Tools for Macro Stress Testing and Macro-Prudential Policy Assessment: The ECB Perspective

Macro Financial Modelling Group

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Disclaimer: The views expressed in this presentation do not necessarily represent the official stance of the ECB
Scope of presentation

- Operational tools for macro stress testing and macro-prudential policy assessment at the ECB
- Institutional setting is complex in Europe and has major implications for modelling choices
- ECB is currently in a transitory phase towards becoming a micro-prudential and macro-prudential regulator
  - The nature and development of policy assessment tools reflect this dynamic process
  - Many tools are still work in progress
- Comments more than welcome…
A. Macro-prudential policy analysis at the ECB – transition towards a "banking union"

B. The ECB (top-down) stress testing framework
   1. Motivation and background
   2. First-round impact of adverse scenario on bank solvency
   3. Spillover and feedback effects

C. Tools for macro-prudential policy impact assessments
   1. Background and concepts
   2. Analytical tools and approaches
Macro-prudential policy analysis at the ECB – transition towards a “banking union”

The ECB (top-down) stress testing framework

1. Motivation and background
2. First-round impact of adverse scenario on bank solvency
3. Spillover and feedback effects

Tools for macro-prudential policy impact assessments

1. Background and concepts
2. Analytical tools and approaches
A. Macro-prudential policy analysis at the ECB

- Financial stability analysis at the ECB has traditionally been part of the monetary policy function with the aim of contributing to a stable financial system (TEU Art. 127,5) capable of withstanding shocks and the unravelling of financial imbalances.

- With the establishment of new EU supervisory architecture the ECB is also providing analytical support to the European Systemic Risk Board (macro-prudential oversight body).

- **Transition towards a banking union**
  
  - EU decision in June 2012 to move towards a Banking Union, conferring specific tasks relating to the prudential supervision of credit institutions on the ECB.
  
  - A Single Supervisory Mechanism (SSM) will create a new system of financial supervision comprising the ECB and the national competent authorities of participating EU countries.
  
  - The establishment of the Single Supervisory Mechanism (SSM) is expected by autumn 2014.
A. The current role of ECB in the euro area monetary and financial system

Level
System
Individual institutions

Policy functions

Preventive stage
Crisis management stage

ECB

Country mission work

Fiscal backstop
Resolution mechanism
Deposit insurance
Lender of last resort

Monetary policy
Macro-prudential
Rule-making
Micro-prudential

D. Schoenmaker (2012), „The missing link in Banking Union: Macro-prudential Supervision“, mimeo.
A. The future role of ECB in the banking union?
- Details of the new structure still to be agreed upon

- Details of the new structure still to be agreed upon

Outline

A  Macro-prudential policy analysis at the ECB – transition towards a “banking union”

B  The ECB (top-down) stress testing framework
   1. Motivation and background
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C  Tools for macro-prudential policy impact assessments
   1. Background and concepts
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B.1 Macro stress testing as a macro-prudential tool

- Macro stress testing is a forward-looking measure of the strength of individual banks (a complement to minimum capital requirements) and of the resilience of the system to future stressed conditions.

- Macro stress tests serve two main purposes:
  1. Measuring the impact of materialisation of systemic risks (do banks have sufficient capital to survive stressed period?)
  2. A macro-prudential policy tool to address banking sector vulnerabilities (e.g. recapitalisation, capital planning, manage investor confidence, assess need for macro-prudential policy intervention)

- In Europe stress tests are conducted by:
  - National supervisory authorities/ECB (bottom-up)
  - European supervisory authorities/ECB (system-wide bottom-up)
  - ECB and national central banks (top-down)
B.1 Top-down stress testing framework
Forward-looking solvency analysis

Scenario
- Funding shock
- Financial shock simulator
- Macro models

Satellite models
- Credit risk models
- Market risk models
- Profit models

Balance sheet
- Loan loss models
- RWA
- Balance sheet and P&L tool => Solvency
- Dynamic adjustment model

Feedback
- Contagion models
- Macro feedback models
B.2 Scenario design

Cross-country macro scenario design has to balance various factors:

