Recent advances in macroprudential and system-wide stress testing, contagion analysis and their application for macroprudential measure calibration

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MNB-OMFIF Financial Stability conference 2022

Budapest, 26 May 2022

Disclaimer: The views expressed are my own and do not necessarily reflect those of the ECB nor the Eurosystem.

Outline: key themes

1. **Objectives and key features**
2. **Macro feedback loops**
3. **Contagion and fire sale effects**
4. **Beyond banks**

1. Objectives and key features

Objectives of macroprudential stress tests

- **What do the Basel Committee's Stress Testing Principles say?**

➢ Authorities may also use, where appropriate and relevant, stress testing outcomes for macroprudential purposes, such as:

  ➢ To identify and assess risks and vulnerabilities at systemic level, possibly including additional sources of stress (e.g. feedback/second-round effects)

  ➢ To quantify the capital needs at systemic level during a time of crisis

  ➢ To inform the calibration of macroprudential policies and instruments

Source: https://www.bis.org/bcbs/publ/d450.pdf.

Key features of macroprudential stress tests

- "These tests capture those losses that can be **endogenously amplified** through
  - macro-financial feedback effects
  - contagion across financial entities
  - …and markets
- that have the potential to magnify moderate exogenous shocks via endogenous feedbacks into substantial negative financial outcomes with significant welfare losses"
- Offering **system-wide, top-down perspective**
- Allow for impact assessments of macroprudential policies along both **time dimension** and **cross-section dimension**

Source: Andersson, Danielsson, Baba, Das, Kang and Segoviano (2018), IMF WP # 18/197.

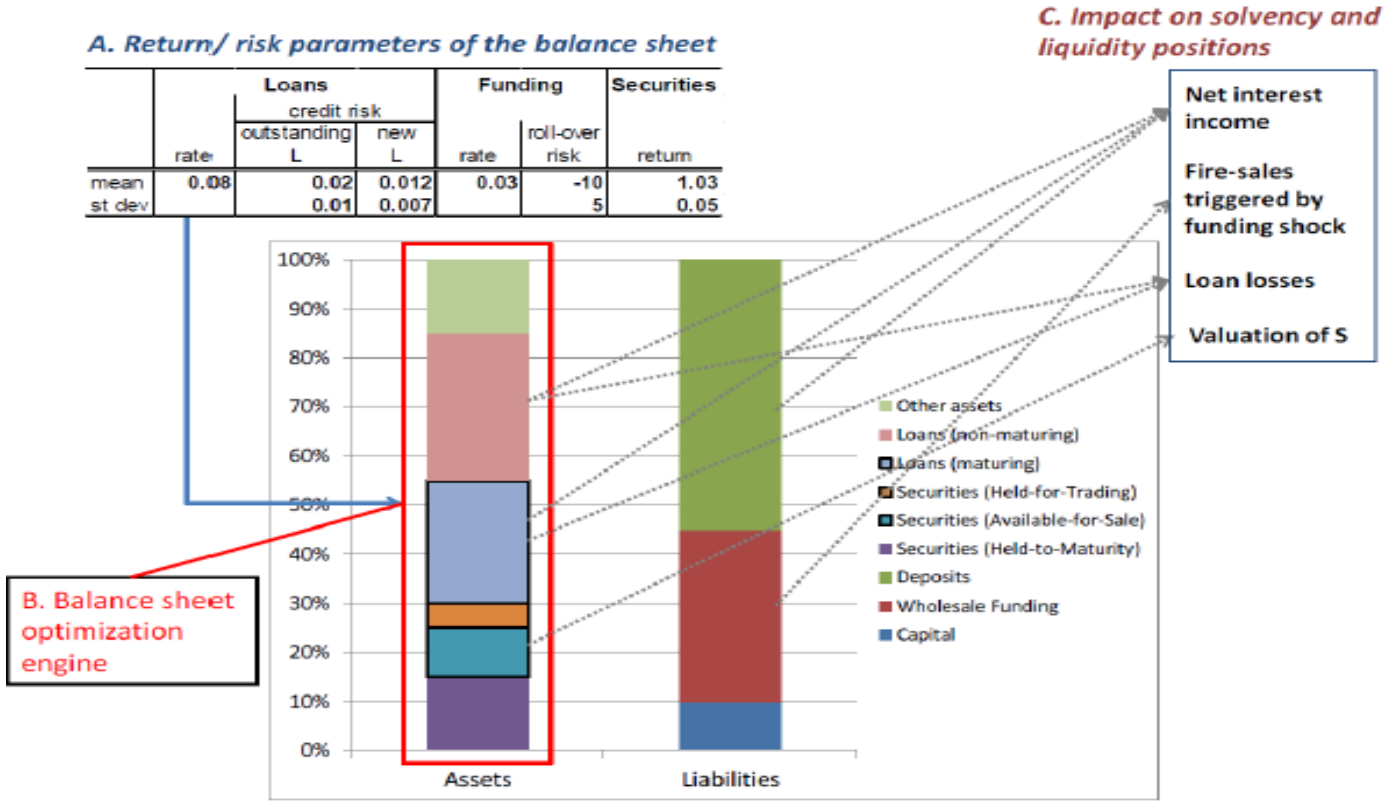
Emphasis on dynamic bank behaviour (1/2)

- How do banks respond to shocks?

