Modelling solvency and liquidity stress interactions

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Oesterreichische Nationalbank

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Disclaimer

The opinions expressed in this presentation are those of the authors and do not necessarily reflect those of the OeNB or the Euro System.

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Austrian stress test models

Solvency stress test model

Liquidity stress test model

Interaction solvency/liquidity

Results & conclusions
Austrian solvency stress test models

Solvency Stress Test

Scenario Models (i.e. exogeneous shocks)
- Two separate models for Austria and „Rest of World“

Macro-2-Micro Models (i.e. risk factor distributions)
- PDs, LGDs, ratings, market risk factors, net interest income, ...

Balance Sheet Model (i.e. loss functions)
- Balance, Profit & Loss, RWAs

Feedback Models
- Interbank exposures

Cash Flow Model (i.e. maturity mismatch)
- Run-off rates and haircuts
## Data sources for stress testing in Austria

<table>
<thead>
<tr>
<th>Reporting</th>
<th>Solvency</th>
<th>Liquidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>All Austrian banks (~600 consolidated, ~800+100 unconsolidated)</td>
<td>29 largest Austrian banks on a consolidated / sub-consolidated basis</td>
</tr>
<tr>
<td>Frequency</td>
<td>Quarterly</td>
<td>Weekly</td>
</tr>
<tr>
<td>Sources</td>
<td>FINREP &amp; COREP (incl. cross-border subs) Central Credit Registry NFC default frequencies Bloomberg data Macroeconomic variables</td>
<td>Weekly liquidity reporting Unencumbered collateral deposited at OeNB Reporting data on NFC bond holdings</td>
</tr>
<tr>
<td>Cut-off date (for this example)</td>
<td>2012Q4</td>
<td>2012Q4</td>
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Austrian stress test models

**Solvency stress test model**

Liquidity stress test model

Interaction solvency/liquidity

Results & conclusions
## Main challenges of solvency stress tests

<table>
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<tr>
<th>Main challenges</th>
<th>OeNB solution</th>
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<tbody>
<tr>
<td>Availability of granular data</td>
<td>Central Credit Registry</td>
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<tr>
<td>Robustness of the scenario</td>
<td>Cooperation with Economics Department</td>
</tr>
<tr>
<td>Uncertainty of the risk factor distributions</td>
<td>Model averaging for macro-2-micro models</td>
</tr>
<tr>
<td>Uncertainty with regard to the loss functions</td>
<td>Bottom-up benchmarks, cross sectional comparisons, extensive back testing</td>
</tr>
<tr>
<td>Explicit link to liquidity</td>
<td>Cost of funding, fire sales (preliminary)</td>
</tr>
<tr>
<td>Network externalities</td>
<td>Only partially addressed (IB contagion)</td>
</tr>
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</table>
Solvency stress testing model (ARNIE**)
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Liquidity stress testing model

**Input / Data**
- Weekly cash-flow based liquidity reporting data
- Treasury data

**Calculation**
- Inflows
- Outflows
- CBC*

**Liquidity surplus/gap**

**Stress Assumptions**
- Roll over rates
- Run off rates
- Haircuts

**Output**
- Open funding gap
- In relation to total liabilities
- Number of failed banks
- ... (* CGI*)

*) CBC = Counter Balancing Capacity

**) A bank fails the stress test (i.e., has a liquidity gap) if it is not able to cover a possible net funding gap (i.e., Inflows < Outflows) with its counterbalancing capacity.
# Main challenges of liquidity stress tests

<table>
<thead>
<tr>
<th>Main challenges</th>
<th>OeNB solution</th>
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</thead>
<tbody>
<tr>
<td>Availability of cash flow data</td>
<td>Weekly cash flow report in six currencies</td>
</tr>
<tr>
<td>Scenario design</td>
<td>Close link to solvency scenario</td>
</tr>
<tr>
<td>Scenario calibration</td>
<td>Extensive empirical foundation</td>
</tr>
<tr>
<td>Parameter uncertainty</td>
<td>Three groups of 12 embedded scenarios</td>
</tr>
<tr>
<td>Explicit link to solvency</td>
<td>Macro-to-PD shifts feed into CC migration matrix in CBC &amp; CIF (loans)</td>
</tr>
<tr>
<td>Treatment of CBs as lender of last resort</td>
<td>Three stage gradual approach</td>
</tr>
</tbody>
</table>
## Data requirements

