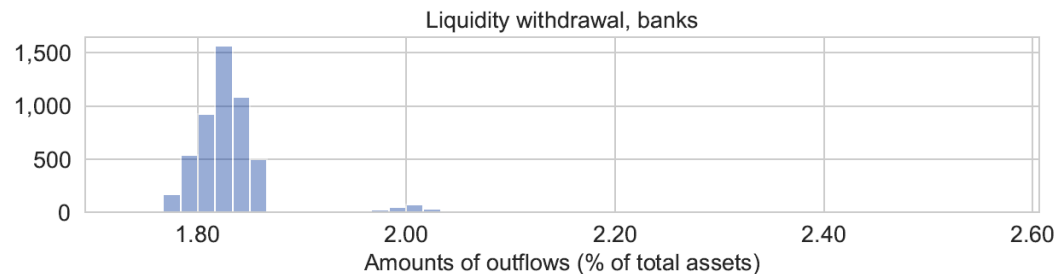
Histogram of losses from exogenous shocks and from endogenous reactions (contagion) for banks based on 10000 Monte Carlo simulations (in percentage of total banking sector assets).

'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

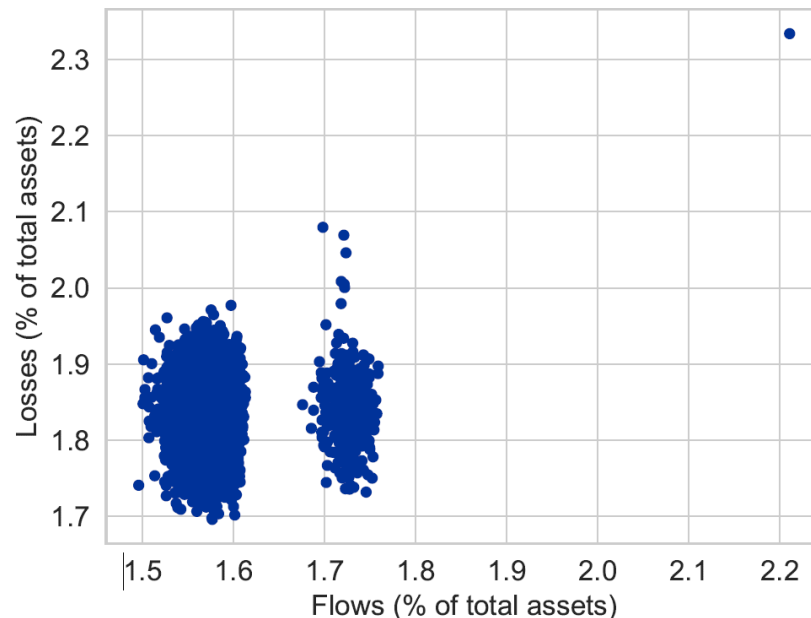
Endogenous funding flows



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



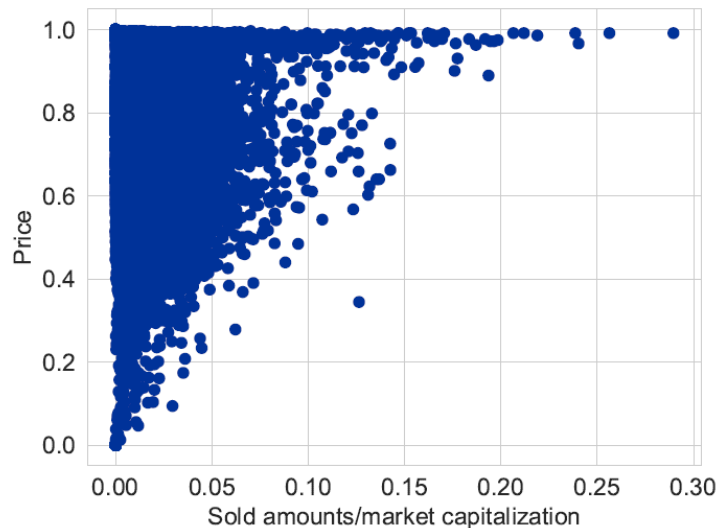
System-level flows and losses based on 10000 Monte Carlo simulations (in percentage of total assets).  
'Flows' represent the total redeemed and withdrawn amount of liquidity in the endogenous loops. 'Losses' cover final losses from endogenous defaults and fire sales at the system level. Each dot represents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