  - **Deleverage** through asset reductions vs. raise equity
  - **Banking book** (loan supply) vs. **trading book** (fire sale losses)
  - Adjustments via **prices or quantities**
  - Subject to **regulatory and other constraints** (solvency and liquidity)

Emphasis on dynamic bank behaviour (2/2)

- Need to capture **banks' behaviour in times of stress**
- Banks' responses to shocks are determined by **balance sheet structure** and **risk-return characteristics**



Source: Darracq Pariès, M., Halaj, G. and Kok C. (2016), "Bank capital structure and the credit channel of asset purchases", ECB Working Paper No. 1916.

2. Macro feedback loop

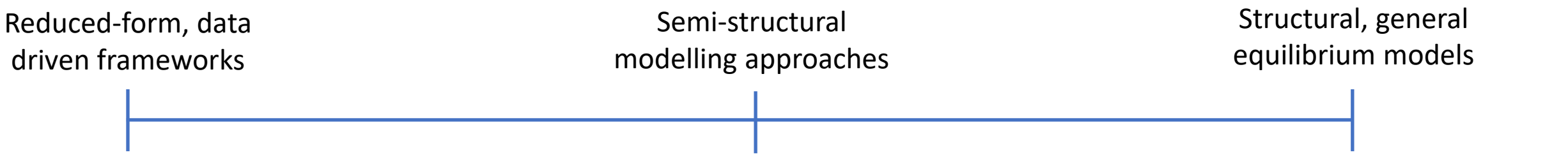
Macro-micro interactions and feedback effects

- Macroprudential stress tests allow for high level of granularity and accounting for bank heterogeneity

- But not trivial task going from micro level impact assessments to the macro level
  - How to make bank heterogeneous responses consistent with system-wide effects?
- More than just the sum of the parts
  - Ideally, heterogeneous bank behaviour should be modelled within a comprehensive and consistent macro model framework
  - Realistically, more piecemeal approaches are likely to remain ‘state-of-the-art’ in the near future

Macro Feedback loop: Modelling approaches

Range of modelling approaches



Modular setup with satellite models linked in a sequential but consistent way

- Granular, micro data based
- Parsimonious
- But feedback loop not endogenous

Examples: Schmieder et al. (2012), Henry and Kok (2013), Montes and Trucharte (2013), Dees et al. (2017), HKMA (2016), Daniels et al. (2017), Bennani et al. (2017).

One model setup with still reduced-form equations which are however solved endogenously

- Endogenous modelling of feedback loop
- Granular, micro dimension more difficult to handle
- Less parsimonious

Examples: Burrows et al. (2012), Kitamura et al. (2014), Gross et al. (2016), Krznar and Matheson (2017), Figue (2017), Budnik et al. (2019, 2020), Catalàn and Hoffmaister (2020).

Micro-founded, fully endogenised setup

- Modelling of feedback loop in a general equilibrium setting
- Stylised description of the banking sector
- Limited/no micro dimension (i.e. no heterogeneity)

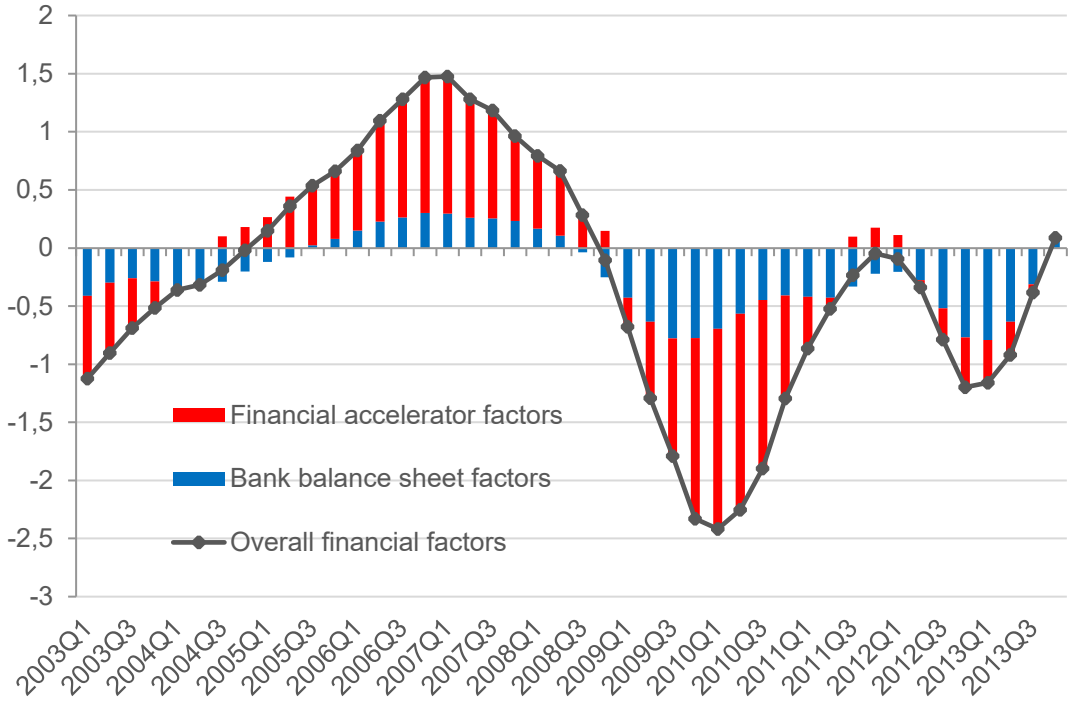
Examples: Christiano et al. (2010), Gerali et al. (2010), Darracq Paries et al. (2011, 2016, 2019), Gertler and Karadi (2011), Clerc et al. (2015), Mendicino et al. (2019, 2020), Adrian et al. (2020).