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contractual / behavioural maturities</td>
<td></td>
</tr>
<tr>
<td>Gross / net cash flows</td>
<td></td>
</tr>
<tr>
<td>Liquidity coverage approach / separation of li risk exposure &amp; risk bearing capacity</td>
<td></td>
</tr>
<tr>
<td>Stock of liquid assets / counterbalancing capacity</td>
<td></td>
</tr>
<tr>
<td>Single currency / multiple currencies</td>
<td></td>
</tr>
<tr>
<td>Frequency, cut-off date and reporting time lag</td>
<td></td>
</tr>
<tr>
<td>Product oriented/accounting balance sheet based versus functional items</td>
<td></td>
</tr>
<tr>
<td>Reporting period and bucket size (9 buckets)</td>
<td></td>
</tr>
<tr>
<td>Consolidated / solo</td>
<td></td>
</tr>
<tr>
<td>Differentiation according to business model / comprehensive template</td>
<td></td>
</tr>
</tbody>
</table>
## Template design crucial

| Contractual & behavioural | Without contractual → **results biased**  
|                          | Behavioural assumptions explicit → **reveal risk tolerance**  
<table>
<thead>
<tr>
<th></th>
<th>Allow for <strong>institution specificity</strong></th>
</tr>
</thead>
</table>
| Gross cash flows          | Allow for differentiated analysis of liquidity risk exposure → **more risk sensitive**  
|                          | More granular stress tests possible |
| Counterbalancing capacity | **Consistency** across inflows/outflows counterbalancing capacity  
|                          | Makes implicit assumptions of stock explicit → **information gain** |
| Multiple currencies       | **Liquidity risk currency specific**  
|                          | Links across currencies product specific |
| Functional items          | **Common language** among li-risk managers & supervisors  
|                          | **Facilitates** scenario design & calibration |
**Austrian maturity mismatch template**

**Inflows (14 line items)**
- Maturing instruments (loans, swaps, ...)
- Fixed / expected issuances (short- and long-term)
- Expected deposit inflows (un/secured, retail / wholesale)

**Outflows (16)**
- New loans, advances, calling of lines, ...
- Tender, Repos, Issuances (due)
- Expected deposit outflows (un/secured, retail / wholesale)

**Counterbalancing Capacity (9)**
- Cash, excess reserves at the central bank (by rating category)
- Tender / unencumbered collateral
- Liquid and other assets available for collateralisation

*) Six currencies include: EUR, USD, CHF, GBP, YEN and a basket of other currencies.
**) Five maturity buckets cover: up to 5 days, 1 month, 3 months, 6 months and 12 months.
Scenario calibration

Consistency with solvency scenario
- Often contain relevant parameters (e.g. bond prices)

Econometric approach not feasible
- Low frequency/high impact events
- Data hardly available

Product & market specific
- Reporting data & academic literature (IMF WP03/12, BCBS WP 24/25 2013)

Case studies
- Bank, market & country level (IMF WP03/12, BCBS WP 24/25 2013)

Output of solvency stress test
- See discussion below
parameter uncertainty – embedded scenarios

- Scenario 1
  - Closure of unsecured interbank markets
  - Closure of FX Swap markets

- Scenario 2
  - Reduced issuance of short term / long term debt
  - Increase in calling of credit commitments
  - Mild haircuts on unencumbered collateral in CBC

- Scenario 3
  - Dry up of funding markets – no future debt issuance
  - Severe increase in calling of credit commitments
  - Increased Haircuts on CBC according to the asset quality
  - Reduction in planned financial investments (mitigating)

- Scenario 4
  - Combines scenario 3 with idiosyncratic shock
  - Reduction of expected roll-over rates of wholesale and retail deposits