- Adherence to macro-financial story line (based on identified systemic risks)
- Probabilistic ex-ante approach to shock sizes vs. ex-post impact-oriented
  - Based on historical patterns
  - How to incorporate forward-looking perspective?
- Model consistency vs. ad hoc assumptions
- Need to ensure substantial stress being imposed on all banks in the exercise?
  - Option: impose additional stress factors on top of macro scenarios (e.g. exogenous shock to PDs, market risk factors, etc.)
- A mixture of model-based and judgemental assumptions
- Cross-check: use top-down stress test framework during scenario design process to gauge severity ex ante
B.2 Overview of scenario generation process

Mapping of systemic risks into exogenous shocks

Calibration of shock sizes and shock profiles

Shock simulation tools

Macroeconomic models

Ex-ante top-down stress test cross-check

Scenario output:
Projection of macroeconomic and financial variables
B.2 Scenario design

- **EU macro**: “Stress Test Elasticities” (STE)
  - Multi-country EU-wide shock simulation tool based on impulse response functions (from ESCB central banks’ models) of endogenous variables to pre-defined exogenous shocks
  - Allow for country-specific shocks and incorporate EU-wide spillovers (via a trade link block)

- **Non-EU macro**: external models (e.g. NIGEM)

- **Large-scale macro models** with financial-to-real feedback (e.g. DSGE, MCM, BVAR, GVAR)

- **A separate toolbox is used to derive pure financial shock scenarios**: non-parametric copula approach to simulate joint/multivariate forward distribution of financial variables (model free, can handle large # variables)
B.2 Satellite equations – Bayesian Model Averaging approach

- Develop ADL-type model equations

\[ Y_t = \alpha + \rho_1 Y_{t-1} + \ldots + \rho_p Y_{t-p} + \sum_{k=1}^{k_i} (\beta_0^k X_t^k + \ldots + \beta_{q_k}^k X_{t-q_k}^k) + \varepsilon_t \]

- Model uncertainty due to short time series for dependent variables of often low quality \( \Rightarrow \) constrain effective size of single model equation

- Use Bayesian model averaging approach – weighing single model coefficient estimates by posterior model probabilities:

\[ h(\beta|y) = \sum_{i=1}^{I} P(M_i|y) \frac{f(y|\beta)h(\beta|M_i)}{f(y|M_i)} \]

- Construct “model space” \( \rightarrow \) all conceivable combinations of \( K \) potential predictors (while limiting number of predictors in single equations to \( L \))

- Number of equations in model space

\[ I = \sum_{l=1}^{L} \frac{K!}{l!(K-l)!} \]
B.2 Satellite equations – Bayesian Model Averaging approach

- Individual equations in model space all estimated
- Use diffuse priors (i.e. each predictor is equally likely)
- Combine equations via weights
- Weights proportional to in-sample or out-of-sample accuracy measures
  - In-sample measure: BIC / AIC / HQ
  - Out-of-sample measures
    - Point forecast accuracy: RMSE
    - Density forecast accuracy: Log score, CRPS
    - Directional forecast accuracy: Signal-to-noise ratio, False alarm ratio, Proportion correct, …
- Sign restrictions on long-run multipliers
B.2 Satellite equations – Bayesian Model Averaging approach

- Model output:
  1) Detailed model and evaluation results in excel file
  2) Posterior model structure (posterior inclusion probabilities +
      long-run coefficient multipliers)
  3) Scenario projections
  4) Residuals / Forecast errors + diagnostics
B.2 Balance sheet tool: P&L and solvency calculations

- Balance sheet tool linking satellite equations with individual bank data
  - Currently covering 91 EU banks (EBA sample) but on-going expansion to cover SSM sample of banks (c. 150-160)
  - Data sources: EBA disclosures, banks’ financial reports, private data vendors (e.g. Bankscope), ECB statistics => supervisory data
  - Balance sheet items: e.g. TA, exposures (broken down by sectors), RWA (broken down by category), capital (various breakdowns)
  - P&L items: income (broken down by category), NPL/LLP, PD/LGD (starting levels), taxes, dividends
- ...to derive individual bank solvency positions contingent on scenarios
B.2 Balance sheet tool: P&L and solvency calculations