Macro-micro interactions and feedback effects

- The adverse scenario is likely to already reflect 2nd round effects

  - How to disentangle macro feedback effects (e.g. loan supply reductions) from the scenario?
  - How to model the "residual" amplifying macro effects?
    - DSGE-based simulations: switching on/off financial amplifiers for given scenario to gauge what would be a "normal" feedback impact
    - Semi-structural models with endogenous empirically-based bank reactions

Contribution of "financial shocks" to real GDP growth
(annual growth in percentage points)

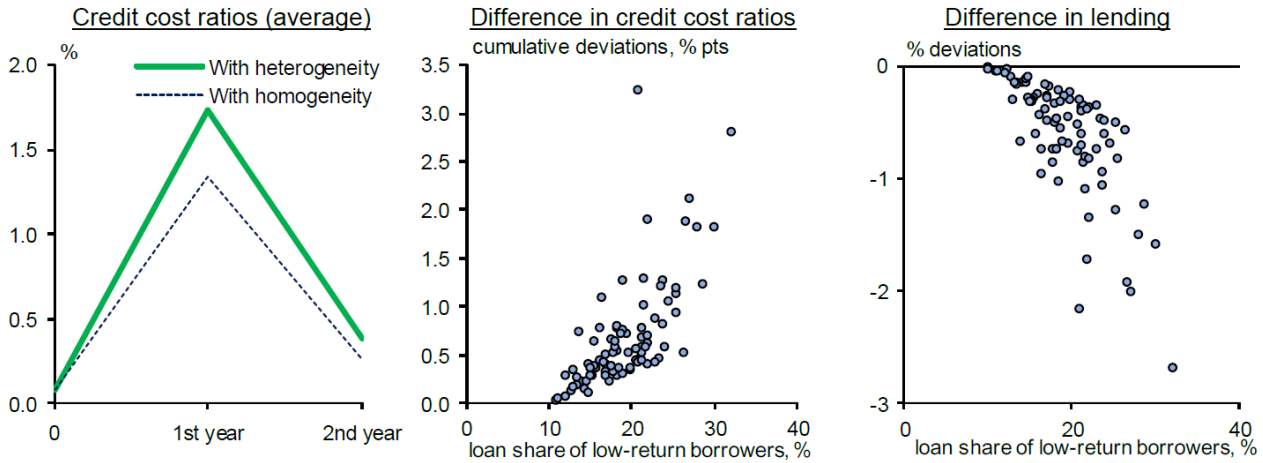


Source: Darracq Pariès, M., Kok C. and Rodriguez Palenzuela, D. (2011), "Macroeconomic propagation across different regulatory regimes: evidence from an estimated DSGE model for the euro area", International Journal of Central Banking, Vol. 7, No. 4, pp. 49-113.

Macro-micro interactions : accounting for heterogeneity

- Amplification through macro feedback effects
- Non-linear responses of banks depending on solvency position

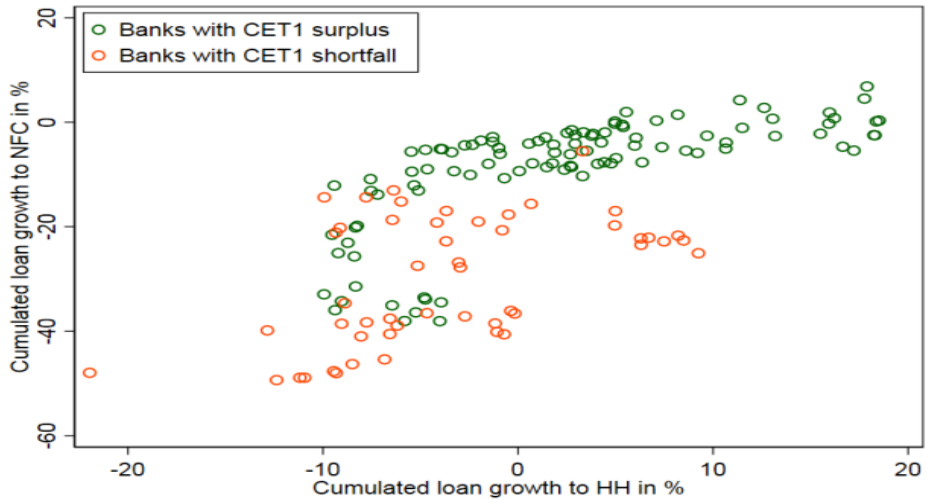
Bank credit cost ratios with and without heterogeneity



Note: 1. The figures show the results of macro stress testing assuming heterogeneity/homogeneity in firms' interest payment capacity. Covers domestic regional banks whose loan shares of low-return borrowers can be estimated.
2. The right-hand chart shows the deviations of domestic corporate loan outstanding at the end of the simulation period.

Source: Bank of Japan (2020), "The Financial Macro-econometric Model (FMM, March 2020 version): Overview and recent developments", Financial System Report Annex Series, August.

Bank loan growth to HH and NFC in the adverse scenario



Source: Budnik et al. (2019), "Macroprudential Stress Test of the Euro Area Banking System", ECB Occasional Paper #226.