Cumulative severity

Reveals liquidity risk tolerance
Treatment of CBs as lender of last resort

Lender of last resort
• Discretionary/extra-ordinary deviation from the standard framework of monetary policy implementation
• Liquidity provided to individual/subsample of institutions on specific terms that are not available to other market participants

Monetary policy implementation
• Reaction to expected increase of the structural liquidity deficit at the target rate
• Always market oriented – never individual bank focused
• Can entail deviations from standard monetary policy
LoLR: focus on markets rather than failing bank

**Arguments for reliance on LoLR**

- Historical experience
- Theory
  - Potential efficiency gains under restrictive assumption (e.g. prevent asset fire sale contagion)

**Arguments against reliance on LoLR**

- Conflicts with raison-d’être for liquidity regulation
  - Internalise externality & moral hazard & efficient allocation of liquidity & risk
  - Qualitative liquidity regulation aims at self-insurance (CEBS 2009, 2010a, BCBS 2010)
- FX liquidity (e.g. Bulgaria)
- LoLR cannot be considered in isolation (subordination, bank resolution)
- Political economy of bail-outs
  - Interference in property rights, fiscal exposure, distributional effects
- CB discretion undermined
  - Delienation of illiquidity from insolvency impossible under time pressure
  - Conflict of interest with monetary policy implementation

**Potential efficiency gains can be achieved by less distortionary alternatives**
### Less distortionary alternatives to standard LoLR

<table>
<thead>
<tr>
<th>Pricing</th>
<th>Charging a fee according to the liquidity risk exposure and liquidity risk bearing capacity of the bank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective: Internalise the externality associated with liquidity risk ➔ banks should be indifferent between effective self-insurance and insurance by the public</td>
<td></td>
</tr>
<tr>
<td>Challenge: unrealistic ➔ fair price difficult to estimate (see pricing of RCLF in AUS)</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Conditionality</th>
<th>Automatic sanctions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacement of board members</td>
<td></td>
</tr>
<tr>
<td>Trigger for early intervention mechanism</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Liquidity provision to market rather than illiquid bank</th>
<th>Address asset fire sale externality</th>
</tr>
</thead>
<tbody>
<tr>
<td>assumes other market participants cannot exploit underpricing due to liquidity constraints</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Original concept of the LoLR according to Thornton and Bagehot</th>
<th>Enables other market participants to profit from underpricing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limits negative price effect</td>
<td></td>
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</tbody>
</table>
Conclusions: No LoLR in liquidity stress testing

Ensure sufficient liquidity risk bearing capacity

- HQLA must be composed of assets that are (extremely) highly liquid → no asset fire sale externality

CB operations should be treated like other repos

- Except for standard monetary policy implementation
- Consistency between the individual building blocks of liquidity stress tests

Liquidity stress testing must ensure self-insurance

- No room for LoLR in liquidity stress testing
- Only standard monetary policy operations
Scenario & parameter uncertainty

Scenario severity increases (for inflows, outflows, counter balancing capacity)

### 30 day Scenario

<table>
<thead>
<tr>
<th>CBC Type</th>
<th>Baseline</th>
<th>Market Mild</th>
<th>Market Medium</th>
<th>Market Severe</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full CBC</td>
<td></td>
<td></td>
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<tr>
<td>Increased focus on market liquidity</td>
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<tr>
<td>Market liquidity</td>
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</table>

### 90 day Scenario

<table>
<thead>
<tr>
<th>CBC Type</th>
<th>Baseline</th>
<th>Market Mild</th>
<th>Market Medium</th>
<th>Market Severe</th>
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<tr>
<td>Market liquidity</td>
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</table>

### 1 Year Scenario

<table>
<thead>
<tr>
<th>CBC Type</th>
<th>Baseline</th>
<th>Market Mild</th>
<th>Market Medium</th>
<th>Market Severe</th>
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Results & conclusions
## Interlinkages solvency / liquidity