Static vs. dynamic balance sheet assumption:

- Top-down stress test well-suited for deviating from standard static balance sheet assumption

- Two approaches:
  - Exogenously imposed paths for key balance sheet items (e.g. loan growth, trading book, funding)
  - Endogenous model approach – based on risk-return optimization problem (Halaj, 2013; ECB WP No. 1533)
B.2 First-round solvency impact of stress test

Euro area average Core Tier 1 ratio under an adverse scenario
(percentage, average for 80 euro area banks)

<table>
<thead>
<tr>
<th>Core Tier 1 ratio, start-horizon</th>
<th>Profit</th>
<th>Other effects</th>
<th>Losses</th>
<th>RWA</th>
<th>Core Tier 1 ratio, end-horizon</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.6</td>
<td>3.6</td>
<td>-0.1</td>
<td>-3.8</td>
<td>-0.7</td>
<td>8.7</td>
</tr>
</tbody>
</table>

An illustrative example of individual bank Core Tier1 ratios under the baseline and adverse scenarios (X-axis: Baseline Core Tier 1 capital ratio in per cent; Y-axis: Adverse Core Tier 1 capital ratio in per cent)

B.3 Second-round effects: interbank contagion

- If shock amplification effects via interbank contagion and macro feedback loops are not accounted for, banking system resilience likely to be overestimated

- At least **four different channels** of interbank contagion:
  1. Direct bilateral exposures
  2. Common exposures (e.g. securities holdings) => fire sale losses
  3. Liquidity hoarding (/funding withdrawal)
  4. Confidence channels

- **Data issue:** bank-by-bank information on bilateral exposures and other bank interrelationships is usually not readily available

- **Main approach:** randomly simulating interbank networks and modelling of banks’ heterogeneous reactions to changes in the macro-financial environment

- Alternative approaches to measure contagion risk based on price-based measures
  - Gray-Gross-Paredes-Sydow (2013): CCA-GVAR
  - Gross-Kok (2013): mixed cross-section GVAR (CDS spreads)
B.3 Second-round effects: interbank contagion using simulated networks

- 3 step approach
  - **Probability map** that a bank makes an interbank placement to another bank in the system (mapping using disclosures on geographical exposures and banks’ international profile)
  - An iterative procedure to generate (many: \(~10^6\)) interbank networks by randomly picking a link between banks and accepting it with probability taken from the probability map
  - The algorithm of *clearing payments* proposed by Eisenberg and Noe (2001) on the interbank market applying two versions:
    - Plain vanilla (without fire sales)
    - With a ”fire sales” mechanism (where price elasticity is based on size of banks’ securities holdings to overall market depth; see also Cont-Wagalath, 2012)
B.3 Interbank contagion models: Simulated networks

A simulated interbank network

Interbank losses across the distribution of generated networks (average CAR reduction in percentage points)

Note: an arrow between bank A and B indicates an interbank deposit of bank B placed in bank A; the width of an arrow reflects the size of the exposure; the lighter the green colour of an arrow, the lower the probability is that the arrow joins a given pair of banks.

B.3 Interbank contagion modelling: simulated networks

Applications

- Link to macro scenario
- Banks whose capital ratio falls below pre-defined threshold (e.g. 6%) under scenario are assumed not to repay its interbank liabilities
- The tool can be used to analyse what are the potential knock-on contagion effects following a common (or idiosyncratic) shock to the banking system
- Typically, accounting for interbank contagion effects amplifies initial shock impact

First-round losses under the adverse scenario vs. second round losses taking into account interbank contagion

B.3 Contagion and feedback modelling: multi-layered networks underline the need for a ‘holistic’ approach

Figure 1: An example of triple-layered network, where the same set of nodes belong to each of the three layers, characterized by its own topology. The first two layers contain directed networks, meanwhile the last one is undirected. The different neighbors in the different layers give the multi-layered networks completely different system dynamics during shock propagation, since the number of affected nodes can drastically be increased due to the multi dimensional structure of the system.