3. Contagion and fire sale effects

Incorporating contagion in macroprudential stress tests

- Macroprudential stress tests need to **look at the financial system in its entirety** in order to see how it absorbs and amplifies shocks (Andersson et al., 2017)

- Cross (direct) holdings and indirect inter-linkages can work as **absorbers and amplifiers at different times**, and various categories of entities will naturally amplify or absorb risk

Contagion: Transmission channels

- **Direct contagion:** Through domino effects via bilateral financial relationships (but typically not sufficient to cause a systemic crisis)

- **Indirect contagion:** Systemic risk is endogenous!
  - **"Fire sales":** through common (overlapping exposures) (see e.g. Brunnermeier-Pedersen (2009), Adrian-Shin (2014); Greenwood et al. (2015))
  - **"Information asymmetry":** news-based contagion via confidence effects (Kapadia et al. (2012))
  - **"Strategic complementarities":** herd behaviour (Morris et al. (2017))

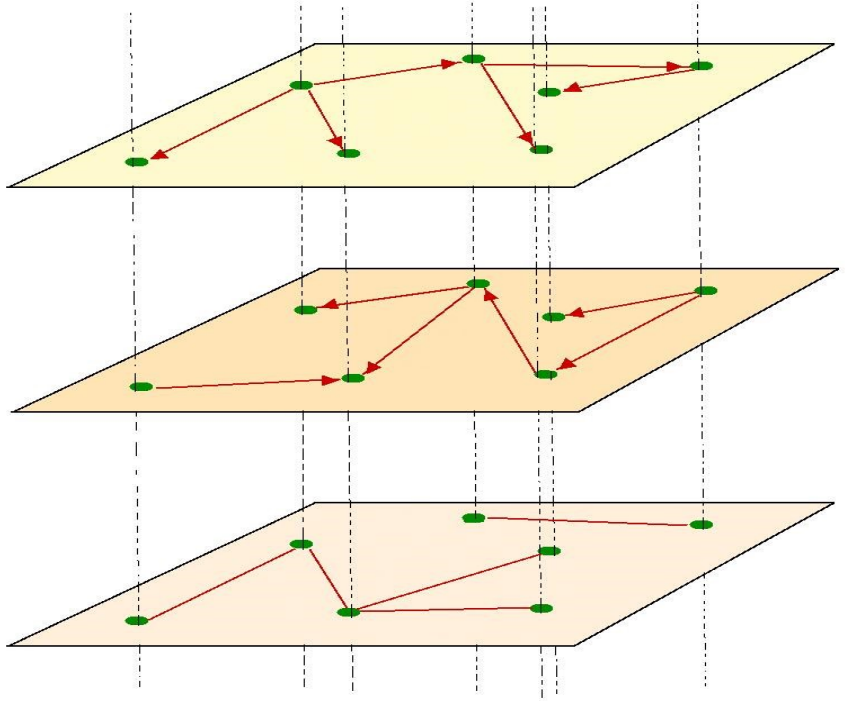
- **Network structure** is important for the spreading of systemic risk (Allen-Gale, 2000; Glasserman and Young, 2015; Acemoglu et al. (2015); Roncoroni et al. (2019))

- **Regulatory (and other) constraints** can serve as amplification mechanisms (Danielsson et al. (2012))

Measuring the network

Prerequisite: **suitable data** on interlinkages

- Data availability is key to assess interconnectedness and implied contagion risk
- More granular data have become available to macroprudential authorities – but much scope for further improvements
- Often it is necessary to rely on simulations, which limits the practical policy use of analytical contagion tools/models

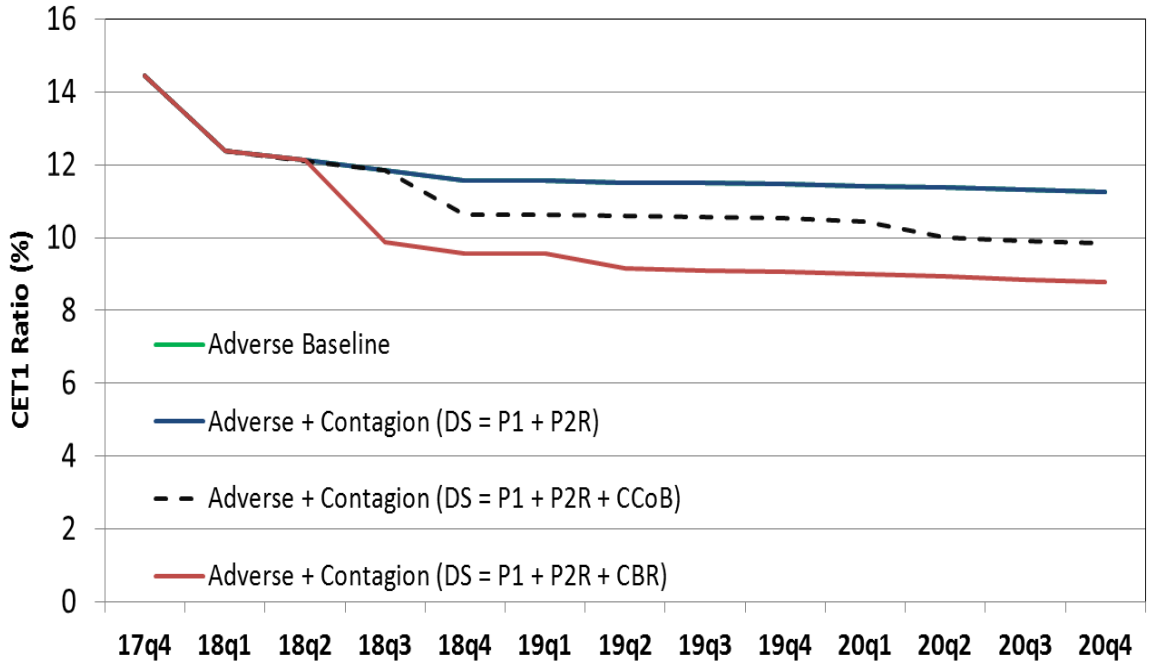


- **Model uncertainty**: estimated contagion cascades hinges on assumptions / modelling choices

Application in macroprudential stress testing

- Assumption about when contagion effects start kick in is crucial for magnitude of amplification
- Do banks start reacting (e.g. withdrawing interbank funding) only when they reach regulatory minima
- …or already when voluntary buffers are sufficiently reduced?