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<thead>
<tr>
<th>Solvency Stress Test</th>
<th>Mapping to Liquidity Stress Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deteriorating Capital Position</td>
<td>Ability to issue new CP &amp; bonds (12M scenario)</td>
</tr>
<tr>
<td>Increase in Expected NPLs</td>
<td>Reduction in expected inflows from loan repayments</td>
</tr>
<tr>
<td></td>
<td>Reduction of expected inflows from NFC bonds</td>
</tr>
<tr>
<td>Macro-driven PD Shifts</td>
<td>Implied rating migration of banks unencumbered collateral deposited at CB</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Liquidity Stress Test</th>
<th>Mapping to Solvency Stress Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquidity gap</td>
<td>Asset fire sales</td>
</tr>
<tr>
<td>Increase in Funding Costs</td>
<td>P&amp;L effects</td>
</tr>
</tbody>
</table>
Timing / sequenzing of interaction

Solvency Bank B (quarterly freq.)
- Solvency Scenario
  - Solvency Position $t_{Q1}$
  - Solvency Position $t_{Q2}$
  - Solvency Position $t_{Q3}$
  - Solvency Position $t_{Q4}$

Liquidity Bank B (weekly freq.)
- Liquidity Scenario
  - Liquidity Position $t_{Q1}$
  - Liquidity Position $t_{Q2}$
  - Liquidity Position $t_{Q3}$
  - Liquidity Position $t_{Q4}$

- PD shifts
- Deteriorating capital position
- NPLs $t_{Q1}$
- Funding costs $t_{Q1}$
- NPLs $t_{Q2}$
- Funding costs $t_{Q2}$
- NPLs $t_{Q3}$
- Funding costs $t_{Q3}$
- NPLs $t_{Q4}$
- Funding costs $t_{Q4}$

Interbank contagion $t_{Q4}$
The interaction of solvency and liquidity

**Solvency Stress Test**
- Rating Migration
- Credit Losses
- Operating Result
- Valuation Losses
- Capital Position
- Risk-weighted Assets
- Solvency Position

**Liquidity Stress Test**
- Collateral Quality
- Defaulted Assets
- Cost of Funding
- Fire Sales
- Counter Balancing Capacity
- Cash Inflows
- Cash Outflows
- Funding Gap

reduced pledgeability of assets
- reduced inflows

(-) Negative impact (from a bank’s point of view).
(+/-) Neutral impact.
(+/-) Positive impact.

impact on behavioural cash flows

(-) Impact on volume effect.
(-) Impact on price effect.
The interaction of solvency and liquidity

Macro-to-PD impact [reduced pledgeability of assets]
- Banks' credit claims pledged at CB – decreases CBC
- Calibration: Detailed bank-level collateral data (incl. fixed/variable rate; time to maturity)
- Assume iid across PD range within credit quality steps
  - PD impact of macro scenario shifts PDs of CCs upward
  - Migration into higher credit quality steps increases haircuts (up to 100%)
  - Volume weighted average across credit quality steps
- Again weighted by share of non-marketable assets in unencumbered collateral pledged at CB

(-) Negative impact (from a bank’s point of view).
(+/-) Positive impact.
The interaction of solvency and liquidity

**Solvency Stress Test**
- Rating Migration
- Credit Losses
- Operating Result
- Valuation Losses
- Capital Position
- Risk-weighted Assets
- Solvency Position

**Liquidity Stress Test**
- Collateral Quality
- Defaulted Assets
- Counter Balancing Capacity
- Cash Inflows

**NPL impact [reduced inflows]**
- Expected inflows from performing loans – decreases inflows
- Calibration: Direct output of solvency stress test
- Expected inflows from performing NFC bonds – decreases inflows
- Calibration: Assume similar distribution of exposure as in loan exposure
- Output of solvency stress test weighted by share of NFC non-loan exposure to liquid assets

(+/-) Positive impact.
Solvency impact on funding [impact on behavioural cash flows]

- Inspired by dynamics in ABCP market after Lehman
- $t_0$: all banks shut out of issuance markets
- $t_1$: markets differentiate across banks based on expected solvency evolution
- Based on similar scenario/model as solvency stress test
- Banks with CET1 ratio $>10\%$ or $+100$ bp at $t_4$ regain market access ($70\%$)
- Empirical foundation is work in progress