B.3 Contagion and feedback modelling: contagion effects within each layer are amplified when considered jointly

Figure 6: On the left, the distribution of the total number of defaults when bank DE023 fails and all the three layers are activated at the same time. The inner panel highlights the fat tail of the distribution compared with the convolution of the three separate layer effects. On the right, the dynamic process when the bank fails for one particular realization of the multi graph. The horizontal axes represents the time, and the vertical axes represents the total number of defaults.

## B.3 Macroeconomic feedback effects

- Linking stress test results with macro models including a banking sector and a regulatory interface that allows for estimating macro-feedback loops:

### 1. DSGE models
- **Angeloni-Faia (2013, JME):** incl. banking sector with capital constraints and subject to deposit runs; calibrated on US data
- **Gertler-Karadi (2011, JME):** incl. banking sector with endogenous capital constraints; calibrated on US data
- **Darracq-Kok-Rodriguez (2011, IJCB):** incl. monopolistic banking sector with endogenous capital constraints; estimated on euro area data
- **Christiano-Motto-Rostagno (2010, ECB WP):** incl. a financial accelerator mechanism with a banking sector providing different types of deposits and granting different types of loans; estimated on euro area data

### 2. Other large-scale macro models with macro-financial linkages
- **Multi-country Model (MTM):** large-scale estimated New Keynesian model estimated for the five largest euro area countries (Dieppe-Gonzalez-Willman, 2011, ECB WP No. 1315 + Dieppe-Gonzalez-Hall-Willman, 2011, ECB WP No. 1316)
- **Large Bayesian VAR model:** estimated on euro area data (Banbura-Giannone-Reichlin, 2008, ECB WP no. 966)
- **CCA-GVAR:** estimated for euro area countries (Gray-Gross-Parades-Sydow, 2013, IMF WP forthcoming)

### Caveats
- Model dependency
- Ad hoc nature of in-build financial frictions
- Non-linearities or other financial instability features
- No cross-sectional dimension
B.3 Macroeconomic feedback effects

Interfaces between top-down stress test and DSGE model with banks:

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C Tools for macro-prudential policy impact assessments
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C.1 Macro-prudential impact assessment tools

Motivation

• Some lessons from the crisis:
  – Credit-fuelled bubbles have more detrimental consequences on financial and macroeconomic stability than bubbles not financed by credit (e.g. 2000-1 crisis vs. 2007-9 crisis)
  – In the run-up to crisis, agents’ incentives tend to get distorted leading to excessive risk-taking
  – A crisis is amplified by amplification mechanisms (run on banks, fire sales and liquidity spirals, bank funding fragility)

• Materialisation of systemic risk can have many forms
  – Macro shocks amplified by financial frictions
  – Cross-sectional contagion (interconnectedness, redistribution effects)
  – Built-up of financial imbalances over time

• Micro-prudential supervisors typically do not have the system-wide perspective to prevent the emergence of systemic risks (do not internalise the externalities on the system caused by individual institutions)

• Monetary policy is too blunt a tool for addressing key systemic risks like interconnectedness and build-up of imbalances in specific segments
The Macro-prudential Research Network (MaRs) was established in 2010.

It pursues and promotes research in three main areas:

1. Macro-financial models linking financial stability and the performance of the economy
2. Early warning systems and systemic risk indicators
3. Assessing contagion risks

Aim is to develop models and analytical tools in support of macro-prudential oversight in the EU.

C.1 Macro-prudential impact assessment tools

Issues and challenges

• In contrast to monetary policy, difficult to pin down objective function of macro-prudential policy maker
  • Elusive definition of system risk; multidimensional concept covering both a „cross-sectional“ dimension (i.e. interconnectedness and distribution of risks) and a „time“ dimension (i.e. reflected in build-up of financial imbalances over time)
  • Range of existing analytical tools for macroprudential policy analysis reflect this split

• Limited practical experience with usage of macro-prudential policy instruments and hence scarce knowledge about their effectiveness (see though Lim et al., 2011; Elliott-Feldberg-Lehnert, 2013)
  • How do the various new instruments interact when applied in parallel?