Significant Institutions' Capital Depletion as Share of RWAs due to Interbank Contagion



Source: Budnik et al. (2019), "Macroprudential Stress Test of the Euro Area Banking System", ECB Occasional Paper #226. Contagion model based on Covi et al. (2019).

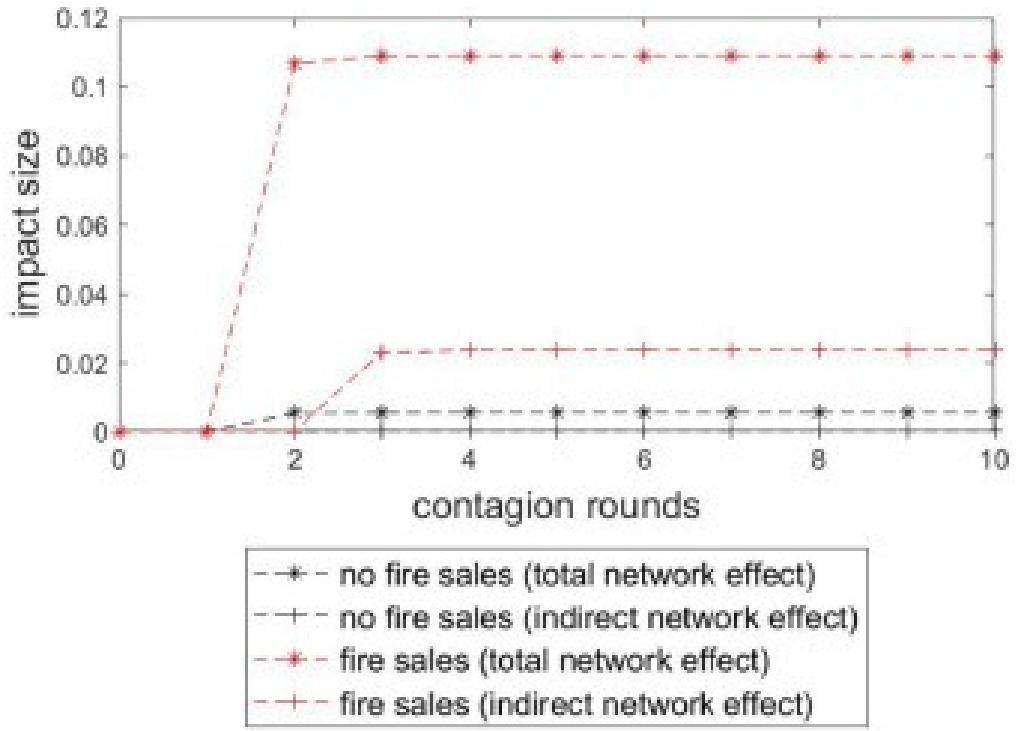
The importance of ‘fire sale’ effects (1/3)

- Decomposing direct and indirect network effects

- With no ‘fire sales’:
- limited direct network effect and negligible additional loss induced by indirect linkages

- With ‘fire sales’:
- direct network-induced losses wipe out 5.5% of system equity, and indirect contagion adds another 2.7%

Additional deleveraging induced by the network
(ratio to total system equity)



Aldasoro, I., Hüser, A.-C. and C. Kok (2022), Contagion Accounting in Stress Testing, Journal of Economic Dynamics and Control, Vol. 137 (https://www.sciencedirect.com/science/article/pii/S0165188922000598?via%3Dihub).

The importance of ‘fire sale’ effects (2/3)

- **Assumptions on ‘fire sale’ mechanism are key**
- …both in terms of revaluation losses on securities holdings due to fire sales
- And in terms of amplification effects on losses via bilateral interbank exposures