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

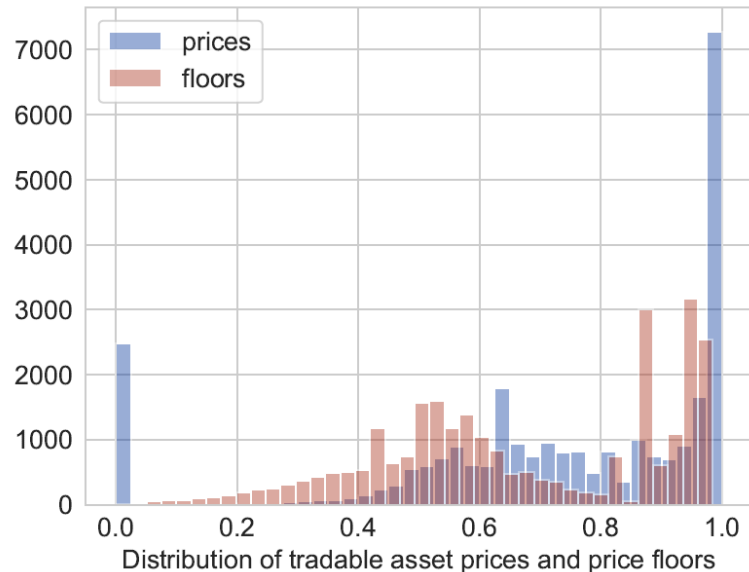


Sold volumes over market capitalization (decimal) and equilibrium prices (decimal; a value of 1 means no price change) after convergence of the algorithm.

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

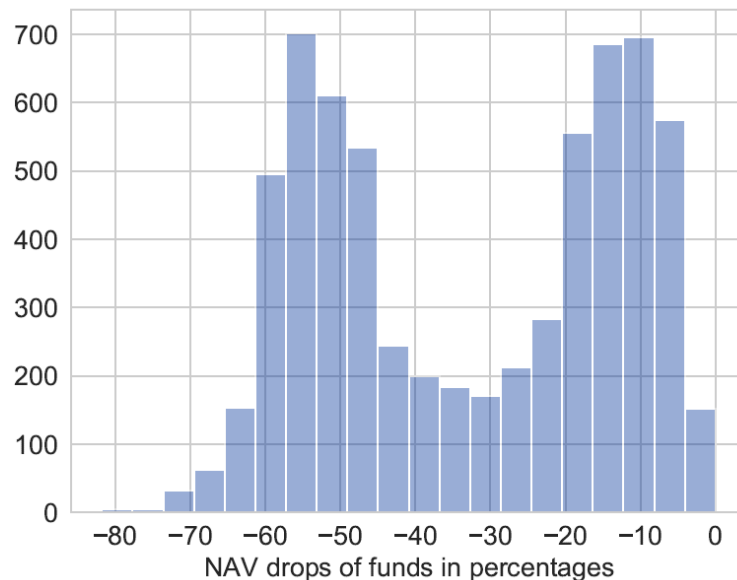


Distribution of tradable asset prices in equilibrium and distribution of estimated price floors after convergence of the algorithm (decimal; a value of 1 means no price change, a value of 0 the default of the issuer)



# 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

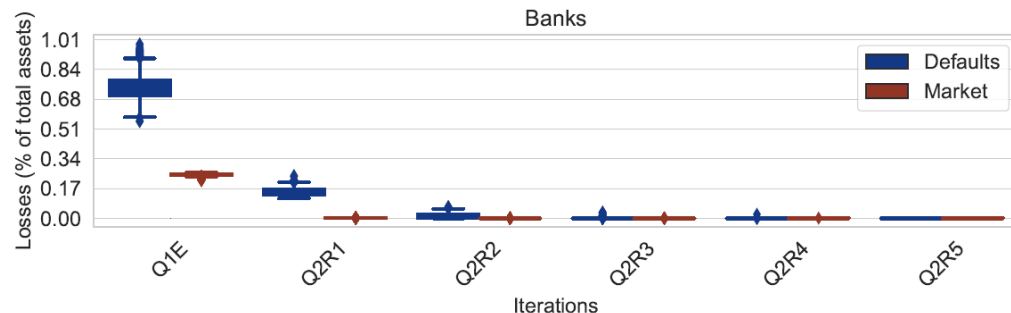


Distribution of declines in net asset values (NAV) for investment funds after convergence of the algorithm (percent).