• Macro-prudential policies vs. other policy functions (e.g. monetary policy, fiscal policy, micro-prudential supervision)
  • What are the trade-offs?
  • Complementarities and/or conflicts of interest?
C.1 Macro-prudential policy function

Macro-prudential tools available to the ECB

- The SSM Regulation attributes to the ECB’s Supervisory Board the ability to adopt measures set out in Union acts only (i.e. CRDIV and CRR)
- For those instruments, the ECB will have the option to “top up” macro-prudential actions by national authorities
- Tools not specified in EU legislation remain of national competence
- Cross-border coordination and policy spillovers will play a major role

<table>
<thead>
<tr>
<th>CRD IV</th>
<th>CRR</th>
<th>outside legal texts</th>
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<tbody>
<tr>
<td>Counter-cyclical capital buffer</td>
<td>Leverage ratio</td>
<td>Margin and haircut requirements</td>
</tr>
<tr>
<td>Systemic risk buffer</td>
<td>Liquidity Coverage Ratio</td>
<td>LTV ratio caps</td>
</tr>
<tr>
<td>SIFIs capital surcharge</td>
<td>Net Stable Funding Ratio</td>
<td>loan-to-income ratio caps</td>
</tr>
<tr>
<td>Levy on non-stable funding</td>
<td>Sectoral capital requirements/risk weights</td>
<td>Loan-to-deposit ratio caps</td>
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<td></td>
<td>Large exposure limits</td>
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<td></td>
<td>Minimum capital requirement</td>
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<td></td>
<td>Capital conservation buffer</td>
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<td></td>
<td>Increased disclosure requirements</td>
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</tr>
</tbody>
</table>

Sources: ECB Financial Stability Review, May 2013, special feature A.
C.1 The macro-prudential policy process

If macro-prudential policy action required

Potential sources of systemic risk

Risk identification

Impact assessment

Policy response

Identify build-up of financial imbalances

Tools:
- Financial stability indicators
- Early warning signal models
- Macro stress tests

Assessment of propagation channels and impact of identified policy action

Tools:
- Macro stress-testing framework
- Contagion and spill-over models
- Macro models with financial stability characteristics

Macro-prudential policy tools:
- Tools to calibrate strength of required policy action
- Micro-prudential tools adapted for systemic risk purposes (available to the ECB)
- Other (fiscal) tools available to national authorities
- Interaction with other policy areas: monetary policy, micro-prudential policy

Monitoring follow-up of recommendations and assessing policy impact
C.2 Macro-prudential impact assessment tools – using the top-down stress testing framework

- The top-down bank stress testing framework can be employed to examine the direct impact of imposing specific macro-prudential instruments across a large cross-section of EU banks
  - Capital surcharges/buffers (discriminating between banks, countries, business models, etc.)
  - Stricter sectoral risk weights / provisioning rules
  - Leverage ratio / liquidity ratio / loan-deposit ratio
- Combines elements of cross-section and time dimensions of systemic risks
  - Can analyse the immediate impact across individual banks of imposing certain macro-prudential instruments
  - Impact assessment can be made contingent on specific macro scenario
- Some limitations:
  - Reduced form (satellite) models => linking to macro models can be artificial
  - Constrained time dimension (typically confined to 2-3 years)
C.2 Macro-prudential impact assessment tools – using the top-down stress testing framework

CT1 capital ratio impact of 20% increase in sectoral risk weights under a baseline scenario (in per cent)

Use capital shortfalls (potentially translated into lending spread shocks) as input to macro models (DSGE) with financial frictions

Illustrative example
C.2 Addressing interconnectedness: using agent-based network models

INITIAL PARAMETERS
Aggregate IB lending / borrowing, capital, RWA, CDS spreads, market interest rates