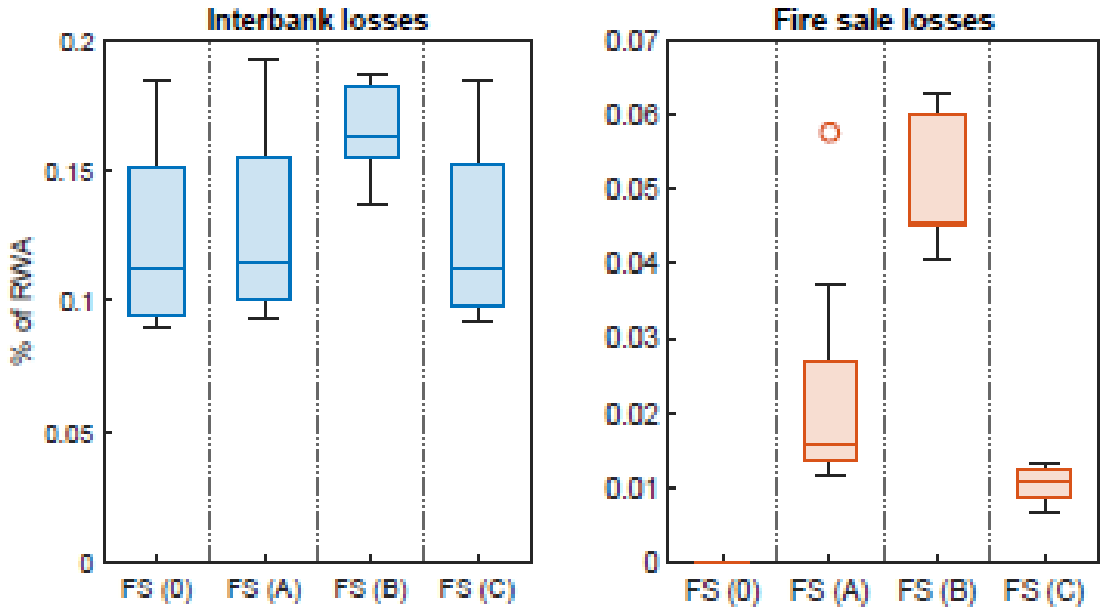
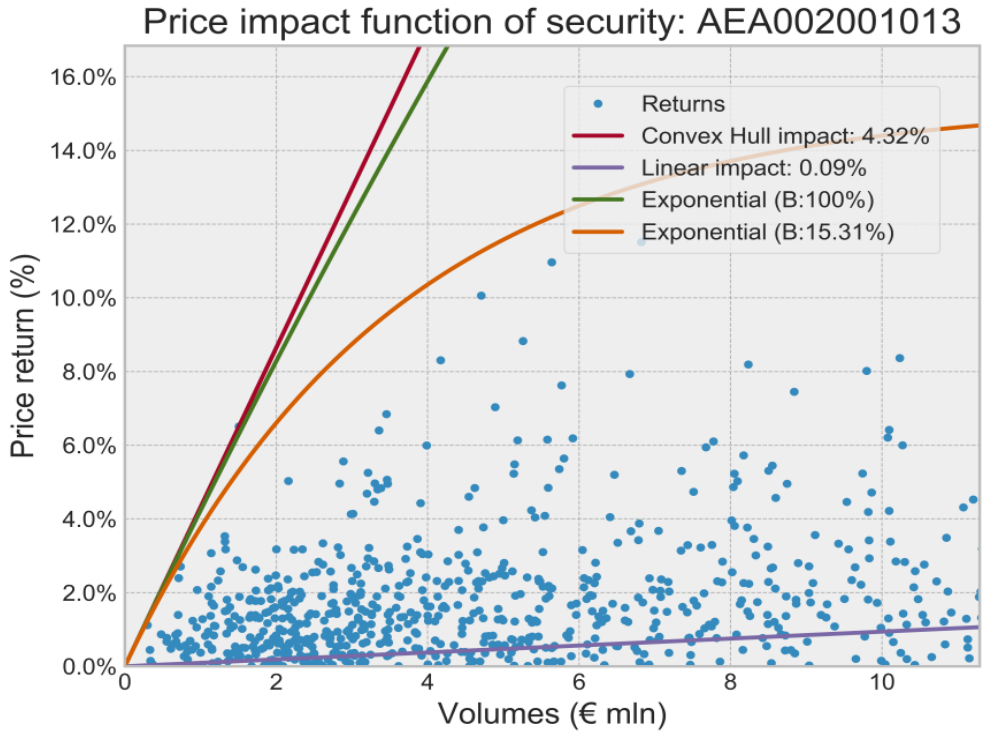


Figure 4: Distributions of interbank and fire sale losses without infusion, for the different fire sale assumptions (FS (0) denotes no fire sales). Distributions are across all quarters: 2019Q1–2020Q4. Interbank and fire sale losses are reported in percentage of risk weighted assets of the stress tested banks.

Source: Fukker, G. and C. Kok (2021), On the optimal control of interbank contagion in the euro area banking system, ECB Working Paper #2554.

The importance of ‘fire sale’ effects (3/3)

- **The calibration of fire sale losses**
- How robust are they?
- **Asset price elasticities**
  - Market depth / price impact function (linear/non-linear functional form)
  - Empirical work needed (ideally using security-by-security transactions data)
- **Deleveraging assumptions**
  - Liquidity and solvency constraints determine what assets banks would shed (i.e. taking into account differences in risk weights, need for an HQLA buffer)
  - Other mitigating options (e.g. capital raising, risk reduction, etc.)