# 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



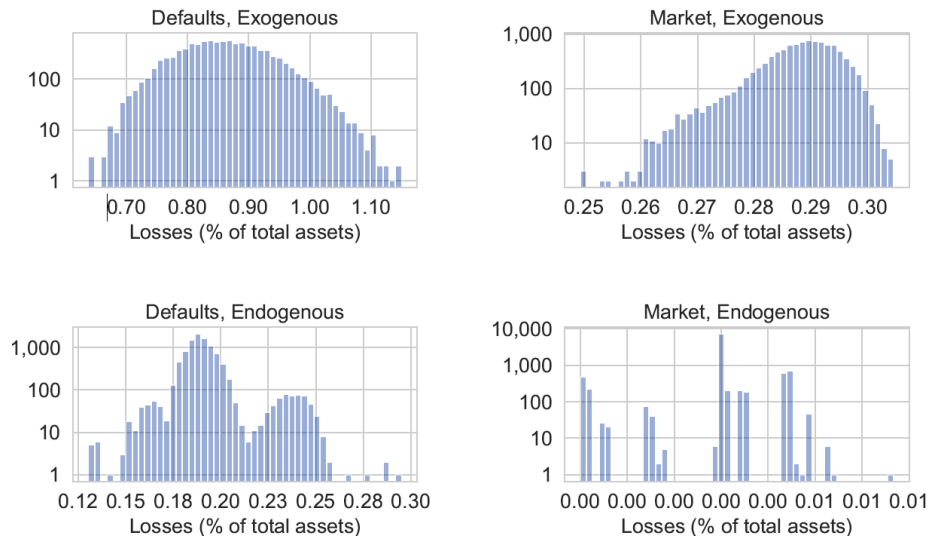
Distribution of market and default losses for 10000 Monte Carlo simulations, without funds (in percentage of total assets in the system of banks). 'Q1E' shows the reaction following the initial exogenous shocks in the first quarter. 'Q2R1' to 'Q2R5' represent the iterations in the second quarter until 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

Bank losses

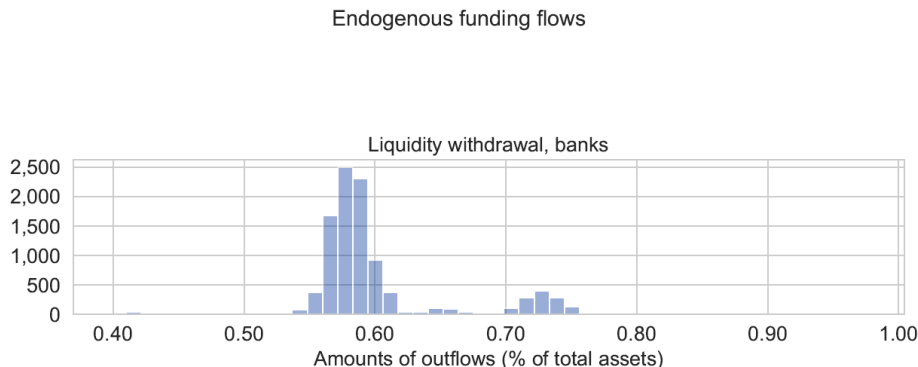


Histogram of losses from exogenous shocks and from endogenous reactions (contagion) for banks based on 10000 Monte Carlo simulations (in percentage of total banking sector assets). 'Defaults, Exogenous' refer to NFC defaults. 'Market, Exogenous' refers to exogenous market losses both from the market 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



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)