1) OPTIMISATION
Preferred asset structure

2) OPTIMISATION
Preferred funding structure

3) BILATERAL GAMES
Bargaining game

4) PRICE
Interest rate adjustment

NEW PLACEMENTS
Part of unallocated IB assets placed in banks as deposits creating IB linkages

4 ROUNDS

REPEATED STEPS

Partial allocation

STEPS Repeated
until all IB assets are allocated

Full allocation

IB Network Completed

Unallocated IB assets and liabilities

C.2 Addressing interconnectedness: - using agent-based network models

- x-axis: CDS spread (in bps)
- y-axis: difference of CAR after adverse stress testing shock between LE=25% and LE=20%, 15% and 10% regimes (in p.p., negative number means that by lowering LE limits the contagion losses decline)
- More stringent LE limits overall tend to lower contagion risk
- Largest benefits for the safest part of the banking system

C.2 Macro-prudential impact assessment tools – using general equilibrium (GE) models

- To properly capture the **time dimension of systemic risk**, and the impact of **time-varying macroprudential tools**, requires a GE modelling framework that accounts for business cycle dynamics
  
  - **Two-period, two-country GE model** with heterogeneous agents, incomplete markets and bank defaults (building on Goodhart-Tsomocos-Kashyap-Vardoulakis, 2012) to analyse channels and interactions between different macro-prudential instruments (MPIs)
  
  - **DSGE models with financial frictions** and ideally a well-specified banking sector can be used to examine the dynamic and endogenous reactions to imposing different MPIs
  
  - **MaRs Network** is developing DSGE model with triple defaults (firms, households and banks) to study macro-prudential regulation

Open issues:

- How to incorporate non-linearities, and other financial instability characteristics, heterogeneous agents (e.g. financial intermediaries), ad hoc specifications of banking sector, macro-prudential policy objectives, etc.?
C.2 Macro-prudential impact assessment tools

- Interactions between monetary and macro-prudential policies

• Some evidence that monetary policy by taking a “leaning against the wind” approach (i.e. asset prices, credit targets) can improve the optimal policy mix
• Countercyclical regulation can support MP in macroeconomic stabilisation and reduces need for MP to lean against the wind
• But unconstrained countercyclical regulation may lead to excessive volatility in bank leverage (i.e. optimal to limit leverage volatility)

[see e.g. Angeloni-Faia (2013) and Darracq-Kok-Rodriguez (2011); see also Kannan-Rabanal-Scott (2009; Angelini-Neri-Panetta (2010); Beau-Clerc-Mojon (2011)]
C.2 Macro-prudential impact assessment tools

- Simulating the macroeconomic impact of selected MPIs suggests a significant role for monetary policy in mitigating effects on output and inflation (LHS).
- MPIs can help alleviate negative implications of financial amplification risks during crisis times (RHS).

Transmission of selected MPIs under endogenous monetary policy
(percentage point deviation from baseline)

Macroeconomic implications of corporate credit risk shock with/without active macro-prudential policy
(percentage point deviation from baseline)

Sources: Carboni et al. (2013) and ECB Financial Stability Review, May 2013.
Note: Simulations based on Darracq et al. (2011).
Gaps and areas for further research

- Liquidity stress testing (under development) – data dependent
- Piecemeal approach to macro stress testing – reduced-form satellite equations vs. general equilibrium approach
- Development of operational dynamic macro-financial models to evaluate macro-prudential policies; embedding:
  - Financial instability characterisations / non-linearities
  - Heterogeneous and interacting agents
- Micro-founded approaches to modelling banks’ reactions to exogenous shocks
Gaps and areas for further research

- How to account for the shadow banking sector and other channels through which macro-prudential policies may leak?
- How do activation of macro-prudential instruments affect agents’ behaviour?
- Communication and governance issues
- When to activate macro-prudential policy action (what are the relevant triggers)?
- How to get the timing right? Also when to ease to macro-prudential policy
- Structural reform measures (Volcker, Vickers, Liikanen)
- How to access their impact? …