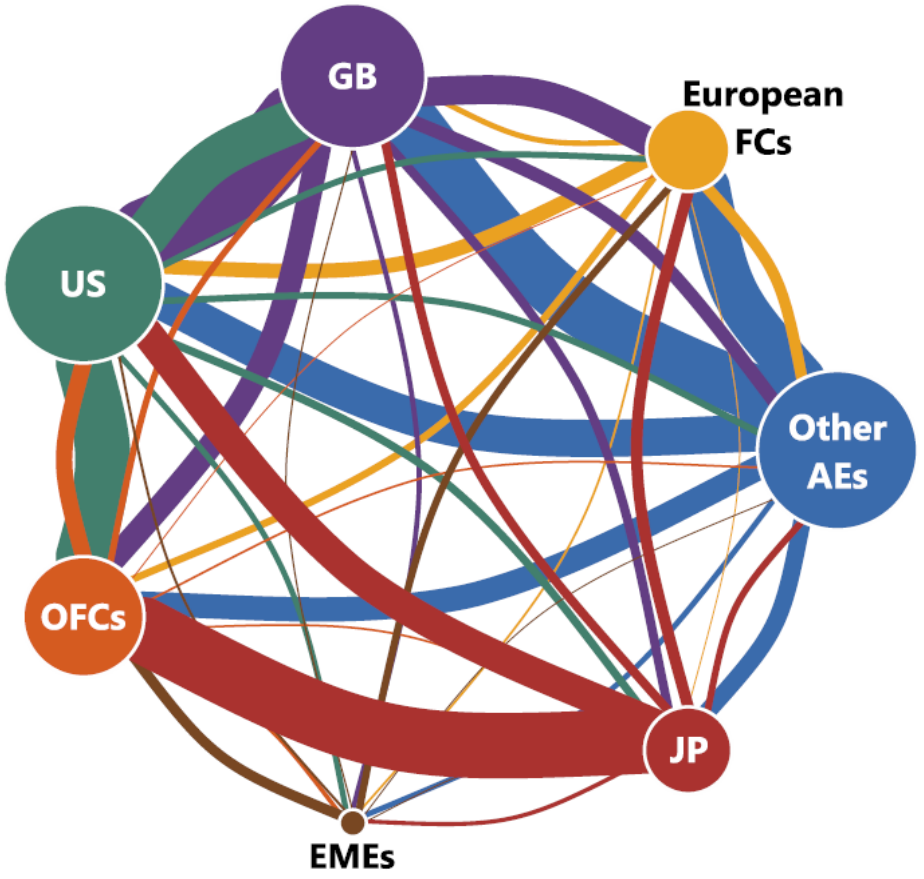
Source: Fukker, G., Kaijser, M., Mingarelli, L. and M. Sydow (2022), Contagion from market price impact: a price-at-risk perspective, ECB mimeo.

4. Beyond banks

System-wide stress testing

- Neither banks nor non-bank financial institutions operate in a vacuum
- Strong interlinkages between institutions and sub-sectors
- Therefore, it is warranted to take a holistic perspective to stress testing
- …by not only accounting for impact on stress within individual sub-sections (e.g. banks, insurers, funds)
- …but also how shocks may propagate across sub-sectors due to interconnectedness

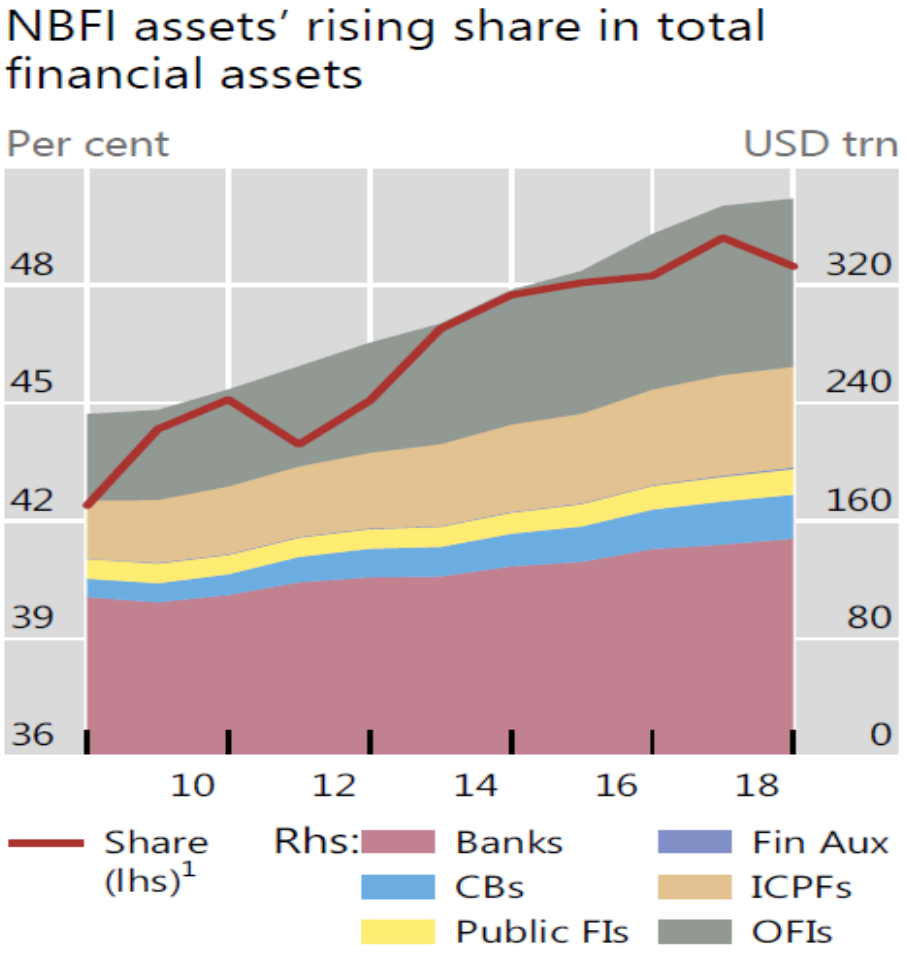
Network of banks' cross-border claims vis-à-vis NBFIs
(end-March 2020)



Source: Aldasoro, Huang and Kemp (2020), Cross-border links between banks and non-bank financial institutions, BIS Quarterly Review, September.