Impact on unsecured MM – complete dry-up pre-empts potential impact of this channel
Cost of funding shock [credit spread increase – price effect]

- Increasing funding costs – impact on P&L
- Calibration: Based on post Lehman spread evolution in AT (not bank specific)
- Impact on stress cash-flows
- New issuance play minor role (loss of/reduced market access)
- Repricing of maturing funding, pass-through to new loans
- Cost of funding shock driven by maturity mismatch (bank specific)

(-) Negative impact (from a bank’s point of view).
(+ ) Positive impact.
Asset fire sales losses [volume effect]

- Captures common exposure to market price & market liquidity effects
- Calibration: Based on HC of liquidity stress scenario & CC migration due to solvency
- Assets: Full CBC except callable, committed credit-lines, liquidity support received from holding company (binding commitment)
- Assumption: banks sell assets proportionally to composition of CBC
- Empirical evidence inconclusive

\[
ASFL_t = \begin{cases} 
0, & \text{if } CNFG_t \leq (\text{cash + excess reserves}) \\
(CBC_{\text{unstressed}} - CBC_{\text{stressed}}) \times \left( \frac{\text{cash + excess reserves + } CBC_{t,\text{stressed}}}{CBC_{t,\text{unstressed}}} \right), & \text{otherwise}
\end{cases}
\]

- Effect: Banks with same level of CBC but higher shares of less liquid assets face higher asset fire sale losses
- Caveats: CB treatment; static, non-behavioural; no additional fire sale loss haircuts

(-) Negative impact (from a bank’s point of view).
(+ Positive impact.)
Important channels disregarded

- Impact of solvency on access to unsecured money market
  - Pre-empt by assumption of complete dry-up
- Impact of own liquidity position on supply of funds on unsecured money market & network dynamics
  - Pre-empt by assumption of complete dry-up
- Contagious bank runs
- Margin calls due to rating downgrades
- Deposit outflows due to rating downgrades
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Measuring the impact of interaction channels

**Liquidity Stress Test**
(share of total impact on cumulated counter balancing capacity)

- Rating migration impact on banks’ credit claims (i.) 54%
- NPL effect on expected inflows from performing loans to non-banks (ii.) 11%
- Losses on inflows from paper in own portfolio maturing (iii.) <4%
- Market funding due to solvency position (iv.) 31%
- Other liquidity impact not associated with solvency stress

**Solvency Stress Test**
(share of total impact on P&L losses)

- Cost of funding 52%
- Fire sale losses 15%
- Credit risk costs 8%
- Other risk costs through P&L 25%
Conclusions

• Supervisory experience, case studies, and the theoretical literature point at a number of potential channels for the interaction between solvency and liquidity stress testing

• Supervisory experience and the example demonstrate that these interactions are material

• Failure to integrate leads to substantially underestimation of the risk exposure of individual banks and banking systems

• Two interesting trade-offs:
  • Trade-off between the quantitative impact of channels and their respective model risk and/or parameter uncertainty
  • Trade-off between conceptual quality and actionable output
Policy recommendations

• The main policy recommendation is the **need to integrate** solvency and liquidity stress tests in order not to underestimate risk
  • Complex interactions require adequately complex models
  • Further research required

• Main **objectives for solvency** stress tests
  • Soundly integrate methodologies to cover the cost of funding
  • Move beyond the constant balance sheet assumption

• Main **objectives for liquidity** stress test
  • Consider the solvency impact on funding costs / volumes
  • Invest in the calibration of asset fire sales

• Decision makers have to understand that even the best models and calibrations cannot exonerate them from the burden of subjective judgement in risk assessment
Further research

- Identify further channels of interaction
- Empirical foundations for calibration
  - Event studies
  - Econometric analysis
- Second round effects
  - Incorporate dynamic balance-sheet
  - Balance-sheet optimisation rather than quantity restrictions
  - Price effects rather than quantity effects in macro-models
- Indirect contagion
  - Empirical evidence
- BCBS RTF TF on Liquidity Stress Testing
  - Studies some of these topics → paper in March 2015
Literature