Non-bank financial intermediation is growing in importance

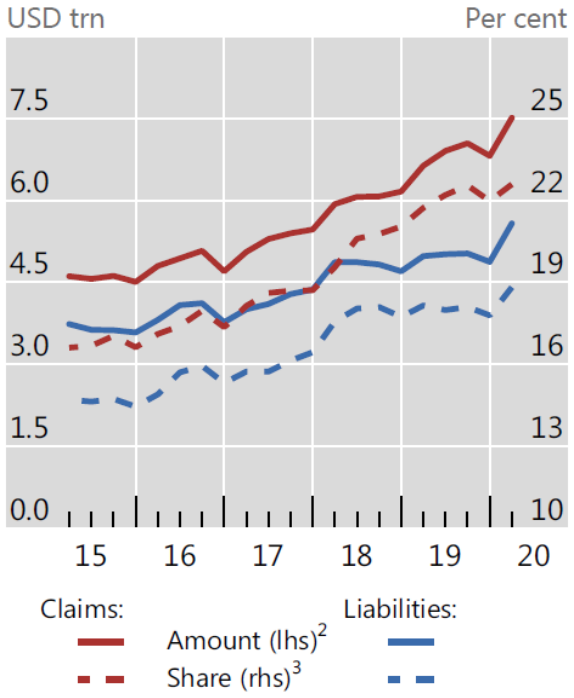
- The growth of NBFI assets exceeded that of bank assets over the past decade, reaching 48% of total financial assets at end-2018, from 42% at end-2008
- As of end-2018, the combined assets of NBFIs – consisting mostly of insurance companies, pension funds and other financial intermediaries (OFIs) – stood at$184 trillion, versus $148 trillion for banks.



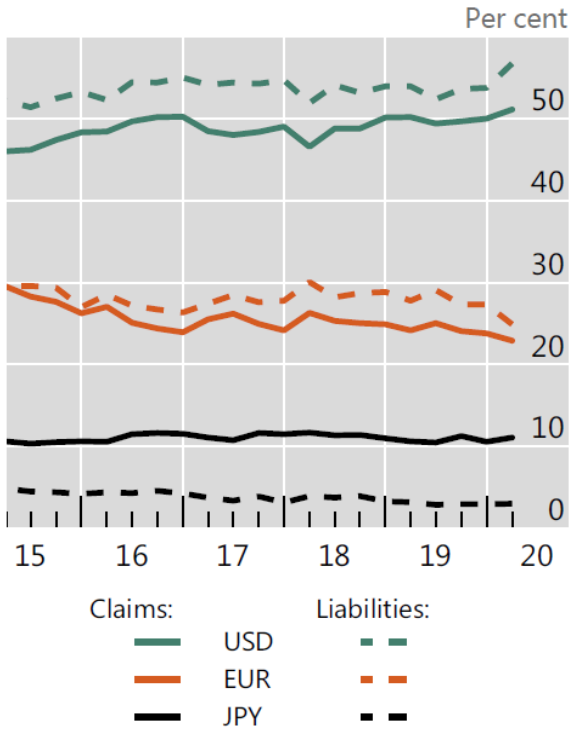
Source: Aldasoro, Huang and Kemp (2020), Cross-border links between banks and non-bank financial institutions, BIS Quarterly Review, September.

Cross-border linkages between banks and NBFIs have increased in recent years

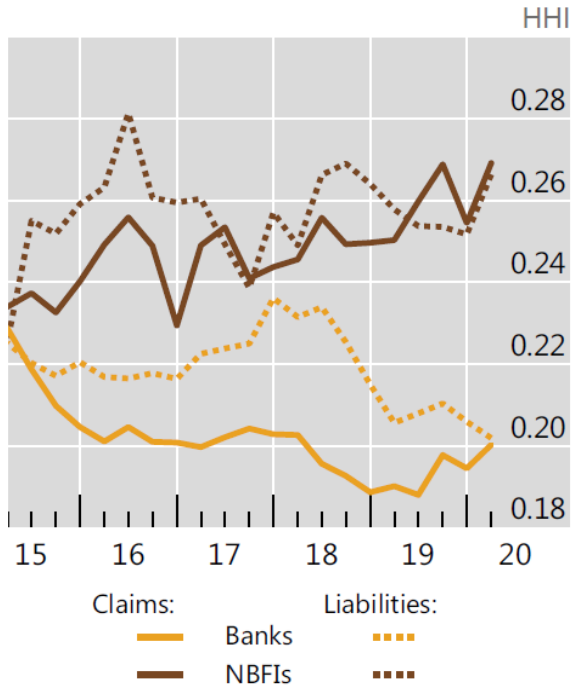
Cross-border links with NBFIs grew strongly in recent years



The US dollar makes up over half of claims and liabilities vis-à-vis NBFIs[4]



Links with NBFIs are more concentrated than interbank ones[5]



Source: Aldasoro, Huang and Kemp (2020), Cross-border links between banks and non-bank financial institutions, BIS Quarterly Review, September.

Concluding remarks

Macroprudential stress test modelling: Best practices

- Macroprudential stress testing is fundamentally about running counterfactual / “what if” scenarios
- Reliance on the consistent linking of suites of models
- Time series of granular data often short
  - More efforts needed to evaluate how well stress testing frameworks capture reality / predictive power
  - Back testing / Case studies
  - Sensitivity analysis of key assumptions (e.g. fire sales)
  - Non-linear effects (e.g. when going from baseline to adverse, dynamic responses)
- Recommended: **Suite of model approach!**